# SANITARY EXAMINATIONS

OF

# WATER, AIR, AND FOOD

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## A Vade-Mecum for the Medical Officer of Health

*WITH ONE HUNDRED AND TEN ILLUSTRATIONS*

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SECOND EDITION

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TO

JOHN SIMON,

C.B. D.C.L. F.R.S.

WHOSE LABOURS IN THE DEVELOPMENT OF

THE SCIENCE OF PREVENTIVE OR STATE MEDICINE

MERIT THE

GRATITUDE OF ALL MEN OF ALL NATIONS

THIS VOLUME

IS

WITH HIS PERMISSION

DEDICATED

# PREFACE TO SECOND EDITION

The universal recognition of the utility of this work, not only by Medical Officers of Health, for whose assistance it was written, but also amongst that portion of the public which is interested in the promotion of Sanitary Science, has rendered the preparation of a new Edition needful.

My retirement from the public health service, in consequence of an inability to sacrifice principle to expediency, is not in one sense, perhaps, to be regretted, since the enforced leisure has afforded me the opportunity of studying those Biological Methods for the examination of Water and Air that have been introduced of late years, and which are considered by our German and French *confrères* to be as important as their chemical analysis. Great improvements have also been recently effected in the examination of Milk.

My thanks are due to those health officers who have, in response to my invitation, sent me memoranda for the improvement of this Handbook.

To Drs. Shea, Ashby, P. Frankland, J. W. Moore, Bond, Mill, and to the late Prof. Ripley Nichols, I am especially indebted for much valuable information.

C. B. F.

ILFRACOMBE, DEVONSHIRE, *September* 1886.

# PREFACE TO FIRST EDITION

THE demand for a third edition of my *brochure* on "Water Analysis," affords me an opportunity of offering to the public the results of an increased and more extended experience. The additions are so great as to compel me to re-write nearly all that I have previously published on the subject.

The many kind appreciative comments that have been made on it by the scientific world, and especially by that section of it that is engaged in the public health service of the country, coupled with the suggestions of friends, have led me to incorporate with my essay on "Water Analysis" sections on "Examinations of Air and Food."

I trust that none of my readers will imagine that I have the presumption to place myself forward as a teacher of the Medical Officers of Health of the country. I wish rather to offer suggestions and hints, that, I am sure, will be helpful to those who have not plodded as I have, along long, tedious, and tortuous paths for many years, at the sacrifice of much time and labour, because I could not find a short cut. It does not follow that because there is "no royal road to learning," that the road which we have to traverse should be beset with all kinds of unnecessary obstacles and difficulties.

The objects which I have kept steadily in view in writing the following pages have been :—

1. To avoid a consideration of these three subjects solely after the manner of an analyst who mechanically deals with chemical operations and arithmetical calculations, but to treat them as a physician who studies them in connection with health and disease.

2. To render such details respecting examinations of water, air, and food, as fall within the province of the Medical Officer of Health, so free from technicalities and all cloudy and chaotic surroundings, as to enable any one who possesses the average chemical knowledge of a physician to teach himself by the aid of this *vade mecum* of the health officer.

Some of the information contained in this book treating of the examination of water and milk, may also be found in other analytical works, amongst which may be mentioned Mr. Wanklyn's "Water Analysis" and "Milk Analysis."

It affords me much pleasure to acknowledge with gratitude the assistance rendered to me by scientific men throughout the country, amongst whom may be mentioned Drs. Attfield, Barlett, Brown, Cameron, F. de Chaumont, Hill, Shea, Thorne, Tidy, and Messrs. Dixon, Slater, Thomas, etc.

CHELMSFORD, *May* 1878.

# CONTENTS

| | PAGE |
|---|---|
| Preface to Second Edition . . . . . | vii |
| Preface to First Edition . . . . . | ix |
| Introductory Observations . . . . . | 1 |


## SECTION I.—SANITARY EXAMINATION OF A DRINKING WATER

### CHAPTER I

| | |
|---|---|
| The Wholesomeness of a Water . . . . | 9 |


### CHAPTER II

| | |
|---|---|
| The Determination of the Amount and Nature of the Organic Matter . . . . . | 13 |
| 1. The Smell of a Water . . . . . | 14 |
| 2. The "Keeping Powers" of a Water . . . | 19 |
| 3. The Colour Test . . . . . | 20 |
| 4. Heisch's Test . . . . . | 24 |
| 5. The Zymotic or Microzyme Test . . . | 25 |

PAGE

6. The Oxygen or Forchammer Permanganate of Potash Process . . . . 26
   A. Qualitative Examination . . . 26
   B. Quantitative Examination . . . 26
      Drs. Letheby and Tidy's Process . . 28
      Drs. Woods' and F. de Chaumont's Process 33
      An Improved Process . . . 38
7. The Wanklyn, Chapman, and Smith Process . 39
8. The Frankland and Armstrong Process . . 53
   Table exhibiting different classes of Waters . 58
   A Comparison between the Results furnished by the three last-named Processes . . 63
   Table of Comparison . . . . 68
   Value of the Frankland and Armstrong, Wanklyn, Chapman, and Smith, and the Quantitative Forchammer Permanganate of Potash Processes in the Detection of Dangerous Pollutions . . . . . 71
9. Koch's Biological Method . . . 74
10. The Estimation of Dissolved Oxygen . . 86

## CHAPTER III

THE DETERMINATION OF THE MINERAL PRODUCTS RESULTING FROM CHANGES IN THE ANIMAL ORGANIC MATTER . . . . . . . 91
1. Ammonia . . . . . . 91
2. Nitrogen as Nitrates and Nitrites . . 95
   A. Qualitative Examination—the Horsley Test 106
   B. Quantitative Examination . . . 111
      Modification of Thorp's Process . . 114

## CHAPTER IV

PAGE

THE DETERMINATION OF THE AMOUNT OF SOLID RESIDUE, ITS APPEARANCE BEFORE, DURING, AND AFTER IGNITION, AND THE LOSS OF VOLATILE MATTERS THEREBY OCCASIONED . . . . . 124
- A. The Amount of Solid Residue or Saline Matters 124
- B. The Appearance of the Solid Residue Before, During, and After Ignition . . . 128
  - Table of Illustration . . . 130
- C. The Amount of Volatile Matters burnt off by Ignition . . . . . 132

## CHAPTER V

THE DETERMINATION OF THE AMOUNT OF CHLORINE . 135

## CHAPTER VI

THE DETERMINATION OF THE HARDNESS . . 139

## CHAPTER VII

THE DETERMINATION OF THE AMOUNT OF MAGNESIA, SULPHATES, AND PHOSPHATES . . . 144
- A. Magnesia—Sulphate, Carbonate, and Nitrate . 145
- B. Sulphates of Lime, Magnesia, and Soda as Anhydrous Sulphuric Acid . . . 147
- C. Phosphates . . . . . 150

## CHAPTER VIII

THE DETERMINATION OF POISONOUS METALS . . 154

## CHAPTER IX

PAGE
Microscopic Examination of a Water . . 161

## CHAPTER X

The Collection of Samples of Water for Analysis 170

## CHAPTER XI

Time occupied in performing an Analysis . . 172

## CHAPTER XII

Entry of Analysis in Note and Record Books . 175

## CHAPTER XIII

Mistakes of Water Analysts, and how to avoid them . . . . . . 177

## CHAPTER XIV

Useful Memoranda for Medical Officers of Health when performing Water Analysis . . 185

## CHAPTER XV

Formation of Opinion and Preparation of Report as to Sample of Water submitted to Analysis . 188

PAGE

A. Summary of Data on which to base an Opinion . 195
B. Valuation Tables and District Standards . 196
C. Diagnosis and Formation of an Opinion . 200
Diagnosis of a Peaty Water . . . 205
Diagnosis of Pollution by Urine, or by Slop and Sink Water . . . . 209
Diagnosis of Pollution by contents of Cesspools and Sewers . . . . 210
D. Preparation of Report . . . . 212

## CHAPTER XVI

CONCLUDING REMARKS ON SECTION I. . . . 215
RECIPES OF STANDARD SOLUTIONS, ETC. . . 216

# SECTION II.—SANITARY EXAMINATION OF AIR

## CHAPTER XVII

PAGE

THE PURITY OF AIR . . . . . 221

## PART I

DIFFERENT KINDS OF IMPURITIES . . . 231

## CHAPTER XVIII

ORGANIC MATTER . . . . . 232

## CHAPTER XIX

PAGE

Oxides of Carbon . . . . . . 240
A. Carbonic Acid . . . . . . 240
B. Carbonic Oxide . . . . . 247

## CHAPTER XX

Putrefactive Processes, Sewage Emanations, and Excremental Filth . . . . . 254

## CHAPTER XXI

Poisonous Gases and Injurious Vapours . . . 257

## CHAPTER XXII

Suspended Animal, Vegetable, and Metallic, as well as Mineral Impurities . . . . 258

## CHAPTER XXIII

Emanations from Ground having Damp and Filthy Subsoil—Subsoil Air, Churchyard Air, Marsh Air . . . . . . . . 264

## CHAPTER XXIV

The Deleterious Effects on Health of the Air of our Houses . . . . . . 270

## PART II

PAGE

The Detection and Estimation of the Amount of the most Important Impurities found in the Air . . . . . . . . 291

### *DIRECT METHOD*

### CHAPTER XXV

Modes of Observing Solid Bodies in the Air, and of Separating them for Examination . . . 292

### CHAPTER XXVI

Microscopical Examination of the Dust of the Air 301

### CHAPTER XXVII

The Chemical Examination of Air . . . . 310

A. Organic Matter . . . . . 312

B. Carbonic Acid . . . . . 328

### CHAPTER XXVIII

The Biological Examination of Air . . . . 340

### CHAPTER XXIX

Metallic Poisons :—Arsenic, Copper, and Lead . 343

## *INDIRECT METHOD*

## CHAPTER XXX

PAGE

Estimation of Ozone and other Air Purifiers . 349

## PART III

Sketch of Relation between certain Meteorological Variations in the Condition of the Air, and states of Health and Disease . . 358

## CHAPTER XXXI

1.—The Influence of Differences of Temperature, Solar Radiation, Moisture, and Barometric Pressure of the Air, Direction of the Wind, etc., on Health . . . . . . 362

A. The Temperature of the Air = Air Warmth . 362

B. The Solar Radiation . . . . 367

C. The Hygrometric State of the Air . . 369

D. The Pressure of the Air . . . 374

E. The Direction of the Wind . . . 378

## CHAPTER XXXII

2.—The Meteorological Conditions which appear to favour or retard the Development of certain Diseases . . . . . . 380

1. Surgical Fever after Operations . . . 381

2. Smallpox . . . . . . 383

PAGE
3. Measles . . . . . . 384
4. Whooping-Cough . . . . 386
5. Scarlet Fever . . . . . 387
6. Fever . . . . . . 389
7. Diarrhœa, Dysentery, and Cholera . . 391
8. Bronchitis, Pneumonia, and Asthma . . 396
9. Phthisis Pulmonalis . . . . 398
10. Diphtheria . . . . . 398
11. Hydrophobia . . . . . 399
12. Erysipelas and Puerperal Fever . . 399
13. Insanity . . . . . 400
14. Rheumatism . . . . . 401
Mortality at Different Ages and of each Sex . 402-405

## PART IV

Mode of Observing the Meteorological States and Variations in the Condition of the Air . 406

## CHAPTER XXXIII

1.—The Atmospheric Pressure . . . 407

## CHAPTER XXXIV

2.—The Temperature of the Air . . . 411

## CHAPTER XXXV

3.—The Hygrometric Condition of the Air . 422

## CHAPTER XXXVI

PAGE

4.—The Direction and Strength of the Wind . 430

## CHAPTER XXXVII

5.—The Electrical State of the Air . . 434

Registration of Meteorological Observations . . 439

# SECTION III.—SANITARY EXAMINATION OF FOOD

## CHAPTER XXXVIII

PAGE

The Purity of Food . . . . . . 443

## CHAPTER XXXIX

Inspection and Examination of any Animal intended for the Food of Man . . . 446

## CHAPTER XL

Inspection and Examination of Carcases of Animals, Meat and Flesh Exposed for Sale, or Deposited for the Purpose of Sale, or of Preparation for Sale, and intended for the Food of Man . . . . . . . 449

PAGE
Characters of Good and Bad Meat . . . . 450
The Prevalent Diseases of Stock in relation to the Supply of Meat for Human Food . . . 454
1. Contagious Fevers . . . . 454
2. Anthracic and Anthracoid Diseases, etc. . 458
Arguments against the Employment of Diseased Meat . 463
Arguments in favour of the Employment of Diseased Meat . . . . . . 464
3. Parasitic Diseases . . . . 468
Immature Veal and Lamb . . . . 476
Poisonous Pork, Ham, Sausages, etc. . . . 477

## CHAPTER XLI

Inspection and Examination of Poultry, Game, etc. 478

## CHAPTER XLII

Inspection and Examination of Fish . . 480

## CHAPTER XLIII

Meat of Poisoned Animals . . . . 482

## CHAPTER XLIV

Destruction of Condemned Flesh . . . 484

## CHAPTER XLV

Inspection and Examination of Fruit and Vegetables . . . . . . . 486

## CHAPTER XLVI

PAGE

Tinned Provisions . . . . . . 488

## CHAPTER XLVII

Inspection and Examination of Corn . . 489

## CHAPTER XLVIII

Inspection and Examination of Flour . . 493

Chemical Examination . . . . 495

Microscopic Examination . . . . 499

## CHAPTER XLIX

Inspection and Examination of Bread . . 508

Microscopic Examination . . . . 509

Adulterations of Bread . . . . 509

Chemical Examination . . . . 513

## CHAPTER L

Inspection and Examination of Milk . . 520

Microscopic Appearance . . . . 522

Physical Peculiarities . . . . . 523

Chemical Examination . . . . 525

Milk supplied by, and tainted by, Diseased Animals . 535

Milk contaminated by water polluted with Organic Impurities . . . . . . 544

## APPENDIX

PAGE

Distilled Water and Chemicals . . . . 547

List of Apparatus requisite . . . . . 548

Rules for Interchange of Different Expressions of Results of Analysis . . . . . . 550

Rules for Conversion of Degrees of Scales of Thermometers . . . . . . 551

Metrical Weights and Measures . . . . 551

INDEX . . . . . . . . 553

# INTRODUCTORY OBSERVATIONS

THE elementary principles on which the greater part of the work of the Medical Officer of Health is based, may be truly said to be the prevention of the pollution of Water and of Air with filth and its products, and the prevention of the consumption of articles of Food deleterious to health.

Pure Water, pure Air, and good, wholesome, unadulterated Food constitute the pillars which form the tripod on which rests the "mens sana in corpore sano."

My ideal of a Medical Officer of Health is that of a physician who is thoroughly conversant with every question affecting Public Health, and who is able to analyze quantitatively water, air, and food; and is so well versed in analytical work as to be able to take his oath in a court of justice respecting any matter requiring the assistance of a scientific expert in state medicine. Such a man should be debarred from private practice, and placed over a large area with definite boundaries, such as a county or riding. His appointment should be permanent, so that he may fearlessly and conscientiously perform his duty. Every medical practitioner in his district should act towards him in the capacity of an assistant. The Medical Officer of Health should in fact be the Head Centre of all Public Health affairs in each county.

First, as to Water.—The examination of drinking waters forms a very important portion of the duty of those who engage in a crusade against preventable disease. A health officer should not only be prepared to answer such a question as, "Does a water contain a deleterious amount of organic matter?" but should be able to reply to such interrogations as, "Is this water wholesome and good?" "Which of several specified wells furnishes the purest water?" etc.

Some are disposed to think that it is unadvisable for a Medical Officer of Health to analyze water. The list of his duties, as laid down by the Local Government Board, certainly contains no order that he should act as a water analyst. The latest Adulteration Acts (Food and Drugs Act of 1875, and the Amended Act of 1879) expressly excludes water from its provisions. Few, I should presume, would hold that water is not in some sense a food (much more so than either mustard or pickles); and that, having regard to the derivation of the word "adulterate," the sewage and water supplied by some wells could not strictly be considered to be "a change to another" (the exact meaning of the word) of an article of daily consumption, of a very serious character.

A Medical Officer of Health who can promptly give an authoritative opinion as to the quality of a water is much more helpful to the Sanitary Authorities with which he may be connected, than one who is unable so to do. Continually cases arise, in the working of a large district, where a Sanitary Authority requires an immediate decision as to the quality of a water, in order that steps may be taken with the least possible delay in the prevention of the extension of a disease. If, as is customary in some places, samples of water are sent to professional analysts living at a distance, great loss of time is generally experienced, and the analyses of waters yield illusory results in consequence of being examined in a stale instead of in a fresh condition. I have often known a month or more to elapse before the report is received, when, frequently, the opportunity for acting on the opinion expressed has passed away. Moreover, a Medical Officer of Health requires, for his own guidance in tracing out the causes of diseases, and in taking measures to stop their spread, to ascertain expeditiously and with precision the state of waters.

Secondly, as to Air.—What can be more important than the establishment of some rules of practice as to the purity of the air of our houses and public buildings? There can be no question but that there is a distinct causative relation between consumption and re-breathed air, between the condition of the air in unventilated and crowded dwellings and the prevalence of lung affections. An enormous field is afforded to the health officer in the study of the subject of the defilement of the air by metallic, mineral, and other visible impurities, with a view to the discovery of some means whereby the condition of those classes who have to earn their daily bread by working at such unwholesome avocations as button manufacture, stone masonry, the cotton, wool, and silk industries, etc., may be ameliorated.

Thirdly, as to Food.—The attention of the Medical Officer of Health should undoubtedly be restricted in his analytical examinations to the necessaries of life, and to those substances that are apt to be injurious in themselves, or are liable to be adulterated with substances deleterious to health. Professional analysts, distinct from Medical Officers of Health, there always must be. On these officials devolves the duty of analysing foods, etc., which contain fraudulent but harmless admixtures, such, for example, as the compound of mustard, and of cocoa, with starch—an innocuous diluent, the mixture of sardines and sprats with anchovies, and of salt with gelatine to increase its weight in the scales, etc.

The duties of the Medical Officer of Health, as laid down by the Legislature, all rest on the assumption that he is the judge *on all subjects relating to public health.* It is of course difficult to draw a hard and fast line in this matter, as in every other in this world.

" 1*st Duty.*—He shall inform himself, as far as practicable, respecting all influences affecting or threatening to affect injuriously the public health within the district.

" 2*d Duty.*—He shall inquire into, and ascertain by such means as are at his disposal, the causes, origin, and distribution of diseases within the district, and ascertain to what extent the same have depended on conditions capable of removal or mitigation.

" 3*d Duty.*—He shall, by inspection of the district, both systematically at certain periods, and at intervals as occasion may require, keep himself informed of the conditions injurious to health existing therein.

" 8*th Duty.*—In any case in which it may appear to him to be necessary or advisable, or in which he shall be so directed by the Sanitary Authority, he shall himself inspect and examine any animal, carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, or flour, exposed for sale, or deposited for the purpose of sale, or of preparation for sale, and intended for the food of man, which is deemed to be diseased, or unsound, or unwholesome, or unfit for the food of man; and if he finds that such animal or article is diseased, or unsound, or unwholesome, or unfit for the food of man, he shall give such directions as may be necessary for causing the same to be seized, taken, and carried away, in order to be dealt with by a justice, according to the provisions of the statutes applicable to the case."

The *First Duty* alone is comprehensive enough to include the consideration of each of the three subjects treated of in the following pages, and even more. As Medical Officers of Health are often at present inundated with analytical work by those who are simply curious as to whether their drinking water is or is not good, or as to the reason why it does not make good tea, or as to why their sugar turns their tea of a black colour, or as to whether their wall-papers contain arsenic, or as to why their brandy and water assumes sometimes an inky hue, it is a great protection to the Medical Officer of Health if he refers all applicants to the Sanitary Authority of the district for an order, with the previous understanding, arrived at with the Sanitary Authority, that it will not give him any instructions to analyze at the public expense, unless evidence is placed before it of a nature calculated to show that the substance respecting which the request is made has been or is likely to be deleterious to health, and that the applicant cannot afford to pay for the analysis out of his or her own pocket.

As all chemical examinations to be exact must be quantitative, and as all inaccurate examinations are of little worth, and as, moreover, the quantitative analysis of a substance is not laid down as one of the duties of a Medical Officer of Health by the Government, it follows as a matter of logical sequence, that all quantitative analytical work conducted for a Sanitary Authority and for the public should be paid for. Work performed gratuitously is rarely valued.

The progress of a knowledge of Preventive Medicine is exceedingly slow. The Medical Officer of Health, who is the schoolmaster of his district as to sanitary matters, must necessarily find his work of a very uphill character. He is continually regarded as an irreverent individual, who is wicked enough to interfere with the purposes and designs of the Almighty. Thousands are still to be found who believe that if a water is bright and clear, and not unpleasant to the taste, it must be good; whilst it has been proved, over and over again, that such a water may be polluted with unspeakable filth, and that an excessive brilliancy of a water is a suspicious sign.

There can be no question, however, but that the elements of sanitary science are slowly and surely influencing the people of this and of other countries for good. Such cases as that of the servant who, coming from an obscure village near the Dartmoor, objected to the pure water of a distant town where she was in service, on the ground of its being devoid of either taste or smell, are becoming rare.

# SECTION I

# SANITARY EXAMINATION

OF A

# DRINKING WATER

# CHAPTER I

## THE WHOLESOMENESS OF A WATER

PURE spring waters, devoid of all metallic impurities, are undoubtedly the most wholesome waters for drinking purposes. Pure shallow and artesian well waters occupy a second place. The saline waters furnished by some artesian wells, and the rain that descends in the country far away from towns and cities, occupy jointly a third position in order of merit; and lastly come the waters of streams and rivulets, the majority of which contain more or less filth, and in times of heavy rains, soil and mineral débris of every description. All will readily understand the reason that spring water should be placed first, and river water last in the order of wholesomeness, but the motive for assigning to highly saline artesian well water and rain water a situation inferior to both spring, shallow and deep well waters is perhaps not so obvious. Artesian well waters frequently contain an excess of saline matters (*vide* page 127). Rain water possesses an infinitesimal amount of saline substances, and is almost entirely devoid of lime—a substance which is so important in building up the bony tissues of young animals. I am aware that some few eminent men think that young creatures solely derive the lime which they require from their food[1] (*vide*, for example, the evidence

[1] One pound of flour contains only 1½ grain of lime, and that in a form which is associated with the more insoluble part of the grain.

of Dr. Lyon Playfair in the Sixth Report of the Rivers Pollution Commissioners, page 189). Those who entertain this view consider, I believe, that water simply acts as a diluent or solvent in nutrition. I have no room here to combat this opinion, but can simply give it as my own that the young animal supplies the wants of its system for lime from every available source. Many towns in England and Scotland are supplied by waters collected from the surface of uncultivated land in lakes and reservoirs. These "upland surface waters" are often insufficiently aerated, and contain an excess of peaty and other vegetable matter which renders them unpalatable, and sometimes gives them a slightly bitter taste. In consequence of their softness, however, they are very useful for domestic and manufacturing purposes.

It is almost impossible to define a wholesome water; but here are two examples of most wholesome spring waters:—

| Name and Description of the Sample of Water. | Grains per Gallon. | | | | Part per Million = Milligramme per Litre. | | Total Hardness. |
|---|---|---|---|---|---|---|---|
| | Solids. | Chlorine. | Oxygen absorbed. | Nitrogen as Nitrates and Nitrites. | Free Ammonia. | Albuminoid Ammonia. | Degrees. |
| Spring supplying village of Woodham Walter, Essex . | 21· | 2·4 | ·02 | nil. | ·00 | ·01 | 6 |
| Spring near Drewsteignton, Dartmoor, Devon . | 14· | 1·6 | ·03 | nil. | ·02 | ·01 | 8 |
| *N.B.*—No metals in either water. | | | | | | | |

It may be useful to give examples of the composition of good shallow well and good artesian well waters and pure rain water:—

| Name and Description of the Sample of water. | Grains per Gallon. | | | | Part per Million = Milligramme per Litre. | | Total Hardness. | |
|---|---|---|---|---|---|---|---|---|
| | Solids. | Chlorine. | Oxygen absorbed. | Nitrogen as Nitrates and Nitrites. | Free Ammonia. | Albuminoid Ammonia. | Degrees. | |
| Good shallow well water. Depth 25 feet . . . | 30· | 7· | ·01 | ·2 | ·01 | ·05 | 13 | Shallow well water. |
| Good Artesian well water. Depth 300 feet . . . | 85·4 | 27·1 | ·02 | nil. | ·74 | ·03 | 5 | Artesian well water. |
| Good Artesian well water. Depth 175 feet . . . | 106·4 | 37·7 | ·04 | nil. | ·07 | ·02 | 9½ | |
| Pure rain water collected in open country . . | 1· | ·6 | ·01 | nil. | ·45 | ·08 | 7 | Rain water. |



In forming an opinion as to the quality of a water for sanitary purposes, the old-fashioned plan of carefully estimating the number of grains per gallon of each saline constituent, often 8 or 10, and at times as many as 18 or 19 in number, is perfectly unnecessary. Of what importance is it to ascertain the exact fraction of a grain of silica or alumina which a water may contain, or whether it does or does not possess a trace of fluorine? It is of not the slightest practical moment as to whether our drinking water contains 3 or 6 grains of carbonate of lime per gallon, or whether 1 or 5 grains of chloride of sodium are dissolved in the same quantity, provided it is pure. In the case of mineral waters, and of waters proposed to be used for brewing and other commercial purposes, a detailed analysis, containing the exact amount of every salt, may sometimes be required.

Equally useless for all sanitary work is the estimation of the number in cubic inches of the nitrogen, oxygen, and carbonic acid gases evolved on boiling a water, and the determination of the temperature of a water.

In forming a judgment as to the character of a water, it is desirable for the Medical Officer of

Health to ascertain some or all of the following particulars :—

Data on which an opinion should be based.

(*a*) The amount and nature of the organic matter, whether animal or vegetable.

(*b*) The existence or not of the products of the oxidation of organic matter, such as the nitrates and nitrites, and in certain cases the quantity of these salts.

(*c*) The amount and nature of the saline constituents.

(*d*) The degree of hardness.

(*e*) The existence and the amount, if present, of metals.

(*f*) The existence and the amount of purgative salts, such as the sulphate and carbonate of magnesia, or the sulphates of soda and potash.

In the majority of cases that present themselves, information on the first two points is alone needed.

# CHAPTER II

## THE DETERMINATION OF THE AMOUNT AND NATURE OF THE ORGANIC MATTER

ALL waters, even the purest, contain some organic matter. The excess is alone objected to; and especially that of animal origin, which is especially prone to pass through certain putrefactive changes.

No process has as yet been discovered for estimating the absolute amount of organic matter present in a water. The best modes of analysis furnish us only with approximations, more or less correct, to the exact quantity.

A great variety of methods have been employed at different times by English and German chemists. Without adverting to the history of the subject, which would be foreign to the purpose of this little work, I shall describe those which have taken the lead and are now believed in and practised by medical officers of health and analysts in their attempts to pronounce on the quality of a water. The employment of these very dissimilar modes has led, unfortunately, to most contradictory results:—

Most popular tests and processes.

1. The odour of a water.
2. The "keeping powers" of a water.
3. The colour test.
4. Heisch's test.
5. The zymotic or microzyme test.
6. The oxygen or Forchammer permanganate of potash process.

7. The Wanklyn, Chapman, and Smith process.
8. The Frankland and Armstrong process.
9. Koch's biological method.
10. The estimation of dissolved oxygen.

## 1. The Smell of a Water.

The smell. The most rough-and-ready way that has been employed for ascertaining whether or not a water is polluted with organic matter is to partly fill a clean bottle with a sample of it, and, having violently shaken the same, to take a hearty sniff at the air of the bottle which has been agitated with the water. If the air smells sweet and fresh, the absence of an injurious amount of organic matter is inferred, and *vice versâ*. There is no doubt but that much may be learnt in this way by those who do not blunt their sense of smell by smoking, especially if they frequently practise this primitive test. It is very easy to distinguish thus between river and spring water; and a very impure water, which may exhibit no fault to the eye, may frequently disclose to the olfactory nerves the fact of its pollution. There is sometimes great difficulty in distinguishing between a water rendered offensive by decomposing starch in any form, *e.g.* rotten turnips, and one polluted by the presence of a dead animal, *e.g.* a rabbit, bird, or rat. If no smell is noticed in the manner described, some may be observed on gently warming the water; and if none then, the addition of a few grains of caustic potash may render it apparent. Prof. Ira Remsen states (Report on the Impurity of the Water Supply of Boston, U.S., 1881) that the best way of detecting the cucumber odour in any water but slightly affected, is to pass about a pint of it through a paper filter which will reveal it, although it may be quite impossible to discover it by warming the water. Mr. Crookes' device is as follows:—"Take two or three ounces of the water, the smell of which is to be tested, and warm it carefully and quickly in a flask to a temperature of about 102° or 104° F., say 4° or 6° above blood heat; then take a glass tube of about $\frac{3}{8}$ inch diameter and 3 feet long, put the flask containing the water on the floor, carefully suck up the water five or six times into this tube until the inside of the tube is thoroughly wetted with the water, then allow the water to escape, and closing one nostril with the finger, take two or three full inspirations through the tube with the other nostril." It should be borne in mind, however, that the existence of an unpleasant odour or taste about the water from a well sunk in clay is no proof of the pollution of that water with organic matter. Water, if allowed to remain long in contact with certain kinds of clay, in some situations, acquires such an objectionable smell as to be sometimes quite undrinkable, and yet may not, at the same time, contain an amount of organic matter that would warrant its condemnation. Complaints are made sometimes of this smell in the case of waters of artesian wells sunk through the clay, where the supply of water is much greater than the demand. A well of this kind can be made to furnish excellent water by the frequent withdrawal of its contents, or, if that is not practicable, and the well be an artesian one, by the filling up of the dug portion of the well and by drawing the supply solely from the bore-pipe. In this way the water is prevented from lying long in contact with the sides of the well. The clay contains in some situations little nodules of iron pyrites—*i.e.* sulphide of iron, and fossils of the same composition. They possess a peculiar odour, which they give forth, especially when wetted and rubbed. This odour seems to be in some cases communicated to the water, and reminds one of sulphurous acid, and occasionally of fennel. These offensive waters often contain such an enormous

"Brackish" water.

excess of chlorides and other saline matters as to be not potable; they are known by the public as "brackish" waters. Here is an example:—

| | Grains per Gallon. Solids. | Chlorine. |
|---|---|---|
| Well behind "Compasses," PH.WH . . | 380· | 29·5 |

"Rotten egg" waters.

Other waters from the clay have a decided smell of sulphuretted hydrogen gas, and become turbid on standing, in consequence of the separation of sulphur. Books tell us that sulphuretted hydrogen is generated from the decomposition of water and iron pyrites. Before this gas is produced, I think with Mr. Slater that a partial decomposition of sulphide of iron probably occurs with a formation by oxidation of sulphuric acid. This acid acts, then, on the remaining sulphide of iron, evolving sulphuretted hydrogen gas.

It has been considered probable by some that this gas arises from the decomposition of sulphates through the instrumentality of certain algæ.

Prof. Kubel states[1] that if water is warmed to 110° F., coal gas if present in a water may be detected by the sense of smell, when chemical means fail to do so.

The waters from wells in towns and villages sometimes contain carbolic acid and paraffin or benzoline which has soaked into the soil from leaky cesspools[2] or vessels.[3] The odour of carbolic acid is easily recognizable, but that of paraffin resembles, if it is in small quantity, gas, and the emanations from drains. The water from a well at Fryerning, Essex, described as extra pure was found by me to possess a suspicious smell of paraffin which disappeared on warming. The employment of Mr. Crookes' device did not increase its perceptibility. On allowing

[1] Anleitung zur Untersuchung von Wasser. Zweite Auflage von Dr. F. Tiemann: Braunschweig, 1874.

[2] *Fallacies of Empirical Standards in Water Analysis*, by Dr. Ashby.

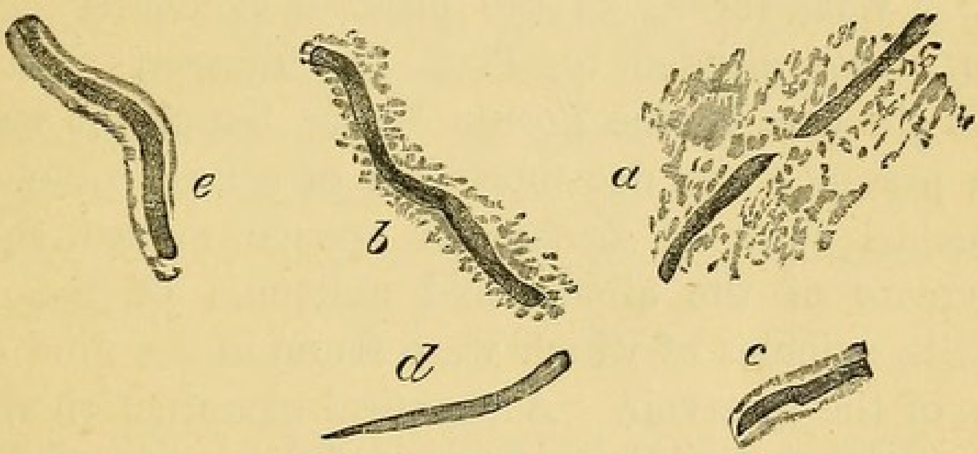
[3] *Vide* Dr. Gilbert Child's Report for 1874, on the Sanitary Condition of the Combined Districts in Oxfordshire.

the deposit to settle, it was found on microscopic examination to be separated here and there by wavy lines of an intensely black colour, surrounded by a brownish coating (of a resinous appearance) evidently produced by the solvent action of the water on the black matter.

**Fish-like odour.**

Peculiar odours and tastes have been observed in some of the lakes and rivers of the United States. The water supplies of New York, Boston, Baltimore, and many other cities, and the water of the Tennessee river near Nashville, have been at times thus unpleasantly affected.

FIG. 1.




*a, b.*—Black wavy lines amongst débris.
*c, e.*—Black wavy lines with brownish coating.
*d.*—Brownish matter apart from black lines.

Musty, fishy, piggery, horsepond-like, are adjectives which have been used to indicate the kind of odours complained of. The odour of green corn has also been noticed. The taste of cucumbers, oily and fishy tastes, have also been described. These peculiarities of odour have been found to be associated with the rapid multiplication and decomposition during the autumnal seasons of the year of certain algæ, notably the *Cœlosphœrium Kuetzingianum*, the *Anabœna flos-aquœ, var. circinalis,* and the *Clathrocystis œruginosa.* Prof. W. G. Farlow divides[1] the fresh-water algæ into two groups: those which are grass-green or yellowish green, and those which are bluish green or

[1] Paper on "Some Impurities of Drinking Water."

purplish, the colour being due to a mixture of chlorophyl, the green (soluble in alcohol), and phycocyanin, the bluish (soluble in water) colouring matters. Whilst the former group is quite harmless, to the presence and decay of the latter are ascribed some of the most disagreeable odours and tastes found in drinking-water. The innocuous grass-green species belong to three different orders, the Zoösporeæ, the Ædogonicæ, and the Conjugateæ, whilst the bluish green algæ are placed by botanists in the order Phycochromaceæ, a sub-order of which forms the family of the Nostocs—a name which has been applied to the whole

'ucumber dour.

group.[1] With regard to the peculiar cucumber taste of waters above alluded to, Prof. Ira Remsen discovered that, in the case of the Boston Water Supply, it was due to the presence and decomposition of a large quantity of a branched form of freshwater sponge named Spongia an increase of the albumenoid ammonia of the water fluviatilis, spicules of which were found in the mud at the bottom of the reservoir. A chemical examination showed during the period of the existence of the unpleasant taste. With respect to the question as to whether these minute algæ give an unwholesome character to water, the Massachusetts State Board of Health, as the result of an investigation, concludes (and Prof. Ripley Nichols agrees with it[2]) that the evidence "tends to show that the plant acts mechanically, chiefly perhaps like unripe fruit, when affecting the health at all, in causing diarrhœa; but that the filtered water is harmless." A case is recorded, however, in *Nature*, xviii. (1878), page 11, where

[1] These unpleasant odours are not confined to certain American waters, for complaints were made some years ago of the fish-like odour of the water supplied to Amsterdam from the "Duins" (sandhills) in the neighbourhood of Haarlem. The deposit of this water was found on microscopic examination by H. Medlock (*Philosophical Magazine*, January 1858) to consist of the filaments of dead and decaying algæ, etc.

[2] *Water Supply—Chemical and Sanitary.*

cattle had been poisoned by drinking pond water containing large quantities of a species of Nodularia—a plant which resembles the Anabœna. No remedy to obviate the recurrence of these annoying odours and tastes in public water supplies has been proposed beyond: (1) the clearance of weeds and substances in which the Nostocs may lodge; (2) the prevention of a rapid fall in the level of the water in hot weather, and of the passage of steam or hot water into streams which feed reservoirs; and (3) the substitution of gravelly for muddy bottoms. Large and deep bodies of water would seem to be less likely to be affected than small dirty and shallow reservoirs. As the branched form of the Spongia fluviatilis is reputed to be the favourite food of swans, it would be well to introduce these birds during the autumn months, when cucumber flavour begins to be noticed, to some of the affected lakes.

## 2. The "Keeping Powers" of a Water.

The rapid development of animal and vegetable life is as a rule a sure indication of the presence of organic matter in a state of decomposition. The property possessed by a water of "keeping" for a greater or less length of time, without undergoing any change perceptible to the unaided eye, has been employed as a gauge of the purity of a water. That a pure water can be preserved unchanged for a considerable time, and that an impure water will soon become altered in appearance, are undoubted facts. It is equally true, however, that some waters of the greatest purity will, very soon after removal from their sources, be found to display vegetable life; for example, some artesian waters, that possess a large amount of free ammonia. The temperature of the air has, of course, much to do with the "keeping powers" of

"Keeping Powers" of a water.

a water; life and growth being more active in hot than in cold weather.

### 3. The Colour Test.

The colour of a water.

It is helpful in forming an opinion as to the quality of a water to pay a certain regard to its colour, although, apart from other indications of its condition, no *reliance* should be placed on this test. Speaking generally, it may be said that waters of great purity exhibit a bluish hue, that waters polluted by filth have various shades of a straw or brownish tint, deeper in proportion to the amount which they contain, whilst peaty waters generally display a nutty-brown colour. To this rule there are many exceptions. A water may possess a strong brown or yellowish tint and yet be free from filth—*e.g.* some peaty waters, and waters containing iron.[1] Certain artesian waters of great purity have a straw tint. The Loch Katrine water, which supplies the city of Glasgow, displays a colour apparent to every one. On the other hand, some waters that are as devoid of colour as distilled water, and exhibit a greater brilliancy, are found to be polluted with a large amount of animal filth. A water may be almost colourless and yet exhibit on analysis much vegetable matter, *e.g.* the water supply of Bournemouth. A water may be colourless and still contain peat, for white peat is occasionally met with, which is a form of incompletely carbonized vegetable matter. Practically, however, peaty waters present various shades of a brownish olive-green colour, passing, if the peaty matter is in larger

[1] The iron existing in certain waters in a soluble form becomes often oxidized and changed into an insoluble hydrated sesquioxide on exposure to the air. Such algæ as depend for their growth on the presence of a soluble iron salt are sometimes found in such waters, especially the Crenothrix Kühniana. The water supplies of Berlin, Halle, Leipsic, Lille, and Ingatestone, have been injured in this way.—Vide *Water Supply, Chemical and Sanitary*, by Prof. Ripley Nichols.

quantity, through a nutty-brown to a coffee colour, when the peat is old and abundant. The following general conclusions as to the teaching of the *two-foot tube* (to be presently described) respecting peaty waters have been published by Dr. Tidy[1]:—

1. Peat producing a colour short of an olive-green tint, invisible in a quart decanter, is less than ·1 grain per gallon.

2. Peat affording a colour short of a brown tint, invisible in a quart decanter, varies from ·1–·2 grain per gallon.

3. Peat furnishing a colour more or less brown, perceptible in a quart decanter, varies from ·2–.5 grain per gallon.

4. Peat yielding a porter colour is present in about 1 grain per gallon.

5. Peat giving a black colour is present in about 2 grains per gallon.

Waters from different sources are often proposed for the supply of a town or village with the object of selecting that one which is in all respects the best. If, on analysis, two or three of the collection should appear to be equally good, the one possessing the least colour should be preferred.

It has been proposed to measure definitely the colour of water in two or three ways. Mr. Crookes, Drs. Odling and Tidy employ[2] two hollow wedges, one filled with a brown solution (made by dissolving ferric chloride and cobalt chloride in distilled water, in such proportions that one litre contains ·7 gramme of metallic iron, and ·3 gramme of metallic cobalt with a very slight excess of free hydrochloric acid), and the other with a blue

[1] "River Water," in *Journal of Chemical Society*, vol. xxxvii. 1880.

[2] Report on the Comp. and Quality of the Water supplied to London, No. III. 1881.

solution (made by dissolving 10 grammes of pure crystallized sulphate of copper in one litre of distilled water). These wedges are made to slide across each other in front of a circular aperture in a sheet of metal, so permitting the production of any desired combination of brown and blue. Each prism is graduated along its length from 1 to 40, the figures representing millimètres in thickness of the solution at that particular part of the prism. On a level just below the prisms is a two-foot tube containing the water under examination, and having in front of it a circular aperture of the same size as that in front of the prisms. The stand supporting the prisms and tube is placed horizontally before the window. The observer compares the two disks of light presented by the apertures, and adjusts the prisms until the colours of the two exactly correspond. A metal pointer affixed over the centre of the upper disk, shows on the prism scales the number of millimètres in thickness through which the light has passed to produce a colour which corresponds exactly with that of the water. The results are recorded in the following way: thus, "February 21 (New River Co. Water) 20 : 21," an entry which means that on that day the colour of this water, seen through a two-foot tube, was represented by 20 mm. of brown, superimposed on 21 mm. of blue solution.

r. F. King's ode of easurement.

The method pursued by Mr. F. King, Analyst, of Edinburgh[1] is the simplest, and in my hands has proved very satisfactory. It consists in passing a standard aqueous solution of caramel into distilled water in sufficient quantity to match the tint of the water under examination. The preparation of the standard is somewhat troublesome, but when once made, it will remain unchanged for a considerable time.

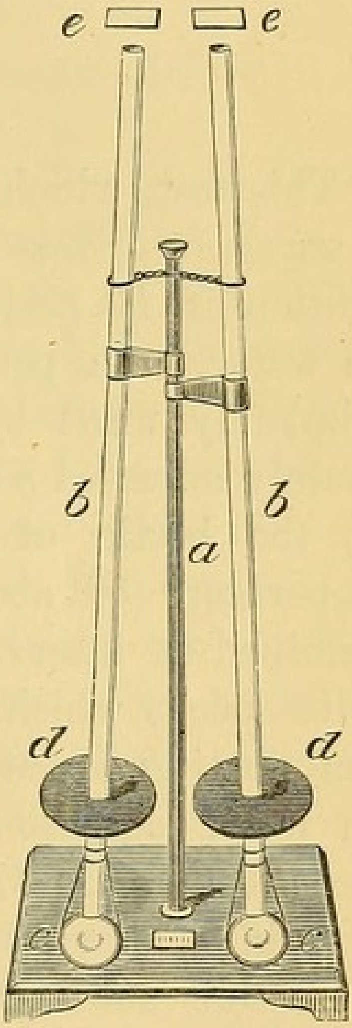
A solution of ammonium chloride 3·17 grains in

[1] *Chemical News*, March 25, 1875.

10,000 grains of distilled water (·0001 grains of ammonia in 1 grain of solution) is first made; 10 grains by volume of this solution is poured into 8 oz. of ammonia-free distilled water contained in a glass tube 12 inches high, and 25 grains by volume of Nessler's solution are added. This ammonia solution, after resting for ten minutes at a temperature of 60° F., assumes a distinct yellowish brown tint. To 8 oz. of distilled water placed in another glass tube 12 inches high, add sufficient of a strong aqueous solution of caramel to match the tint of the ammonia solution. Some of the caramel standard thus formed is placed in a burette graduated into grains. A pair of two-foot tubes, exactly similar, and at least $\frac{3}{4}$ inch in diameter, sealed up at their lower extremities, provided with reflecting mirrors, and at such a distance from each other that both eyes can easily look down their whole length simultaneously, are now brought into requisition.

Colorimeter.

FIG. 2.




*a.*—Brass upright.
*bb.*—Glass tubes 2 feet in length.
*cc.*—Small looking-glasses.
*dd.*—Vulcanite rings.
*ee.*—Thin glass squares.

One tube is filled with the water under examination, and the other tube is nearly filled with distilled water. Sufficient of the standard caramel solution is dropped from the burette into the distilled water to match the tint of the water under examination, when the tube is filled to the summit. A piece of thin glass, about an inch square, covers the overflowing end of each tube, and a comparison between the two tubes verifies the accuracy of the imitation. The quantity of the caramel standard solution employed is read off, for every 10 grains corresponds with one degree of the colour scale.

The kind of colour and its depth are data which should always be obtained, for the colour gives an indication of the kind of organic matter present, and its depth is a guide as to the amount.

### 4. Heisch's Test.

This test, which is believed to indicate the presence of germs or spores of the sewage fungus, consists in the addition of 10 grains of the purest sugar to 5 ounces of the water, in a perfectly clean bottle, which should be completely filled by it. The stopper having been accurately adjusted so as to throughly exclude atmospheric air, the bottle of water is exposed to daylight at a temperature of about 70° F. The bottle should be examined at intervals of three hours for minute floating white specks which, if the water contains sewage, may be seen floating about, provided we look carefully through the water against a black cloth suspended behind it. These bodies are found to consist, when examined by $\frac{1}{4}$ or $\frac{1}{8}$ inch objective, of cells with very brilliant nuclei. These cells subsequently group themselves like grapes in a bunch. Ultimately the odour of butyric acid becomes perceptible. Dr. Frankland found that growths were producible in pure water containing in solution nitrate of ammonia, phosphate of soda and sugar, and came to the conclusion that the presence of phosphates in a water is solely needful to occasion this phenomenon. Mr. Heisch contends that the growths considered by him as distinctive of the existence of sewage differ altogether from those seen by Dr. Frankland as resulting from the presence of phosphates. He holds that the bodies due to sewage are developed without the presence of air (he had indeed first observed them in a liquid saturated with carbonic acid); whilst those noticed by Dr. Frankland in waters containing phosphates will not form if air is excluded, and are then always accompanied by bacteria, and are not attended by the formation of butyric acid.

### 5. The Zymotic or Microzyme Test.

The water to be operated on is collected by heating the tube or flask intended for its transportation to a high temperature, and hermetically sealing it. The neck thus sealed is broken underneath the surface of the water of which a sample is to be taken. Some of Pasteur's solution [1] (clear and fresh) having been boiled, one or two cubic centimetres of it are dropped into a test tube that has been heated to 395° F. Four or five drops of the water to be examined are then added, and the mouth of the tube is plugged with cotton wool. The amount of impurity in a water is estimated by the degree of opacity occasioned by the quantity of bacteria and the greater or less rapidity with which this degree is reached. Micro-organisms are found in the purest waters in an infinitesimal amount. Their presence in any quantity indicates the co-existence of certain organic substances in a state of decomposition.

Unfortunately no unchangeable line or basis, on which comparative examinations of waters could rest, is discernible in this or in the last described methods.

[1] Recipe—Crystallized sugar, 10 grammes; ammonium tartrate, ·5 gramme; yeast ash (well burnt), ·1 gramme; distilled water, 100 cub. cent.

## 6. The Oxygen or Forchammer Permanganate of Potash Process.

### A. *Qualitative Examination.*

In the year 1850, Prof. G. Forchammer of Copenhagen proposed [1] to employ a solution of permanganate of potash for determining the amount of organic matter in water. Permanganate of potash readily yields oxygen to many substances capable of combining with this element, of which organic matter is one amongst several others, such as iron, nitrites, and sulphuretted hydrogen, that are liable to occur in drinking waters. This chemical change is accompanied by the substitution of a brownish colour for the characteristic violet-tint of the solution. It has proved, as a qualitative test for organic matter, most fallacious in its indications.

### B. *Quantitative Examination.*

Some scientific men, such as Dr. W. A. Miller, Mr. V. Harcourt,[2] and Dr. Woods, have applied it in a quantitative manner for the analysis of water with better success. Solutions so different in strength [3] are used,

[1] *Trans. Royal Danish Socy.*, 5th series, Physical and Mathem. Section, vol. ii.

[2] "Observations on some Points in the Analysis of Potable Waters," in *Journal of Chemical Society*, May 1865, Sec. II. vol. iii. p. 117.

[3] *Variable results obtained by employing Solutions of Permanganate of Potash differing in strength.*

| | 1 gr. in 2520 minims—strength employed by Drs. M., H., and W. | 1 gr. in 3840 minims—strength employed by Dr. Tidy. |
|---|---|---|
| | *Gr. of Oxygen per gallon.* | *Gr. of Oxygen per gallon.* |
| Water from well—Typhoid Outbreak. | ·176 | ·156 |
| Water from Ilfracombe. | ·032 | ·130 |
| Water from private well at Great Baddow, Essex. | ·080 | ·100 |

and there are such diverse ways of employing them, that it is difficult, and in some cases impossible, to institute any comparison between the results arrived at. Some add an acid, *e.g.* sulphuric acid, and others add an alkali, *e.g.* milk of lime, to the water before treating it, with the permanganate solution. Some conduct the process at the temperature of 140° F., and others at the temperature of the air. Some allow the permanganate to act for a few minutes, and others for hours. Some who employ this test prepare a solution by dissolving two grains of the pure salt in $10\frac{1}{2}$ oz. of distilled water. Ten minims of this solution is said to yield $\frac{1}{1000}$ of a grain of oxygen. The quantity of the solution required for a known quantity of the water is divided by 10, the result giving the number of thousandths of a grain of oxygen consumed. The calculation is as follows:—

Well water labelled A B, 2 ounces $= \frac{1}{80}$ of 70,000 grains (1 gallon) taken for examination.

22 minims of Sol. Permanganate Potash required to give a decided pink colour.

$22 \times 80 = 1760$ minims necessary for 1 gallon.

$1760 \div 10 = 176$ which are thousandths of a grain of oxygen.

*Result.*—·176 of a grain of oxygen per gallon.

The three best known quantitative processes are:—(1) that for many years practised by the late Dr. Letheby, and now employed by Dr. Tidy; (2) that adopted by Drs. Woods and F. de Chaumont; and (3) Prof. Kubel's variety of the permanganate of potash process. The first mentioned is preferable to either of the others; the second is employed much by army surgeons, being taught at Netley; whilst the third, which is conducted at the boiling point, is open to the suspicion that loss of organic matter by volatilization with the escaping steam is inevitable. The higher figures yielded by Kubel's method are probably due to the increased length of time during which the permanganate of potash is allowed to act.

### *Drs. Letheby and Tidy's Permanganate of Potash Quantitative Process of Water Analysis.*[1]

The following mode of employing the Forchammer or oxygen process has been almost exclusively practised by Dr. Letheby and his successor.

Before commencing the analysis the following solutions should be ready:—

1. *Dilute Sulphuric Acid.*—1 part of pure strong sulphuric acid with 3 parts of distilled water.

2. *Solution of Potassic Permanganate.*—2 grains in 1000 septems ($\frac{1}{10}$th of a gallon) of water. (20 septems or ·04 grain of potassic permanganate, contain ·01 of available oxygen.)

3. *Solution Potassic Iodide.*—1 part of potassic iodide in 10 of water.

4. *Solution of Sodic Hyposulphite.*— 5·4 grains in 1000 septems ($\frac{1}{10}$th of a gallon) of water. As a solution of this salt quickly decomposes, it is necessary to make a fresh one very frequently.

5. *Solution of Starch.*—100 septems of distilled water to be placed in a flask, and 10 grains of powdered starch having been added, the mixture should be boiled and filtered.

Two glass flasks, each of about 20 oz. capacity, having

[1] I am indebted in the description of this process which follows, to an exhaustive paper entitled "The Processes for determining the Organic Purity of Potable Waters," by Dr. Tidy, in *Journal of Chemical Society*, vol. xxxv. 1879, p. 46. It contains an account of a mode of conducting the process which is an improvement on that shown to me some time previous to its publication, in Dr. Tidy's laboratory, by his assistant in his absence.

been thoroughly cleansed, 500 septems ($\frac{1}{20}$th part of a gallon) of distilled water are poured into each. Take two other flasks of the same dimensions, and pour the same quantity of the water to be examined into each. Label each flask thus:—

| | | |
|---|---|---|
| 1. | Distilled water . . . . | (1 hour.) |
| | " " . . . . | (3 hours.) |
| 2. | Water under examination . | (1 hour.) |
| | " " " . | (3 hours.) |

Any number of waters can be commenced at the same time, one set of the distilled water series being sufficient as a blank experiment for all.

(*a*) 20 septems of the dilute sulphuric acid should be added by the help of a pipette, graduated into septems, to the contents of each of the four flasks.

(*b*) 20 septems of the permanganate of potash solution should then be run, by the aid of another similar pipette, into each of the four flasks. Note the exact time of this addition of the solution of potash permanganate, and place the four flasks in a dark cupboard. If the pink colour produced in the water under examination disappears within the prescribed time of 1 hour or 3 hours, which rarely happens, a second, and if needful, a third or even fourth dose of 20 septems should be added, until the colour is permanent. The change on adding permanganate of potash may be thus represented:—

$$Mn_2O_8K_2 + 3H_2SO_4 = 2MnSO_4 + K_2SO_4 + 3H_2O + 5O.$$

The oxygen consumed by the constituents of the water is to be estimated *at the end of* 1 *hour* in one of the flasks containing the water under examination, and in one of the distilled water flasks; and *at the end of* 3 *hours* in the other flask containing the water under examination, and the other distilled water flask.

At the expiration of the hour, it is first necessary, in consequence of the changes to which the solution of the sodic hyposulphite is subject, to ascertain its exact value by means of a blank experiment with the contents of the "distilled water flask (1 hour)."

It is thus effected :—Add 2 drops of the potassic iodide solution to the "distilled water (1 hour)," when the colour of a very weak solution of iodine is produced, which substance is in fact liberated from the potassic iodide, *the quantity set free being dependent on the amount of potash permanganate remaining in the water undecomposed*—

$$MN_2O_8K_2 + 10KI + 8H_2SO_4 = 2MnSO_4 + 6K_2SO_4 + 8H_2O + 5I_2.$$

The quantity of iodine liberated is thus determined. The sodic hyposulphite solution is placed in a burette graduated into 100 septems. Run it septem by septem into the flask labelled "distilled water (1 hour)," until the yellow colour of the iodine very nearly disappears. Then add a few drops of the starch solution, when a beautiful blue colour is produced from the formation of the iodide of starch, and resume the dropping of the hyposulphite solution into the flask until the exact spot is reached, when the blue colour disappears. That the exact mark has not been overshot must be proved by the addition of a drop of the solution of the permanganate of potash, which immediately restores the blue colour. A similar return of colour is observed after the flask has been standing exposed to the air for a few minutes. Read off the amount of hyposulphite used.

Reaction of the hyposulphite solution on the free iodine—

$$2S_2Na_2O_3 + I_2 = 2NaI + Na_2S_4O_6.$$

Immediately refill the burette with the sodic hyposulphite solution thus standardized and examine the contents of flask labelled "Water under examination (1 hour)," in precisely the same manner noting the amount of sodic hyposulphite solution employed. At the end of 3 hours the contents of flasks labelled "Distilled water (3 hours)" and "Water under examination (3 hours)," should be examined in the same way.[1]

*Experiment.*—Suppose the usual amount of 20 septems of solution permanganate potash has been added in each case.

*At the end of 1 hour.*

| | |
|---|---|
| Septems of sodic hyposulphite solution required to combine with the free I in the distilled water . . | 50 |
| Septems of sodic hyposulphite solution required to combine with the free I in the water under examination . . . . . . . . . | 40 |

*At the end of 3 hours.*

| | |
|---|---|
| Septems of sodic hyposulphite solution required to combine with the free I in the distilled water . . | 50 |
| Septems of sodic hyposulphite solution required to combine with the free I in water under examination . | 30 |

In each case 50 septems of the sodic hyposulphite solution were employed in the blank experiment with

[1] Prof. Mallet of the University of Virginia has suggested in his Report on the Results of a Supplementary Investigation, made by the direction of the National Board of Health, the three following improvements in this process :—"(1) The time during which the permanganate of potash is allowed to act should be increased to at least 12, better 24 hours, *several* determinations (on different samples set aside at the same time) being made at such intermediate intervals as 1, 3, 6, 9, and 12 hours, in order to trace the progress of the oxidation ; (2) Instead of using a fixed amount of permanganate of potash at first, and adding a second or third charge only when the former has been completely reduced, there should be present a constant excess all through the process ; (3) It is desirable that the process be carried on at a pretty nearly fixed temperature of, say 38° F." (For experiments on the varying extent of action of permanganate upon organic matter in water at different temperatures, vide *Bericht d'Deutsch, Chem. Gesellsch.*, 14, 1015.)

distilled water, and this amount is equivalent to ·01 of oxygen.

*At the end of 1 hour.*

40 septems of the sodic hyposulphite solution being used in the water under examination, the quantity of oxygen consumed may be thus found :—

| | Septems of Sodic Hypo. Sol. required by distilled water. | | Septems of Sodic Hypo. Sol. required by water under examination. | | Oxygen. |
|---|---|---|---|---|---|
| (A) | 50 | : | 40 | : : | ·01 |

$$\begin{array}{r} 40 \\ \cdot 01 \\ \hline 50 \,)\, \cdot 400 \,(\, \cdot 008 \\ 400 \end{array}$$

| | Oxygen equivalent to 50 septems. | | Oxygen equivalent to 40 septems. | | |
|---|---|---|---|---|---|
| (B) | ·01 | – | ·008 | = | ·002 the |

quantity of oxygen required to oxidize the organic and other matters in 500 septems of water.

(C) $\cdot 002 \times 20 = \cdot 04$ oxygen required to oxidize organic matters, etc., in 10,000 septems or 1 gallon of water.

In exactly the same manner the oxygen consumed *after* 3 *hours* may be calculated. The calculation may be simplified thus :—

Let X = number of septems of the solution sodic hyposulphite used in the distilled water.

Let Y = number of septems used in water examined.

If 20 septems of the solution of potash permanganate have been employed—

$$\frac{X - Y \times \cdot 20}{X} = \text{Oxygen required to oxidize organic matter in 1}$$

gallon of water.

If 40 septems have been necessary—

$$\frac{X \times 2 - Y \times \cdot 20}{X} = \text{Oxygen required by 1 gallon.}$$

If 60 septems have been added—

$$\frac{X \times 3 - Y \times \cdot 20}{X} = \text{Oxygen required.}$$

Drs. Frankland and Tidy have suggested[1] the following Scale of Classification :— Rules.

| UPLAND SURFACE WATER. | WATER OTHER THAN UPLAND SURFACE. |
|---|---|
| CLASS 1. *Great organic purity.* Water absorbing from permanganate of potash not more than ·07 grain of oxygen per gallon. | Not more than ·035 grain per gallon. |
| CLASS 2. *Medium purity.* From ·07 to ·21 grain per gallon. | From ·035 to ·1 grain per gallon. |
| CLASS 3. *Doubtful purity.* Absorbing from ·21 to ·28 grain per gallon. | From ·1 to ·15 grain per gallon. |
| CLASS 4. *Impure.* Absorbing more than ·28 grain per gallon. | More than ·15 grain per gallon. |

Dr. Tidy evidently leans to the opinion that the putrescent easily oxidized animal organic matters are oxidized within the first hour, whilst the oxidation of vegetable organic matter does not begin until after the second hour. Prof. Mallet and his assistants, however, found that the proportionate consumption of oxygen within *the first hour* is rather greater for those waters containing vegetable than for those containing animal matter. My own experience shows that those matters which are in an actively putrescent condition, be they vegetable (*e.g.* decomposing starch), or be they animal, are more rapidly acted on by the permanganate of potash than those which are in a comparatively fresh state.

### *Drs. Woods' and F. de Chaumont's Permanganate of Potash Process.*

1. Introduce into a flask 250 c. c. of the water to be examined, and add to it about 5 c. c. of dilute sulphuric Estimation of total oxidizable matter.

[1] Dr. Frankland on *Water Analysis for Sanitary Purposes.*

acid (1 part of the strong pure acid to 10 parts of distilled water). Drop into the acidified water a solution of the permanganate of potash (·395 gramme of the salt dissolved in one litre of distilled water: 1 c. c. yields ·1 of a milligramme of oxygen in presence of acid) sufficient to make the water pink; then warm this pink mixture up to 140° F., taking care to add more permanganate of potash solution should the colour disappear during heating. When this temperature is reached, take away the lamp, and continue adding the permanganate of potash solution, until a pink colour is established that is permanent for ten minutes. Note the number of cub. cents. of permanganate of potash solution employed, and record them as required for *total oxidizable matter.*

Estimation of oxidizable organic matter only.

2. Take another 250 c. c. of the same water, and add to it 5 c. c. of dilute sulphuric acid. Boil the acidified water for twenty minutes. Allow it to cool down to 140° F., and then test with permanganate of potash solution as before. Record the amount used as required for *oxidizable organic matter only.*

Estimation of nitrous acid.

3. The difference between the amount of permanganate of potash solution needed in the first and second operations represents the quantity required for *nitrous acid* only.

## Examples.

### *Total Oxidizable Matter.*

250 c. c. or $\frac{1}{4}$ litre of sample of water employed.

No. 1.—4·2 c. c. of permanganate of potash solution required:—$4·2 \times 4 = 16·8$ c. c. per litre.

$16·8 \times ·0001$ (co-efficient for oxygen) $= ·00168$ or 1·68 milligramme of oxygen for *total oxidizable matter.*

### *Oxidizable Organic Matter.*

250 c. c. or $\frac{1}{4}$ litre of sample of water employed.

No. 2.—3·6 c. c. of permanganate of potash solution required:—3·6 × 4 = 14·4 c. c. per litre.

14·4 × ·0001 (co-efficient for oxygen) = ·00144 or 1·44 milligramme of oxygen for the *oxidizable organic matter.*

*Nitrous Acid.*

No. 3.—The difference between the amount of total oxidizable matter (1·68 milligramme per litre) and that of the organic oxygen (1·44 milligramme per litre) is ·24 milligramme per litre of oxygen.

·24 × 2·875 (co-efficient to convert oxygen into nitrous acid) = ·69 milligramme of nitrous acid per litre.

| Total Oxygen. | Organic Oxygen. | Nitrous Acid |
|---|---|---|
| Milligramme per Litre. | | |
| 1·68. | 1·44. | ·69. |

The permanent pink colour established by adding the permanganate of potash solution to the sample of water must be the lightest tint distinctly visible. As about ·6 c. c. of the solution will give a red or pink colour to a litre of *pure* water, a correction for colour must be made when great accuracy is required. This correction would amount to ·06 of a milligramme of oxygen in both the total and the organic oxygen. Dr. Woods' investigations, on which this process is based, may be found in the *Journal of the Chemical Society* for 1861. In 1868-69, Dr. F. de Chaumont made other observations which improved this process, by showing:—(1) that when water polluted with sewage was boiled with acid, no change in its behaviour with permanganate of potash was produced; (2) that if the organic matter in it was mingled with nitrites, all of the nitrous acid contained in them could be boiled away in twenty minutes without material loss in the operation; and (3) that the reaction of the mixture equalled the sum of the reactions of the two estimated separately.

It has been found that the action of permanganate of potash is slow and imperfect in the cold, when each equivalent only gives off three instead of five atoms of oxygen, but that the organic matter is acted on rapidly when the temperature is raised. Dr. F. de Chaumont, unlike Drs. Letheby and Tidy, does not give any opinion respecting the amount of organic matter in a water. He neither declares that it is eight or nine (as Dr. Tidy asserts) nor twenty times (as Dr. Woods stated) the amount of oxygen of which the permanganate of potash is robbed, as the proportion is no doubt variable; for the organic matter may be of different kinds originally, or in different stages of oxidation. He simply and solely furnishes the amount of oxygen used up by the organic matter. The correction necessary in consequence of the action of permanganate of potash on iron is but seldom made in practice, on account of the infrequent (?) occurence of this metal in drinking water. When, however, this correction is made, the iron is separated by careful concentration, and the employment of the colorimetric test with ferrocyanide of potassium.

Hydrogen sulphide, which affects the permanganate of potash, can easily be detected by smelling the water after violent agitation of it. This gas should be expelled by gently warming the water before the analysis is commenced.

The pure artesian waters derived from the Thanet and Woolwich sandbeds, which contain a large excess of free ammonia (*vide* page 92), yield a great amount of total oxidizable matter when examined by this process, and but little organic oxygen. The difference cannot be ascribed to nitrous acid, for these waters are almost destitute of such. This acid may, however, be produced as the result of the reducing action of ammonia on the permanganate of potash.

*Rules.*—1. A *good* water contains of organic oxygen less than 1·0 milligramme per litre (= ·07 gr. per gallon). Rules for guidance.

2. A *usable* water contains of organic oxygen more than 1·0 milligramme per litre, and less than 1·5 milligramme per litre (= ·10 gr. per gallon).

3. A *suspicious* water contains of organic oxygen more than 1·5 and less than 2·0 milligrammes per litre (= ·14 gr. per gallon).

4. A *bad* water contains of organic oxygen more than 2·0 milligrammes per litre (= ·14 gr. per gallon).

5. Nitrites ought to be *absent* from *good* and *usable* waters; their presence makes waters *suspicious*, and if in *marked quantity* a water should be pronounced to be *bad*.

### *The Objections to the Oxygen or Forchammer Permanganate of Potash Test.*

Applied quantitatively, by either of the two last methods, may be thus summarized:—

1. Permanganate of potash readily oxidizes salts of iron, nitrites, and hydrogen sulphide, which are not uncommonly found in drinking water. If there is any suspicion afforded by the taste, or by a rusty deposit, of the presence of iron, the water should be subjected to one of the methods for its detection described on page 157. Objections.

The detection and estimation of nitrites or nitrous acid is a very easy matter (*vide* page 106). If the presence of sulphuretted hydrogen is recognized by the sense of smell (*vide* page 14, on the odour of waters) this gas can be altogether expelled by warming the water before it is analyzed.

2. It affects but slightly urea, kreatin, sugar, and gelatine, and does not act on fatty matters. Nor does it furnish the total amount of oxidizable matter present in a water. Notwithstanding these defects the perman-

ganate of potash test employed quantitatively is a useful auxiliary to the other methods of water analysis.

*An Improved Quantitative Oxygen or Forchammer Permanganate of Potash Process.*

Dr. Dupré and the Society of Analysts have recommended (1) that stoppered bottles be employed instead of flasks, otherwise the test becomes useless in a water containing appreciable quantities of chlorides. Dr. Dupré has pointed out [1] that "the test fails in an open vessel on account of the mutual action of permanganate of potash and hydrochloric acid, whereby the former becomes reduced and the latter oxidized into water and chlorine, part of which escapes. When, however, the experiment is carried on in a closed vessel, the chlorine is retained in solution, and when at the end of the experiment iodide of potassium is added, this free chlorine liberates exactly the same amount of iodine as would have been liberated by the permanganate from which it was produced, and the effect is the same as if no permanganate had been destroyed by the presence of chlorides." (2) That the water to be examined should be raised to a temperature of 80° F., by the immersion of the bottle in a water bath or suitable air bath, before the addition of the sulphuric solution and standard potash permanganate. As more oxygen is absorbed at that temperature than at lower temperatures in all but the purest waters, the water should be maintained at that temperature for 4 hours. If, in the course of the 4 hours, the pink colour of the water in the bottle is either discharged or even materially reduced, another dose of standard permanganate must be added, as the water must be always kept strongly tinted.

The bottle should be in the dark during the period

[1] *Analyst*, July 1885, p. 118.

when the water is under the influence of the permanganate of potash. The 1 hour observation practised by Dr. Tidy, and the $\frac{1}{4}$ hour observation by the Society of Analysts, are not of much value, for the information afforded by these brief exposures which is arrived at in other and better ways, does not compensate the operator for the additional labour.

7. THE WANKLYN, CHAPMAN, AND SMITH PROCESS,

consists in the estimation, by means of Nessler's test, of the amount of ammonia present in a water before and after it is distilled with a solution of permanganate of potash and a large excess of caustic potash—a mixture which possesses the property of converting organic matter into ammonia. Nessler's test, named after its discoverer, is an alkaline solution of the iodide of mercury (*vide* recipe on page 216), and is capable of detecting 1 part of ammonia in 20,000,000 parts of water. The addition of Nessler test to the distillate of a water containing ammonia is attended by the production of a yellowish brown or amber tint, similar to that of sherry, due to the formation of the iodide of tetramercurammonium, the depth of which is measured, as it varies according to the amount of ammonia present. Some consider that it is only sufficient to add a small quantity of the Nessler test to the water to be examined for organic matter, and that the depth of the brownish tint produced exhibits the amount of organic impurity. The Nessler test is simply a test for ammonia, and is not a test for organic matter until that organic matter has been converted into ammonia, by boiling it with permanganate of potash and a large excess of caustic potash.

Distillation of the water to be examined for ammonia adds to the delicacy of the process, for ammonia admits of concentration, and minute quantities are more visible in a small quantity of water than in double the amount.

Distillation, moreover, by the separation of the salts in a water, such as magnesium chloride, etc., prevents the milkiness often created on the addition of the Nessler re-agent, which interferes materially with, if it does not altogether prevent, a correct estimation of the quantity of ammonia contained in a water. I cannot too strenuously urge on analysts the importance of the relation between the free ammonia in a water and that developed by the caustic and permanganate of potash solution, for on it is mainly based the indication as to the *kind* of organic matter contained in a water. The manner in which the ammonia distils over is a matter also of importance. Both of these subjects will more properly be discussed in the chapter entitled, "The Formation of an Opinion, and Preparation of Report," page 188. Before describing this process it will be useful to direct attention to the apparatus, chemicals, and solutions required (*vide* pages 43, 216, and 548). It is very important that the greatest cleanliness should be secured in the following chemical operations. The distilled water employed for the final washings of the glass vessels, and for all other purposes, should give no coloration with Nessler test, otherwise it should be redistilled.

The process consists of two distinct stages—the estimation of the free ammonia and the calculation of the amount of albuminoid ammonia, alias the organic matter.

*Estimation of the Amount of Free Ammonia, called by some the Actual or the Saline Ammonia.*

'ree .mmonia. Distil a little distilled water through the apparatus in order to thoroughly cleanse it. If we know it to be clean, it will be sufficient to wash out, by means of the Gmelin's wash bottle, the glass tube of the Liebig condenser with a little distilled water. Fit the tube of the retort carefully to the tube of the condenser either through the medium of an adapter (*vide* fig. 3), or by means of a packing of paper. The best plan, perhaps, is to select a retort which possesses a small tubular portion, around which a strip of clean writing-paper is rolled, sufficient to make it screw, not too firmly, otherwise there will be a fracture, into the condenser tube. It is very important to make this junction secure, so as to prevent the loss of steam. Place a half litre = 500 c. c. of the water to be examined in the retort by the aid of a perfectly clean funnel to prevent spilling. If the operator can introduce the sample into the retort without losing a single drop it is best to dispense with the funnel, for it is an additional article to keep clean. To facilitate the expulsion of the ammonia, it was formerly the practice to drop into the retort 1 gramme of freshly ignited carbonate of soda. Before returning the stopper to the retort throw a jet of distilled water on it with the wash bottle. The passage of a very slow stream of cold water through the Liebig's condenser should be maintained during the whole period of the distillation. The distillation should be conducted slowly, otherwise there may be a loss of ammonia in consequence of imperfect condensation. Distil over into a Nessler glass 50 c. c. Add to the distillate by means of a bulb pipette 2 c. c. of Nessler test. If it contains ammonia a yellowish brown or amber colour is produced; the deeper the colour the greater is the quantity of ammonia present in it. If the amount of ammonia be very small, the tint will be that of straw. Dr. Charles Smart has pointed out[1] that the presence in a water of vegetable matter in a state of fermentative change is indicated by the development of a yellow colour in the water on the addition of carbonate

[1] *Sanitary Water Analysis*, 1886.

of soda, and by a green coloration (accompanied by a haziness) of the Nesslerized distillates, of an olive or citron tint, which masks the characteristic amber brown colour produced by Nessler test in a solution of ammonia. Imitate the depth of tint by mixing in a Nessler glass with 50 c. c. of distilled water more or less of the dilute standard solution of ammonia contained in the burette and add 2 c. c. of Nessler test. Wait always about three minutes for the colour to be developed. Nessler re-agent, which takes a longer time to produce its maximum tint, is not sufficiently sensitive. (To make Nessler test "quick" add a little cold saturated solution of corrosive sublimate to it.) If the tint of the prepared standard of ammonia be too light, add to the prepared standard so much of the standard ammonia solution contained in the burette as is deemed to be sufficient to match the tint of the Nesslerized distillate. If the colour of the prepared standard be too dark, make up a fresh standard containing less ammonia. In conducting these colour test comparisons it is always desirable that the waters contrasted should be about the same temperature. It is the practice of some analysts to throw away the second, third, and fourth distillates of 50 c. c. that distil over, as the first distillate generally contains $\frac{3}{4}$ths of the total quantity of ammonia. They simply add to it $\frac{1}{3}$d in order to arrive at the sum total, *e.g.*—

If the first distillate contains ·09 milligramme in $\frac{1}{2}$ litre
Add $\frac{1}{3}$ . . ·03
—
Total quantity in the $\frac{1}{2}$ litre ·12 milligramme =
·24 milligramme per litre or part per million.

It is sometimes necessary to Nesslerize the fourth or last distillate to assure oneself that all of the ammonia has passed off, for in some cases, as *e.g.* when urea is present, the ammonia may come off in the three

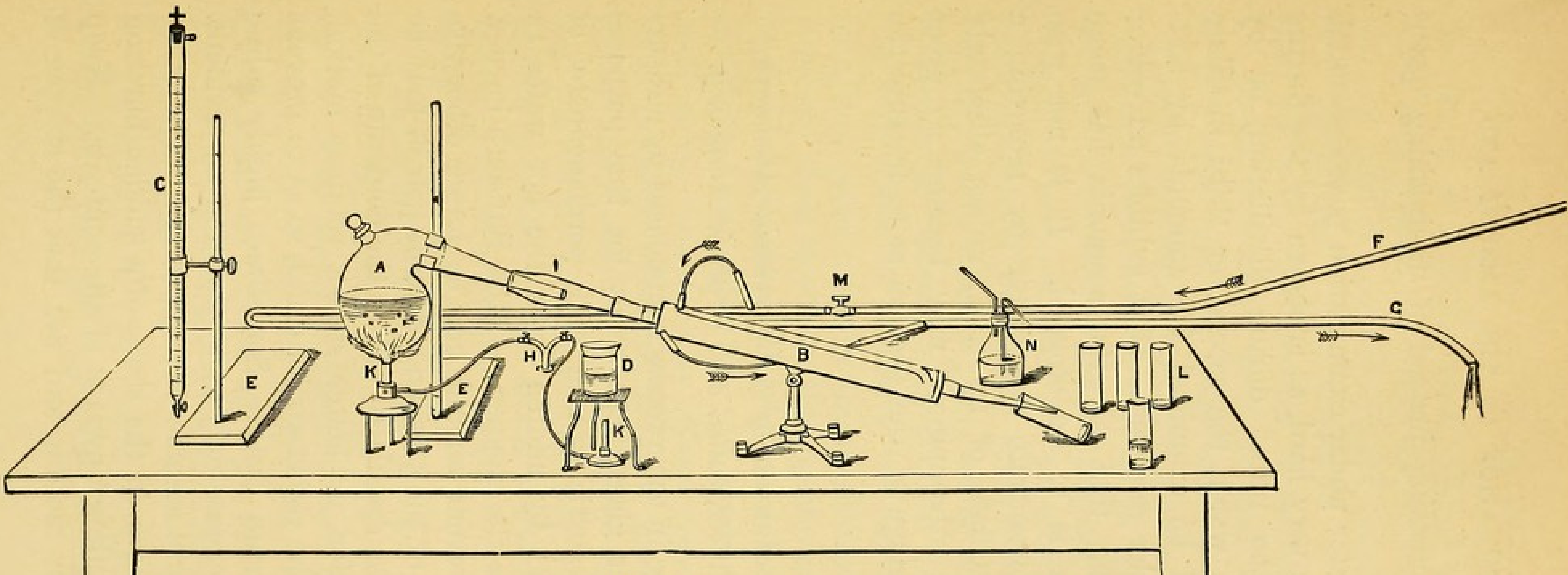



Fig. 3.

| | | | |
|---|---|---|---|
| A. | Retort. | G. | Waste Water Pipe. |
| B. | Liebig's Condenser. | H. | Gas Pipes. |
| C. | Burette. | I. | Adapter. |
| D. | Water Bath and Platinum Dish. See Fig. 13. | K, K. | Bunsen's Burners. |
| E, E. | Retort Stands. | L. | Nessler Glasses. |
| F. | Water Supply Pipe. | M. | Water Tap. |
| | | N. | Gmelin's Wash Bottle. |

last 50 c. c. in increasing instead of diminishing quantities.

Again, if the water under examination possesses much saline matter, or is very hard, as is shown by the furring of the sides of the retort during distillation, or by "bumping" of the water, the second or third distillate of 50 c. c. should be examined for ammonia by adding 2 c. c. of Nessler re-agent. If it exhibits no colour whatsoever, showing that all the ammonia has come off, the distillation is to be stopped. It is not wise to still further concentrate the water by removing a third or fourth distillate of 50 c. c., unless absolutely necessary, for the "bumping" may become so great during the second stage of the process as to fracture the apparatus.

### *Estimation of the Amount of "Albuminoid Ammonia,"* alias *Organic Matter, called also Organic Ammonia.*

"Albuminoid Ammonia."

The second stage in the process commences by measuring out in a Nessler glass (kept solely for this purpose) 50 c. c. of the caustic potash and permanganate of potash solution, and by adding it to the hot water in the retort. Replace the stopper and the Bunsen's burner. The flame of the burner should not be large, otherwise some of the colour of the permanganate of potash may be communicated to the distillate. Give the contents of the retort a wavy motion, or, better still, a rotatory motion, by gently moving the retort on its stand, so as to prevent "bumping," and again distil. Sometimes highly saline waters "bump" so exceedingly as to threaten an accident. Never let the mixture assume the appearance of a calm, for it portends a storm, in the shape of a sudden bursting into bubbles and boiling upwards of the contents. Keep the fluid always in motion, and see that the stopper of the retort is securely fixed. Some persons, in dealing with such waters, drop into the retort scraps of tobacco-pipe, or bits of recently ignited pumice-stone, to lessen this "bumping." The objection to this practice is, that we may inadvertently introduce sources of error, for these substances may contain organic impurities. It is a good plan in some cases to incline the neck of the retort upward, so that the liquid spirted up may fall back into that from which it is ejected. It is very needful to prevent this "bumping," apart from the danger of fracture; for, if the colouring-matter of the permanganate of potash be carried over into the distillate, the colour usually produced by the Nessler re-agent is somewhat altered, and it then becomes difficult, if not impossible, to measure its depth of tint. Distil slowly in order to allow the caustic potash permanganate sufficient time to act on the organic matter, and in order to avoid imperfect condensation of the ammonia. Three distillates, each of 50 c. c., must be taken off, and each must be carefully Nesslerized. The colour of each distillate must be matched exactly in the manner above laid down when describing the mode of estimating the amount of free ammonia, by adding a certain known quantity of the dilute standard solution of ammonia contained in the burette, to 50 c. c. of distilled water in a Nessler glass.

The comparison between the colour of the standard and the distillate is made by placing the Nessler glasses on the white porcelain tile, and by looking down through the columns of fluid on to the tile. The amount of the dilute standard solution of ammonia employed to match the tint of the distillate represents the amount of ammonia in the distillate.

For example, if the amount of dilute standard solution of ammonia required to match the tint of the

1st distillate be 5 c. c.
2d „ „ 3 c. c.
3d „ „ 1 c. c. we arrive at these figures—

| | |
|---|---|
| Alb. Ammonia . . . . | ·05 |
| „ „ . . . . | ·03 |
| „ „ . . . . | ·01 |
| Total . | ·09 |

'reparation f standards. Beginners find it troublesome at first to match the colour, without making up several standards containing different proportions of the standard dilute solution of ammonia. It has been suggested by some that strips of glass, and by others discs, should be manufactured of the various depths of the sherry or amber colour, corresponding to the different tints developed by the Nessler re-agent with definite quantities of the dilute standard solution of ammonia. If such could be prepared so as to indicate accurately the various shades, a great saving of time might be effected. At one time I employed a dozen stoppered standard comparison bottles, of a capacity of about 50 c. c. Each bottle was provided with known and different quantities of the dilute standard solution of ammonia, and immediately filled up with twice distilled water. One c. c., 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, and 23 c. c. were the amounts of the standard ammonia selected. To the contents of each bottle 2 c. c of Nessler test were added. The weakest standard contained 1 c. c., and the strongest 23 c. c., of the dilute standard solution of ammonia. In making an analysis, the contents of the bottle or bottles that are considered likely to match the tint of the distillate are poured into a Nessler glass, and at its conclusion are replaced. These solutions slowly absorb ammonia, and get slightly darker in time, or they decompose, losing their colour and precipitating red iodide of mercury. Sometimes they become turbid, and sediments are deposited. Dr. Mills' portable colorimeter[1] has been employed for estimating the tints of the distillates, as well as for that of degrees of turbidity, but is, I find, of little help. Although one of these instruments stands in my laboratory, it is never used. These supposed helps waste much time, and are not so accurate as the old plan of preparing a fresh standard solution when wanted. Practice very soon enables the water analyst to guess very closely the amount of the standard solution of ammonia which he will require to match any given tint, so that he does not often find the necessity of making up a second standard. I would recommend the Medical Officer of Health to make himself, by practice, skilful in matching tints, rather than rely on instruments as aids. The tapped graduated Nessler glasses, introduced by Mr. Hehner, are useful to the novice, or when rough calculations are alone requisite. Some analysts, instead of distilling over the four distillates, each of 50 c. c., separately, mix them together and thus Nesslerize them. In so doing they lose valuable information, for it is important to note the proportions in which the ammonia distils over in each distillate. (*Vide* the opinion of Prof. Mallet on page 208.) Sometimes a water yields nearly equal instead of decreasing quantities of ammonia, so that it is almost impossible to extract all the ammonia from a water before the distillation is at an end. This experience may occur in the examination of waters polluted with urine, or dirty from the presence of soot (*vide* page 207). In such cases it is good policy, as has been pointed out by Mr. Sidney Rich,[2] to Nesslerize the first 50 c. c., and to return into the retort the succeeding 150 c. c. that are distilled over, of course Nesslerizing the distillate or distillates

[1] Described in *Proc. of Glasgow Philosoph. Socy.*, March 12, 1877. The instrument is made by Cetti & Co., of Brooke Street, Holborn, London.

[2] *Chemical News*, June 9, 1876.

procured by this redistillation. It is of no practical utility, in making sanitary analyses of water, to estimate the amount of ammonia derived from organic matter that is in excess of ·50 milligramme per $\frac{1}{2}$ litre = 1 milligramme per litre, as that quantity is so much more than is sufficient to condemn. If it is desirable to measure the exact amount of the large quantity of ammonia evolved, a funnel tube with a glass stopcock should be adjusted by the help of a perforated cork in the retort through the stoppered opening, so that ammonia-free distilled water may be introduced in order to maintain the volume of the liquid in the retort *constant*.

The process is now at an end. Allow the retort to remain uncleansed until another analysis is to be made, when the fur should be removed by strong hydrochloric acid and an abundance of water. As half a litre has been taken for analysis, multiply the results by 2, in order to make them give the proportion for the litre. In the foregoing analysis, then, the results are the following:—

| | | | |
|---|---|---|---|
| Free ammonia, | ·24 | milligramme per litre = | part per million. |
| Albuminoid ammonia, | ·18 | do. | do. |

I should like to indelibly print on the minds of all water analysts the following truth:—If you rely solely on the indications of this process, you will sometimes come to a correct conclusion as to the quality of a water, but very often a mistake will be made. Couple the evidence afforded by it with other evidence of a chemical and microscopical character, and an error will never be committed. I regard this process as a most valuable aid to the formation of an opinion by the Medical Officer of Health as to the nature of a water, as indispensable indeed as is auscultation to the physician in the diagnosis of lung and heart diseases. The evidence afforded by the stethoscope is brought by him in juxtaposition to other evidence bearing on the same point, and an opinion is formed from the sum total of all the evidence which is forthcoming. No physician dreams of relying solely on the character of the sounds heard from the lung by his ear, and of shutting himself away from all other sources of information. It appears that a member of the Society of Public Analysts, who holds two public analytical appointments, believes that the determination of the free and albuminoid ammonia is all that is necessary for forming an opinion on the quality of a drinking water, and he pronounces a verdict solely on the evidence afforded by these two estimations. Mr. Allen points out,[1] as I have on several occasions, the absurdity of such a proceeding, for the rain water of country places would certainly be condemned as polluted with filth by such an analyst.

*Rules.*

The following are the most recent rules which have been laid down by Mr. Wanklyn for the guidance of those who work this process:— Rules.

He writes,[2] "If a water yield ·00 parts of albuminoid ammonia per million, it may be passed as organically pure, despite of much free ammonia and chlorides; and if, indeed, the albuminoid ammonia amounts to ·02, or to less than ·05 parts per million, the water belongs to the class of very pure water. When the albuminoid ammonia amounts to ·05, then the proportion of free ammonia becomes an element in the calculation; and I should be inclined to regard with some suspicion a water yielding a considerable quantity of free ammonia, along with more than ·05 parts of albuminoid ammonia per million. Free ammonia, however, being absent, or very

1 "On some Points in the Analysis of Water, and the Interpretation of the Results;" by A. H. Allen. *The Analyst*, July 1877, p. 61.

2 *Water Analysis.* Fourth Edition, p. 53.

small, a water should not be condemned unless the albuminoid ammonia reaches something like ·10 per million. Albuminoid ammonia above ·10 per million begins to be a very suspicious sign; and over ·15 ought to condemn a water absolutely."

*Objections.*

Several objections have been urged against this process, the principal of which are:—

Objections. 1. Taking a series of nitrogenized bodies, the proportion of nitrogen procured in the form of ammonia is not obtained in definite and simple fractions, but varies widely. The value of the process is not impaired because piperine yields the whole of its nitrogen as ammonia, because morphia yields one half, or theine yields one quarter, whilst albumen yields two-thirds; for piperine, morphia, theine, and similar bodies are not usual constituents of well water. It has been remarked by Dr. Tidy that the importance of the fact that organic bodies yield their nitrogen as albuminoid ammonia in different proportions is much overrated, if the yield of albuminoid ammonia is found to keep pace with the purity or impurity (as the case may be) of waters. Messrs. Wanklyn, Chapman, and Smith, have distinctly affirmed that their process is designed for estimating the relative quality of drinking water, and is not one for the quantitative determination of nitrogen.

2. That the amount of ammonia obtainable from albumen by the action of alkaline permanganate is influenced by the degree of concentration of the solution and the rate of distillation. Mr. Wanklyn has stated most positively that the yield of ammonia is not affected by these circumstances, and in proof of this assertion refers to a set of experiments published by himself in 1867.

3. "If 20 grains of urea were present in a gallon of

water," wrote the late Mr. Wigner,[1] "the sample would be passed by the Wanklyn, Chapman, and Smith's process as absolutely pure." It is stated by Mr. Wanklyn that fresh urea is not decomposed into ammonia by distilling with or without the mixture of caustic potash and potassium permanganate. It has been pointed out by Prof. Mallet that it is erroneous to assert that urea is not convertible into ammonia, and evidence is given by him to the contrary.[2] In the experiments conducted by Dr. Cory at the instance of the Local Government Board[3] it was found that the statement that urea yields no ammonia "is substantially correct," if it is dissolved in distilled water, but yet not quite accurate. He writes, "the impurities of a water will occasion a much greater proportion of ammonia to be formed from urea." Urea in a drinking water can hardly ever occur in a fresh condition. The ready fermentation of urea into carbonate of ammonia is a peculiarity of urea. The rapidity with which this change takes place is such that, in the examination of drinking waters which are polluted with urine, we may be pretty confident that sufficient of the urea has been decomposed before the water reaches our distilling apparatus to give a large excess of ammonia.

4. The inability of some eyes to arrange and classify tints, renders it possible that there may be several errors of observation in the comparison of so many distillates. If the analyst has any defect of vision approaching to a condition of colour blindness, it is desirable to receive all the ammonia distillates together (unless the amount distilled over after the first distillate is calculated by dividing by 3) and all the albuminoid ammonia distillates together, thus minimizing this source of error, although

[1] *Analyst*, March 1878. [2] *Op. cit.*

[3] *Vide* Eleventh Annual Report of the Local Government Board 1881-82, containing Medical Officer's Supplement for 1881, p. 127.

by so doing valuable information is lost. (*Vide* pages 47 and 208).

5. "Peaty waters yield a flood of albuminoid ammonia." The absence of any excess of nitrates and nitrites, as indicated by their respective tests, shows that the organic matter is not animal but vegetable.

6. In the determination of both "free" and "albuminoid" ammonia there is a loss resulting from imperfect condensation of the ammonia during distillation, and this loss is less marked in the estimation of small quantities of organic matter in a water than when it is in larger amount. This difficulty may be overcome by conducting the distillation very slowly, or by connecting to the end of the condenser tube a Nessler glass to which a U tube containing 25 c. c. of ammonia-free distilled water is fitted, such as is employed in the estimation of the nitrates and nitrites, page 115, so as to catch any ammonia that may be otherwise lost.

7. In some cases the albuminoid ammonia obtained as ammonia is actually less than the ammonia known to be present in the caustic and permanganate of potash solution. I do not remember ever to have encountered such an anomaly, which at all events could only occur in a water of great purity. In some cases nitrogenous organic matter is volatilized during the distillation for free ammonia, which if it had been retained would have yielded up its nitrogen as albuminoid ammonia, such nitrogenous matter escaping detection under either head.

These are the weak points of the process which teach us that we should not rely on its indications to the exclusion of other information. The practical question answered by this process is not, however, as to how much nitrogen is contained in a water, but whether a water is wholesome or not.

### 8. The Frankland and Armstrong Process.

This process, which is based upon the principle, that when the residue on evaporation of the water is burned with oxide of copper, nitrogen and carbonic acid are eliminated from the organic matter, consists in the determination of the amount of organic nitrogen and organic carbon by a measurement of the respective volumes of these gases.

The late Prof. Parkes, in his text-book on *Practical Hygiene*, writes respecting it:—"This plan requires so much apparatus, time, and skill, as to be quite beyond the reach of medical officers, and it would also appear that *in the hands of even very able chemists it gives contradictory results;*[1] the quantities are in fact so small, and the chances of error so repeated that, in its present form, this really beautiful plan seems not adapted for hygienic water analysis. It is also difficult to know what construction should be put on the results; a water containing much non-nitrogenous organic matter may give a very much larger amount of 'organic carbon' than a water containing a much smaller amount of nitrogenous matter, and yet be much less hurtful."

The Rivers Pollution Commissioners (Sixth Report, page 5), confess that "this process is both troublesome and tedious." It is generally admitted to be attended with a high experimental error, and is considered by some as yielding illusory results.

As it is quite unadapted to the wants of the health officer, I shall not here describe the process, but must refer my readers to Sutton's *Volumetric Analysis*, or Dr. T. E. Thorpe's *Quantitative Chemical Analysis*, page 299. Some idea may be formed of the cumbrous and complicated nature of the process by glancing at the engravings in these works of two of the principal pieces of apparatus employed. The smaller is a Sprengel's Pump, which is

[1] The italics are mine.

attached to the combustion tube in which the solid residue is burnt with oxide of copper in a furnace. The larger is the apparatus employed for the analysis of the gases thus obtained. Any one who is practically acquainted with modern quantitative analysis can learn this process in about a month. The large majority of medical men who are not provided with this foundation would require a six months' course in chemistry to prepare them for learning this process of water analysis. Again, the cost of the apparatus is a considerable, although of course not an insuperable obstacle to its employment, being as much as thirteen guineas. Prof. M'Leod's apparatus for gas analysis, which is considered to be an improvement on Dr. Frankland's, is still more complex, and twice as costly, being £26 : 5s., whilst the price of Thomas' improved modification is £30.

Prof. Mallet thus writes, "From the hands of a person without proper laboratory training its results are utterly valueless. It is but a method of approximation, involving sundry errors, and in part a balance of errors."

The certificate of an analysis made by Dr. Frankland's elaborate process is about as incomprehensible as the process itself to all who are not chemical experts or analysts. Members of Sanitary Authorities and their medical officers often find these certificates perfectly unintelligible, although they are accompanied by explanatory notes for their interpretation. Can anything be more confusing to the public than the contents of the column headed "Previous Sewage or Animal Contamination"? I recently saw one of his certificates of an analysis of an excellent spring water, which contained in this column the numbers 1710, which was accompanied by the following remark :—"As this is spring water the evidence of previous sewage contamination which it exhibits may be safely disregarded." The expression "Previous Sewage or Animal Contamination" is a very unfortunate one, for it has given rise to an endless amount of misconception.

Animal matters in passing through the pores of clean soil become oxidized and converted into ammonia, nitrates, and nitrites, which are harmless. This oxidation, in other words this beneficial cleansing power of earth, does not continue for an indefinite period. Soil is liable to be in time overdone with filth, and is then unable to carry on this purifying action, so that the animal matters pass through it unchanged. Its particles require rest and free exposure to the air, before it recovers its expended power. Earth becomes relieved of the products of this dressing with filth by means of vegetation, which greedily incorporates them into its substance. "Previous Sewage or Animal Contamination" then, is the record of the past history of the water, being the sum total of the products of animal matter that have been oxidized, namely, the ammonia, the nitrates, and nitrites. This total, after the removal of the average amount of ammonia in rain, is represented as the mineral residue of the previous animal contamination of the water, in terms of average London sewage, 100,000 parts of which are roughly estimated to contain 10 parts of these three nitrogenous matters. Here is an example of the manner in which the figures in this column are obtained:—

"Previous Sewage Contamination."

| | |
|---|---|
| Nitrogen as nitrates and nitrites . . | 5·911 |
| Ammonia . . . . . . . | ·002 |
| | 5·913 |
| Deduct for nitrogen as nitrates, nitrites, and ammonia in rain . . . . . . | ·032 |
| | 5·881 |

Add 0 and remove decimal point, and the figures 58810 are arrived at, which represent the "previous sewage or animal contamination." Or it may be calculated by multiplying the sum of the quantities of nitrogen present as nitrates, nitrites, and ammonia, by 10,000, and by subtracting 320 from the result. Some of Dr. Frankland's disciples, perceiving doubtless the extreme liability to the misunderstanding of this expression, have omitted or altered it; for example, Dr. C. Brown's certificates do not contain this column, whilst Mr. W. Thorp has substituted the term "total inorganic nitrogen," which corresponds with Dr. Frankland's "previous sewage contamination," minus the deduction for the ammonia in rain. The "total combined nitrogen" of these chemists, is the sum of (1) the organic nitrogen; (2) the nitrogen as nitrates and nitrites; and (3) the ammonia.

### *Rules.*

Rules.

It is useful for medical officers of health and other sanitarians to remember the following rules,[1] which guide those who employ this process, in order that they may be able to interpret the results:—

Quantity.

*Quantity of Organic Carbon and Organic Nitrogen.*—"The weight of the organic carbon found in different samples of water indicates the amount of organic matter with which the water is contaminated, but it does not reveal the source, animal or vegetable, whence that organic matter is derived."

"*Cæteris paribus,* the smaller the proportion of organic carbon the better the quality of the water."

"If the source of the organic matter be altogether vegetal a larger proportion of organic carbon than ·2 part in 100,000 parts of water is undesirable, because it renders the water slightly bitter and unpalatable. A larger proportion of organic carbon if it be contained in animal matter does not interfere with the palatability of the water, but it exposes the consumer to the risk of infection."

[1] Sixth Report of the Rivers Pollution Commission, 1874, and W. Thorp's Article on Water Analysis in Sutton's *Volumetric Analysis.*

Vegetable organic matter is far from being destitute of nitrogen; for instance, peat contains much of it.

"Surface water and river water, which contains in 100,000 parts more than ·2 part of organic carbon or ·03 part of organic nitrogen, is not desirable for domestic supply, and ought, whenever practicable, to be rejected. Spring and deep well water ought not to possess more than ·1 part of organic carbon or ·03 part of organic nitrogen in 100,000 parts. If the organic nitrogen reaches ·15 part in 100,000 parts, the water ought to be used only when a better supply is not obtainable."[1]

When the quantities of organic carbon and organic nitrogen exceed 2·0 and 0·5 parts, respectively, the sample may be considered as belonging to the class of sewages, the intermediate quantities indicating various degrees of pollution. Sewage usually contains about four parts of organic carbon and two parts of organic nitrogen.

*Ratio of Organic Carbon to Organic Nitrogen.*—When the organic matter is of vegetable origin the ratio is very high, and when of animal origin it is very low. As a qualification of this statement, it should be said that in the case of unoxidized peaty waters the ratio is diminished by oxidation; and in the case of waters polluted by organic matter of animal origin a reverse action takes place, the ratio being increased by oxidation. In peaty waters the ratio may amount to as much as 20. In sewage it varies from 1 to 3. In unpolluted upland surface waters the ratio fluctuates from about 6 to 12, and in water from shallow wells from 2 to 8. The ratio in water for domestic supply may vary from 5 to 12, and that in polluted river water from 3 to 5. Ratio.

*Previous Sewage or Animal Contamination.*—If the water be derived from a deep-seated spring or a deep well, and the previous sewage contamination does not exceed 10,000 *parts* in 100,000 parts of water, it is "Previous Sewage or Animal Contamination."

[1] Vide *Water Analysis*, by Dr. Frankland.

TABLE EXHIBITING DIFFERENT

*Result of Analyses expressed*

| DESCRIPTION. | Total solid Impurity. | Organic Carbon. | Organic Nitrogen. | Ammonia. |
|---|---|---|---|---|
| RAIN WATER . . . . . | 2·95 | ·070 | ·015 | ·029 |
| UPLAND SURFACE WATER . . | 9·67 | ·322 | ·032 | ·002 |
| DEEP WELL WATER . . . . | 43·78 | ·061 | ·018 | ·012 |
| SPRING WATER . . . . . | 28·20 | ·056 | ·013 | ·001 |
| *Upland Surface Water.* | | | | |
| The Teign above Old Wheal, Exmouth, Sept. 26, 1873 . . | 6·08 | ·582 | ·058 | ·004 |
| Loch Katrine, the Water Supply of Glasgow, August 3, 1870 . . | 2·40 | ·185 | ·022 | ·001 |
| *Surface Water from Cultivated Land.* | | | | |
| The Thames at Thames Ditton, Jan. 31, 1873 . . . . . | 31·36 | ·325 | ·076 | ·003 |
| *Shallow Well Waters.* | | | | |
| Water from well at Alford, on the Don, Scotland, March 8, 1872 . | 16·80 | ·048 | ·007 | ·000 |
| Water from well in Well Close Square, London, June 5, 1872 . | 396·50 | ·278 | ·087 | ·000 |
| Churchyard Well, Leigh, Essex, Nov. 28, 1871 . . . . . | 112·12 | ·210 | ·065 | ·000 |
| *Deep Well Water.* | | | | |
| Water from Grays, South Essex Water Company, Feb. 15, 1873. | 44·80 | ·064 | ·017 | ·001 |
| Well at Waterworks, Colchester, April 2, 1873 . . . . . | 96·20 | ·174 | ·030 | ·021 |
| *Spring Waters.* | | | | |
| Rabate Fountain, Balmoral, March 9, 1872 . . . . . . | 1·40 | ·119 | ·014 | ·000 |
| Spring supplying Town Well, Southam, Dec. 3, 1869 . . | 57·30 | ·282 | ·054 | ·011 |
| Beacon Hill Spring, Bath, Feb. 17, 1871. . . . . . . | 40·62 | ·253 | ·041 | ·000 |
| Norwegian Block Ice . . . | ·47 | ·029 | ·005 | ·005 |
| SEA WATER. . . . . . | 3898·70 | ·278 | ·165 | ·006 |
| SEWAGE . . . . . . | 72·20 | 4·696 | 2·205 | 5·520 |

To convert parts per 100,000 into grains per gallon and the Hardness

[1] Sixth Report of the Rivers Pollution Commission,

## Classes of Waters.[1]

*in parts per* 100,000.

| Nitrogen as Nitrates and Nitrites. | Ratio. Organic Carbon. / Nitrogen. | Previous sewage Contamination. | Chlorine. | Hardness. — Total. | Remarks. |
|---|---|---|---|---|---|
| ·003 | 4·7 | 42 | ·22 | ·3 | Average Composition of Unpolluted Waters. |
| ·009 | 10·1 | 10 | 1·13 | 5·4 | |
| ·495 | 3·4 | 4743 | 5·11 | 25·0 | |
| ·383 | 4·3 | 3559 | 2·49 | 18·5 | |
| ·000 | 10· | ... | 1·40 | 2·6 | A peaty water, which contains more vegetable matter than is admissible for drinking. |
| ·000 | 8·4 | ... | ·85 | ·9 | A very good water. |
| ·312 | 4·3 | 2820 | 1·75 | 23·9 | Certain amount of animal pollution. Nitrates and nitrites present from use of manures. Most efficient filtration needful. |
| ·033 | 7·0 | 10 | 2·85 | 9·3 | Good shallow well water. |
| 25·840 | 3·2 | 258080 | 34·60 | 191· | Highly polluted shallow well water. |
| 5·047 | 3·2 | 50150 | 13·75 | 60· | Polluted shallow well water. |
| ·929 | 4· | 8980 | 5·05 | 29·4 | Very pure, although containing much nitrates from the chalk. |
| 2·582 | 5·8 | 25670 | 21· | 25·7 | Polluted deep well water. |
| ·000 | 8·5 | ... | ·55 | 1·2 | Exceedingly pure. |
| ·397 | 5·2 | 3740 | 2·00 | 33·5 | |
| 1·205 | 6·0 | 11730 | 2·60 | 30· | |
| ... | 5·8 | ... | ·05 | ... | |
| ·033 | 1·7 | 103 | 1975·60 | 796 9 | |
| ·003 | 2·1 | ... | 10·66 | ... | |

into degrees of Clark's Scale, respectively, multiply by ·7.

1874, and *Water Analysis*, by Dr. Frankland.

*reasonably safe,* provided all contaminated surface water has been rigidly excluded from the well or spring.

River or flowing water which exhibits any proportion, however small, of contamination, and well or spring water containing from 10,000 *to* 20,000 *parts* of previous contamination in 100,000 parts of water, are considered *suspicious* or *doubtful.*

Waters more impure than those classed as suspicious must be regarded as *dangerous.*

*Objections.*

Objections.

The principal are the following :—

Whilst professing to measure the organic bodies contained in a water, such substances are more or less decomposed and dissipated during the preliminary process of evaporation.

The experimental error is often greater than the total quantity to be measured.

There exists considerable doubt as to the accuracy of the results when a water contains some unstable form of organic matter *in presence of a large excess of nitrates.*

Inconsistencies.

There can be no question but that Dr. Frankland is sometimes inconsistent in his interpretation of the results of his analyses. Here is an example :—

PARTS PER 100,000.

| Description. | Organic Carbon. | Organic Nitrogen. | Ratio. Carbon. / Org. Nitrogen. | Ammonia. | Nitrogen as Nitrates and Nitrites. | Chlorine. | Opinion. |
|---|---|---|---|---|---|---|---|
| Water from bore, 90 feet deep, Clayton West . . . | ·202 | ·051 | 3·9 | ·008 | ·000 | 2·45 | Good. |
| Water from deep boring in Bourne, Lincolnshire . . | ·217 | ·047 | 4·6 | ·000 | ·000 | 2·10 | Polluted. |

Prof. Mallet states that the extent of the disagreement of the results of multiplied analyses of the same water by the combustion process proved in his hands to be much greater in the case of organic nitrogen than in that of the organic carbon.

This conclusion is supported by the opinion of Dr. Tidy, that the results of the combustion process are less to be relied on for nitrogen than for carbon. The professor writes, "We find loss of carbon and excess of nitrogen in the artificially prepared waters of known composition. Our experiments furnish for the first time, so far as I know, direct evidence of the fact that, for some organic substances at least, and those of a kind liable to occur among the products of putrefaction, there is material, nay, very great loss of carbon. The excess of nitrogen is, in part at least, due to absorption during the evaporation of the acidified water of ammonia *from the atmosphere surrounding the gas flame* furnished by the gas during combustion, partly balanced, no doubt, by loss of that originally present in the water. These two errors are relatively greatest when the quantity of organic matter in the water is small."

Dr. Dupré writes,[1] "Sea water shows a ratio between organic carbon and nitrogen worse even than is found in pure sewage!"

The reason assigned by the French chemists for not employing the combustion process at the Municipal Laboratory of Paris is that it "is subject to many causes of error, and is of so extremely delicate a nature as to be almost abandoned at the present time."

The late Mr. Wigner, the analyst, wrote thus[2] respecting it:—"Supposing that the organic nitrogen yielded by the Frankland and Armstrong process were a

[1] *Analyst*, July 1885.

[2] *Sanitary Record*, October 19, 1877, p. 256.

positive quantity, instead of a quantity needing a heavy correction for personal equation and for impurities in the chemicals used, yet the danger of error involved in the process, and the risk of contamination by atmospheric impurities, are in my opinion sufficient to prevent it from ever coming into general use; and unless generally used, it is undesirable for reports which appeal to public sense and public understanding."

Modifications of the Frankland and Armstrong process, devised for the saving of time and manipulative skill, have been adopted by A. Dupré and H. Wilson Hake,[1] and by W. Dittmar and H. Robinson.[2]

In the estimation of the organic carbon the former chemists pass the carbonic acid evolved from the organic carbon into baryta water. The carbonate of baryta is converted into the sulphate of baryta, which is weighed and the amount of carbon calculated. It would seem from the experiments detailed in an inquiry "On the results of examination of certain samples of water purposely polluted with excrements from enteric fever patients, and with other matters," by Dr. Cory, contained in the Supplement of the Eleventh Annual Report to the Local Government Board, 1881-82, proof was afforded (*vide* page 157) that the organic carbon was over-estimated by Drs. Dupré and Hake's process.

In the estimation of the organic nitrogen, Messrs. Dittmar and Robinson burn the water residue with caustic soda in a current of hydrogen, the ammonia produced being passed into very dilute hydrochloric acid and then fixed as chloride, the amount of which is estimated by the Nessler test.

[1] *Chemical Society Journal*, 1879, vol. xxxv. p. 159.

[2] Determination of the Organic matter in Potable Waters.—*Chemical News*, 1877, vol. xxxvi. pp. 26-29.

A COMPARISON BETWEEN THE RESULTS FURNISHED BY 1. THE PERMANGANATE OF POTASH PROCESS; 2. THE WANKLYN, CHAPMAN, AND SMITH PROCESS; 3. THE FRANKLAND AND ARMSTRONG PROCESS.

The Permanganate of Potash process and the Frankland and Armstrong process.

The permanganate of potash test applied, qualitatively, as a test for organic matter, cannot be compared, in the results afforded by it, with any other process, for they are thoroughly misleading and unreliable. If the test is employed quantitatively, in the most approved and most recent fashion, it is most useful.

The permanganate of potash process has clearly more to do with the estimation of the carbon than the nitrogen of a water, whilst the Wanklyn, Chapman, and Smith process is concerned more with the evolution of nitrogen as ammonia.

Prof. Mallet remarks, "It is not easy to admit the soundness of the logic with which Tidy points to the concordance of the results obtained by the permanganate of potash and combustion processes and the disagreement with both these of the results by the albuminoid ammonia process, hence apparently inferring that the two former are trustworthy and the last not so. He uses the sum of *organic carbon and nitrogen* to represent the results by the combustion process, and as the carbon forms generally much the larger part of this, he naturally arrives at an agreement with the results of the process, mainly depending on the oxidation of carbon (the permanganate of potash process) and disagreement with those of the process (namely, the albuminoid ammonia) evolving nitrogen as ammonia."

The permanganate of potash method cannot be correctly described as a process, for it in reality forms only a part of one. The indications it gives should be considered in conjunction with those afforded by an estimation of the amount of free and albuminoid ammonia, the nitrogen products resulting from the oxidation of organic matter, and the quantity of chlorine, etc. Occupying this subsidiary position, and controlled to a great extent by other evidence, it exhibits a remarkable agreement not only with the Frankland and Armstrong's process, but also with the Wanklyn, Chapman, and Smith process, when the latter is associated with a determination of the nitrates and nitrites. The agreement between the results afforded by the Frankland and Armstrong process, and the permanganate of potash method, is the more remarkable, because Dr. Frankland has publicly denounced the permanganate of potash test as perfectly useless and mischievous. The indications as to the quality of a water afforded by this salt are so corrected by those furnished by the other examinations of the same water, as to render it unlikely that any marked disagreement should occur between this permanganate of potash test, as carried out in the most approved manner, and the other two processes.

The Frankland and Armstrong and the Wanklyn, Chapman, and Smith process.

The processes, which have assumed an antagonistic rivalry, and are credited with furnishing contradictory decisions, are the Frankland and Wanklyn methods. Prof. Mallet finds "a good deal of similarity between the figures of albuminoid ammonia and those for organic nitrogen by the Frankland combustion process, but with frequent discrepancies of varying extent, such as prevent the one being taken as the accurate measure of the other."[1]

Dr. Hill's mode of comparison.

Dr. Hill of Birmingham has made a comparison between the two processes, by placing by the side of the organic nitrogen of Frankland's method the amount of nitrogen calculated from the albuminoid ammonia of Wanklyn's method, thus:—

[1] *Op. cit.*

*Birmingham Public Water Supply.*

| Date. 1875. | Organic nitrogen by Frankland and Armstrong process. | Albd. Amm. by the Wanklyn, Chapman, and Smith process. | = N. | Ratio of organic nitrogen to nitrogen by the two methods. |
|---|---|---|---|---|
| January | ·097 | ·016 | ·013 | 7 : 1 |
| February | ·070 | ·022 | ·018 | 4 : 1 |
| March | ·099 | ·020 | ·016 | 6 : 1 |
| April | ·064 | ·014 | ·011 | 6 : 1 |
| May | ·048 | ·011 | ·009 | 5 : 1 |
| June | ·049 | ·016 | ·013 | 4 : 1 |
| July | ·090 | ·014 | ·011 | 8 : 1 |
| August | ·120 | ·018 | ·015 | 8 : 1 |
| September | ·072 | ·010 | ·008 | 9 : 1 |
| October | ·070 | ·014 | ·011 | 6 : 1 |
| November | ·124 | ·024 | ·020 | 6 : 1 |
| December | ·080 | ·014 | ·011 | 7 : 1 |

He argues therefrom, that (1) as the amount of nitrogen yielded by the albuminoid ammonia of the Wanklyn process is very much less than that furnished by the Frankland process, which every one admits, and (2) as the ratio is not constant, the Wanklyn process is worthless. Now this mode of comparison appears to be unfair, because it proceeds on the assumption that Dr. Frankland's process of water analysis is a standard of accuracy, a pretension which is open to considerable doubt, although as one for the analysis of gases it may be most excellent. (*Vide* Prof. Mallet's opinion on page 61).

Although, then, anything like a contrast of numbers is out of the question, a comparison of the opinions of a water formed according to the rules laid down by the inventors of the respective processes, from a consideration of the figures obtained, is a perfectly feasible project, and one likely to be attended by useful results. These opinions may not be strictly correct,[1] but sufficiently so

[1] It is an excellent rule, which unfortunately could not be followed here, to decline to give any decision respecting the nature of a water until

to ascertain whether or not any distinct antagonism exists.

The following is a copious abstract of a paper entitled, "A comparison between the Frankland and Armstrong, and the Wanklyn, Chapman, and Smith processes of water analysis," which was presented by me to the State Medicine Section of the British Medical Association, at its annual meeting held in 1877, in Manchester, and was accompanied by a table that contained 93 analyses of waters made by these two methods at or about the same time.

Many analyses of waters performed by both the Frankland and the Wanklyn processes have been sent to me, notably those from Clayton West, near Huddersfield, which I have not inserted in the table of comparison, simply and solely because they were not made simultaneously, but with an interval of weeks and months elapsing between the periods at which the water was submitted to the rival processes. Waters change much in the amount of organic matter which they may contain at different seasons. The waters of wells are greatly influenced by :—(1) height of the subsoil water, which is always varying; (2) by the amount of water that is passing through the subsoil of a country; and (3) by heavy downfalls of rain or periods of drought. I have many times found a water pure at one time and impure at another, and this occasional pollution of a water is often due to the periodical washing of filth into a well by heavy rains. The disagreement in the opinions of able analysts respecting the purity of samples of water taken perhaps within a short interval of time from the same well is often due to these causes.

furnished with the fullest information regarding its source,—as, for example, the geology of the district, depth of the well, character of the surroundings, etc.

Dr. Ashby's analyses.

Dr. Ashby, Medical Officer of Health, made six analyses of different waters, employing the Wanklyn, Chapman, and Smith process, and reported certain of them to a sanitary authority as unfit for use. The agent of the property to which the wells belonged, immediately, and in a private manner, sent samples of the same waters to an analyst who used the Frankland and Armstrong process. The opinions formed by both analysts of all the waters examined by these two rival processes coincided in every instance. The figures are unfortunately not obtainable, so that they are not included in the table, but that the same general result was afforded in each case, and that similar conclusions were drawn about the quality of these six different waters, some pure and others impure, is an interesting fact.

An examination of the complete table shows that in only one single instance is there a distinct contradiction of opinions, and here the conflict of views is readily accounted for. In every other case where the opinions are not identical, the adjectives used to denote the decisions respecting the character of the water are qualified by some adverb. For example, when an analysis of a water by one process indicates the sample to be "good," or "bad," an analysis by the other process of the same water gives a verdict of "very good," or "highly suspicious," etc.

Before studying the following table, which is an abstract of the complete one, it should be clearly understood that this comparison is confined to the question of the quality of a water as regards the amount of animal and vegetable organic matter contained in it. Several of the waters in the table, as for example the last, viz. "Raven's Well," would pass muster solely from the consideration of the amount of organic matter contained therein, but would be objected to for other reasons. The

ANALYSES OF WATERS MADE *at* OR *about the same*

*Frankland and Armstrong process.*

| Parts per 100,000. | | | | | | | |
|---|---|---|---|---|---|---|---|
| Description of Sample. | Organic carbon. | Organic nitrogen. | Org. carbon / nitrogen. Ratio. | Ammonia. | Nitrogen as nitrates and nitrites. | Chlorine. | Opinion. |
| Deeply bored well . . . | ·229 | ·055 | 4·2 | ... | ·299 | 2·97 | Good.* |
| Water used for the washing of milk cans at an Islington Dairy . . . | 1·820 | ·710 | 2·5 | ·120 | ·400 | 7·10 | Horribly polluted. |
| West Middlesex Water Company, January 1873 . . . | ·341 | ·034 | 10·0 | ·001 | ·266 | 1·9 | Indifferent. |
| Surface spring . | ·128 | ·027 | 4·7 | ·004 | ·471 | 6·92 | Suspicious.* |
| Well water . . | ·177 | ·017 | 10·0 | ·004 | ·184 | 2·72 | Good.* |
| Deeply bored well . . . | ·093 | ·009 | 11·4 | ... | ·241 | 3·61 | Good. |
| Water from deep well . . . | ·110 | ·062 | 1·9 | ·002 | ·253 | 3·1 | Good.* |
| Well in Rowe's Square, Cardiff | ·181 | ·037 | 5·0 | ... | 3·76 | 15·5 | Bad.† |
| Artesian Well of Maldon Water Works . . . | ·148 | ·029 | 5·1 | ·110 | ... | 35·8 | Good.† |
| "Raven's Well" (deep) . . . | ·261 | ·023 | 11·3 | ·001 | ·007 | 9·9 | Pretty Good. |

*time* BY THE FRANKLAND AND WANKLYN PROCESSES.

*Wanklyn, Chapman, and Smith process.*

| Milligramme per Litre. Ammonia. | Milligramme per Litre. Albuminoid ammonia. | Grains per Gallon. Nitrogen as nitrates and nitrites. | Grains per Gallon. Chlorine. | Opinion. | Remarks. |
|---|---|---|---|---|---|
| ... | ·04 | ·2 | 2·0 | Very good. | *Opinion of the analyst, Dr. C. Brown. |
| 1·10 | ·08 | ·2 | 5·1 | Horribly polluted. | Analyses made by Dr. Bartlett, who states that 29 cases of typhoid fever occurred amongst the customers of the dairy. |
| ... | ·08 | ·18 | 1·4 | Not first rate. | |
| ·04 | ·12 | ·32 | 4·8 | Suspicious. | |
| ·04 | ·09 | ·12 | 1·9 | Pretty good. | |
| ... | ·06 | ·1 | 2·5 | Good. | |
| ·02 | ·10 | ·17 | 2·1 | Moderately good. | † Opinion of the analyst, Dr. Frankland. |
| ... | ·12 | 2·64 | 10·81 | Bad. $\gamma$ | $\gamma$ Opinion of the analyst, Mr. Thomas. |
| 1·40 | 1·13 | ·67 | 10·81 | Bad. $\delta$ | $\delta$ Opinion of the analyst, Mr. Scott. |
| ·31 | ·12 | 7·40 | 11·80 | Bad. $\eta$ | $\eta$ Opinion of the analyst, Mr. Wanklyn. |
| ·03 | ·04 | Trace. | — | Good. $\lambda$ | $\lambda$ Opinion of the analyst, Dr. Tidy. |
| ·88 | ·02 | ·07 | 25·7 | Good. $\omega$ | $\omega$ Opinion of the analyst, Dr. Whitmore. |
| ·80 | ·11 | ·06 | 25·5 | Bad. $\chi$ | $\chi$ Opinion of Messrs. Hassall and Hehner, the analysts. |
| ·32 | ·01 | — | 25·5 | Good. $\beta$ | $\beta$ Opinion of Dr. Cornelius Fox, the analyst. |
| ·04 | ·08 | ·00 | 7·3 | Pretty good. | *N.B.*—The sample received by Hassall and Hehner was probably obtained from a dirty cistern. |

water was condemned because of its large amount of saline matter and its excessive hardness.

A very careful study of the two processes, and the comparative results afforded by them, lead me to the following conclusions:—

Conclusions.

1. In one instance only out of 99 analyses, details of 93 of which are in my possession, is there a distinct conflict of opinion, and in this exceptional instance the divergence in the results obtained is easily explained.

2. The opinions do not in a great many instances coincide exactly, but the adjectives denoting them are modified by some qualifying adverb.

3. When the results of analyses made by the two processes at or about the same time do not at all agree, the divergence is generally due to the neglect on the part of those who practise the Wanklyn, Chapman, and Smith process, to estimate the amount of nitrates and nitrites, and to be guided by the evidence thus afforded.

4. The results are not concordant unless the analyses are performed upon the same water at the same time.

5. A really bad water would not be likely to escape detection by either process if the nitrates and nitrites are always estimated.

6. The danger of the delivery of contradictory opinions respecting any given sample of water, lies chiefly in the fact that Frankland's process gives higher results than Wanklyn's method, so that a water pronounced as just passable by the latter process might be condemned by the former.

VALUE OF THE FRANKLAND AND ARMSTRONG, WANKLYN, CHAPMAN, AND SMITH, AND THE QUANTITATIVE FORCHAMMER PERMANGANATE OF POTASH PROCESSES IN THE DETECTION OF DANGEROUS POLLUTIONS.

An investigation was carried out during the years 1880-81 by Dr. Cory, at the instance of the Medical Department of the Local Government Board, to determine whether chemistry was able to distinguish between water contaminated by common or specifically infected filth. The experiments lead to conclusions of rather a startling character which, unless faced and dealt with, may diminish the faith of water analysts in their powers of diagnosis.[1] Waters were polluted with weighed portions of excrement from a case of typhoid fever and from a man in perfect health, and comparisons were instituted. On page 137 of the Report is a table and comment on the same, of which the following is an abstract.

| Increments indicated by analysis to have been gained by additions of known quantities of material to a gallon of water. | Polluted with ·05 grm. of typhoid stool. | Polluted with ·05 grm. of healthy stool. | Polluted with ·1 grm. of typhoid stool. | Polluted with ·1 grm. of healthy stool. |
|---|---|---|---|---|
| CHEMICAL INCREMENTS IN GRS. PER GAL. | | | | |
| Volatile matters | 1·12 | 1·96 | 1·12 | 1·68 |
| Ammonia | ·0004 | ·0015 | ·0006 | ·0026 |
| Alb. ammonia | ·0020 | ·0059 | ·0048 | ·0216 |

"The addition of the typhoid stool gave to water far less indication of pollution than was given by an equal quantity of healthy stool."

(*a*) As regards this table, it is worthy of note that the

[1] The inconclusive nature of this Report is described in detail in a paper entitled "Remarks on the Examination of Water for Sanitary Purposes," read before the Socy. of Med. Officers of Health on February 16, 1884, by C. E. Cassal and Dr. Whitelegge.

healthy man was fed during four days previous to the experiment on a much larger amount of soluble nitrogenous organic matter than the patient with whom he was compared, hence the striking difference observable in the amount of volatile matters, which were nearly twice as much in the healthy as in the typhoid case.

(*b*) The proportion of the highly carbonaceous matter of the biliary discharges to nitrogenous matter may have been greater in the one case than in the other.

(*c*) The solubility of constituents of stools was not shown to be alike in both cases.

Again we are confronted on page 142 with a table, of which the following is an abstract:—

| | Unpolluted Samples. Lambeth water. | | | Polluted Samples. Lambeth water polluted in the proportion of ·21 gr. of soluble solid matter of typhoid stool to each gall. | | |
|---|---|---|---|---|---|---|
| | Dupré | Frankland | Wanklyn | Dupré | Frankland | Wanklyn |
| | *Grains per Gallon.* | | | *Grains per Gallon.* | | |
| Oxygen absorbed from Permanganate | ·2415 | ... | ... | ·2512 | ... | ... |
| Ammonia | ·0011 | ... | ·0014 | ·0016 | ... | ·0007 |
| Alb. Ammonia | ·0090 | ... | ·0056 | ·0100 | ... | ·007 |
| Organic Carbon | ... | ·2114 | ... | ... | ·2205 | ... |
| Organic Nitrogen | ... | ·0371 | ... | ... | ·0399 | .. |

The result is in accordance with our previous knowledge as to the impossibility of distinguishing between healthy and specific contamination of drinking water. The three different processes supply general indications, which require to be checked by other evidence. Whilst the albuminoid ammonia process furnishes us with ammonia evolved by a portion only of the organic matter, and the oxygen process only records the oxygen used up by a part of the organic matter, the combustion process yields the carbon and nitrogen contained in the residue of a water to the exclusion of that lost during the evaporation of the same.

Duplicates of the samples of water polluted by typhoid and healthy excrements were examined microscopically, and each sample that was thus examined was found to contain "crowds of bacteria"—a fact of itself most damaging to the character of any drinking water. I do not remember ever to have seen a natural water containing "crowds of bacteria" in each field of the microscope that did not present other evidence, sufficient when combined to condemn it as a water supply. The inquiry affords a confirmation of the accuracy of the opinion expressed by me for the last eight or ten years, that a sole reliance on the results afforded by these processes for the detection of the carbon and nitrogen (apart from subsidiary analytical evidence, in which respect the Medical Officer of Health's method differs from all others) often leads to mistakes. It does not follow that, because chemical analysis might have failed to detect the accidental poisoning by a workman of a vast quantity of pure water by specifically infected matter, as at the Caterham and Redhill outbreak of enteric fever (of which failure no proof was afforded[1]), therefore water analysis is useless. In ninety-nine cases out of one hundred (1) such specifically infected matter is introduced into a well *in conjunction with* other animal organic matter; (2) the presence of animal organic matter indicates an open door or channel for the chance entrance of specific poison; and (3) as a matter of experience it may be confidently asserted that, as a rule, minute quantities of specifically infected matter do not *alone* gain admission into well water. If the "filth diseases" are propagated either through the instrumentality of living organisms with their

[1] The author possesses evidence which tends to show that a great change did take place in the amount of the *mineral* constituents of the water.

power of unlimited self-multiplication, or by animal poisons, associated each with its characteristic organism, it is probable that a large amount of organic matter in a water is more objectionable than a small amount, as furnishing more material and conditions suitable for the development of noxious as well as harmless organisms. So far as regards the bacillus anthracis, it has been shown[1] that this micro-organism does not flourish in pure water. Its food supply is used up within a few hours, and the water which has been infected with it soon loses, when applied to a suitable culture-medium, its infective property. The duration of infectivity in purposely infected water was found to vary with the proportion of nutrient animal matter contained therein. As Tiemann and Preusse have well pointed out,[2] although an impure water is not necessarily pernicious, a polluted water is more likely to contain disease ferments than a pure one.

### 9.—Koch's Biological Method.

The determination of the amount of organic and mineral matters contained in a water may be usefully supplemented by an estimation as to the number and nature of the micro-organisms in it, which supplies us with information that a chemical examination does not afford.

Bacteriological researches as to the nature and life-history of micro-organisms belong to laboratories devoted to biological investigations, but the power of ascertaining whether their number in a water is beyond the normal amount is within the reach of the health officer. The difficulties which attend the employment of the following adaptations of Koch's biological process to water examination are involved in the necessity of the expenditure of a great deal of time, a close attention to details, the

[1] Reports on London Water Supply, for June and August, 1886, by Mr. W. Crookes and Drs. Odling and Tidy.

[2] *Chemical News*, January 16, 1880, pp. 30, 31.

observance of scrupulous cleanliness, and the want of a *thoroughly satisfactory* mode of numerically distinguishing waters of similar organic impurity one from another. The first to be described is a qualitative examination, which has given some very striking results in the hands of Dr. Muter.[1] Obtain some good fresh gelatine[2] in very thin *laminæ.* Thoroughly dessicate it at the highest possible temperature, and enclose it in a carefully cleansed and dried bottle. Then 100 c. c. of redistilled water is well boiled in a clean flask, the mouth is closed by cotton wool, and the whole is allowed to cool to 90° F. Four grammes of the gelatine and two centigrammes of sodium phosphate are now placed in the flask, and the mouth having been again closed, agitation is persisted in until entire solution takes place. A fresh egg is now broken, and a little of the white is added to the contents of the flask, which are then boiled and filtered through a paper sterilized by heat; 25 c. c. of the filtered liquid are then mixed with an equal volume of the suspected water in a tube closed by cotton wool, and kept at a temperature of 60° to 70° F. A comparison tube is also set up with redistilled and previously boiled water. With really infected water, a cloudy layer of bacteria will form within a comparatively short space of time, and the gelatine will liquefy from the surface downwards, and will disengage putrid-smelling inflammable gases.

Dr. Muter's plan.

*The late Dr. Angus Smith's adaptation of Koch's Method of Water Examination.*[3]

A 5 per cent solution of the thin leaf gelatine, which solution melts at about 80° F., is clarified by filtration or

Dr. A. Smith's adaptation.

[1] *Analyst*, September 1885.

[2] French gelatine, sold in thin transparent sheets, of the best quality, is preferred in biological experiments.

[3] Second Report under the River Pollution Prevention Act of 1876, to the Local Government Board, "On the Examination of Waters."

by fresh albumen. Of this solution 25 c. c. are placed in a test tube and then mixed with 25 c. c. of the water to be examined, and kept for some minutes at that temperature; but much smaller quantities are frequently sufficient. The tubes in which the experiments are made are about 8 inches long and 1 inch in diameter, with stoppers of cotton wool only. After the mixture cools it becomes solid around any organisms which may be present, transparent spheres forming which contain active and inactive bacteria. Distilled water, if examined, exhibits no change, but other waters display, according to their purity, a greater or less number of these spheres or colonies, which may be counted. A number of very minute white dots are sometimes visible, and seem to indicate the number of points of vitality in the water. Sugar and phosphate of soda were in some experiments, by Dr. A. Smith, added to the gelatine, both together and separately; but gelatine alone seemed to give clearer and simpler results. He writes, "Of all the forms of change in these tubes, that which seems to be connected with the most offensive waters is the liquefying of the surface. The number of points of activity one naturally considers a measure of impurity."

### *Dr. Percy Frankland's adaptation of Koch's method of Water Examination.*[1]

Dr. P. Frankland's adaptation.

"COMPOSITION OF MEDIUM AND MODE OF PREPARATION.

| | |
|---|---|
| Lean meat . . . . . . | 1 lb. |
| Gelatine . . . . . . | 150 grms.[2] |
| Peptone (solid) . . . . . . | 10 ,, |
| Common salt . . . . . . | 1 ,, |
| Distilled water . . . . . . | 1 litre. |

[1] "New aspects of Filtration and other methods of Water treatment: The gelatine process of Water examination." A paper originally presented to the Socy. Chem. Industry, but since reprinted.

[2] Koch employs 100 grms., which has been found insufficient, as it liquefied at as low a temperature as 68° F.

The meat is finely minced and infused with a half litre of cold distilled water for 1 to 2 hours, the solid part being then strained off through linen. The gelatine is allowed to soak in the other half litre of water, and to this the extract of meat is added. The whole is now heated until the complete solution of the gelatine has taken place, the peptone and salt being then added and allowed to dissolve. This liquid exhibits a distinctly acid reaction, which must be carefully neutralized by means of carbonate of soda. The neutralized liquid is then clarified by beating into it the contents of two or three eggs, along with the broken shells, the whole being briskly boiled for a few minutes. The coagulated albumen rises to the surface and carries with it the other solid particles suspended in the liquid. On then straining through linen, a fairly clear liquid is obtained, which is finally clarified by passing through filter-paper placed

**Filtration of meat, peptone, and gelatine medium.**

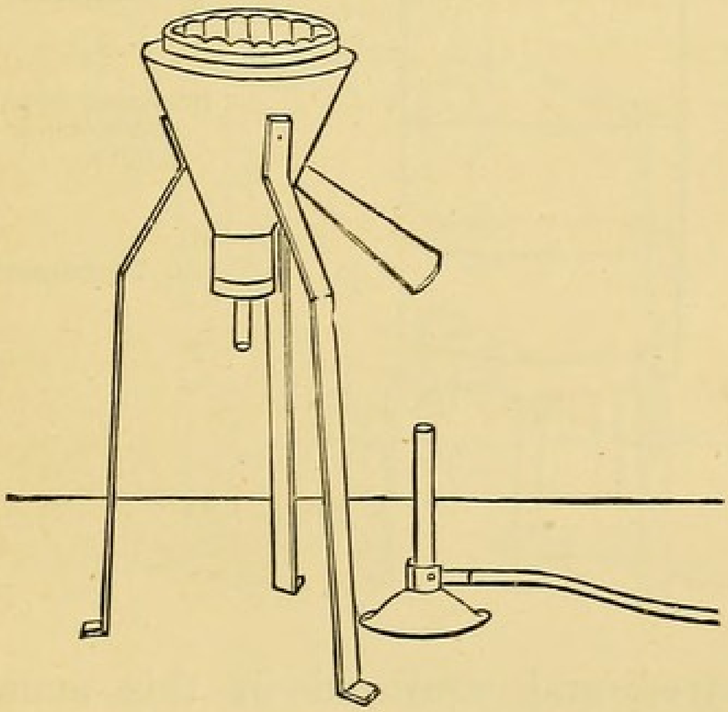


FIG. 4.

Glass funnel surrounded by Copper Jacket for filtering Gelatinized Meat Infusion.

in a funnel provided with a hot water jacket, the filtrate being rejected until it runs perfectly clear and limpid.

The filtrate sets on cooling to a yellowish brown transparent jelly. Whilst still liquid it is poured into clean test tubes, the quantity which I employ in each tube being exactly 7 c. c. The test tubes are tightly plugged with cotton wool and then at once sterilized by steaming them for half an hour on three consecutive days in a vessel made expressly for the purpose, and the construction of which is shown in the accompanying figure.

Sterilization by steam.

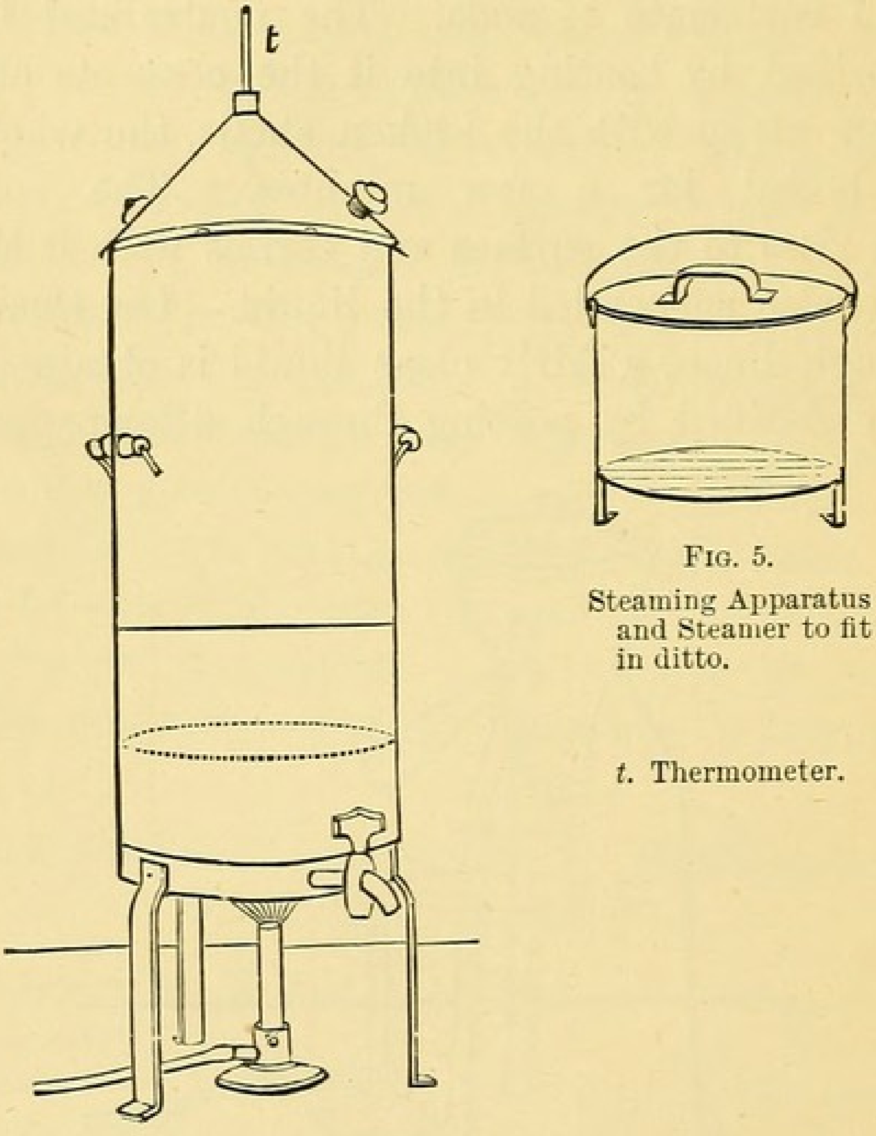



FIG. 5.
Steaming Apparatus and Steamer to fit in ditto.

*t.* Thermometer.

Tubes prepared and sterilized in this manner I have found to remain unchanged for an indefinite period of time."[1]

[1] If it is desired to avoid the trouble of preparing sterilized meat peptone gelatine, it can be purchased from Dr. H. Rohrbeck of Berlin in test tubes or flasks.

*Collection of Samples of Water.*—Glass stoppered bottles of about 70 c. c. capacity are cleansed, rinsed with distilled water, dried and kept in an air bath at from 302° F. to 356° F. for at least 3 hours. In taking a sample the outside of the bottle should be rinsed in the water before removing the stopper, and exposure to the air be reduced so far as possible to a minimum. The mouth of the bottle should not be allowed to come into contact with the tap. In collecting samples from ponds or rivers, the stopper should not be removed until the bottle is completely immersed in the water, and should be replaced whilst still below the surface. Collection of samples.

*Sterilization of Apparatus.*—It is necessary to sterilize every article that is used in these experiments. Sterilization by hot air.

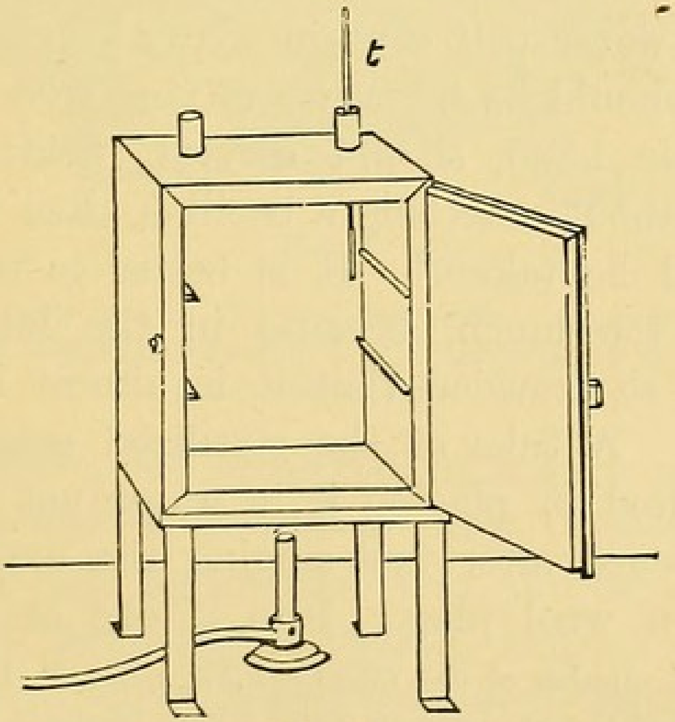



Fig. 6.

Hot air chamber for sterilizing Pipettes, Glass Plates in metal box, cotton wool, etc.
*t.* Thermometer.

Dr. Klein states[1] that cotton wool should be exposed in a loose state in a hot air chamber to a temperature

[1] *Micro-organisms and Disease.*

as high as from 266° F. to 302° F., for several successive hours, for several successive days, and that it ought to be just singed. Glass apparatus is sterilized by exposure in the hot air chamber for 3 hours to a temperature of from 302° F. to 356° F., and by washing in sterilized distilled water or a 2 per cent solution of corrosive sublimate.

Examination. *The Examination of Sample,* which should be performed as soon as possible after collection,[1] must be violently shaken to ensure an even distribution of the organisms throughout the water. At this stage Koch determines[2] approximatively, by making a cover glass preparation (*vide* page 161), the number of micro-organisms present, in order to judge as to the quantity of the water under examination which should be used. "If on microscopic examination one bacillus be detected in each 'field,' one drop of the water will contain many hundreds, and less than 1 c. c. should be taken for mixing with the gelatine. On the other hand, should several 'fields' have been examined without detecting a bacillus, then 1 c. c. of the water should be taken." It is better to take too little water than too much, because in the latter case the colonies are so crowded that it is almost impossible to count them. A tube of the sterilized gelatine peptone medium, melted by placing it in water not heated above 86° F., is opened after first singing the external portion of the cotton wool plug. Into it one or more drops[3]

[1] In a recent number of the *Chemical News*, Dr. T. Leone is reported to have found that the pure spring water which supplies Munich enters it with 5 organisms in each 1 c. c., which on standing 24 hours increased to 100, in 2 days to 10,500, and on the 5th day to half a million, this multiplication occurring at a temperature of from 57·2 to 64·4° F.

[2] The Biological Examination of Water as carried out in the Reichs Gesundheits Amt. Berlin, *vide* paper by Professor Warden in *Chemical News*, July 31, 1885.

[3] It is necessary to ascertain how many drops, delivered by the pipette employed, form 1 c. c., as drops differ so much in size.

(according to the quantity it has been predetermined to employ) of the water under examination is transferred by means of a graduated pipette (which has been previously sterilized in a tin box by heating it from 302° F. to 356° F.) and the water and gelatine are rapidly mixed (carefully avoiding the formation of bubbles) by agitation in the tube, which is held in a slanting position to prevent the entrance of dust.

*Arrangement for reception of Glass Plate.*—A soup plate, in which rests a very short-legged tripod, which Plate cultivations.

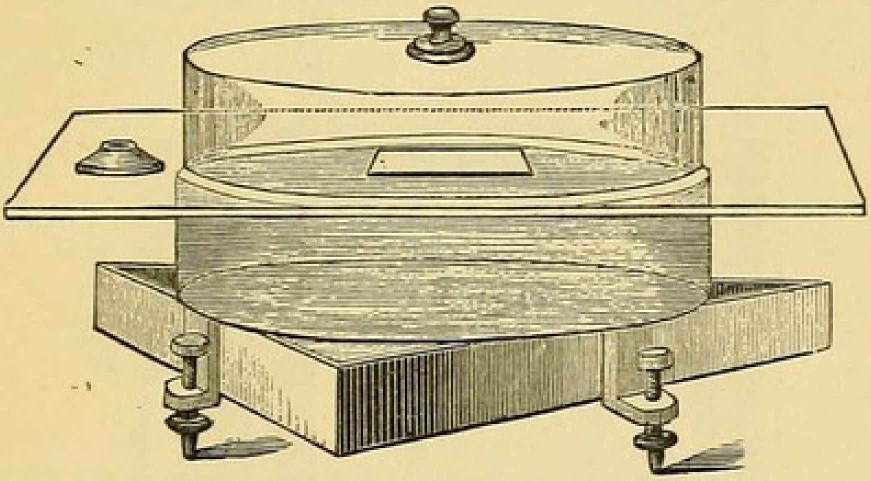


FIG. 7.

APPARATUS EMPLOYED FOR PLATE CULTIVATIONS. (After Crookshank.) Tripod stand; Glass dish, filled with cold or iced water; Sheet of Plate-glass; Spirit Level, and Glass Bell.

supports a glass plate protected by a glass cover, having with its contents been rinsed with boiled redistilled water immediately before use, is by the help of a spirit level rendered perfectly horizontal, and a little of the same sterilized distilled water is poured into it so as to form a seal between the outer and inner air. Dr. Edgar Crookshank recommends[1] that the solidification of the liquid nutrient jelly should be hastened by placing the glass plate on a slab of glass covering a vessel full to the brim with cold water, which may be iced in warm weather.

[1] *Introduction to Practical Bacteriology.*

Prof. Warden states that this arrangement may be improved by placing the water-receiver in an empty shallow vessel into which it fits loosely, and in which it is supported on three pieces of cork. This outer vessel which rests on the tripod serves to receive the overflow water and any moisture which may condense on the sides of the iced water-receiver. A sterilized glass plate is now withdrawn (the future upper surface being held

Incubator.

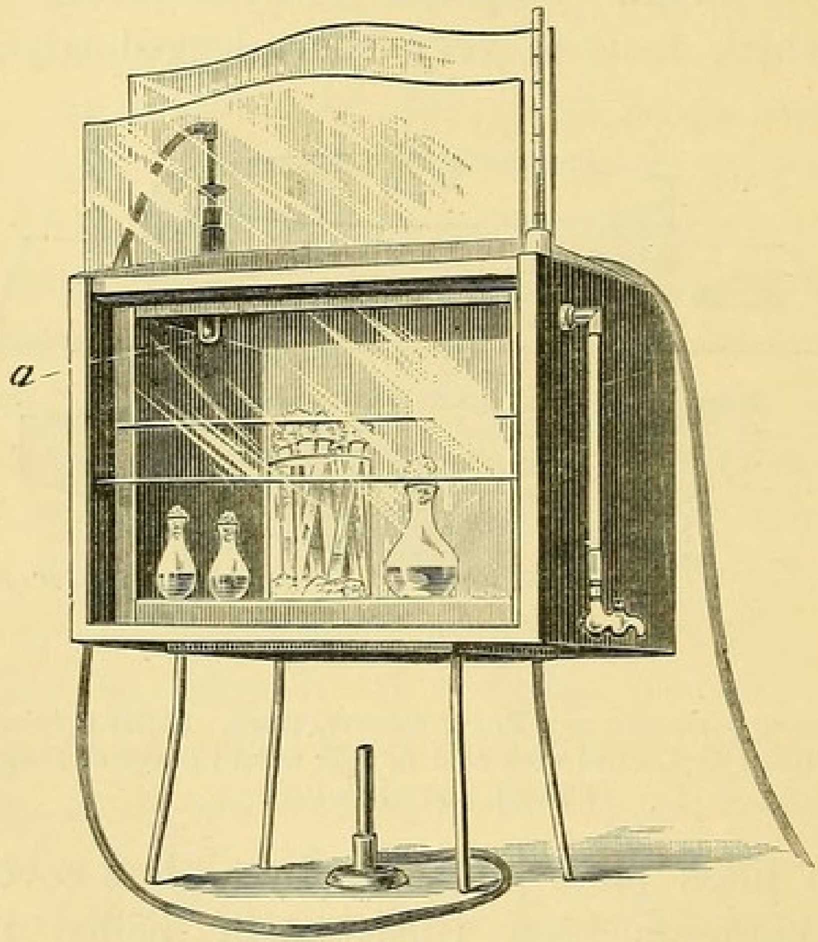



FIG. 8.
Incubator, with a gas regulator (*a*) in air chamber. (After Woodhead and Hare.)

downwards) from a metal box in which it has been sterilized, and is placed on the levelled plate, and the contents of the test tube are poured on to it. Koch and others advise that the gelatine be evenly spread over the plate by the help of a sterilized glass rod so as to form a square. As soon as the gelatine has set on the plate it is at once removed in its dish into an incubator, maintained at a temperature of from 68° F. to 77° F. Koch recommends that the glass plate after solidification of the gelatine should, instead of being placed in an incubator, be transferred to the glass bench of the "damp chamber," where in the course of a day or two, according to the temperature of the room which should be from 60° F. to 65° F., the colonies will develop. The "damp chamber" consists of a shallow glass dish, a covering bell, and glass rack, all of which have been thoroughly cleansed and washed with a solution of corrosive sublimate (1 part to 1000 of water). The bottom of the glass dish is covered with two or more layers of filter-paper cut to the

Damp chamber.

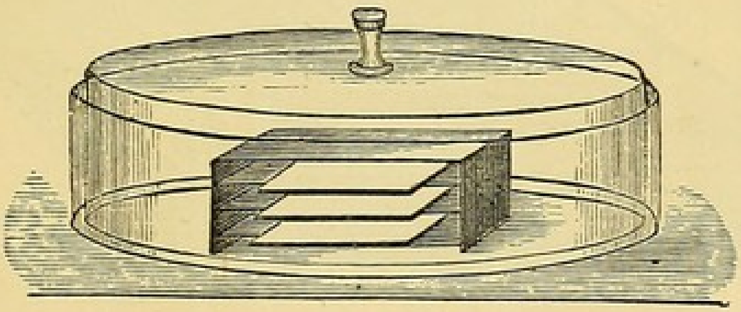


FIG. 9.

DAMP CHAMBER FOR PLATE CULTIVATIONS. (After Crookshank.)
It contains a glass rack on which rest gelatine glass plates.

size, taking care that it does not project beyond the edge of the covering bell. The vertical portion of the glass cover is lined internally by some with a circular strip of blotting-paper to prevent any drops of condensed moisture from falling on the plates. All of the blotting or filter-paper is moistened with the corrosive sublimate solution. Dr. P. Frankland writes, "The period of incubation generally varies from 3 to 5 days, but sometimes it is continued for a longer period of time, to make sure that all the organisms present have had a due opportunity of development." The gelatine plates are daily inspected during the period of incubation, without removing the glass cover, so that the progress of the colonies derived from the individual organisms may be watched; when these have reached such dimensions that they are distinctly visible to the naked eye, and before the contours of different colonies have begun to coalesce, the plates are withdrawn for examination. The colonies are counted with the aid of a strong hand-lens, the more doubtful ones being further examined by means of a simple microscope. In order to arrive at an accurate conclusion with respect to the number of colonies, it is necessary that they should all be counted individually; but, in cases in which the

Enumeration of colonies.

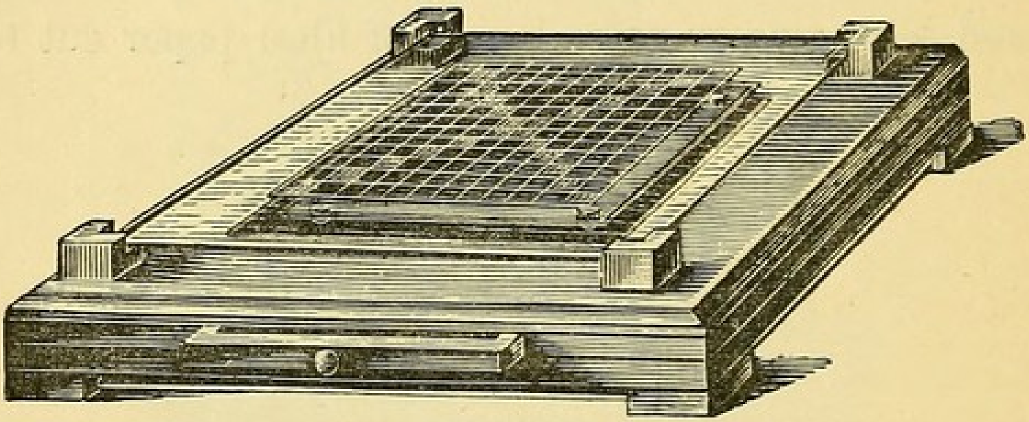


FIG. 10.

APPARATUS FOR ESTIMATING THE NUMBER OF COLONIES IN A PLATE CULTIVATION. (After Crookshank.)

The ruled plate divided into centimètre squares, some of which are sub-divided into ninths, is so arranged as to cover the gelatine plate without touching it.

colonies are very numerous, an estimate of the total number may be formed by placing the gelatine plate on or beneath a second glass plate ruled in squares, the arrangement resting upon a black ground. The colonies present in a few of these squares are counted and then multiplied accordingly. A substitute for this appliance is made by ruling with a white lead-pencil, on a piece of dull black paper pasted on cardboard, a square divided by horizontal and vertical lines into 100 centimètre squares, several of which may be sub-divided by two horizontal and vertical lines into nine smaller squares. Dr. P. Frankland found that if boiled distilled water is examined, the gelatine plates almost invariably remain unchanged. Koch considers that 3 colonies is the average obtained with distilled water.

The following observations on the Metropolitan Waters are interesting as an earnest of what this method is capable :—

Micro-organisms in London waters.

MICRO-ORGANISMS IN 1 CUB. CENT. OF METROPOLITAN WATERS, 1885.

| | Jan. | Feb. | Mar. | May. | June. | | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|
| River Thames at— | | | | | | | | | | |
| Hampton[1] . . | ... | ... | ... | ... | 155 | ... | 1644 | 714 | 1866[2] | ... |
| Chelsea . . . | 8 | 23 | 10 | 14 | 22 | 81 | 13 | 34 | 3 | 9 |
| West Middlesex | 2 | 16 | 7 | 3 | ... | 26 | 2 | 2 | 5 | 15 |
| Southwark . . | 13 | 26 | 246 | 24 | ... | 47 | 18 | 24 | 32 | 73 |
| Grand Junction | 382 | 57 | 28 | 3 | 21 | 18 | 43 | 40 | 40 | 134 |
| Lambeth . . | 10 | 5 | 69 | 30 | ... | 38 | 103 | 26 | 26 | 124 |
| River Lea at— | | | | | | | | | | |
| Ching ord Mill[1] | ... | ... | ... | ... | ... | ... | ... | ... | 954[2] | ... |
| New River . . | 7 | 7 | 95 | 3 | ... | 27 | 3 | 2 | 11 | 18 |
| East London . | 25 | 39 | 17 | 121 | ... | 22 | 29 | 53 | 14 | 317 |
| *Deep Wells.* | | | | | | | | | | |
| Kent—(Well at Deptford) . . | ... | ... | ... | ... | 6 | ... | ... | 6 | 8 | 5 |
| Supply . . . | 10 | 41 | 9 | 20 | 26 | ... | 14 | 18 | ... | 7 |

The water of the Kent Company leaves the well, as is seen, almost wholly destitute of organic life, and the few organisms which it does contain are almost certainly imported into it *en route* to its supply.

I would recommend the adoption of Dr. Angus Smith's method to those who have but little time to expend in such examinations. To those who have had some experience in the observation of micro-organisms I would commend Dr. P. Frankland's method, with the modifications of others, which is undoubtedly the best that has been devised.

[1] These figures represent results obtained by the examination of the waters above the intakes of the Water Companies, and show the effect of the storage and filtration of the waters which they supply.

[2] Heavy floods during November.

## 10. The Estimation of Dissolved Oxygen in Water.

The old custom of judging of the purity of a water by the amount of its dissolved oxygen has recently been revived. The question, however, as to whether the quantity of oxygen bears any constant ratio to the organic impurities is an open one, and requires elucidation. As water becomes more and more contaminated with putrescent organic substances, the quantity of dissolved oxygen in it rapidly diminishes. Dr. Odling has shown that at a temperature of 59° F. three volumes of oxygen are dissolved in 100 volumes of water, and that an increase of solubility is obtained by a reduction of temperature. At the summer temperature of 70° F. water contains 1·8 cub. in., and at the winter temperature of 45° F. 2·2 cub. in. of oxygen per gallon. The processes for the determination of the dissolved oxygen are all, with one exception, beyond the reach of the Medical Officer of Health, requiring complex apparatus and consuming more time than he can afford. The method described in A. Proust's *Traité d'Hygiene*, p. 427, is the only one which can be suggested as at all suitable for him, if he desires to launch out into the unknown on this new branch of water analysis. A copy of a translation of the manuscript notes of M. Gerardin, who with Schützenberger invented this process, have been kindly sent to me by Mr. J. W. Slater.

Schützenberger and Gerardin's process.

A solution of the hydrosulphite of soda is made thus:—Place some zinc turnings in a 100 gramme flask, and fill it three parts full with water. Add 10 c. c. of a solution of bisulphite of soda, of a specific gravity of 1·16 (which should have been saturated with sulphurous acid by passing a current of this gas through it for several hours).[1] Insert a caoutchouc stopper and agitate several times. In half an hour the re-agent is ready. The hydrosulphite of soda differs from the bisulphite only by an atom of oxygen. In presence of free oxygen it instantly absorbs this body and is converted into the bisulphite

$$S_2O_2NaOHO + O_2 = S^2O^4NaOHO$$

There are colouring matters, such as "Coupier's soluble aniline blue," which are instantaneously decolourized by the hydrosulphite of soda, though they resist the action of the bisulphite. For instance, if to a litre of water well freed from air by boiling, and coloured faintly with Coupier's blue, we add dilute hydrosulphite of soda, avoiding access of air, we shall observe that a few drops are sufficient to destroy the colouration. If, on the contrary, the water is aerated, the decolouration is not produced until enough hydrosulphite has been added to absorb all the dissolved oxygen. If the solution of hydrosulphite of soda were capable of being preserved, it would be merely requisite to determine once for all the volume of oxygen which a known volume of the liquid can absorb; but, in consequence of its great instability it is necessary to standardize the solution every time before its employment. This is easily effected by the decolouration which the hydrosulphite of soda produces in a solution of the ammoniacal sulphate of copper, as it reduces cupric oxide to cuprous oxide. Bisulphites and sulphites are without action on the solution of copper, as long as there remains an excess of ammonia. We prepare then a strongly ammoniacal solution of sulphate of copper containing 4·471 grammes of the crystallized salt per litre, 10 c. c.

[1] Sulphurous acid gas is prepared by allowing pure sulphuric acid to act on clean copper cuttings, and must be washed by passing it through a small quantity of water. *Vide* any book on chemistry.

of which solution having the same action upon the hydrosulphite of soda as 1 c. c. of oxygen. Suppose that we take 20 c. c. of this ammoniacal copper solution, and find that 17·5 c. c. of the solution of the hydrosulphite of soda are needful to bring the blue solution to a colourless state. We know that the 20 c. c. correspond to 2 c. c. of oxygen. If a litre of the water to be examined, slightly tinted with Coupier's blue requires 36·4 c. c. of the solution of the hydrosulphite of soda to be decolourized, we have—

$$x = \frac{36{\cdot}4 \times 2}{17{\cdot}5} = 4{\cdot}16 \text{ c. c. of oxygen dissolved per litre of water.}$$

There remains a small correction to be applied for the quantity of hydrosulphite of soda needful to decolourize the Coupier's blue employed, which may be determined once for all.

This process is marvellously sensitive. If two portions of the same water are taken, and one is poured boldly into a beaker whilst the other is allowed to flow quietly down the side of a beaker, the two will show a decided difference. The testing should be performed in a vessel which exposes as little surface to the air as possible, stirring must be minimized, and a little light petroleum oil or pure mineral naphtha may be poured on to the surface to exclude oxygen.

Dr. Tidy's observations.

Dr. Tidy has made a few observations on Thames water[1] which show that the oxygen in solution during the winter months (November to April) is very nearly double the amount held in solution during the summer months (May to October), being 2·19 in the former case and 1·19 cub. in. per gallon in the latter, the least oxygen being thus present during the months of the greatest organic purity.

[1] "River Water," *Journal of Chemical Society*, vol. xxxvii. 1880.

Dr. Dupré has also made similar observations[1] on the Thames water at various points from Richmond towards the sea. Dr. Dupré's observations.

*Permanganate of Potash Test.*

| | Oxygen absorbed per gall. |
|---|---|
| Teddington Weir . . . | ·109 |
| Chelsea . . . . | ·165 |
| Greenwich . . . . | ·204 |
| Barking . . . . | ·272 |
| Northfleet . . . . | ·151 |
| Thames Haven . . . . | ·106 |
| Yantlet Creek . . . . | ·070 |

*Dissolved Oxygen Test.*

| | | Percentage of Aeration. |
|---|---|---|
| Aug. 9, 1882. | Richmond Bridge . . . | 100 |
| | Kew Bridge . . . . | 100 |
| | Hammersmith Bridge . . . | 67·3 |
| | Westminster Bridge . . . | 54·5 |
| Sept. 22, 1882. | Tunnel . . . . | 25 |
| | Barking Creek . . . . | 19·7 |
| | Jenningtree Point . . . | 23·3 |
| | Erith . . . . . | 23·7 |
| | Northfleet . . . . | 38·1 |
| | Coal House Point . . . | 52·6 |
| | Hole Haven . . . . | 75 |
| | Southend . . . . | 96 |

Both processes show the gradual increase of pollution in the water of the river as the sewage outlet of the metropolis at Barking Creek is approached, and its gradual diminution when proceeding from this point to the sea. In a recent experimental research "On Changes in Aëration of Water as indicating the Nature of Impurities present in it,"[2] Dr. Dupré has shown the probability that chemistry may enable us to distinguish between *living* organic matter and *dead* organic matter. The samples of water on which he operated were fully aerated

[1] *Analyst*, July and September 1885.

[2] Fourteenth Annual Report of the Local Government Board, 1884-85, containing Supplement of Medical Officer for 1884.

by vigorous shaking and maintained at the same temperature. He found that a peaty water (*dead* organic matter) took more oxygen from the permanganate of potash than from the oxygen dissolved in the water, and that a water containing animal organisms consumed more of the dissolved oxygen in the water than oxygen derived from the permanganate of potash. He concludes thus: "The consumption of oxygen from the dissolved air of a natural water is in the vast majority of cases, at all events, due to the presence of growing organisms, and in the complete absence of such organisms little or no oxygen would be thus consumed." Our powers of diagnosis between waters containing a slight excess of animal and vegetable organic matter, which is admittedly difficult, are likely to be increased by a development of this scheme for estimating the dissolved oxygen in a water.

# CHAPTER III

## THE DETERMINATION OF THE MINERAL PRODUCTS RESULTING FROM CHANGES IN THE ANIMAL ORGANIC MATTER.

### 1. Ammonia,

which is in itself harmless, is a product of the decomposition of animal organic matter, and is present in air in exceedingly variable quantity,[1] out of which it is washed by the great air-cleanser, rain. Rain contains ·49 part per million of ammonia. River water rarely possesses more than ·1 part per million of ammonia. Unpolluted well water contains less than this amount, whilst spring water is generally free from it. Ammonia.

### *Excess in Rivulets and Shallow Well Waters.*

As ammonia in contact with animal matter, and subject to oxidizing influences, is very rapidly converted into nitrates and nitrites, its presence in large quantity in rivulets and shallow well waters indicates their very recent and direct pollution with animal matters. The excess is always accompanied by an excess of albuminoid ammonia. In the case of shallow wells a contamination of the water by urine is more than probable (*vide* page 209). Rivulets and shallow wells.

[1] Vide *Ozone and Antozone*, p. 226.

*Excess in Deep Well Water.*

Deep wells.

Ammonia is found in considerable quantity in the waters of some deep wells, especially of those that enter the sand-beds which lie underneath the London clay. In these waters the amount of albuminoid ammonia is so exceedingly small as to preclude the possibility of supposing the existence of any animal defilement. Here, for instance, are the analyses of three waters, all from deep artesian wells situated in a little village:—

Waters renowned for purity which contain an excess of free ammonia.

| | Milligramme per Litre. | |
|---|---|---|
| | Free Ammonia. | Alb. Ammonia. |
| A. Depth 385 ft. . . | ·59 | ·04 |
| B. Very deep . . | ·41 | ·07 |
| C. Depth 330 ft. . . | ·37 | ·06 |

Here are analyses of waters of another village, possessing locally a high repute for purity:—

| | Milligramme per Litre. | |
|---|---|---|
| | Free Ammonia. | Alb. Ammonia. |
| A. Depth 250 ft. . . | ·76 | ·04 |
| B. ,, 300 ft. . . | ·74 | ·03 |

An excess of free ammonia, when associated with a permissible amount of albuminoid ammonia, may be due either—

Possible causes of the presence of an excess of ammonia in waters free from excess of organic matter.

1. To entrance of rain water into well.

2. To the beneficial transformation of harmful organic matter into the harmless ammonia, through the agency of sand, clay, and other substances, which act on the water in a manner similar to the action on it of a good filter.

3. To some salt of ammonia existing in the strata through which the water rises; or,

4. To the decomposition of nitrates in the pipes of the well. Mr. H. Slater suggests that the agent concerned in this reduction may, in the case of the deep well waters, be the sulphide of iron which is found in the clay.

Ammonia may be converted into nitrates and nitrites by a process of oxidation, or be obtained from these salts by one of reduction. We conclude, then, that the presence of free ammonia in such comparatively large quantities in these deep well waters is due to the reduction of nitrates and nitrites by sulphide of iron, or some kinds of organic matter, or some other agent, such oxidized nitrogen salts having been produced in past ages by the oxidation of organic matter. In the case of deep artesian wells, the borings of which pass through the London clay into the chalk beneath, the nitrates that, by reduction, furnish the waters of these wells with free ammonia, doubtless come from the chalk itself. Sometimes a pure deep well water containing a minute quantity of free ammonia may be found within a few yards of another deep well water equally pure, which exhibits a large excess, the difference between the two wells being only one of depth and strata perforated:—

| Water. | Grs. per Gall. | | Parts per Million. | | Hardness. |
|---|---|---|---|---|---|
| | Solids. | Chlorine. | Free Amm. | Alb. Amm. | |
| Well 175 feet deep . | 106·4 | 37·7 | ·01 | ·02 | 9·5 |
| ,, 50 ,, ,, . | 98·0 | 36·6 | ·63 | ·01 | 4·5 |

Mr. Wanklyn formerly regarded with suspicion a water yielding a large quantity of free ammonia, along with ·05 part per million of albuminoid ammonia. The above analyses of deep well waters, which are renowned for purity throughout all the country in which they form centres, prove that he was wrong. In the fourth edition of his *Water Analysis* he shows that he has discovered his mistake, but he altogether omits to make any allusion to his error, or to the individual who not only privately but publicly pointed it out to him.[1] He thus signalizes his conversion on page 131:—

"*Well* 230 *feet deep at Blackfriars.*

| Date. | Grains per Gallon. | | Milligramme per Litre. | |
|---|---|---|---|---|
| | Solids. | Chlorine. | Free Ammonia. | Alb. Ammonia. |
| July 20, 1876. | 57· | 10·2 | ·80 | ·05 |

This water exhibits what is occasionally found, namely, a large quantity of free ammonia in pure deep spring water of the first class."

Mr. Allen of Sheffield has fallen into a similar error. He writes,[2] "It is not unusual to find a very large proportion of ammonia in the water of very deep wells. In the great majority of instances it is associated with an excessive proportion of chlorides—a fact which points to sewage or urine as the *original* source of the contamination." Both statements are correct, but the conclusion arrived at by him is altogether wrong.

Mr. Wanklyn has accordingly altered his standard of rules by changing the wording of one of his sentences. In the previous editions we read, "I should be inclined to regard with some suspicion a water yielding a considerable quantity of free ammonia, *along with* ·05 part of albuminoid ammonia per million." In the fourth edition he

[1] Vide *Water Analysis for the Medical Officer of Health*, first edition, p. 18.

[2] *Public Health*, February 9, 1877.

writes, "I should be inclined to regard with some suspicion a water yielding a considerable quantity of free ammonia, along with *more than* ·05 part of albuminoid ammonia per million,"—a very material difference.

The mode of estimating the quantity of free ammonia in a water is described on page 40.

## 2. Nitrogen as Nitrates and Nitrites.

*Nitrates and Nitrites.*

The controversy between Dr. Frankland and Mr. Wanklyn concerning their respective modes of water analysis has waged very much around the question as to the value of an estimation of the amount of these salts in a water. Whilst the former appears to give a preponderating weight to the indications afforded by the past history of a water, and seems to consider that the determination of the mineral products of the animal pollution of a water affords the key to the whole situation; the latter denounces, in the strongest terms, all reliance on the presence, in any quantity, or absence, of these products of the oxidation of filth. Mr Wanklyn says,[1] "It cannot be too strongly insisted upon that the nitrates afford no data of any value in judging of the organic quality of a water;" and again, "The progress of investigation has completely discredited the nitrates as criteria of unwholesomeness."[2] The pupils of these analysts follow very closely in the paths of their respective teachers. Dr. Hill of Birmingham, in his Report for 1876, which contains a sheet of the analyses of waters from 114 different private wells, shows that he forms an opinion of each water solely from the amount of the products of oxidation, such as nitrates and nitrites, coupled with the proportion of chlorides, without

[1] *Op. cit.* Fourth edition, p. 84.

[2] Hart's *Manual of Public Health*, p. 309.

ever attempting to estimate the quantity of organic nitrogen, and organic carbon contained in each. Mr. Thomas, public analyst of Cardiff, also states that if he found nitrates and chlorides in excess, and knew that this excess could not be ascribed to the peculiar character of the strata from which the water was derived, he should not determine the organic carbon and nitrogen unless required to do so, but would immediately condemn the water. This exclusive reliance on the evidence vouchsafed by the chlorides and nitrates is to be found in Dr. Cameron's *Manual of Hygiene*. On page 71 he writes, "In a soft water, remote from the sea, the decided presence of chlorine and nitric acid should be considered as clear evidence of previous sewage pollution, and such water should be regarded as dangerous to health." G. W. Wigner, F.C.S., also writes thus,[1] "There are many cases where a sample of water must be condemned on the evidence of nitrates, nitrites, and the microscope only."

Whilst one leader is at one extreme, the other is at the opposite. Looking at the matter judicially, apart from all preferences for either of these rival processes, and governed simply by the results of a large practical experience of all kinds of water, I should say that the truth lies midway,—

"Media in res tutissimus ibis."

Dr. Frankland, although falling into the mistake, whilst judging a water, of making his decision almost entirely rest on the degree of previous sewage contamination, and the amount of nitrates and nitrites, makes the following statements,[2] with which we must all agree.

In the presence of oxygen the nitrogen of animal matters is transformed, in great part, into nitric and

[1] *Sanitary Record*, October 19, 1877.

[2] Rivers Pollution Commission.—*Sixth Report.*

nitrous acids; and these, by combining with the basic substances always present in polluted water, are in their turn converted into nitrates and nitrites.

The change is most rapid and complete when polluted water passes through aerated soil.

Whilst the oxidation of animal matters in solution in water yields abundance of nitrates and nitrites, vegetable matters furnish under like circumstances mere traces, or none, of these compounds.

**Bristol water supply.**

The late Mr. Stoddart, Analyst for Bristol, directed attention in the *Analyst* of March 1878, page 212, first, to the abundance of diatoms in the Bristol water supply, secondly, to the production of ammonia by their decomposition, and thirdly, to the origin of nitrates from the ammonia thus formed. Notwithstanding the large quantity of diatoms, the amount of these products of their decay is insufficient to raise the insignificant proportions of the ammonia and nitrogen as nitrates when diluted with such immense volumes of water as are contained in the reservoirs.

Upland waters, which have been in contact only with mineral matters, or with the vegetable matter of uncultivated soil, contain, if any, mere traces of these salts; but as soon as the water comes into contact with cultivated land, or is polluted by the drainage from farmyards or human habitations, nitrates in abundance make their appearance. The presence of nitrates and nitrites in sufficient quantity is therefore trustworthy evidence of the previous pollution of the water with animal matters.

Nitric and nitrous acids are present in minute quantity in the air, out of which the rain washes them. In 71 samples of rain water collected at Rothamsted, near St. Albans, the proportion of nitrogen, as nitrates and nitrites, varied from nil up to ·03 grain per gallon. The largest amount, which occurred only once, was exceedingly small.

Waters which, it is well known, cannot be defiled by manure or by sewage, never contain nitrates in a proportion bringing them near to the "point of contamination."

The average amounts of oxidized nitrogen found by the Rivers Pollution Commissioners [1] in the pure waters of the various geological strata are as follows:—

*Nitrogen as Nitrates and Nitrites.*

| | Grain per Gallon. |
|---|---|
| Rain | ·002 |
| *Upland Surface Water.* | |
| (From Non-calcareous Strata.) | |
| From Igneous Rocks | ·001 |
| ,, Metamorphic, Cambrian, Silurian, and Devonian Rocks | ·004 |
| ,, Millstone Grits | ·007 |
| (From Calcareous Strata.) | |
| From Mountain Limestone | ·008 |
| ,, Lias, Trias, and Permian Rock | ·007 |
| ,, the Oolites | ·03 |
| *Deep Well Water.* | |
| In the Coal Measures | ·14 |
| ,, New Red Sandstone | ·5 |
| ,, the Chalk | ·4 |
| ,, ,, ,, below London Clay | ·05 |
| ,, Devonian Rocks and Millstone Grit | ·2 |
| ,, the Lias | ·3 |
| ,, ,, Oolites | ·4 |
| ,, ,, Hastings Sand, Greensands, and Weald Clay | ·1 |
| *Spring Water.* | |
| From Granite and Gneiss Rocks | ·07 |
| ,, Devonian Rocks and Old Red Sandstone | ·5 |
| ,, New Red Sandstone | ·2 |
| ,, the Lias | ·3 |
| ,, ,, Hastings Sand and Greensand | ·2 |
| ,, Silurian Rocks | ·12 |
| ,, Mountain Limestone | ·16 |
| ,, Millstone Grits and Coal Measures | ·24 |
| ,, the Oolites | ·28 |
| ,, ,, Chalk | ·27 |

[1] *Op. cit.*

*The Objections of Mr. Wanklyn and those who think with him, to the Determination of Nitrates and Nitrites, may be thus summarized:*

Objections to the estimation of Nitrates and Nitrites.

1. Nitrates find their way into waters from the various geological strata which they traverse; for example, chalk springs, which contain an infinitesimal amount of organic matter, are often highly charged with nitrates.

2. The processes of vegetation in rivers and lakes are calculated to withdraw nitrates from the water; accordingly, an absence of nitrates may be due to a rife aquatic growth as well as to absence of sewage.

3. Raw sewage is said to be free from nitrates.

The examples adduced in support of these statements prove nothing. If we examine seriatim the objections themselves, we shall find that they amount to very little.

Answers to the objections.

1. Nitrates are found in excess in certain pure waters from the chalk, but the largest amounts discovered do not generally exceed ·7 grain per gallon, an amount which would simply throw suspicion on the water of a shallow well, or of a spring, if this result was confirmed by other evidence. Knowing this peculiarity in the waters of deep wells in the chalk, namely, that they possess an excess, and sometimes a large excess, of nitrates, the objection falls to the ground.

2. It is perfectly true that vegetable life assimilates these salts, and so removes them, especially in spring and summer. Accordingly, their amount will then show a slightly more favourable result than really exists during the quiescent months of the year. This optimist indication in the growing season appears to be a very feeble objection, especially when it is remembered that the estimation of the nitrates and nitrites is only one of several data on which an opinion of a water should be based.

3. In undiluted sewage putrefaction rapidly occurs, during which process the nitrates are destroyed.[1] I cannot consider this as a valid objection.

### *Utility of the Estimation of Oxidized Nitrogen Salts.*

Utility of the determination of Nitrates and Nitrites.

The presence of an excess of these salts in a water affords no indication, taken by itself, that such water deserves condemnation, nor does the complete absence of nitrates and nitrites warrant any one in pronouncing a water to be pure. Some of the purest waters, such, for example, as those from deep wells in the chalk, contain much nitrates, which have aptly been termed fossil organic matter, or the skeleton of sewage; whilst waters so full of vegetable matter as to be injurious to health may not contain a vestige of them. The estimation of the amount of these salts not only teaches us, as to whether the soil from which the water is derived is clean or defiled with filth which it has oxidized,[2] but, taken in conjunction with other evidence, it affords valuable aid to us in the formation of an opinion. Although the water of a well far away from any chalk may be found to be organically pure, yet the presence of any large quantity of nitrates and nitrites, which are, so far as our knowledge extends, harmless in themselves, informs

[1] Some believe that in sewage, nitrogenous organic matter is destroyed without the formation of nitrates, the nitrogen being evolved in the form of gas; whilst others consider that when sewage is allowed to stand, a process of fermentation occurs, and as this subsides, oxidation commences with the formation of nitrates and nitrites at the expense of the organic matter and the ammonia.

[2] The contrast displayed by samples recently sent to the author of the water of the River Jordan, which contains a mere trace of nitrogen as nitrates and nitrites, and that of the Pool of Siloam, which holds in solution more than 22 grains of nitric acid per gallon, whilst each water exhibited between 30 and 40 grains of chlorine per gallon, is very striking.

us that the water is in imminent danger of pollution. This discovery tells us that the natural oxidizing process of cleansing and purification by the soil is proceeding. Experience teaches us that a time will come, and we know not how soon, when the soil will become overdone with filth, and will, at first imperfectly, and at length finally cease to, cleanse by filtration the polluted water, when the organic matters will themselves enter the well; or the organic animal filth may be washed into the well at any moment by a sudden downfall of rain. The presence, then, of these salts, in considerable proportion, in shallow well waters, in non-chalky districts, is an ominous sign. A public analyst has recently written:— "Nitrates in a deep well water represent *fossil* excreta, but nitrates in a shallow well water represent *recent* excreta." The former part of the sentence is true enough, but the latter is misleading. I have known shallow well waters in chalky districts, that could not possibly have been defiled, exhibit an excess of nitrates.

There exists a widely spread dread lest the poisons of diseases, be they soluble or in the form of micro-organisms or of infinitesimal insoluble particles, may survive the almost complete oxidation by earth of dead organic matter, and may co-exist with nitrates and nitrites in a water devoid of any excess of organic matter.[1] Some,

[1] This fear has recently been very forcibly expressed by Dr. Ashby and Mr. Hehner ("On So-called Previous Sewage Contamination," in *Analyst*, April 1883), with respect to waters from the surface wells, 7 or 8 to 20 or 25 feet in depth in Derby and Newark-on-Trent. These waters come from the variegated marl of the trias, the marlstone rock-bed of the middle lias, and the chalk. They seem as a class to be notorious for high solids, an excess of nitric acid, phosphoric acid, sulphuric acid, and chlorine associated with a *comparatively* small amount of free ammonia and albuminoid ammonia. Some soils soon lose the power of oxidizing filth, especially if overdone with it; whilst others may be converted into a nitre bed, and still retain the property of carrying on this purifying change.

indeed, believe that water from a well within a yard or two of a cesspool cannot possibly be pure. I have known several wells in clay soil, varying in distance from one to five yards from cesspools, which have supplied water of the greatest purity, their safety being due to the retentive properties of the clay, and the water-tight condition of the cesspools. I am acquainted with a family that has for years, without apparent ill effects, been drinking water from a well in porous gravelly soil, within two yards from an enormous cesspool, which is evidently not water-tight. The water is organically pure, but contains between 1 to 2 grains per gallon of nitrogen in the form of nitrates and nitrites. Highly dangerous of course it is to drink such water, for the well may be defiled, or the earth may cease to act as an efficient filter, at any instant. The curious spread of typhoid fever at Lausen, in Switzerland,[1] by water that had passed through an immense thickness of earth, has excited the suspicion that the poison of enteric fever may possibly be a soluble rather than an insoluble particle. Under the supervision of Prof. Mallet a number of natural waters believed to be good and wholesome, including the regular water supply of some of the principal cities of the United States, were arranged together as class 1; and a number of natural waters, which there was fair ground for believing had actually caused disease on the part of those drinking them, were arranged as class 2. Both series of waters were examined by the Frankland Combustion process, by the Wanklyn, Chapman, and Smith process, and the Letheby and Tidy permanganate process, with this result—"No marked difference exists between the *highest*, *lowest*, or *average* result obtained by any of the processes for the waters of class 1 and the corresponding

Prof. Mallet's experiments in the United States.

[1] *Beiträge zur Entstehungsgeschichte des Typhus und zur Trinkwasserlehre.*—Von Dr. A. Hägler.

result for those of class 2. No one could, with these figures to guide them, refer a water of unknown origin to one or other of the two classes on the evidence afforded by chemical analysis, using either or all of the processes in question." On examining these same waters for nitrates and nitrites "we find a very obvious connection between the results of chemical examination and the known sanitary character of the several waters, the salts of nitrous and nitric acid being either absent or present in but trifling amount in waters of class 1, believed to be wholesome; whilst they were almost universally present, and in many cases in large quantity, in the pernicious waters of class 2."

Griess has expressed[1] a strong opinion as to the unfitness of water for drinking purposes which contains nitrates and nitrites. Dr. Angus Smith writes,[2] "the presence (of nitrates) shows that the most dangerous state of the organic matter is past. The water may, however, be still dangerous to use." Ekin states that[3] "waters which have undoubtedly given rise to typhoid fever have been found by the writer over and over again not to contain more than ·05 part of albuminoid ammonia in 1,000,000, and which, notwithstanding their containing a large excess of nitrates, have been passed by analysts of undoubted ability as being fit for drinking purposes." R. Haines of Philadelphia has published[4] cases which partially corroborate the opinions of Mr. Ekin.

Examples.

Here is an analysis of a well water kindly sent to me by Dr. Armistead, of the Cambridgeshire district, which would have been passed as pure if sole reliance had

[1] *Ann. d. Chem. u Pharm.* cliv. 336.

[2] *Chemical News*, September 3, 1869.

[3] "Potable Water."

[4] "Methods of judging of the wholesomeness of Drinking Water," from *Journal of the Frankland Institute*, February 1881.

been placed on the indications afforded by the Wanklyn, Chapman, and Smith process:—

| Grains per Gallon. | Milligramme per Litre. | |
|---|---|---|
| Chlorine. | Free Ammonia. | Album. Ammonia. |
| 4· | ·14 | ·06 |

The amount of chlorine did not exceed the average for the neighbourhood. Suspicions were aroused when the well was found to be near a churchyard, and oxides of nitrogen were sought for. These filth products were found in abundance, and a considerable quantity of phosphates were also discovered.

Here is another example of a water that would have been deemed, if trust had solely been placed on the amount of free and albuminoid ammonia, to be of indifferent quality, but passable:—

| | Milligramme per Litre = Part per Millon. |
|---|---|
| Free ammonia . . . . | ·005 |
| Albuminoid ammonia . . . | ·10 |

Chlorine in excess, but not above the average of the pure waters in the vicinity. Nitrogen, as nitrates and nitrites, 3·7 grains per gallon. This water came from a well which proved, on inquiry, to be situated in a highly dangerous place. Such a water, exhibiting so large a proportion of nitrates and nitrites, deserved condemnation.

Here is a third analysis, of the water from a well 25 feet deep, which, as regards its organic contents, would be pronounced of the utmost purity:—

| Grains per Gallon. | | Milligramme per Litre. | |
|---|---|---|---|
| Solids. | Chlorine. | Free Ammonia. | Alb. Ammonia. |
| 23· | 2·2 | ·01 | ·04 |

As there was an excessive brilliancy about the water, my suspicions were aroused; so I examined the water for nitrogen in the form of nitrates and nitrites, of which I found 1·11 grains per gallon. My opinion, expressed to the applicant, was that the water was pure at the time of analysis, but was in great danger of pollution; that the soil cleansed the water at present, but would cease to do so after a certain period, when filth would enter the well. The applicant then informed me that there was a cesspool two or three yards from the well. How would the Wanklyn, Chapman, and Smith process, unaided by the estimation of the nitrates, have enabled me to see the danger ahead, and sound the note of warning?

The analyses made by the late G. W. Wigner of the water supply of Clacton on Sea,[1] where the proportion of free ammonia and albuminoid ammonia was very low, whilst the amount of nitrates was high, and the microscope disclosed the presence of numerous particles of decomposed muscular fibre, etc., are of interest in connection with the subject under consideration. Many additional instances could be given, if space permitted, to show the value of an estimation of the nitrates, but such must surely be unnecessary.

The omission to pay any regard to the amount of nitrates and nitrites in a water is practically to ignore the infiltration of filth into a water supply that is not very recent.

It is not needful in every case to make a quantitative examination of the nitrogen as nitrates and nitrites. If any doubt exists after estimating the amount of free ammonia, albuminoid ammonia, and chlorine—if one's diagnosis is somewhat obscured by any curious results—if, indeed, there is the slightest haze or mist in connection with an analysis, it is wise to calculate the quantity of

[1] *Sanitary Record*, August 31, 1877.

nitrates and nitrites. I should not think of making an estimate of these salts in the water of a spring, far removed from any filth, that is always running, or in an artesian well water, respecting both of which there existed no suspicion, and both of which showed infinitesimal amounts of free and albuminoid ammonia. In Dr. Armistead's analysis the numbers of these two kinds of ammonia afforded a suspicious indication; and in the analysis which immediately follows it, the quantity of albuminoid ammonia, coupled with the knowledge of the dangerous position of the well, would have led me to test for salts of nitrogen.

*Qualitative.*

## A. QUALITATIVE EXAMINATION.

The Horsley Test.

*The Horsley Test.*—The directions given by the discoverer of this test are as follows:—Take a large sized conical test glass holding about $1\frac{1}{2}$ or 2 oz. of the water to be examined, and dissolve in it, by the aid of a glass rod, about 1 grain of pyrogallic acid. Measure out $1\frac{1}{2}$ or 2 fluid drachms of *pure*, strong sulphuric acid. The test glass containing the water and pyrogallic acid being held in the right hand and its edge depressed, carefully pour down the side of the vessel the sulphuric acid, which will lie as a layer underneath the water. Drop gradually into the water a pinch of salt. When the salt reaches the sulphuric acid, effervescence takes place which mingles the upper and lower layers, giving rise in the lower layer to a more or less purplish violet or black colour, according to the quantity of nitrates. Nitrites, if present, will show themselves in the upper layer by producing a yellowish or even brown tint indicative of nitrous acid in a gaseous state, which gradually disappears (*vide* fig. 11). Twice distilled water remains colourless when treated as above.

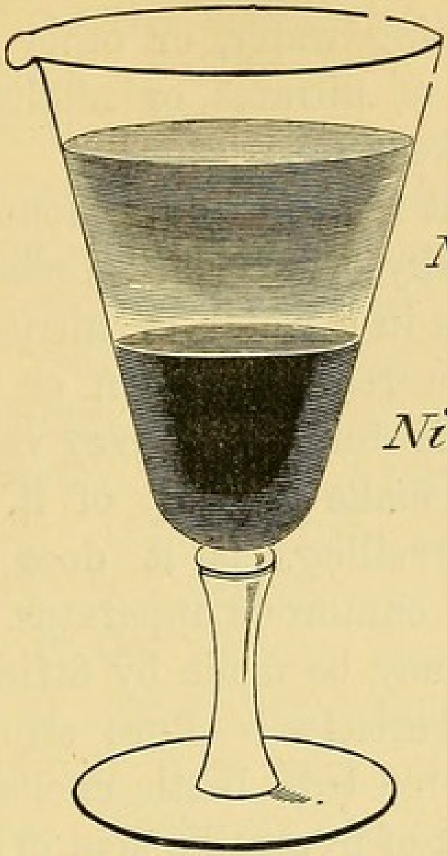



FIG. 11.

Dr. Bond of Gloucester practises the following modification, which is preferable:—20 minims of pure sulphuric acid are placed in a very small test tube, to which 10 minims of the water to be examined are added. One drop of a solution of pyrogallic acid (10 grains to 1 ounce of distilled water acidulated with 2 drops of sulphuric acid) is then dropped into the mixture. The depth of the dark amethyst or vinous brown coloration is a measure of the amount of the salts present.

It is wise to make one or two blank experiments with twice distilled water, when fresh chemicals are employed, so as to be assured of their purity. After allowing the colour to develop for a few minutes, the contents of the test glass should be shaken, so as to mix the sulphuric acid with the water, and no opinion should be formed as to the water under examination until a quarter of an hour has elapsed after such commingling has been effected. It will be found useful to keep some spring water, or other waters containing known quantities of nitrates or nitrites, ready at hand, with which to make comparisons.[1]

It is stated that if nitrates are alone present, the tints will be of an amethyst and dark brown hue, whilst the exclusive existence in a water of nitrites is shown by a preponderance of a reddish brown or vinous red colour. This Horsley test is found to convey very useful information to those who make a study of it, and is especially convenient in travelling, as it does not involve the conveyance of any cumbrous apparatus. A portable and safe arrangement may be made by fitting up a small box with the following articles:—Pure strong sulphuric acid in a capped stoppered tube bottle enclosed in a vulcanite tube case; solution of pyrogallic acid in a capped dropping bottle; stoppered test glasses, each marked by a file to indicate the height reached by 20 minims of sulphuric acid; and a minim measure.

### *Nitric Acid or Nitrous Acid?*

Nitric Acid or Nitrous Acid?

The occurrence of nitrites in springs and deep well waters, otherwise unobjectionable, is without significance; for their presence indicates the result of a reduction by some mineral substances or ancient organic matter of nitrates into nitrites and ammonia. The determination

[1] The Medical Officer of Health may find it convenient to prepare a few standard waters, made by mixing $\frac{1}{4}$ gr., $\frac{1}{2}$ gr., 1 gr., 2 grs., 3 grs., and 4 grs. of nitrate of potash, each with a gallon of distilled water.

Mr. Horsley makes standards by dissolving 1 grain of nitrate of ammonia in 100 drops of distilled water and adding the solution in different quantities to 16 ounces of distilled water thus:—

| | | | | | |
|---|---|---|---|---|---|
| 5 drops | to 16 ounces | of distilled | water | = $\frac{1}{2}$ gr. | per gallon. |
| 10 | ,, | ,, | ,, | = 1 gr. | ,, |
| 20 | ,, | ,, | ,, | = 2 grs. | ,, |

of nitrites in river waters is of little value, for they often derive these salts from the manure applied to the arable land which they drain.

It is sometimes desirable, in the case of shallow well waters that are threatened with pollution, to ascertain whether the oxidized nitrogen is in the form of the higher oxide, viz. nitric acid, or the lower oxide, viz. nitrous acid. If all the combined nitrogen is in the form of nitrates, which contain an atom more of oxygen than nitrites, we know that a complete oxidation of the organic matter has occurred. If the nitrates are accompanied by nitrites, we learn that this oxidation is imperfect, and not thorough. Lastly, if the nitrites abound, we conclude that contamination is near at hand, that the soil is overdone with filth, and that it is only able very imperfectly to cleanse the water. These are the broad lessons learnt by making a discrimination between these two oxides of nitrogen.

### *Nitric Acid.*

Nitric Acid.

*Brucine Test.*—Evaporate 2 c. c. of the water to be examined in a small Berlin dish, about the size of a watch glass, to dryness over a spirit lamp. Add one drop of strong pure sulphuric acid to the saline residue. Endeavour, as far as possible, to bring the drop in contact with all the saline residue by tilting up the dish. Allow the smallest crystal of brucine to fall on the drop. If nitric acid be present in even the minutest quantity the drop of sulphuric acid will become pink, and afterwards of a yellow colour. The late Prof. Parkes says,[1] "Half a grain of nitric acid per gallon gives a marked pink and yellow zone." "·01 grain per gallon can be easily detected."

Prof. Sanders, who represents to some extent the

[1] *Manual of Practical Hygiene.* Fifth Edition.

opinions of his German fellow-countrymen, considers[1] that a water to be deemed pure should contain no appreciable amount of nitric acid.

Nitrous Acid.

### *Nitrous Acid.*

*Potassium Iodide and Starch Test.*—Boil a little powdered starch in distilled water so as to form a thin solution. Place a little of the water to be examined in a test tube, and add about 5 minims of a solution of potassium iodide, free from iodate (5 grains to 1 ounce of distilled water), and a little of the cold starch solution. Pour into the mixture a few drops of pure sulphuric acid. If the water contains nitrous acid or nitrites, a blue colour will be produced, in depth of tint proportioned to the amount present.

*Permanganate of Potash*, as described on pages 34 and 35.

*Meta-phenylene Diamine* is a more delicate test, since it is capable of detecting one part of nitrogen in ten million volumes of water. A solution of sulphuric acid should be prepared by mixing one volume of strong sulphuric acid with two volumes of distilled water. Half a gramme of meta-phenylene diamine should be dissolved in 100 c. c. of distilled water, decolourized if necessary by passing it through animal charcoal, and rendered acid with sulphuric acid. 1 c. c. of each of these solutions is added to about 100 c. c. of the water to be examined in a Nessler glass. If nitrous acid be present a yellow colour is produced, the depth of tint being proportioned to the amount present. The chief objection to this test is that the development of colour is slow, the final shade not being reached for twenty minutes.

[1] *Handbuch der öffentlichen Gesundheitspflege.* Leipsig: Hirzel. 1877.

A still more delicate test for nitrous acid exists, which enables one part of this acid to be detected in 1,000,000,000 parts of water, and which has been employed in air analysis (*vide* page 357).

### B. QUANTITATIVE EXAMINATION.

*Quantitative.*

Experience has shown me that it is of no practical service whatsoever for sanitary purposes—in fact a waste of time—to estimate to the third decimal point the amount of nitrates and nitrites; for such extremely accurate results should not influence our opinion respecting a water in one way or the other. Dr. Frankland and his followers exaggerate the importance of the determination of minute amounts of these salts. The majority of them subtract from the figures which they obtain ·0224 grain per gallon, as an allowance for the amount of inorganic nitrogen in rain water. The average total amount of ammonia, nitrates, and nitrites in a pure upland surface water is ·0077 grain per gallon, or practically *nil.* Dr. Frankland would then make a deduction of ·0224 grain per gallon on account of the ammonia in rain; or, in reality, more than the total quantity of inorganic nitrogen contained in this pure water.

There is, as we all know, a strong tendency in nature to the establishment and maintenance of an equilibrium. Roughly and generally, it may be said, that the excess of inorganic nitrogen that may find its way into the soil, and into streams and lakes, through the washing-out of the ammonia in the air by rain, is compensated for by the abstraction of the ammonia by vegetation on land, and the removal of the nitrates and nitrites by aquatic plant life.

The quantitative processes for the estimation of the nitrogen products of the oxidation of organic matter are very numerous. The aluminium process of Schultze (modified by Chapman and Wanklyn) and Walter Crum's process with mercury (as modified by Frankland and others), and the indigo process, have been perhaps the most popular. The objection to the first is, that it is useless for waters containing large quantities of nitrates; and the objection to the second is, that it necessitates the employment of large and costly apparatus for the measurement of gases, and an expensive mercurial bath. The third process is still employed, although grave doubts have been thrown on its accuracy.

The indigo process.

A number of sanitary analyses were some years ago published,[1] in which the estimation of the nitrates would seem to have been made by means of the indigo process. The experience of myself and some others with it has been most unsatisfactory, on account of the difficulty in obtaining concordant results. As some, however, entertain a belief in its value, it is perhaps desirable to refer to it somewhat in detail. Fischer,[2] Boussingault, Marx, Trommsdorff, Goppelsrœder, and Bemmelen, have worked particularly at this indigo process in various ways, but the most recent mode of applying it is that described by Sutton.[3] An investigation has also been made at the Rothamsted Laboratory as to the value of the indigo process,[4] which appears to have been of an exhaustive character, A few extracts from the papers referred to may advantageously be given. "The method of running indigo from a burette

[1] "On the Water Supply of Seaside Watering-Places," by the late G. W. Wigner, F.C.S., in *Sanitary Record*, commencing in No. 165, August 24, 1877, and appearing in subsequent numbers.

[2] *Journ. Pract. Chemie.* (2) vii. 57.

[3] *Volumetric Analysis.*

[4] "On the Quantitative Determination of Nitric Acid by Indigo," by Robt. Warington, in *Chemical News*, February 2 and 9, 1877, and in *Journal of Chemical Society*, 1879, vol. xxxv. p. 578.

into a nitrate solution mixed with a fixed quantity of sulphuric acid can never yield reliable results." "The tints obtained differ somewhat according to the proportion of sulphuric acid used, the mode in which it is added, and other circumstances: the presence of chlorides also affects the colour." After pointing out that nearly all the purest distilled oil of vitriol that is sold contains either nitrous acid or sulphurous acid and other reducing impurities, and sometimes both of these acids, and that it is necessary for the operator to himself purify his oil of vitriol, the author writes:—"The various writers on the subject, from Marx to Sutton, all recommend the use of a double volume of oil of vitriol. We have seen that with this large proportion of sulphuric acid the errors caused, both by organic impurities and by impurities in the acid itself, are at their maximum. Evidence has also been adduced to show that with this proportion of acid the indigo scale has not the same value in every part. Chlorides tend to reduce the amount of indigo required."

Notwithstanding these warnings of its fallacious indications published in 1878, it was employed in the Governmental inquiry conducted in 1880-81 by Dr. Cory, to the results of which is appended the following sentence:—"The presence of albumen in the water interferes with the indigo test and prevents it from indicating the true amount of nitric acid present."

The proceedings of the Society of Public Analysts of February 16, 1881, informs us that Dr. Dupré spoke very strongly of "the failure of the indigo method in certain waters" and of the probability that it broke down in nearly every case. "It broke down entirely in the presence of urine in water and almost entirely with albumen in water."

A study of the researches at Rothamsted cannot fail to render any one a convert to the conclusion of Mr. Warington and his fellow-workers respecting the indigo process as it has been and is applied, namely, that "it can only be exact under very exceptional circumstances."

V. Harcourt and Siewert's process.

Vernon Harcourt's process for the estimation of nitrogen in nitrates, which has been modified by Siewert,[1] of zinc-iron couples and caustic potash, is not adapted for sanitary work. The determination of nitric acid by means of its reaction with ferrous salts,[2] and by means of the platinum magnesium couple,[3] are two of the most recent methods. The copper-zinc couple process, and the sulphophenic acid process of MM. Grandval and Lajoux, to be presently described, are to be recommended in preference to all others.

### *Modification of Thorp's Process for the Estimation of the Nitrogen as Nitrates and Nitrites.*

Modification of Thorp's process.

Thorp's process for the estimation of these salts is based on the fact discovered by Dr. Gladstone and Mr. Tribe, that a thin plate of zinc, coated with copper, decomposes water, and that the hydrogen evolved is capable of reducing nitric acid in combination into nitrous acid and then into ammonia.

$$NO_3K + 4H_2 = NH_3 + HKO + 2H_2O$$

The apparatus, as depicted in the accompanying engraving (fig. 12) is first cleaned with tap and afterwards with distilled water.

Five grammes of the thinnest zinc foil, which has been thoroughly cleansed from all grease, cut with a scissors into little squares about the size of a 5-centigramme weight, are then placed on a piece of paper ready

[1] Sutton's *Volumetric Analysis.*

[2] R. Warington (1882). *Trans. Chem. Socy.*, xli. 345.

[3] F. P. Perkins (1881). *Analyst*, April, p. 58.

for use. Some *strong*[1] solution of sulphate of copper (made by dissolving the pure salt in distilled water) is introduced into a flask of the capacity of ½ litre, or 1 deci-gallon, provided with a long neck and thick strong mouth for the insertion of an india-rubber cork. The quantity of the solution should be sufficient to cover the fragments of zinc foil when they are introduced. The solution should be gently warmed over a Bunsen's burner,

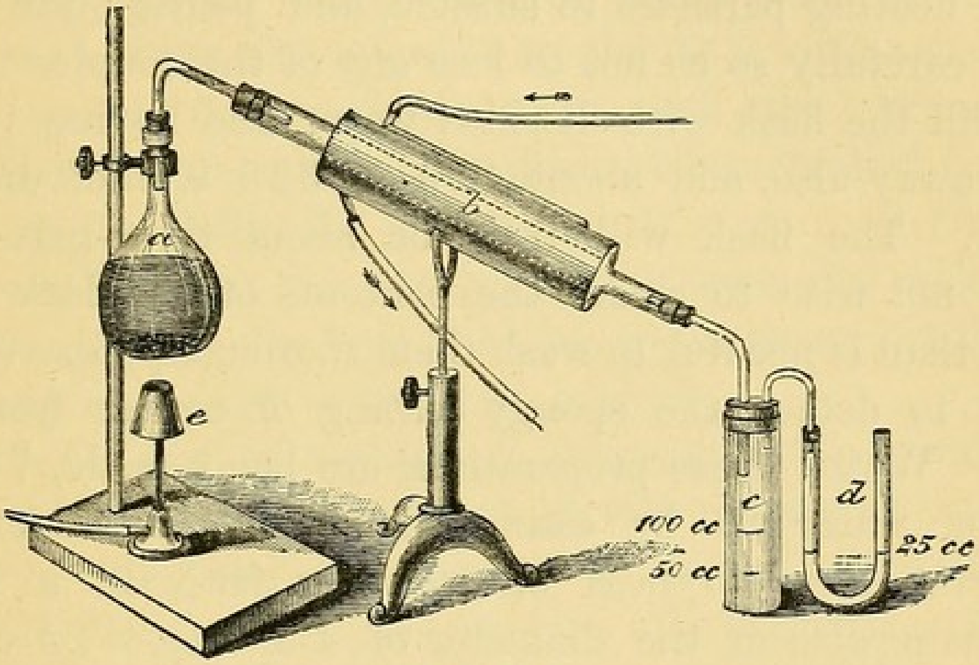



FIG. 12.

*a.* Flask.
*b.* Condenser—medium size.
*c.* Receiver, which resembles a very large Nessler glass, provided with an india-rubber cork.
*d.* U Tube containing 25 c. c. of distilled water.
*e.* Bunsen burner with chimney.

and the bits of zinc foil should then be passed into the flask. The zinc should not be allowed to float on the solution. A gentle swaying motion will suffice to cause them to sink. Let the copper solution act on the zinc for about ten minutes, when the scraps of zinc will have become perfectly black by the copper deposited on them. A copious firmly adherent coating of black copper is desirable. If the zinc has not entirely lost its metallic

[1] The Society of Public Analysts recommends the employment of a three per cent solution.

appearance, the solution of sulphate of copper has not acted on it sufficiently long. Spongy flocculent masses of copper, easily detached from the zinc by washing, will be noticed if the exposure of the zinc to the solution of copper has been too long. When the zinc is well coated with copper, pour off the copper solution as completely as possible. Fill up the flask with tap water three or four times, stopping for a moment on each occasion in order to allow floating particles to subside, and pouring the water away carefully so as not to lose any of the couple. Then half fill the flask with distilled water, and having poured that away also, add about 300 or 325 c. c. of distilled water. The flask will then be about three-parts full. It is not wise to shake the contents of the flask about more than is needful to wash them thoroughly, for violence tends to detach the spongy coating of copper from the zinc. Whilst these preparations are being made, 70 c. c. of the water to be examined should be undergoing evaporation to dryness on a water bath in a Berlin porcelain dish of the diameter of 4 inches. 25 c. c. of distilled water is to be added to the solid residue, together with a bit of recently burnt quicklime (preserved in a stoppered bottle) about the size of a hempseed, and the liquid is then boiled (to decompose any urea which may present) until about 4 or 5 c. c. remain. Care should be taken in boiling that none of the fluid be ejected from the dish. Pour these 4 or 5 c. c. into the flask, and thoroughly wash out the dish in which the water was evaporated with as little distilled water as possible, transferring the washings, which generally amount to 15 or 20 c. c., to the flask. If the presence of a large excess of nitrogen salts is probable, a U tube should be attached to the receiver, into which 25 c. c. of distilled water have been placed. Distil over 100 c. c., of which a half (50 c. c.) should be placed in a Nessler glass and 2 c. c. of

Nessler test be added. If the tint is deeper than can conveniently be measured, as for example that of ·30 or ·40 milligramme of ammonia, take 5 or 10 c. c. of the remaining 50 c. c., and having mixed them with 45 or 40 c. c. (so as to make 50 c. c.) of distilled water in a Nessler glass, add 2 c. c. of Nessler test. The depth of tint should be imitated by making up standards with the standard ammonia solution (1 c. c. = ·01 milligramme of ammonia), as in the Wanklyn, Chapman, and Smith process. If the tint afforded by the 50 c. c. is not deeper than can be conveniently estimated, the amount of ammonia producing it is simply to be multiplied by 2 to yield the quantity for 100 c. c. If 5 c. c. or 10 c. c., however, be taken, the result should of course be multiplied by 20 or 10, as the case may be, in order to obtain the quantity contained in the 100 c. c.

Whilst this calculation is proceeding a second 100 c. c. is distilling over, which should be treated like the first. During the examination of the second 100 c. c. a third distillate is passing into the receiver. Unless there is a large amount of nitrogen salts present the third distillate need only be 50 c. c., and this quantity will be found to be the last that it is necessary to remove in the majority of cases, as all the ammonia will have distilled over. If the U tube has been employed, the 25 c. c. of distilled water in it should be mixed with an equal bulk of distilled water in a Nessler glass and tested for ammonia with Nessler re-agent. If any colour is produced, which will be the case if the nitrates and nitrites be very abundant, the proportion should be measured by preparing a standard.

Before this process is employed for the determination of the nitrogen as nitrates and nitrites, it is necessary to ascertain the amount of impurities in the chemicals used. Ammonia, like soda, is omnipresent. It is exceedingly difficult to get anything perfectly free from either. Accordingly, three or four blank experiments should be made, and an average of the amount of free ammonia yielded by the chemicals must be subtracted from the results arrived at by each analysis of a water. The above-mentioned quantities of *my* chemicals furnish about ·06 of a milligramme, which I deduct from each water analysis, for example—

70 cub. cents. of the water analysed supplied.

| | |
|---|---|
| (1) Distillate of 100 c. c. . | ·85 |
| (2) Distillate of 100 c. c. . | ·02 |
| (3) Distillate of 50 c. c. . | ·01 |
| | ·88 |
| Average of error | ·06 |
| | ·82 |

*Milligrammes.*

| Ammonia. | Ammonia. | Nitrogen. |
|---|---|---|
| 17[1] | ·82 | 14[1] |

```
     ·82
     14
    ----
    328
    82
  -------- Nitrogen.
17)11·48(  ·67
    102
    ---
     128
     119
     ---
       9
```

*Ans.* ·67 milligramme of nitrogen in 70 c. c. of water under examination, which is equivalent to ·67 grain per gallon. As 70 c. c. is what has been termed "a miniature gallon," the amount in milligrammes of nitrogen from nitrates and nitrites thus found represents the quantity of this element in grains per gallon.

An expeditious modification of this process has been

[1] The atomic or combining weights of ammonia and nitrogen.

suggested[1] by M. W. Williams, and recommended by the Society of Public Analysts, which cannot, unfortunately, be employed in the case of waters exhibiting any tint in a Nessler glass, nor with those containing magnesia or other substances capable of being precipitated by the Nessler re-agent. After washing the zinc and copper couple with distilled water, which should be displaced by washing with some of the sample of water,[2] the wide-mouthed stoppered bottle containing the couple is filled up with about 3 or 4 oz. of the water under examination. The stopper is then inserted, and the contents of the bottle are allowed to digest in a warm place for a few hours,[3] or over night. If the water is soft, a little salt quite free from ammonia (1 part to 1000) should be added to hasten the reaction. As the nitrous acid formed by the reduction of the nitrates does not disappear until the reaction is finished, a small portion of the fluid contents of the bottle, acidified with sulphuric acid, should be tested with a solution of meta-phenylene diamine, which gives a yellow colour in a few minutes if nitrous acid is present (*vide* page 110). When no nitrous acid is found, the water is poured off the couple into a stoppered bottle, and, if turbid, allowed to settle. From 2 to 10 c. c. of the clear fluid are withdrawn in a graduated pipette and placed in Nessler glasses, where they are made up to 50 c. c. with distilled water, and titrated with Nessler re-agent in the ordinary way.

M. W. Williams' expeditious mode of employment.

[1] *Analyst*, March 1881.

[2] Dr. R. B. Lee always at this stage adds ·5 gramme of oxalic acid (free from ammonia and nitric acid), in order to precipitate the lime and to form an insoluble compound with the zinc.

[3] If the bottle be maintained in a water bath at a temperature of from 55° F. to 60° F., the reduction will be rapid, and will be found to be completed in from 1½ to 2 hours; the employment of oxalic acid permitting the elevation of the temperature without loss of ammonia.

A deduction must of course be made for the ammonia pre-existing in the water under examination.

### *MM. Grandval and Lajoux's Process for the Determination of Nitric Acid.*[1]

Grandval and Lajoux's Process.

This process is based on the change of carbolic acid into picric acid under the influence of nitric acid, and on the intensity of colour exhibited by the picrate of ammonia.

A solution of sulphophenic acid, and a titrated solution of nitrate of potash are necessary. The sulphophenic re-agent is prepared by mixing

| | Grammes. |
|---|---|
| Carbolic acid, pure . . . | 3 |
| Acid sulphuric . . . | 37 |
| | 40 |

The titrated solution of nitrate of potash is made by dissolving ·936 gramme of this salt in 1 litre of distilled water. 1 c. c. of this solution contains ·0005 gramme of nitric acid or ·0001 gramme of nitrogen.

*Method.*—10 c. c. of the water to be examined are evaporated to dryness in a porcelain dish over a water bath. The dish is allowed to cool, and an excess of sulphophenic acid is added. This re-agent should be led by the help of a glass rod around the sides of the dish, so that no particle of the residue may escape its influence. A few cubic cents. of distilled water are poured into the dish, followed by an excess of ammonia. We should continue to add ammonia until the yellow colour produced does not disappear on stirring with the glass rod. This solution of picrate of ammonia is diluted with distilled water so as to bring it to a *volume* suitable for the colorimeter employed.

We operate in the same way on a certain quantity of

[1] *Comptes Rendus*, July 6, 1885.

the titrated solution of nitrate of potash, taking care to bring the solution of the picrate of ammonia obtained to the *same volume* as that of the water under examination. In the analysis of a drinking water, which a qualitative test, such as Horsley's Pyrogallic acid test (*vide* page 106), has shown to be exceedingly pure, it is wise to employ only 1 c. c. of the titrated solution of the nitrate of potash. If the public water supply from one of our cities or towns is to be submitted to examination, in which a qualitative test points in the direction of purity, it is advisable not to employ more than 2 or 3 or 4 c. c. of the titrated solution which we evaporate to dryness, in either case bringing the volume operated on up to 10 c. c. by the addition of distilled water. It is sometimes convenient, in order to be able to judge within certain limits of the amount of the titrated solution of nitrate of potash which should be operated upon, so as to arrive at a colour similar to that of the water under investigation, to keep in store standard solutions of nitrate of potash of different strengths and depths of colour. I am in the habit of using as a colorimeter a pair of Hehner's tapped graduated Nessler glasses, and in cases where there is no need for great acccuracy they answer well. The details of this process may advantageously be inserted. Suspecting a water under treatment in my laboratory whilst writing these lines to be an impure one, as much as 10 c. c. of the titrated solution of nitrate of potash were evaporated to dryness. 10 c. c. of the water to be examined were also evaporated to dryness. The residue of each was treated as above directed. The solution of picrate of ammonia in each dish was then diluted up to the 50 c. c. mark in the colorimeter. The 50 c. c. of titrated solution exhibiting the darker colour, as much as 30 c. c., were run off by the tap, and the remaining 20 c. c. exactly equalled in depth of tint that of the 50 c. c.

of the water under examination. It will be remembered that 10 c. c. of titrated solution of nitrate of potash (·001 gramme of nitrogen) were contained in the 50 c. c. of titrated solution in the tapped Nessler glass.

| c. c. of titrated sol. | | c. c. of titrated sol. equivalent to tint of 50 c. c. of water under examination. | | Gramme of N. | | Gramme of N. |
|---|---|---|---|---|---|---|
| 50 | : | 20 | :: | ·001 | = | ·0004 |

The 50 c. c. of the water under analysis equal, therefore, 20 c. c. (·0004 gramme of nitrogen) of the 50 c. c. of the titrated solution of nitrate of potash. As only 10 c. c. of the water under examination were operated on, this ·0004 gramme of nitrogen must be multiplied by 100 to ascertain the amount of nitrogen in a litre—

```
 ·0004
  × 100
 ------
 ·0400   gramme per litre of nitrogen.
   × 70
 ------
2·8000   grains per gallon of nitrogen as nitric acid.
```

I learn that this method, which is more rapid than that of the copper zinc couple, is highly approved of by American analysts.

There are two objections to it: (1) that it entails the employment of ammonia, which should be rarely, if ever, used in a laboratory where processes for its detection and estimation in water and air are in frequent operation; and (2) that the addition of sulphophenic acid to the residue of a water which contains a *considerable* amount of nitric acid is attended by the evolution of peroxide of nitrogen or nitrous acid, which is thus lost.

*Rules for Guidance.*

Rules

Spring waters contain on an average ·2 grain per gallon of nitrogen as nitrates and nitrites. The water supplied to London by the Thames Water Companies possesses about ·15 grain per gallon, whilst that which is furnished to the metropolis by the Kent Company from the chalk, holds in solution about ·3 grain per gallon. Some wells that enter the chalk yield a larger amount, viz.:—·6 and ·7 grain per gallon, and sometimes much more of nitrogen as nitrates and nitrites, in other words, of fossil organic matter, and are, notwithstanding, perfectly pure. When, however, from ·3 to ·7 grain per gallon is reached in waters that do not come from the chalk, the excess becomes an increasingly suspicious circumstance. A water exhibiting 1·5 grain per gallon is regarded as approaching that class of waters which would be considered dangerous for drinking purposes. Peaty waters and sewage contain none, or only a minute quantity.

EXAMPLES.

| SAMPLE OF WATER. | NITROGEN AS NITRATES AND NITRITES. |
|---|---|
| | *Grains per Gal.* |
| Well, P.B.R. . . . . . | 1·11 |
| Art. Well, O.P.S. . . . . | ·09 |
| Art. Well, J.T. . . . . | 8·47 |
| Well, R.H.S.W. . . . . | 2·55 |
| Spring, G.H.G.B. . . . . | ·26 |
| Gray's Water, Brentwood. . | ·67 |

# CHAPTER IV

THE DETERMINATION OF THE AMOUNT OF SOLID RESIDUE, ITS APPEARANCE BEFORE, DURING, AND AFTER IGNITION, AND THE LOSS OF VOLATILE MATTERS THEREBY OCCASIONED.

A. The Amount of Solid Residue.

B. The Appearance of the Solid Residue Before, During, and After Ignition.

C. The Amount of Volatile Matters burnt off by Ignition.

## A. *The Amount of Solid Residue or Saline Matters.*

Solid Residue.

The mineral constituents conduce in conjunction with dissolved air and carbonic acid gas to render a water palatable. Rain water and distilled water, which are almost destitute of the same, are notoriously flat and insipid. The saline matters have been improperly called by some "solid impurities." Dr. Frankland, who was the originator of this unfortunate expression, defends its use by stating that the solid matters in water are "quite useless." A medical man would not make such an assertion, unsupported as it is by any trustworthy evidence known to the profession. He adds, "A very large proportion of the potable water supplied to towns is employed for washing and manufacturing purposes, and here the presence of a large amount of solid matter giving hardness to the water is undoubtedly injurious."[1] This

[1] Rivers Pollution Commission.— *Sixth Report*, p. 5.

sentence must not lead to the inference that waters characterised by an excess of salts are always hard. Strongly saline waters are often very soft, as for example the waters of many artesian wells. Highly saline and hard waters are admitted on all hands to be extremely undesirable as supplies to towns, and are especially objected to for washing and business purposes. The

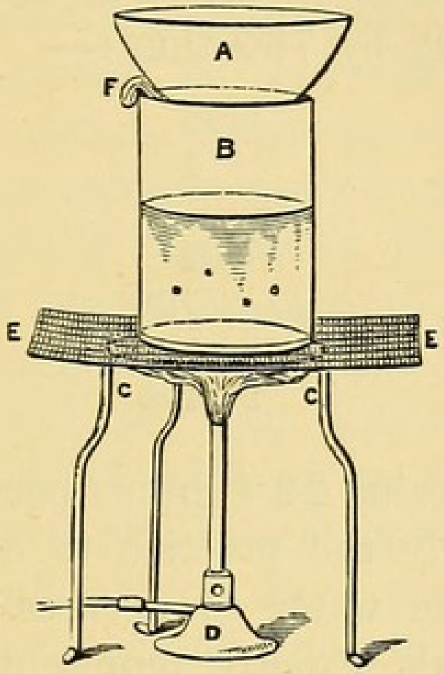



FIG. 13.

A. Platinum Dish.
B. Beaker containing Water.
C. Tripod Stand.
D. Bunsen's Burner.
E. Coarse Wire Gauze, on which a pipe triangle rests to support the beaker.
F. Thick bit of paper between Dish and edge of Beaker, to permit of escape of steam.

excess of salts in such cases may perhaps be termed impurities, but it is ridiculous to speak of the small quantities of saline matters in the purest (organically) spring waters as impurities!

To estimate the amount of solid residue at 212° F. proceed thus:—

Weigh an empty platinum dish of 100 c. c. capacity, place it over a water bath, and pour into it 25 c. c. of the water to be examined. Evaporate to dryness. Wipe the outside of the dish quite dry. Again weigh the dish *promptly* to avoid the error from deliquescence of salts.

| | | | |
|---|---|---|---|
| For example :— | Dish and residue . | 26·240 | grammes. |
| | Dish . . . | 26·232 | ,, |
| | Weight of residue . | ·008 | |

As 25 c. c. are a quarter of 100 c. c., multiply the result by 4, and then, to arrive at the number of grains per gallon, multiply by 700 thus :—

$$\begin{array}{r} \cdot 008 \\ 4 \\ \hline \cdot 032 \\ 700 \\ \hline 22\cdot 400 \end{array}$$

The water contains 22·4 grains per gallon.

It was formerly the practice to evaporate 100 c. c. or 70 c. c. of the water to dryness. If 70 c. c. are selected, the result exactly represents the number of grains per gallon. Time is however saved in the analyses of several waters by employing a smaller quantity of water. The objection has been raised that the experimental error, inseparable from all analytical operations, would fall rather heavily on such a small quantity as 25 c. c. I have found, without taking any extra care, a variation of 1 grain per gallon in the results obtained by taking the large and the small amount, a difference of not the slightest practical importance. It is quite immaterial, from a sanitary point of view, whether our drinking water contains 22·4 or 23·4 grains of saline matters per gallon.

Physicians well know that a water in which a moderate quantity of salts is dissolved (medicinal waters administered with a specific object, and for a limited period only, are of course excluded from consideration) is better than one possessing an excess; for the constant imbibition of fluids strongly impregnated with saline substances tends to diminish the richness of the blood, and to render some people anæmic. Although the waters from the artesian wells in Essex contain, as a rule, a very minute proportion of organic matter, yet they hold in solution a large quantity of salts, derived from sand beds beneath, and sometimes alternating with, strata of the London clay. These waters, associated as they are with so large a quantity of saline matters, cannot be considered so wholesome as waters from artesian wells containing a moderate amount of salts, equally free from a deleterious amount of organic matter. I have often seen the ill effects of the continued employment of waters rich in saline matters. Some well waters have been found to contain an enormous proportion of salts. I once analyzed a water from an artesian well which held in solution 341 grains of solids in each gallon; and have examined waters exhibiting the large amounts of 485 grains, and even 795 grains per gallon. Sea water is stated to have 2400 and 2700 grains per gallon of solids.

Saline matters in excess.

Spring water of the best quality usually contains about 14, 17, 18, or 19 grains per gallon of solid residue. A water should not possess more than 30 or 40 grains per gallon of solids; but waters holding a larger amount dissolved in them are in certain cases permissible, if the salts are quite harmless. It is generally found, according to my experience, that when a water contains much more than 110 or 120 grains of saline matters per gallon, the public will complain of it as brackish or hard, and refrain from employing it continuously, unless obliged so to do.

### B. *The Appearance of the Solid Residue Before, During, and After Ignition.*

The effect of Ignition.

Much may be learnt as to the character of a water by observing the solid residue obtained by the evaporation of a water on a water bath to dryness before, during, and after its incineration at a dull red heat; and very little knowledge is to be acquired by the estimation of the loss on burning the same.

After the calculation of the amount of solids, the appearance of the residue is carefully observed and noted. The platinum dish is then placed on the pipe triangle, which rests on the tripod stand. The smallest sized Bunsen's burner should be lighted, and held by its foot in the hand. The flame should be allowed to play gently to and fro around the bottom and sides of the dish, so as to raise all its contents in turn to a *dull red heat.* Heat may be conveniently applied in a manner equally gradual and gentle by holding the platinum dish with a pair of laboratory tongs or pincers over the flame.

It will be found that—

1. In cases where a water is practically free from any organic matter, and the solids are principally lime salts, there will be no discoloration of the residue during ignition. The residue will become whiter, until at length it assumes a clean pearly-white appearance.

2. In cases where the organic matter is small in amount, there is a slight brownish discoloration, which is very fleeting, and passes like a smoky cloud away as the ignition proceeds, leaving the residue of a dirty white or neutral colour. If no charring is observed, and the loss on ignition is very small, that loss is due to the volatilization and decomposition of saline matters and not to organic matter.

3. When the organic matter is in still larger amount

(especially if it be vegetable) the residue blackens in patches or waves. The colour is more persistent; and, to dissipate it, the flame of the Bunsen's burner has to be steadily directed beneath the blackened places.

4. When the organic matter is excessive, the whole of the residue blackens rapidly, even in the upright sides of the dish, evolving a smell of burnt feathers when of animal origin. The colour is extremely persistent, and in some cases it is very difficult, if not impossible, to dispel it by the application of a dull red heat. In bad waters (especially when urine is present) the organic matter disappears from the bottom of the dish, but at the sides there is frequently a black residue which it is extremely difficult to burn off even by prolonged ignition.

Dr. Ashby has noticed that, if nitrates are abundant in a water polluted with much organic matter, there will be very little blackening and perhaps not much darkening of the ignited residue.

The residues of very bad waters will sometimes deflagrate. The tiny sparks visible are due to the presence of nitrates in excess. An iodized starch-paper, erroneously called an "ozone test," is held over the dish by some during the ignition to detect any nitrous acid that may be given off. Red fumes are sometimes evolved when these oxidized compounds of nitrogen are large.

The employment of the olfactory nerves may also aid us. The smell of burnt hair or horn produced by the destruction of the organic matter is often observed. The development of a strong empyreumatic odour is suggestive of a bad water.

The smell of sulphurous acid is not uncommon, indicating the presence of sulphur compounds. The residue of a very bad water will sometimes emit an offensive smell on incineration.

The observations of Dr. Shea of Reading on water

| Name of Sample of Water. | Grains Per Gallon. | | | Milligramme per Litre = Part per Million. | | Degrees. |
|---|---|---|---|---|---|---|
| | Solids. | Chlorine. | Nitrogen as Nitrates and Nitrites. | Free Ammonia. | Albu-minoid Ammonia. | Total Hardness. |
| Public Artesian well at S. | 85 | ... | ... | ·36 | ·01 | ... |
| Shallow well at B.'s, Gay Bowers . . . | 52 | 9·2 | ... | ·30 | ·44 | ... |
| Spring water from clay soil supplying G. H., Great Baddow . . | 23 | 2·6 | ·26 | ·00 | ·03 | 13 or 14 |
| Shallow well belonging to cottages near "King's Arms," B. . . | 101 | 12·5 | ... | Above 1·0 | ·24 | ... |
| Peaty spring water . | 5 | 1·1 | None. | ·03 | ·11 | 2 or 2½ |
| Shallow well of B. P. . | 23 | 2·2 | 1·11 | ·01 | ·04 | ... |
| Artesian well of Mr. P. T. | 210 | 31 | 8·47 | ·10 | ·35 | 37 |
| Shallow well of Mr. A. R. of G. W. . . | 103 | 16 | Abundant. | ·69 | ·28 | ... |
| New public shallow well at G. S. F.—*Soil* blue clay and black sand . | 89·6 | 8·2 | Very little. | ·13 | ·02 | 32 |

| Incineration. | | | Grains per Gallon. | Opinion. |
|---|---|---|---|---|
| Appearance of Residue *Before.* | Behaviour of Residue *During.* | Appearance of Residue *After.* | Loss on burning solid Residue. | |
| Pearly white. Faint brown around base of dish. | Faint brown line became darker, and rapidly disappeared, evolving smell of organic matter. | Pearly white, copious. | 5 | A good water. |
| Ochreish or dirty yellow spots. | Sides of dish almost black. The greater part of residue turned nearly black. | ... | 9 | Very impure. Contains water fleas. Has produced diarrhœa, in one case proving fatal. |
| Dirty white. | Light brown wavy lines. | Dirty white. | 6 | A good water. |
| Dirty white; rapidly attracts moisture. | Became brown. | Dirty white. | 15 | Exceedingly impure from presence of filth. |
| Wavy, almost black, lines. | Wavy lines disappeared slowly, evolving peculiar odour. | ... | 1·4 | More vegetable matter than is desirable for a public supply. |
| Transparent film. | Dirty greenish yellow lines which soon disappeared. | Whitish film. | 7 | Pure, but in danger of pollution by filth in neighbourhood, if in non-chalky district. |
| Light ochreish colour. | Became a dirty ochreish colour, which was followed by a grayish tinge. All colour finally disappeared. | Dirty white. | 37 | Polluted, hard, and highly saline. |
| Dirty white. | Became a very dark brown colour, and evolved unpleasant odour. | Light-brown tint. | 17 | Polluted by animal filth. Persistent uncontrollable diarrhœa produced by it. |
| White film. | No discoloration. Became chalky white. | Resembles white enamel. | 19·6 | A very hard but pure water. Slight excess of free ammonia is probably due to entrance of rain water into well. |

residues agree closely with my own. The late Prof. Parkes has laid down the following rules for the guidance of the analyst, on which I could not place much reliance :—

"Three grains per gallon of either vegetable or animal organic matter cause some blackening; six grains per gallon, a good deal; and ten grains per gallon, a great amount.

The preceding analyses are not selected for the purpose of confirming or verifying the accuracy of the foregoing attempt at rules for guidance, but are taken indiscriminately from my note-book. Instead of being illustrative and typical, they would seem to exhibit some variations.

### C. *The Amount of Volatile matters burnt off by Ignition.*

Volatile Matters.

The amount of organic matter was formerly calculated by burning the dried solids and noting the loss—a most fallacious mode of estimation,—for the water of crystallization is driven off, carbonates are decomposed, nitrates and nitrites disappear, and even chlorides [1] if the residue is strongly ignited. This "loss on ignition" has accordingly been spoken of as "substances driven off by heat."

Speaking generally, impure waters may be said to lose much by incineration, but this statement cannot safely be regarded as an established rule, because the exceptions to it are so numerous. Mr. Allen has expressed the opinion that in a good water the loss on ignition is rarely more than one-fifth of the total solids in weight.

Dr. Shea, who has had some experience with silica residues, states that such residues retain water very

[1] An intense yellow colour imparted to the flame of the Bunsen's burner indicates the volatilization of chloride of sodium.

persistently, and only lose it on strong ignition; and that an impure water of this class which he encountered lost 55 grains out of 129 grains of solids per gallon.

I have known good chalk waters lose 12 and 14 grains per gallon on ignition of the solid residue.

If the Medical Officer of Health should decide to ascertain the amount of "substances driven off by heat," he should, when he takes the solid residue, evaporate 70 c. c. instead of 25 c. c. of the water to dryness, unless

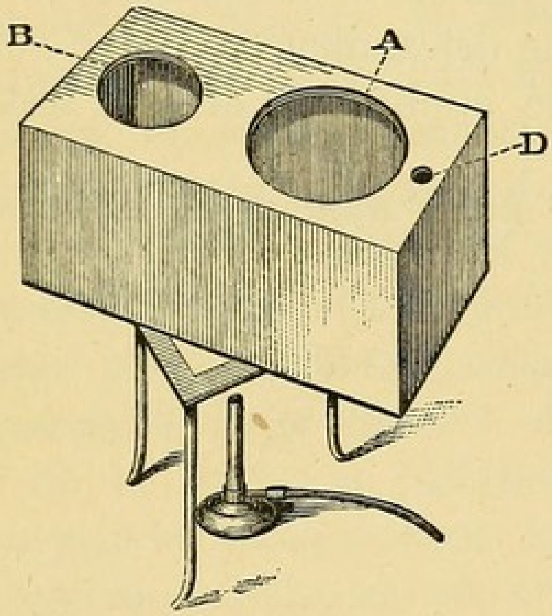



FIG. 14.—A Copper Water Bath.

A, Hole for Berlin evaporating dish. B, Hole for platinum dish. C, Tripod stand. D, Aperture of safety tube.

*N.B.*—The insertion of a small piece of paper between one of the dishes and the edge of the aperture on which it rests, suffices to permit of the escape of steam.

he possesses a first-rate balance, otherwise small differences cannot be measured.

If the health officer thinks it requisite to estimate quantitatively the amount of nitrogen as nitrates and nitrites, the proportion of solid residue, the quantity of volatile substances, and to note the appearances of the residue before, during, and after the application of a dull red heat, it will be found most convenient to employ a water bath, similar to that used for evaporating milk to dryness, but provided with larger holes, one to hold the

Berlin evaporating dish, and the smaller to support the platinum dish.

Dr. F. de Chaumont makes the following entry in his hygienic classification of waters :—[1]

| 1. *Pure and Wholesome.* | 2. *Usable.* | 3. *Suspicious.* | 4. *Impure.* | *Remarks.* |
|---|---|---|---|---|
| Under 1 grain per gallon. Solids on incineration should scarcely blacken. | Under 3 grains per gallon. Solids may blacken a little, but no fumes should be given off. | 3 to 5 grains per gallon. Much blackening on incineration, or nitrous fumes given off. | Above 5 grains per gallon. Much blackening and nitrous fumes given off, or smell of burnt horn. | In peat waters the incinerated solids may blacken considerably. |

The ignited residue in the platinum dish should at the conclusion of the determination of the volatile matters be reserved for the application of the test for phosphoric acid.

[1] Parkes' *Hygiene.* Fifth Edition.

# CHAPTER V

## THE DETERMINATION OF THE AMOUNT OF CHLORINE

THE estimation of the amount of chlorine in a water is in some circumstances worth little in itself, unless we know the amount of organic matter contained in it. The determination of the amount of chlorine in the water of a district, where an excess of chlorine does not occur in all waters, is an indirect guide as to whether or not the water is contaminated with sewage. Urine and sewage possess a large amount of chlorides. The presence of 5 or 10 grains of chlorine per gallon in a water is a suspicious circumstance in such localities. Good natural waters contain, on an average, from ·7 to 1·2 grains per gallon.

Observation as to amount of chlorine of little value, unaccompanied by calculation of quantity of ammonia and organic matter.

Waters from the greensand formation, and from the London clay, have generally an excess of chlorine, derived from the chloride of sodium and other salts of chlorine in the sand. The waters of Essex, which come from layers of sea-sand and clay enclosing marine fossils, possess as a rule a great deal of chlorine. One artesian water, which I examined recently in this county, contained as much as 103·6 grains per gallon.

Some geological strata furnish waters containing an excess of chlorine.

In the neighbourhood of the sea, which is always contributing its spray in greater or less quantity to the land, and wherever there are natural deposits of salt, an excess of chlorides is apt to be found.

A Medical Officer of Health, whose work is situated in a district where waters exhibit an excess, should ascertain, by making a number of examinations for chlorine, the average amount of it in waters from wells of different depths. Some years ago a tube well was sunk at Deal, where most of the wells are brackish. At 25 feet the water was too salt for use, but at 45 feet fresh water was obtained free from brackishness, whilst at 117 feet it was as salt as brine. If a sample of water holds in solution an amount of chlorine below the average in the district, the probability is that there is no sewage contamination. If, on the other hand, an excess of chlorine is accompanied by an excess of albuminoid ammonia and ammonia, pollution with sewage is almost certain. If sulphates were found to be in very small quantities, the excess of chlorine would be shown to be not due to a pollution by urine, for this excretion contains a large amount of sulphur salts. The amount of chlorine is also a guide as to the quantity of the salts of sodium, potassium, and magnesium in a water.

It should always be remembered, then, that in all cases the estimation of the amount of chlorine and of ammonia must, to possess any value as a guide to the pollution or otherwise of a water, be taken in conjunction with the quantity of organic matter, and in doubtful cases, with the amount of the nitrates and nitrites.

To estimate the proportion of chlorine in a water, we must proceed thus:—Place 70 c. c. of water to be examined in an evaporating dish, and add a minute morsel of neutral chromate of potash (free from chlorine). Then, by means of a pipette graduated to $\frac{1}{10}$th of a c. c., and filled with 5 c. c. of the solution of nitrate of silver (*vide* recipe on page 218), this standard should be allowed to drop into it until the red colour produced ceases to disappear. Directly the red tint becomes permanent, note the amount of nitrate of silver solution necessary to attain this point. Run a little more nitrate of silver into the water, to be sure that the water is not acid, for chromate of silver is soluble in acids.

I believe the existence of a free acid (non-gaseous) in a water to be rare, for only on one occasion have I found the chlorine test interfered with in this way. In this solitary instance a minute quantity of potash was introduced to neutralize the acid, and the fresh sample of 70 c. c. thus treated was operated on. The number of c. c. of the nitrate of silver solution employed will represent the number of grains of chlorine per gallon.

Pollution by sewer gas, and foul gaseous fæcal emanations.

A very interesting case has been recorded[1] by Dr. F. de Chaumont, showing the value of the chlorine test in cases where a water has been vitiated by sewage gases. The water of a house in London where typhoid fever had appeared was found to contain a large excess of "albuminoid ammonia," and but a small amount of chlorine. A sample from the reservoir of the company that supplied this house was analyzed, and found to possess an almost identical quantity of chlorine, but an extremely small proportion of "albuminoid ammonia." It was ascertained that the water used in the house was derived from a cistern, and that it was vitiated by the poisonous gases ascending through its overflow pipe from the sewer. On disconnecting the overflow pipe the amount of "albuminoid ammonia" gradually diminished. Dr. Robert King describes[2] an outbreak of enteric fever in his own family, where the following change took place in the water supply of his house, in consequence of the contamination of one of his cisterns by sewer gas through its overflow pipe which was in *direct* communication with a drain.

[1] *Lectures on State Medicine*, p. 77.
[2] *Medical Times and Gazette*, August 2, 1879.

| | Part per Million. Free Ammonia. | Alb. Ammonia. |
|---|---|---|
| Water Supply of House . . | ·010 | ·060 |
| „ of Cistern . . | ·025 | ·240 |

A very clear and brilliant water was recently sent to me by a medical man in attendance on an isolated case of enteric fever in a rural district of North Devon, which, whilst possessing an unpleasant odour, and a large excess of organic matter, contained only 1½ grain of chlorine per gallon, and no nitrogen as nitrates and nitrites. A microscopic examination exhibited an abundance of bacteria and micrococci. The water had come from a well, the overflow pipe of which passed into the contents of a garden closet at a lower level, with the evident object of cleansing the same. The water was contaminated by the foul gaseous emanations proceeding from the decomposing fæcal matter.[1]

The discovery of an excess of organic matter, accompanied by a small amount of chlorine and nitrogen as nitrates and nitrites, coupled with the presence of bacteria and micrococci, would tend to the conclusion, if vegetable contamination is out of the question, that sewage in the solid or liquid form has not been the cause, but that the source of impurity is probably gaseous.

[1] Vide *Disease Prevention*, p. 45. J. and A. Churchill.

# CHAPTER VI

## THE DETERMINATION OF THE HARDNESS

THE degree of hardness is a matter to be considered in pronouncing on the wholesomeness of a water. The average total hardness of good waters is between 3 and 14 degrees. Some deep artesian wells made in the London clay, extending to the sandbeds lying underneath, and occasionally to the chalk below, furnish water that is excessively soft, from the presence of bicarbonate of soda that replaces the bicarbonate of lime derived from the chalk. The deepest clay strata have doubtless a softening effect on the waters of these deep wells by virtue of the precipitating action of the alumina of the clay on the salts held in solution. Pipeclay mixed with sea water is well known by marines to soften it and increase its cleansing properties.

An error has been made by some in judging of the hardness of a water solely by the amount of solid residue contained in it. Mr Wynter Blyth writes,[1] "It is obvious that the soft waters have a small solid residue; the hard a large. A water with 8 or 10 grains of solid residue is a moderately soft water; the lake waters, with from 2 to 3 grains of residue, are extremely soft; whilst those with 50, 60, 70, and 80 grains of saline residue must be hard; so that any other test, except taking the

[1] *Dict. of Hygiene and Public Health.*

solid residue, is really superfluous." It is perfectly true that a hard water will have a large solid residue, but it is quite an error to state that a water possessing a large solid residue will always be hard.

Here are examples of organically pure and *soft* waters exhibiting a large excess of solids :—

| Wells | Solids—Grains per Gallon. | Total Hardness—Degrees. Clark's Scale. |
|---|---|---|
| A. Steeple. | 98 | 4½ |
| B. Do. | 103 | 5 |
| C. Maldon. | 84 | 4 |
| D. Tillingham. | 236 | 4 |

70 c. c. of the water to be examined for hardness should be placed in a stoppered bottle, holding about 250 c. c. The standard soap solution is dropped slowly, by means of a pipette graduated to $\frac{1}{10}$ths of a c. c., into the bottle, which is frequently shaken violently to note the amount of soap solution necessary to create a persistent lather. The stopper of the bottle should after each shaking be removed for an instant to allow of the escape of the carbonic acid gas which is evolved. If a water is so hard that the addition of 16 c. c. of soap solution does not produce a lather, add 70 c. c. of distilled water, and mix. Then continue the addition of the soap solution. If the dropping of soap solution be proceeded with until a second 16 c. c. be consumed, without the formation of a permanent lather, a second 70 c. c. of distilled water must be added. Suppose, for example, 19 c. c. of soap solution are necessary :—

Total.

| | |
|---|---|
| | 19 |
| Deduct for hardness of each 70 c. c. of distilled water employed . . . . . . . . | 1 |
| Degrees of hardness . . . . . . . | 18 |

When a water is very hard it is desirable to decant the contents of the bottle into a larger one of the capacity of about 500 c. c. To know the quantity of carbonate of lime, or other hardening and soap-destroying ingredients contained in the water, subtract 1 degree. The water just cited possesses 17 grains of carbonate of lime, or salts equivalent, per gallon. If a water is found to be exceedingly hard, 35 c. c. of it should be placed in the 70 c. c. flask, and the measure filled up to the 70 c. c. mark with distilled water. The quantity of soap solution required to form a lather with this mixture must necessarily be doubled in recording the result. A rough and ready method of determining the hardness of very hard waters consists in measuring 10 c. c. of the water into a 70 c. c. measure, in filling up the same with distilled water, and multiplying the result obtained with the soap test by 7. It is necessary to distinguish between the *false* lather, or scum produced by magnesian salts present in the water, and the *true* persistent lather.

Permanent.

Boil a sample of the water for about a quarter of an hour (some boil for half an hour), and when cold replace what is lost as steam with distilled water. Allow any floating particles that may be present to subside, and examine it with the soap test. In this manner the *permanent* hardness is obtained.

Temporary.

The difference between the *permanent* and the total hardness is termed the *temporary* hardness.

The carbonate of lime waters, such as are employed by large populations in the chalk districts on the south coast of England, lose most of their hardness by boiling. When the hardness of a water is mainly due to the presence of the sulphates of lime and magnesia and chloride of calcium, boiling makes but little difference. There are some grounds for thinking that, whilst the former class of

Influence on health.

waters are not deleterious to health, and in certain cases possess remedial properties,[1] the latter class should be objected to if the hardness is excessive. Whilst revising these lines I have been engaged in the examination of a spring water employed by villagers living on the new red sandstone, which possesses a total hardness of 84° and a permanent hardness of 35°! A hard water will sometimes produce for a time diarrhœa, and at others constipation. Dyspeptic symptoms are often complained of by those who have been accustomed to drink soft water on coming into a hard water district. Lumbago and suppression of urine have also been ascribed to the use of such waters. Dr. Murray of Newcastle-on-Tyne gives[2] a terrifying description of the evils resulting in the limestone district in which he lives, from the supply of very hard waters.

There is a strong feeling in the medical profession of this, and especially of Continental countries, that there is a connection between the development of certain calculous disorders, goitre, and certain forms of dyspepsia, and the employment of hard waters, but no evidence exists of a very demonstrative character on which this belief rests. Certain it is (1) that soft waters are superior to hard for domestic and manufacturing purposes; (2) that moderately hard waters are more palatable than very soft waters; and (3) that of hard waters those which lose much are preferable to those which lose little of their hardness by boiling.

Independent of the hygienic aspect of the question, the waste of money and labour is not to be overlooked in the case of town supplies. Each degree of hardness

[1] To the hardness of the water supply of Clifton is attributed its beneficial effects in patients suffering from chronic diarrhœa.

[2] "On the Influence of Lime and Magnesia in Drinking Water in the Production of Disease." *Brit. Med. Journal*, September 28, 1872.

signifies the destruction of 12 lbs. of the best hard soap by every 10,000 gallons of water. If soap is not employed to soften a hard water, fuel and carbonate of soda are expensive substitutes.

# CHAPTER VII

## THE DETERMINATION OF THE AMOUNT OF MAGNESIA, SULPHATES, AND PHOSPHATES

A. Magnesia—Sulphate, Carbonate, and Nitrate.
B. Sulphates of Lime, Magnesia, and Soda as Anhydrous Sulphuric Acid.
C. Phosphates.

Salts of magnesia and sulphates are objectionable in waters if in excess. A good water does not possess more than traces of these ingredients. Their estimation is sometimes required when the question is raised as to the wholesomeness of a suggested new water supply, or as to the comparative merits of several waters from which it is proposed to select the purest.

It cannot be otherwise than a matter of astonishment that so little attention has been paid in the past to the influence on health of the earthy constituents of waters that do not come under the designation of mineral waters. Parisian physicians, although living in a basin of sulphate of lime, appear to be totally ignorant of the effects of this substance on health. A noticeable feature in Dr. Frankland's sanitary analyses is the complete absence of all reference to the amount of sulphates in a water. And yet we know that the presence of an excess of sulphates in a drinking water is often found to be associated with obscure forms of dyspepsia, with obstinate diarrhœa, alternating with constipation, etc. Selenitic waters injuriously affect strangers more than those who are habituated to their use.

Some wells furnish water so purgative as to preclude the possibility of employing them as a regular water supply. I have met with many waters of this kind in Essex. They yield sulphate or carbonate of magnesia. I look upon them in this county,—which contains ague, such a large amount of liver disorders, hæmorrhoidal, and other malarial affections,—as mineral waters of some value. Holding in solution, as they do, not only a purgative salt, but a large proportion of other saline matters, they are not wholesome waters for general and constant use. In localities where these mineral waters exist, the people are, for the most part, compelled to drink pond water. Malarial affections are often traceable to the employment of pond water for drinking purposes. These aperient waters may be regarded as in some sense the remedy to counteract the effects of the poison, for they are, in all probability, of great service in congestion of the liver and in hæmorrhoids, by relaxing the portal system of vessels. Purgative waters.

### A. *Magnesia—Sulphate, Carbonate, and Nitrate.*

There are two or three modes of making approximative calculations as to the amount of magnesia in a water, all being similar in principle, for they consist in precipitating the lime with oxalate of ammonia, and then estimating the remaining hardness with the soap test. Boutron and Boudet take 200 c. c. of the sample of water for examination, and add to it the smallest quantity of a clear concentrated solution of oxalate of ammonia, that is sufficient to throw down all the lime, and then they allow the mixture to stand for 24 hours. The water is then boiled for half an hour, and filtered, the loss being re- Magnesia.

placed by distilled water. When cool the hardness is determined by the soap test, and the number of degrees are multiplied by ·14, to bring them into grains per gallon. Wanklyn adopts the following plan,[1] which is more rapid, and on that account is preferable, if equally accurate. "Powdered oxalate of ammonia is added to the water in the proportion of one gramme of the oxalate to one litre of the water. The mixture is shaken for a minute, and filtered. Having convinced oneself of the absence of any free acid in the filtrate, and having tested it with a little oxalate to make sure of the removal of the lime, 70 c. c. of the filtrate are triturated with the soap test to ascertain its hardness. If there be any degree of hardness beyond the one degree required by pure water, magnesia is present. Its amount may be calculated by multiplying the remainder, after the deduction of the one degree, by the fraction $\frac{42}{75}$, which will give the quantity of carbonate of magnesia per gallon of water."

It should never be forgotten, in employing the soap test, that a certain lapse of time is required for the production of the lather when the hardness is due to magnesia, whilst in that occasioned by lime the lather is immediately observable.

As examples of the amount of magnesia in potable waters, the following analyses, which have been published by Wanklyn and Playfair, may be cited :—

| Name of Waters. | | Grains per Gallon. Total Magnesia in terms of Carbonate of Magnesia. |
|---|---|---|
| Croydon Water . . . | | 1·4 |
| Sunderland Water . . | | 9·46 |
| Thames . . . | Metrop. | 1·10 |
| New River Company . | Metrop. | ·76 |
| Kent Company . . | Metrop. | 1·56 |
| Buxton Water . . . | | 4·5 |

[1] *Op. cit.*

B. *Anhydrous Sulphuric Acid* ($SO_3$) *from Sulphates.*

The amount of these salts may be roughly estimated thus:—Acidulate a large test tube full of the water to be examined with two or three drops of hydrochloric acid, and then add a small quantity of a solution of chloride of barium. If there is a precipitate, the amount of sulphuric acid exceeds one grain per gallon. If there is a precipitate after standing, there is at least $1\frac{1}{2}$ grain per gallon. 3 and 4 grains per gallon give immediately a turbidity differing in degree according to the presence of the lesser or the greater amount. Practice with waters to which known quantities of sulphates have been added will soon enable the Medical Officer of Health to form rough estimates. When it is desirable to calculate the exact amount of sulphuric acid as sulphates, it is conveniently done in either of the following ways:— Sulph

The method which I practise is the following:—About 10 c. c. of a strong solution of chloride of barium are placed in a beaker, and then acidified with a few drops of pure hydrochloric acid. 70 c. c. of the water to be examined are added, and the contents of the beaker are boiled, the precipitate being allowed to settle for two hours. Then the supernatant liquid, and finally the turbid liquid below, are filtered off. The very best Swedish filter-paper is required, otherwise the filter will not remove entirely the sulphate of baryta. The precipitate may be thoroughly detached from the sides of the beaker by the aid of the feather of a quill pen. Wash out the beaker with hot distilled water. The washings are to be passed through the filter until the fluid that drops from the funnel leaves no residue when evaporated on a platinum spatula or foil. Allow the filter to drain, and dry it gently by suspending the funnel on a retort ring at some distance above a lighted spirit lamp. Ignite the filter in a platinum crucible and weigh. The difference between the weight of the empty crucible, and the weight of the crucible and its contents minus the weight of the ash of filter,[1] furnishes a number of milligrammes that represent grains per gallon of sulphate of baryta, which should be recorded in terms of anhydrous sulphuric acid, *e.g.*—

| | | $BaSO_4$ | | Amount of $BaSO_4$ found. | | $SO_3$ |
|---|---|---|---|---|---|---|
| Crucible and its contents . | 17·776 | 233 | : | ·004 | : : | 80 |
| Crucible . . | 17·770 | | | 80 | | |
| | ·006 | | | 233)·3200(·0013 | | |
| Deduct weight of | | | | 233 | | |
| ash of filter . | ·002 | | | | | |
| | | | | 870 | | |
| | ·004 | | | 699 | | |
| | | | | 171 | | |

*Result.*—Rather more than 1 milligramme, or 1·3 gr. of anhydrous sulphuric acid per gallon.

Houzeau's Method.

Houzeau's method[2] is a very simple and perhaps a more rapid one. Prepare a solution of barium chloride 30·5 grammes in a litre of distilled water. Obtain a dropping tube which furnishes 25 drops for each c. c. To 10 c. c. of the water to be examined after acidifying with one drop of acetic acid, add 2, 4, 6, 8 or 10 drops of the barium chloride solution by means of the dropping tube. Wait for 3 minutes and if a deposit is formed, filter the liquid. The filtrate is to be treated with one or more drops of the barium chloride solution. If a deposit

[1] The average weight of ten filter-papers should be estimated and marked on the packet. The labour of weighing each filter-paper when employed is thus avoided. The ash is about ½ per cent the weight of the filter. If, for example, the filter weighs 400 milligrammes, the weight of the ash will be 2 milligrammes.

[2] *Comptes Rendus*, lxxxvii. 109.

is noticed after an interval of 3 minutes, the liquid is again poured on the filter. The addition of diminishing quantities of the barium chloride solution is repeated, until the filtrate ceases to exhibit the faintest cloud after an interval of 3 minutes.

Water employed 10 c. c. + 1 drop of acetic acid.

| | Solution of Chloride of Barium. | |
|---|---|---|
| First Addition . . | 16 drops. | (Abundant deposit.) |
| Second " . . | 2 " . | (Notable turbidity.) |
| Third " . . | 1 " . | (Feeble turbidity.) |
| Fourth " . . | 1 " . | (Very feeble turbidity.) |
| Fifth " . . | 1 " . | (No cloud at the end of 3 minutes.) |
| Total drops | 21 | |
| Total drops used | 20 | |
| Deduct ½ drop from fourth addition | ·5 | |
| | 19·5 drops. | |

As 1 drop = ·485 milligramme of anhydrous sulphuric acid, 19·5 drops × ·485 = 9·46 milligrammes.

Hence a litre of water contains ·946 grammes or 66·2 grains per gallon of anhydrous sulphuric acid.

The following list (page 151) will afford some idea of the remarkable differences exhibited by various kinds of water in respect to the amount of this mineral ingredient.

The water of the well in Hutton is avoided by the occupants of the cottages to which it belongs, on account of its purgative properties; whilst that from the well at Mountnessing is occasionally used after boiling. Both of these wells are shallow, and are situated in the London clay formation.

Of the Metropolitan waters, that of the Kent Company is objected to by some on the ground of the excess of sulphates. As much as from 20 to 70 grains of sulphates per gallon have been found in some drinking waters in Dublin by Dr. Cameron.

A water may exhibit a large amount of magnesia and but a very small quantity of sulphates, that alkaline earth being in the form of carbonate, as for example, in the waters of the dolomite formation.

I have examined well waters, pure as to organic matter, containing $4\frac{1}{2}$ grains per gallon of sulphuric acid in the form of sulphate of lime, but have not felt warranted in publicly expressing disapproval of the use of such waters for drinking purposes. If samples of water were brought to me in order that I might select the best, I should certainly at the outset place a water containing this amount of sulphates out of competition.

We have very little reliable information as to the effects of these salts in drinking water on the health, but that they must have a very decided influence admits of no doubt. Can it be a matter of no moment from a public health point of view whether people are drinking water containing 100 grains per gallon, as at Mountnessing, or ·5 of a grain per gallon, as at Croydon, of anhydrous sulphuric acid from sulphates?

I have never yet seen a person who habitually employs a drinking water containing a large amount of sulphates that could be regarded in any sense by a medical eye as "a picture of health."

## C. *Phosphates.*

Phosphates. When we remember the important rôle played in the human organism by phosphates, and in how many

| Names of Waters. | Sulphuric Acid ($SO_3$) from Sulphates. Grs. per Gal. | Remarks. |
|---|---|---|
| Spring in Admiral's Park, near Chelmsford, Essex | 1·3 | Proposed as public supplies. |
| Spring in Trinity Lane, Springfield, Essex | 5·8 | |
| Spring supplying Grove House, Great Baddow, Essex | 2·7 | |
| Manchester water | 1·1 | |
| Sunderland water | ·93 | |
| Croydon water | ·5 | |
| The Rhine at Bonn | 1·4 | |
| Clareen well, Carrick-on-Suir | 1·2 | |
| Do. river do. | ·9 | |
| Public pump, Waterford | 17·76 | |
| Pump at University Club, St. Stephen's Green, Dublin | 49·4 | Closed, as it caused diarrhœa and dyspepsia |
| Flooded stream, Holmfirth, Yorkshire Moors | ·87 | |
| Carlisle Waterworks | 1·5 | |
| Water of shallow well in Rose Valley, Brentwood | 4·54 | |
| Water of deep well, Stanwix, Carlisle | 3·79 | |
| Fountain water from High Town, near Haltwhistle | ·81 | |
| Water from pump in Rutherford's Court, Stanwix, Carlisle | 10·57 | |
| Pump in yard, Prospect Place, Stanwix | 4·03 | |
| The water of the river Ouse, near York, on September 1, 1876 | 4·3 | |
| The water of the river Ouse, near York, on September 6, 1876 | 1·58 | |
| Water from shallow well of Jeffrey's Endowed School, Great Baddow, Essex | 16·36 | |
| Water from well at Brentwood Hall, Brentwood | 3·13 | |
| Water from Maldon Waterworks | 4·51 | |
| Water from well at Little Burstead | 64·5 | |
| Water from well in Mountnessing | 100·0 | |
| Water from well in Hutton | 182·0 | |
| Water from well at Hutton Railway Bridge | 2·7 | |
| Thames Water Companies. Grand Junction | 1·5 | |
| Thames Water Companies. West Middlesex | 1·47 | |
| Thames Water Companies. Southwark and Vauxhall | 1·43 | |
| Thames Water Companies. Chelsea | 1·52 | |
| Thames Water Companies. Lambeth | 1·56 | |
| Other Companies. Kent | 2·82 | |
| Other Companies. New River | 1·05 | |
| Other Companies. East London | 1·59 | |

different forms they occur in the various parts of the body, it is a matter of great interest to study the relation between the use of waters emanating from phosphatic strata, and the condition of health of those who employ them.[1]

The presence of an excess of phosphates when they cannot thus be accounted for is often due to sewage impregnation. Tiemann has noticed phosphates in large quantity in the water derived from marshy meadows.

Mr. Wanklyn states,[2] that "much nonsense has been talked about phosphates in drinking water." "Carbonate of lime and phosphates are incompatible in drinking water." Dr. Dupré has affirmed that he never examined a water in which he could not detect phosphoric acid. In Prof. Kubel's *Treatise on Water Analysis*, edited by Dr. Tiemann, is to be found the following description of the mode of testing for phosphoric acid: "Boil the water; the precipitate contains the phosphates; dissolve this precipitate in hydrochloric acid; evaporate to dryness, and heat for a short time a little over 212° F. Then dissolve in a little hydrochloric acid and water, filter, and add filtrate to a slightly warm clear solution of ammonium molybdate and nitric acid, when a yellow colour and precipitate occur." The nitric acid employed should be of the greatest purity, and free from all colour. If the phosphates

[1] Mons. Joly, in an interesting paper to one of the Parisian scientific societies, says that the importance of the phosphates in the animal economy may be measured by the fact that five different phosphates are found in the body: in the red blood corpuscles, phosphate of iron; in the liquor sanguinis, phosphate of soda; in the nervous system, phosphate of potash; in the muscles, phosphate of magnesia; and in the bones, phosphate of lime. In each case the phosphoric acid fulfils very different functions, according to the bases with which it is united.

[2] *Op. cit.*

are in very small proportion, the water should be concentrated by evaporation previous to the analysis.

Dr. Dupré in the experiments undertaken by the Local Government Board in 1880-81, already referred to, employed the following qualitative method:—The solution of the total dry residue obtained in the estimation of solids was "warmed in nitric acid, after filtration, with a strongly acidified solution of molybdate of ammonia."

The Society of Public Analysts thus describes the plan which it recommends: "The ignited total residue is to be treated with a few drops of nitric acid, and the silica rendered insoluble by evaporation to dryness.[1] The residue is then taken up with a few drops of dilute nitric acid, some water is added, and the solution is filtered through a filter previously washed with dilute nitric acid. The filtrate, which should measure 3 c. c., is mixed with 3 c. c. of molybdic solution[2] gently warmed, and set aside for 15 minutes at a temperature of 80° F." The amount of phosphoric acid in phosphates found is generally recorded either as "traces," "heavy traces," or "very heavy traces."

Method of the Society of Public Analysts.

[1] Dr. Ashby suggests the removal of the contents of the platinum dish to a porcelain one before evaporation to dryness, as this metal is dissolved in the presence of chlorides.

[2] "One part pure molybdic acid is dissolved in 4 parts of ammonia (sp. gr. ·960). This solution after filtration is poured with constant stirring into 15 parts of nitric acid of 1·20 sp. gr. It should be kept in the dark and carefully decanted from any precipitate which may form."

# CHAPTER VIII

## THE DETERMINATION OF POISONOUS METALS

The poisonous metals which water analysts are called upon to consider are lead and copper. The occurrence of arsenic, zinc, tin, and barium, etc., in drinking water, is so rare as to hardly merit the attention of the health officer. In the Afghanistan campaign of 1839 there was a large mortality amongst the British detachment stationed at Ali Musjid, which was ascribed to the strong impregnation of the water with antimony.

Lead and copper are usually the poisonous metals, especially the former, with which waters are liable to be contaminated. A water sometimes contains iron, which is of course undesirable in all cases, except for medicinal purposes, and hurtful in some.

Place 70 c. c. of water to be examined in a porcelain dish, and stir it with a glass rod moistened with sulphuret of ammonium. Note whether or not there be any coloration. If so, it may be owing to a sulphuret of iron or lead, or of copper. If, on adding two or three drops of hydrochloric acid, the brown colour disappears or diminishes, iron is present, for the hydrochloric acid dissolves the sulphuret of iron. If, on the other hand, the colour does not vanish or diminish on this addition, lead or copper is present. It matters not which, for both are equally injurious. Wanklyn writes, "If there be coloration," on introducing the sulphuret of ammonium, "it should only be just visible, and on adding two or three drops of hydrochloric acid, it ought to vanish absolutely." Water which answers to this test in a satisfactory manner is registered as sufficiently free from poisonous metals, and water which does not, is to be condemned as contaminated with metallic impurity. If the quantity of either of these metals in a water be required, it is necessary to employ standard solutions, containing one milligramme of each metal in each cub. cent. of its solution (made by dissolving 1·66, 3·93, and 4·96 grammes of crystallized acetate of lead, or sulphate of copper or proto-sulphate of iron in a litre of distilled water); and, if we desire to ascertain whether lead *or* copper be present, it is needful to operate on a larger quantity of water, and to work according to the directions in that distinguished chemist's exhaustive treatise on water analysis.

The above simple mode of testing for poisonous metals is sufficient for the Medical Officer of Health, for it enables him to say that a water contains less than $\frac{1}{10}$th grain of lead or copper per gallon, an amount which should condemn a drinking water. Water is considered to be admissible for domestic purposes if containing $\frac{1}{2}$ grain of iron per gallon, but the presence of one grain of this metal per gallon is deemed to be sufficient to justify its rejection. The French chemists consider that the amount of iron should not exceed ·21 grain per gallon in a potable water.

Medical literature teems with instances of poisoning by lead and copper. It is curious to note the timidity with which Cornish miners look upon waters issuing from strata known to contain metals, and how they altogether ignore the risk of drinking water contaminated with filth of the filthiest description.

Lead.

*Lead.*—The action of different kinds of water on lead forms a very large subject, which cannot here be even briefly adverted to.

Lead poisoning sometimes occurs when the water of a well is very soft and free from saline ingredients, in consequence of its action on the leaden pipe that descends into it from the pump, and through which it is raised. This danger does not exist in the case of highly saline waters, for the salts so encrust the leaden pipe as to prevent the solution of the lead by the water. Lead pipes should never be employed in wells. It has been pointed out to me by Dr. Ashby that waters from the oolitic-limestone district in which he lives do not act on lead, owing to the protective action of the traces of phosphoric acid contained in them.

Sheffield water supply.

Several of the Yorkshire cities, such as Sheffield, Huddersfield, Rochdale, and Keighley, are reported to suffer from impregnation of their water supply with more or less lead. A very excellent report on that of Sheffield has recently been issued by Dr. Sinclair White, the Medical Officer of Health, who found that a portion of it furnished by certain springs supplied to a particular section of the city was acid and contained an amount of lead varying from ·07 to ·7 grain per gallon, from which the water supply of the remainder of the city (derived from another source) was free. He attributes the acidity either to ulmic and humic acids from the decomposition of peat, or to sulphuric acid produced by the oxidation of the iron pyrites contained in the shale underlying the moorland peat, from which the former or "high level" supply proceeds. He suggests that a protective property be imparted to the water by passing it for fifteen minutes over small fragments of limestone.

An approximation to the proportion of lead present in a water may be arrived at by means of Mr. Wynter

Blyth's cochineal colour test,[1] but the exact quantity is calculated by the author in the following simple manner. Take two Nessler glasses graduated into c. c. and precisely alike. Place 70 c. c. of the water under examination in one, and 50 or 60 c. c. of distilled water into the other. Let them rest on a white slab. Introduce a glass rod dipped in ammonium sulphide into each. If any lead is present in the water, a brown colour is developed. Match its depth by adding to the distilled water, by the help of a burette graduated into cub. cents., a standard solution of acetate of lead (1·66 grammes of crystallized acetate of lead to 1 litre of distilled water of which 1 c. c. = 1 milligramme of lead) in sufficient quantity to exactly match the tint. Bring the volume of the diluted standard up to the 70 c. c. mark, and then make a final comparison. The number of cub. cents. of the standard lead solution employed represent the number of grs. of lead in a gallon of water.

*Iron.*—The plan recommended by Dr. Tidy[2] for the detection of iron and for ascertaining the form in which it is present is as follows:—Fill 3 tubes (each 2 ft. long) with the suspected water; into one (*a*) place a drop or two of a solution of ammonic sulphocyanide, which gives a blood-red colour with ferric salts; to the second (*b*) add first of all a few drops of nitric acid (to oxidize ferrous salts if present) and then a few drops of the ammonic sulphocyanide solution. Compare the tint depths of these tubes with one another, and of both with the pure water tube (*c*). If no red tint is observable in (*a*) tube, but is developed in (*b*) tube, iron is present in the form of ferrous salts.

Iron.

Dr. Tidy's Qualitative Method.

Dr. Franklin Parsons suggests the following method of rapidly estimating small quantities of iron:—"Take the residue of 70 c. c. used in the determination of the

[1] *Asclepiad*, January 1884, p. 91.

[2] *Op. cit.*

Dr. F. Parson's Quantitative Method

solids, ignite it gently (a strong heat renders the ferric oxide insoluble) dissolve it in a little warm nitric acid (which oxidizes the iron to the ferric state) dilute to about 25 c. c. with water, and add a single drop of a solution of ferrocyanide of potassium. The blue colour resulting is gauged by comparison with that of a standard solution in the same way as ammonia is estimated colorimetrically. The standard solution is easily made by dissolving one decigramme of iron wire in dilute sulphuric acid, adding a few drops of nitric acid and boiling; when cold it is to be diluted to 100 c. c. Each c. c. contains a milligramme of iron. This solution is kept in stock. When required 1 c. c. of this solution is run into a 100 c. c. test mixer, diluted, a drop of ferrocyanide solution added, and the test mixer filled up to 100 c. c. Two cylinder glasses of equal diameter are then taken and placed on a sheet of white paper; in one the dissolved water residue is placed and treated with ferrocyanide solution; into the other is poured as much of the standard blue solution from the test mixer as will produce, when looked down through, an equal shade of colour. The amount is known by reading the graduations on the test mixer, each c.c. corresponding to ·01 grain of iron per gallon: ·05 grain per gallon may in this way be estimated in the residue of 70 c. c. of water. Prussian blue in solutions so dilute precipitates very slowly, so that the same standard solution will serve for several determinations. The solution of ferrocyanide need not be of any definite strength, but had better be somewhat dilute: enough must of course be added to combine with all the iron present, but, on the other hand, care must be taken not to add a large excess, as it gives a yellow tinge to the solution which interferes with the correct estimation of the blue." The question, of course, arises as to the practical utility of making such minute determinations of iron in a sanitary analysis.

If we have occasion to ascertain whether or not a water defiled by mines or manufactories contains arsenic, $\frac{1}{2}$ litre of such water, being rendered slightly alkaline by hydrate of soda or potash free from arsenic, should be evaporated to dryness. The residue having been digested in strong hydrochloric acid should be poured into the apparatus described on page 346 and depicted in Fig. 40, and examined by Marsh's test or by Davy's method, page 347.

*Copper.*—The amount of this metal in a water is usually determined by a colorimetric method, which is conducted in a manner precisely similar to those employed in the other volumetric processes already described. The depth of brown or chocolate colour produced by a 4 per cent aqueous solution of ferrocyanide of potassium in a water containing copper, is imitated by that displayed in an equal volume of distilled water to which different quantities of a standard solution of sulphate of copper (3·93 grammes in 1 litre of distilled water, of which 1 c. c. = 1 milligramme of copper) have been added. The amount of standard solution of sulphate of copper consumed of course furnishes the datum on which rests the simple calculation as to the amount of copper present in the sample of water. Mr. Wynter Blyth suggests the addition of a solution of nitrate of ammonia, which renders the reaction much more delicate. Copper.

*Zinc.*—A case has been reported[1] by the Medical Officer of Health of Llanelly of the impregnation of the public water supply to the village of Cwmfelin with zinc derived from the galvanized iron water pipes. The total solids being 18·9 grains per gallon, 6·41 grains of them consisted of zinc carbonate. It seems that pure zinc is easily dissolved by water through which a current of oxygen and carbonic acid gas is passed. This metal may be detected by evaporating to dryness a little of the water on Zinc.

[1] *Lancet*, March 1, 1884, p. 403.

a piece of platinum foil; when the volatile matter is burnt away the residue will be found to be yellow when hot, and white when cold. This residue, transferred to a piece of charcoal and treated with a solution of nitrate of cobalt, yields a green colour when heated in the outer flame of the blow-pipe.

Should water stored in leaden cisterns be used for drinking purposes?

My experience teaches me the wisdom and expediency of recommending a strict avoidance for drinking purposes of all water that has been stored in leaden cisterns, or has otherwise rested for some time in contact with lead, until we possess data of a less contradictory and more definite description than at present as to the influence of various kinds of water under different circumstances on this metal.

## CHAPTER IX

### MICROSCOPIC EXAMINATION OF A WATER.

A. *The Examination of a Water free from Deposit.*—The approximative estimate of the number of micro-organisms and the diagnosis of the kind, whether bacteria, bacilli, micrococci, vibrios, spirillæ, etc. may be accomplished by the aid of a microscope by making (*a*) a cover glass preparation and (*b*) a "drop culture."

Cover glass preparations.

(*a*) *Cover glass preparations.*—The author finds it useful to examine a water in the manner practised by Koch as described by Prof. Warden.[1] With a glass rod sterilized by passing it several times through a flame of a Bunsen's burner, a drop of the water to be examined is placed on a clean cover glass, which is allowed to dry under a bell glass. "When the water has evaporated, the edge of the cover glass being held by a pair of pincers, and the side containing the residuum being upwards, the cover glass is rapidly drawn *three times* with a downward motion through the colourless flame of a Bunsen's burner or through a large spirit flame." The cover glass still held by the pincers is then flooded with methyl blue solution,[2]

[1] *Op. cit.*

[2] *Mode of Preparation.*—Methyl blue, 2 grammes rubbed in a mortar with 10 c. c. of absolute alcohol to which 90 c. c. of distilled water is gradually added. The mixture is filtered into a bottle provided with a perforated cork carrying a pipette, by means of which a small quantity can be removed as required. A small fragment of camphor should be placed in the filtered solution.

which is allowed to act for about 3 minutes. The dye is then washed off by a gentle stream of water. The cover glass should be allowed to dry under a bell glass and finally mounted in Canada balsam when it is ready for the microscope. The easiest plan, perhaps, is to kill and precipitate the microbes by adding to the water a $1\frac{1}{2}$ per cent solution of osmic acid, in the proportion of 1 c. c. of the latter to 30 or 40 c. c. of the former.

Drop cultures.

(*b*) "*Drop cultures*" have been recommended by Dr. E. Crookshank[1] as suitable for the study of the life history of the micro-organisms in water. He gives the following directions for their management:—"Clean an excavated microscope slide and sterilize it by holding it cupped side downwards in the flame of the Bunsen's burner. A ring of vaseline is painted around the excavation. A clean cover glass is sterilized in the same manner. With a platinum needle bent at its extremity into a minute loop or ring (which has been sterilized by holding it in the flame) transfer a drop of sterile bouillon[2] to the cover glass and this drop is inoculated by touching it with another sterilized platinum needle charged with the water under examination." The slide is then inverted and placed over the cover glass, so that the drop will come exactly in the centre of the excavation, and is gently pressed down. On turning the slide over again the cover glass adheres, and an additional layer of vaseline is painted around the edge of the cover glass itself. The slide must if necessary be placed in the incubator (*vide* fig. 8, page 82). In this manner the gradual growth of a micro-organism can be watched.

B. *Examination of Deposit.*—The best and most simple

[1] *Introduction to Practical Bacteriology.*

[2] Made in the same manner as Koch's nutrient jelly (*vide* p. 76) with the omission of the gelatine and salt. The use of the hot water jacket is not needful during its filtration.

mode of examining the deposit from any sample of water is, first, to allow suspended matters to subside in the sample bottle; and secondly, to decant the greater part of the water, and pour that at the bottom of the bottle containing the sediment into a conical glass. After subsidence a drop of the water containing the deposit may be removed by means of a pipette to the cell of a microscope slide and be allowed to evaporate, or the drop may be immediately covered with a thin glass, the

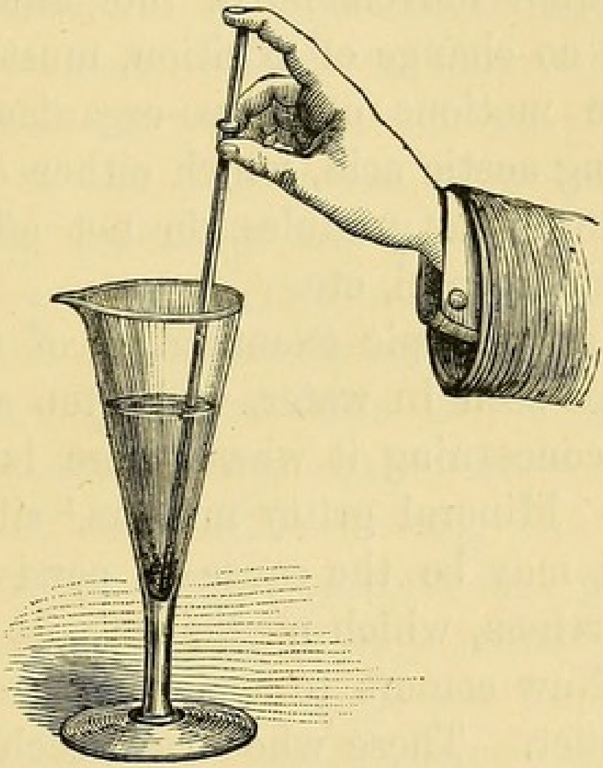


FIG. 15.
Conical Glass and Pipette.

excess being removed with blotting-paper, and examined. If a water possesses much turbidity this transfer to a conical glass is of course unnecessary. If the amount of sediment procured in this way is practically nil, the greater part of the water in the conical glass should be poured away, and that remaining in the angle of the cone should be transferred to a burette similar to, but of much larger diameter than, that depicted in Fig. 3. After subsidence the solid bodies may easily be removed in single drops of fluid on to microscope slides. In the microscopic examination of waters we require a $\frac{1}{4}$-inch object glass, a Powell and Lealand or Zeiss' oil immersion $\frac{1}{12}$th-inch object glass, and an Abbé's condenser. A polariscope is a useful addition for the diagnosis of starch granules.

The deposit of every water is treated by the French with the following reagents: a solution of iodine for the detection of starch; a solution of carmine in glycerine and alcohol, which imparts to the nuclei of cells a red stain; and methyl violet for bacteria. The tremulous molecular or Brownian movement of inorganic particles, in which there is no change of position, must not be confounded with the motions of micro-organisms. Liquor potassæ and strong acetic acid, which either alter or remove fatty and albuminous granules, do not affect micro-organisms such as micrococci, etc.

Inorganic particles.

The microscopic examination of the floating particles sometimes seen in water, will often afford valuable information concerning it where there is any doubt as to its quality. Mineral gritty matters,[1] silt of clay, and sandy particles, may be the cause of persistent and unaccountable diarrhœa, which medicines will only temporarily relieve. New comers to a place where such water is used often suffer. Those who drink such waters long become generally unaffected by these intestinal irritants. Chalky particles are dissipated by the addition of a little mineral acid, whilst the other inorganic matters apt to occur in drinking waters are unaffected thereby.

The existence of animal life in a water affords good evidence in itself of the presence of a tangible amount of organic matter, *alias* filth, whether it be the micro-organism seen in the fairly pure waters supplied by the majority of the London companies, with an average of

[1] The mountain dysentery prevalent in certain districts in India has been shown to be due to the employment of drinking water containing in suspension minute particles of mica.

about ·08 milligramme of albuminoid ammonia per litre, or the various humble animal organisms of pond water, with its ·38 milligramme of albuminoid ammonia per litre. These little creatures feed and flourish on what we call organic matter, and in perfectly pure water they cannot live.

Pasteur has shown that there are certain waters coming from deep-seated springs that are destitute of organic life, and are sterile; but 99 out of every 100 waters contain a greater or less number of micro-organisms, and the great majority of these 99 waters exhibit organisms of much larger dimensions than those which are known as micro-organisms.

Description of animal and vegetable life should be ascertained

The kind of animal and vegetable life seen in water gives a certain clue to the description of water we are examining. Speaking generally, the infusoriæ, the confervæ, and vorticellæ, are the inhabitants of the least pure of spring waters; then come the diatoms[1] and desmids; entomostraca or water fleas[2] are seen in spring ponds, lochs, and impounded waters; euplota and fungoid growths, etc., abound in pond and ditch waters, and in well water polluted with filth; whilst bacteria and paramecia and spirilla are prominent in sewage-polluted water. There is no evidence to show that those low forms of life, commonly known as the fungi, are in themselves hurtful if taken into the system, although their appearance is an unfavourable symptom. It is highly probable, however, that the poisons of several of the zymotic diseases are

[1] Some erroneously believe that the presence of diatoms is an indication of evil omen. The Bristol water, which is a fairly good one (*vide* p. 97), contains a quantity of diatoms of different kinds of which I have made drawings. Sometimes when very abundant they present the appearance of an exceedingly faint milky cloud settling down to the bottom of the vessel which holds the water.

[2] To the presence of vast numbers of dead entomostraca the fishy odour noticed by passengers in the steamboats on the Lake of Geneva has been attributed. These minute crustaceans secrete an oily substance under their carapaces, to which certain bad tastes of public water supplies have been ascribed (*Water Supply—Chemical and Sanitary*, by Prof. Nichols).

either identical with, or are products of, certain micro-organisms (which can be distinguished by their appearance or behaviour from one another) or find a congenial soil amongst such organisms, which act as carriers, to which they attach themselves, and amongst which they multiply.

Dr. Frankland and his followers regard the presence of anything like a moving organism in a water as a danger-signal, for the reason that, if the poisons of such diseases as cholera and typhoid fever attach themselves to particles of organic matter, and can operate in inconceivably minute quantities, as is generally believed, there is a possibility of the disease ferment or germ of such maladies accompanying elementary forms of life. Dr. Mills of Glasgow, following Dr. Frankland's example as to the metropolitan waters, frequently refers in his public reports to the presence of living organisms in the water of Loch Katrine as detracting from its purity.

---

## DESCRIPTION OF PLATES OF MICROSCOPIC OBJECTS FOUND IN DRINKING WATER.[1]

1. Actinophrys Sol. *Order—Radiolaria.*
2. Algæ, with bacteria and diatoms.
3. Bacillus. } *Family—Bacteriaceæ.*
4. Bacteria. }
5. Amœba. *Class—Rhizopoda.*
6. Vorticellæ. *Class—Infusoria.*
7. Ova of Entozoa.
8. Euplotes Vannus. *Class—Infusoria.*
9. Paramecium. *Class—Infusoria.*
10. Young Filaria, or thread worms.
11. Confervæ.
12. Muscular fibre.
13. Spirillum. *Family—Bacteriaceæ.*
14. Hair (human).
15. Linen fibre.
16. Cotton fibre.
17. Mineral particles.
18. Fragment of deal wood.
19. Stomata of leaf.
20. Epithelial scales.
21. Closterium moniliformis. *Family—Desmidiaceæ.*
22. Tabellaria floccosa. *Family — Diatomaceæ.*
23. Chætophora Elegans.
24. Euglenia. *Class—Infusoria.*
25. Anguillula. *Order—Nematoda.*
26. Rotifera.
27. Cyclops Quadricornis. *Order — Copepoda. Sub-class—Entomostraca.*
28. Cosmarium Margaritiferum. *Family—Desmidiaceæ.*
29. Diatoma Vulgare.
30. Diatom.
31. Fungi.
32. Vegetable cellular tissue.
33. Scenedesmus. *Family—Desmidiaceæ.*
34. Daphnia pulex. *Order — Cladocera. Sub-class—Entomostraca.*
35. Micrococcus. *Family—Bacteriaceæ.*
36. Infusoria.
37. Ova of Nais. *Class—Annelida.*
38. Vegetable débris.

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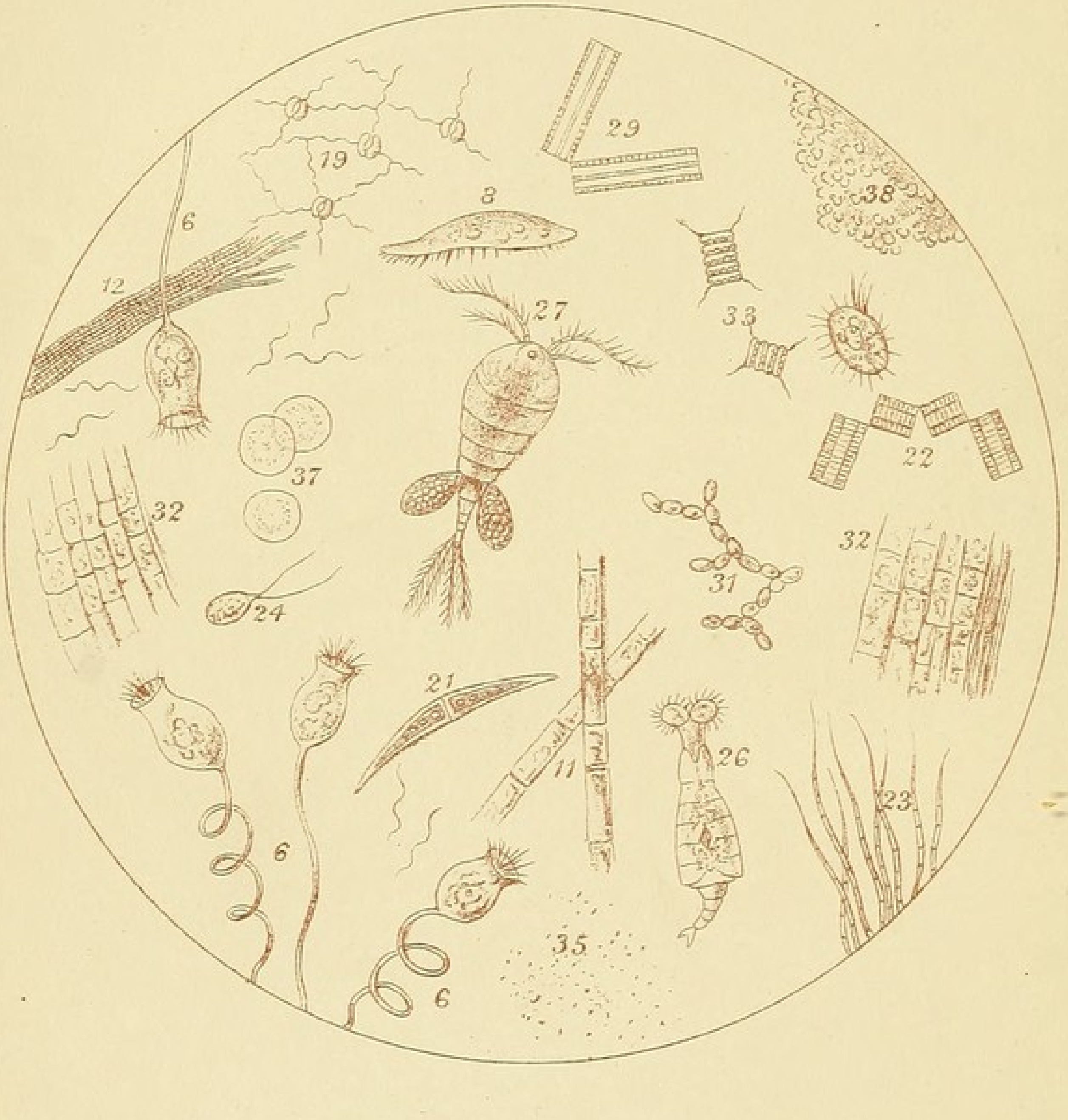
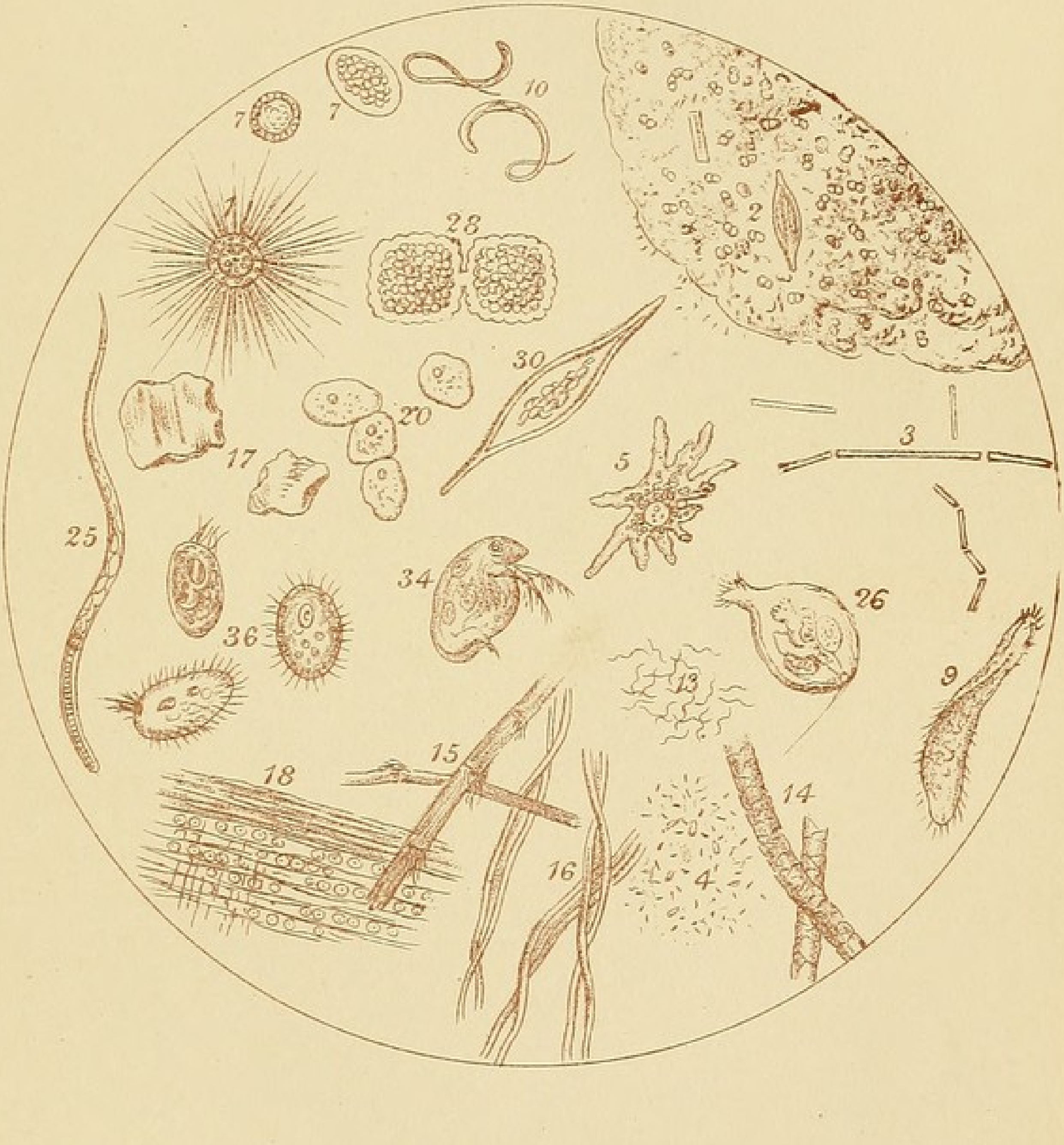
[1] The objects are depicted as magnified by means of glasses of different powers, but this is unimportant. My sole desire is to fix on




MICROSCOPIC OBJECTS F...

*To follow...*




ND IN DRINKING WATER.

e 166.

The public water supply of Llandudno was condemned some years ago by the late Mr. Wigner, the analyst, on the ground of its unfavourable appearance when examined by the microscope, for the results of his chemical study of it would not certainly warrant a censure.

| | | |
|---|---|---|
| Free Ammonia . | ·068 | Milligramme per litre. |
| Alb. Ammonia . | ·06 | |
| Nitrogen as Nitrates and Nitrites . . | ·24 gr. per gallon. | |

Another class of scientific men regard insects in water as scavengers that assist, like plants, in its purification, and place the greatest reliance on those great natural purifying processes of oxidation and dilution, the existence of which we are all too prone to forget. They urge that there is no reason for supposing that an animal poison will attach itself to an infusorian animalcule, but rather to organic matter in a state of putrefactive change, and that there exist good grounds for thinking that an animal poison when enormously diluted with water, becomes harmless, as it does when very freely mingled with the other medium, air. Personally I feel a greater sympathy with the latter than with the former class, although there can be no doubt but that when Dr. Frankland sees, by the aid of his microscope, fragments of partially-digested muscular fibre which has been excreted by some carnivorous biped, in the water of the Thames, as furnished to a portion of the inhabitants of London, he is perfectly justified in making the fact public, and in urging the need for some amendment in the condition of the metropolitan water supply.

An animal poison, when enormously diluted with water or air, becomes innocuous.

Sufficient attention has not hitherto been directed to the kind of moving organisms found in drinking water,

the attention the *forms* and *appearances* of the various animal and vegetable bodies visible in waters, and of the extraneous substances with which they are most liable to be mingled, in order that a recognition of their differences may prove of diagnostic value.

and the lessons taught by these differences. Mr. Ivison Macadam has expressed the opinion[1] that the presence of the Daphnia pulex and Cyclops quadricornis in a water is a proof of its purity, because these water-fleas are not found in bad waters, in which it appears they cannot live. He finds them in all our good impounded waters, such, for example, as that of Edinburgh, Rothesay, etc.

Daphnia pulex.

A perfectly pure water contains no suspended matter, nor any animal or vegetable life; but such is very rarely found. The ova of the entozoa, such as those of the round and the thread worms, the eggs and joints of the tape-worm, and small leeches, which may give rise to grave disorders, should not be forgotten in making microscopic examinations of drinking waters. The endemic hæmaturia of Egypt and the South of Africa has been shown to be due to a hæmatozoon named bilharzia hæmatobia, which is disseminated by water containing its ova. The germs of the parasitic disease named rishta, which is so prevalent in Bokhara, are considered by Jenkinson, Klopatoff, Fedchenko, and others to be diffused through the medium of water. The excellent illustrations in Dr. Macdonald's *Guide to the Microscopical Examination of Drinking Water*, will be very helpful to students of this branch of water analysis. As scientific literature is possessed of this valuable guide, I shall only add the following extract from the Hygienic Classification of Waters contained in Parkes' *Hygiene* (5th edit.) :—

| 1. *Pure and Wholesome.* | 2. *Usable.* | 3. *Suspicious.* | 4. *Impure.* |
|---|---|---|---|
| Mineral matter; vegetable forms with endochrome; large animal forms; no organic débris. | Same as No. 1. | Vegetable and animal forms more or less pale and colourless; organic débris; fibres of clothing or other evidence of house refuse. | Bacteria of any kind; fungi; numerous vegetable and animal forms of low types; epithelia or other animal structures; evidences of sewage; ova of parasites, etc. |

[1] Paper entitled "Animal Life in Fresh Water Reservoirs."—Aberdeen Meeting of Social Science Congress, 1877.

Those who are conversant with the use of the microscope will recognize vegetable tissue, starch, epithelial scales, human hair, the hair of cats and other animals, wool, bits of deal, fibres of silk and linen, cotton filaments, scales and legs of insects, and feathers, and will not be puzzled by such apparitions in the field of the microscope. Those who are not familiar with the appearances presented by these objects when magnified, should make themselves as soon as possible acquainted with them under low and high powers. Medical Officers of Health who are thus well grounded will find the microscopic contents of water an exceedingly interesting and instructive subject of study.

# CHAPTER X

## THE COLLECTION OF SAMPLES OF WATER FOR ANALYSIS.

EVERY water analyst should have his samples of water collected in strong stoppered glass bottles, supplied by himself, which have been thoroughly cleansed with a strong acid before leaving his laboratory. Stoneware bottles should not be used, for that material is liable to introduce calcic sulphate, silicates, and common salt into the water. It is wise to have an ample supply of the water to be examined, so as to have a reserve in case of such accidents as the bursting of a retort, etc. A stoppered Winchester quart bottle holds a convenient amount. By avoiding waste, I find that about one litre of water is, as a general rule, sufficient for analysis, unless it is wished to make any special examination, as, for example, an estimate of the amount of magnesia in a water, when a stoppered "Winchester Quart" is employed.

Quantity equired.

Label.

| |
|---|
| ——————— *Sanitary District.* |
| SAMPLE FOR ANALYSIS. |
| *Date of Collection* ——————— |
| *Source* ——————— |
| *Spring, Pump or Draw Well* ——————— |
| *Depth of Well* ——————— |
| *Nature of Soil and Subsoil* ——————— |
| *Distance of nearest Filth or Drain* ——————— |
| *Distance of nearest Cultivated Land* ——————— |
| *Reason for Analysis* ——————— |

*About twice the above size will be found the most convenient.*

Before taking a sample, the bottle should be well rinsed three times with the water to be collected. The stopper should be firmly tied down by twine or tape, and a printed label, with gummed back, of the accompanying description, should be filled up and affixed to the bottle. It is a good plan to tie down over the mouth and stopper of the bottle a bit of guttapercha sheeting, to exclude the dust. These bottles are advantageously protected in their frequent transits about the country by enclosing them in a strong box, similar to that which is herewith sketched. Hay and straw, which are generally very dusty packing materials, are thus avoided.

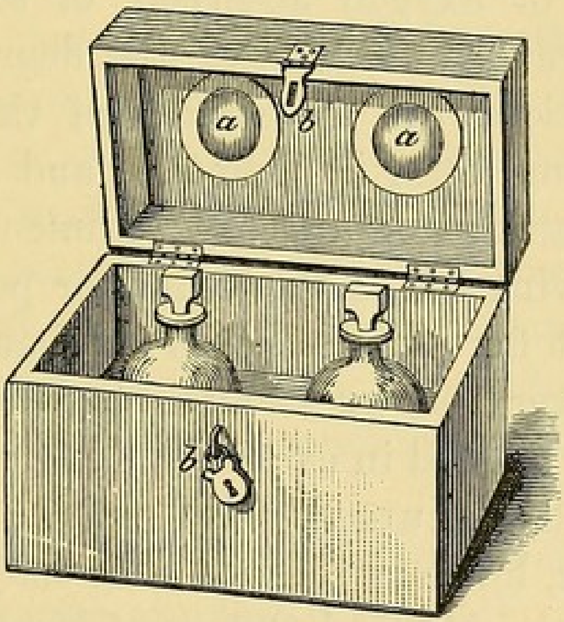



Fig. 16.

Sample Box.

*a a*. Elastic pads that press on stoppers of bottles when box is closed.
*b b*. Padlock and fastener.

## CHAPTER XI

### TIME OCCUPIED IN PERFORMING AN ANALYSIS.

HAVING estimated the amount of free ammonia, of albuminoid ammonia, of oxygen absorbed, of solid residue, of chlorine, of nitrates and nitrites, the degree of hardness, and having noticed the appearance of the solid residue before, during, and after incineration, and having made a microscopic examination of any sediment that may be present, and having tested the water for poisonous metals, and examined it for magnesia and sulphates, we are in a position to answer the question as to whether the water submitted to us is good in every respect for a public water supply. It will be urged, with reason, that such an analysis as this, however desirable it may be, cannot be undertaken by the Medical Officer of Health, for so much time would be consumed in water examinations as to leave but little for other work. It is but rarely that I make a complete analysis of this kind, because it is seldom requisite. A head centre on all matters relating to public health should be able to conduct such an investigation, in order that when a question arises as to which of several waters would be the best in every respect for the public water supply of a town or village, he may be able to give an answer based on quantitative determinations of the several ingredients that affect the wholesomeness of a water.

If the estimation of the free and albuminoid ammonia, the oxygen absorbed, and the chlorine, and the qualitative test for nitrates, does not show conclusively the character of a water, then it is advisable to add other tests, such as a quantitative determination of the nitrates and nitrites, the incineration of the solid residue, the calculation of the amount of saline matters, and the degree of hardness.

**Mode of limiting extent of analysis.**

If the question, "Is this water wholesome and good?" be addressed to me, I immediately ask whether any illness or disease has been attributed to the employment of it. If there is a suspicion lest the water has interfered with the health of any person or persons, inquiries are made of the applicant as to whether there is any reason for suspecting the presence of organic matter or metallic poisons, or whether the water is found to be too hard for domestic purposes, or whether it is brackish or purgative. In fact, I ask what reason there is for complaining of the water. In this way the extent of the analysis is limited, and the applicant obtains the information required. In the majority of cases that present themselves, the question arises as to the amount of organic matter, whether within or beyond the permissible limit.

Now, what amount of time is occupied in answering this last question with absolute certainty? Thirty minutes. If it is needful, as is often the case, to estimate the exact amount of organic matter present in a water, forty minutes are consumed. If a more complete analysis is required, it is best to commence by starting the permanganate of potash process for the absorption of oxygen, and whilst it is proceeding to determine the amount of chlorine, and the quantity of nitrates and nitrites in, and the hardness of, the water, whilst the distillation is going on. The evaporation of the 25 c. c. of water to procure the solid residue, and the weighing of the dish both before and after this operation, of course proceed simultaneously with the distillation. If any special determination of the sulphates or other mineral ingredients is demanded, extra time is required.

Unlike the Frankland and Armstrong process, which consumes two and oftener three days, the Wanklyn, Chapman, and Smith process is very rapid, as it can be completed within an hour by the most inexperienced. The Medical Officer of Health process described in this work, which is a modification of the latter, is generally rather more lengthy, its duration being dependent on the greater or less rapidity with which we arrive at conclusive evidence as to the character of a water.

The Wanklyn, Chapman, and Smith method may be expedited by submitting for examination a $\frac{1}{4}$ litre instead of a $\frac{1}{2}$ litre of water, and multiplying the results by 4 instead of by 2. This rapid modification of the process is suitable only for the Medical Officer of Health who has had some experience in water analysis, to whom I would recommend it. Messrs. Townson and Mercer have made for me Nessler glasses of a size adapted for the examination of half the usual quantity of distillate, namely, 25 c. c.

## CHAPTER XII

### ENTRY OF ANALYSIS IN NOTE AND RECORD BOOKS.

THE entry of an analysis may be conveniently made in the note-book thus :—

*Well at Woodhouse Farm.*

*Date of Collection.*—April 4/77. *Source.*—Well, with pump, 25 ft. deep.

„ *Analysis.*—April 5/77. *Soil.*—Sand and gravel.

*Distance of nearest Filth.*—7 yards.

*Reason for Analysis.*—Diarrhœa suspected from use.

*For Chlorine*, 70 c. c. taken. Required of sol. nitrat. silver 20 c. c. ∴ 20 grains per gallon.

*For Solids* 25 c. c. taken.—Dish and Residue . 26·251
Dish . . . 26·230

| | |
|---|---|
| | ·021 |
| ∴ 58·8 grains per gallon. | 4 |
| | ·084 |
| | 700 |
| | 58·800 |

| | | | |
|---|---|---|---|
| Free ammonia | ·02 | Alb. ammonia | ·06 |
| „ „ | ·007 | „ „ | ·03 |
| | | „ „ | ·01 |
| | ·027 | | ·10 |

In litre free ammonia ·054, and alb. ammonia ·20 milligram.
Nitrogen as nitrates and nitrites $1\frac{1}{2}$ grain per gallon.
Total hardness 19 degrees.
Oxygen absorbed in 4 hours at 80° F. ·2 grain per gallon.
*Opinion.*—Water condemned as unfit for drinking purposes.

It is useful to keep a record book of all analyses for each sanitary district alphabetically arranged in parishes, the pages being ruled in a manner similar to the lines on the certificate of an analysis (*vide* page 213).

Some make entries of the free ammonia and the albuminoid ammonia in terms of nitrogen, and, combining the nitrogen obtained from the nitrates and nitrites, add together the nitrogen from all sources. The amount of ammonia, be it free or directly derived from organic matter, may easily be represented as nitrogen by multiplying by 14 and dividing the result by 17. In the foregoing analysis the two ammonias thus expressed would be registered as follows :—

| | | | | |
|---|---|---|---|---|
| | | | | Milligramme per litre. |
| Free Ammonia | ·054 | = | Nitrogen as Free Ammonia | ·044 |
| Alb. ,, | ·20 | = | Nitrogen as Alb. ,, | ·170 |
| | | | Total amount of Nitrogen | ·214 |

## CHAPTER XIII

### MISTAKES OF WATER ANALYSTS, AND HOW TO AVOID THEM

To avoid errors in analytical work it is important to be very cleanly, orderly, and methodical. Many mistakes arise from a want of cleanliness and care in the collection of samples. Dirty bottles and corks should not be employed. It is desirable never to rely on the memory, but to be business-like and exact in everything. All the details of an analysis should be written in a book kept for the purpose, at the time of its performance.

Analysis of a water in a fresh and stale condition.

A water should always be examined in a fresh state; for, by keeping, some of the free ammonia leaves the water, and other changes take place. On April 13 the water of an artesian well yielded free ammonia ·36, and albuminoid ammonia ·015 milligramme per litre. On April 16 another portion of the water, withdrawn from the same stoppered bottle as the first sample, was tested, and this second analysis gave of free ammonia ·125, and of albuminoid ammonia ·015 milligramme per litre. The water had lost ·235 milligramme of free ammonia per litre in three days. This water was a very pure one. If, however, it had contained an excess of albuminoid ammonia as well as of free ammonia, confervoid growths would have formed in it (very rapidly in warm weather), and have fed on the free ammonia.

With a decrease of free ammonia there would have been a decided increase in the amount of albuminoid ammonia. Waters should be examined, if possible, within thirty-six hours, in summer, after their removal from their source, and in the interim they should be kept in a cool dark place in stoppered bottles.

Want of chemico-geological knowledge.

A mistake on the part of an analyst may arise from a want of chemico-geological knowledge. Here are examples. An analyst received a sample of water which did not prove on analysis to be perfectly clean, but, nevertheless, could not be condemned on the score of an excess of organic matter. Bearing then a somewhat indifferent character for cleanliness, he tested it for chlorides, and found a large excess, which led him to condemn the water. He was not acquainted with the fact that this water came from the greensand, and that the purest waters from this formation contain an excess of chlorine.

A water from a deep well in Essex was sent to an analyst who obtained the following data on which to form an opinion :—

| Grains per Gallon. | | Milligrammme per Litre= Part per Million. | | Degrees. |
|---|---|---|---|---|
| Solids. | Chlorine. | Free Ammonia. | Alb. Ammonia. | Hardness. |
| 97·4 | 37 | ·73 | ·04 | 6½ |

He saw first that the solids were in excess. The large amount of chlorine made him look with the strongest suspicion on the water. Then, on finding such an enormous quantity of free ammonia he concluded — overlooking the fact that the albuminoid ammonia was exceedingly small — that this well was polluted with urine. This water, however, is quite pure. He did not know—(1) That the water came from beds of sand lying underneath the London clay, at a distance of about 250 feet from the surface; and (2) That these sandbeds furnish, in certain situations, water of great purity, which possesses an excess of chlorides and free ammonia.

The following case occurred some time since in one of the south-western counties, which has utterly shaken the confidence of the local public in their opinion of their health officer. Two waters from neighbouring pumps, which were open to some suspicion, were examined by him. The water from one pump was pronounced to be pure, and the water from the other was declared to be impure and quite unfit for drinking purposes. It was ultimately discovered that both pumps derived their water from one and the same well. Such a lamentable mistake could hardly have occurred had not some utterly fallacious mode of examination been practised. In justice, however, to this gentleman, it should be stated that a most extraordinary case has recently been published by Sir Charles Cameron, the well-known health officer and analyst of Dublin, where good and bad water would seem to have been present in a deep well at the same time, the pure lying in a layer at the bottom of the well, and the impure forming a stratum on the surface.

A pure water and an impure water at the same time from the same well.

| Sample. | Grains per Gallon. | | Qualitative. | | Part per Million= Milligramme per Litre. | |
|---|---|---|---|---|---|---|
| | Solids. | Chlorine. | Nitrous Acid. | Nitric Acid. | Free Amm. | Alb. Amm. |
| No. 1 | 29 | 2·1 | Large amount | Small amount | ·14 | ·35 |
| No. 2 | 47·4 | 1·7 | None. | Trace. | ·00 | ·08 |

No. 1 water was taken from the well by dipping it out from the surface, whilst No. 2 was withdrawn from a tap, the pipe of which descended to within two inches of the bottom of the well. Sir Charles Cameron comes to the following conclusion:—"The water which enters the lower part of the well through its side and bottom is derived from springs, or at any rate it is water which had percolated throughout a considerable quantity of clay, and had thereby been deprived of any organic matter which it might originally have contained. On the other hand, the drainage of the surface of the surrounding soil must have in part made its way into the well through the sides, but near its mouth. As this drainage would undergo but little filtration, it would probably be contaminated with organic matter, as surface drainage so generally is." The writer has noticed a similar difference in quality of the water drawn at different depths from four other wells; in one case, the solids per gallon amounting to 66·23 grains in the bottom water, and to only 3 grains in the top water. I on one occasion analyzed samples of water taken from two different pumps connected with one and the same well (depth 18 feet), both samples proving exceedingly filthy. The pipe of the pump that drew water from the bottom of the well furnished a water which was more impure than that from the pump that obtained its supply at a higher elevation. The lesson taught by these facts is, that it behoves the collector of well waters for analysis to take precautions to secure samples representing the average composition of the *whole contents* of a well.

Omission to test for metals.

The mistakes of water analysts may arise from sins of omission as well as from those of commission. Two or three samples of a spring water were some time since submitted by a Rural Sanitary Authority to a distinguished analyst with the object of discovering whether or not it was adapted for the public supply of a neighbouring town which was destitute of clean water. Foolscap papers of formidable appearance, containing details quite incomprehensible to all but experts, were received after a delay of two or three months, which contained the assurance that the water was a very excellent one, and in all respects adapted for dietetic and all domestic purposes. No mention, however, was made as to the presence or absence of metals. I maintain that no one is justified in giving such an opinion as the above, unless he has made an examination for lead, copper, and iron in a water. Resting on the opinion of the analyst, expensive water-works have been constructed, and the water has been "laid on" to the town. The water contains so much iron as to be very unpopular, the public preferring for drinking purposes the water of their polluted surface wells.

The water from a well about 25 feet in depth was sent to a London analyst, who pronounced on the following data the opinion that the water was "polluted with sewage," and "cannot be drunk without danger to health."

| Grains Per Gallon. | | | Part per Million= Milligramme per Litre. | |
|---|---|---|---|---|
| Chlorine. | Nitrogen as Nitrates and Nitrites. | Volatile Matters. | Free Ammonia. | Albuminoid Ammonia. |
| 3·2 | ·4 | 5·6 | ·070 | ·058 |

The analyst adds, "The quantity of chlorine is so large as to be strongly suggestive of the source of pollution." Here, in this instance, two mistakes were committed. The above results would not warrant any one in affirming that the water was polluted with sewage, for it manifestly is not. They indicate that the water is a doubtful one, and should have led to further investigation. I analyzed the water of this same well on two distinct occasions, separated by an interval of several months. My figures did not materially differ from the above, except that the proportion of free ammonia was slightly less, *e.g.*—

| | Part per Million = Milligramme per Litre. | |
|---|---|---|
| | Free Ammonia. | Albuminoid Ammonia. |
| First Analysis . . | ·02 | ·06 |
| Second Analysis . . | ·02 | ·05 |

A microscopic examination of the sediment showed the presence of an abundance of confervoid filaments on both occasions. The amount of chlorine is rather below the average of the surrounding district, all the purest waters of which furnish an abundance of chlorides derived from sandy strata. It is perfectly evident that the water contains vegetable impurities to some slight extent, and is accordingly not of the best quality. Here was a very serious error made by an analyst of note, who evidently relied on the indications afforded by the test for chlorine and the loss by incineration, to the exclusion of that obtained by microscopic examination, which is always desirable in doubtful water.

Five analyses of the same water yielding different results.

The apparent disagreement between the results obtained in water analysis by different analysts was brought forward by a gentleman in the *Chemical News* of November 19, 1875. He publishes five analyses with opinions by five chemists of repute, of the water from the same well, and appends his conclusion—

| | Degrees. | | | | Grains per Gallon. | | | | | Part per Million = Milligramme per Litre. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Hardness. | Permanent Hardness. | Temporary Hardness. | Solids. | Nitrates. | $CaSo_4$. | Cl. | $CaCo_3$. | $SiO_2$. | Free Amm. | Alb. Amm. |
| A. | 23·0 | 7·0 | 16·0 | 27·5 | 2·500 | 6·5 | 0·78 | 15·8 | 0·6 | | |
| B. | — | — | — | 22·8 | 3·500 | 0·5 | 0·78 | 17·0 | 0·7 | | |
| C. | 31·0 | 9·0 | 22·0 | 27·0 | 0·587 | — | 1·25 | — | — | ·01 | ·10 |
| D. | 18·6 | 5·8 | 12·8 | 24·1 | — | — | 0·91 | 18·6 | — | | |
| E. | 22·3 | 4·4 | 17·9 | 26·6 | 1·852 | 4·3 | 1·27 | 16·9 | — | ·00 | ·01 |

A.'s verdict is—That the water is of good quality.
B.'s ,, It is surface water and is bad.
C.'s ,, So much organic matter as to be unfit for drinking.
D.'s ,, A perfectly pure water, and quite fit for all domestic purposes.
E.'s ,, The water is unusually pure.

After such verdicts, surely it is necessary we should have some reforms in our practice of analytical chemistry.

The prominence given in these analyses to the mineral constituents of this water, to the exclusion, in three out of the five, of the more valuable information as to the amount of filth, is noticeable. The only analyses on which it would be safe to offer an opinion, namely, those labelled C and E, show the water to be one of a variable, and for this reason of a doubtful, or suspicious character. When one meets with such a water, it is wise to make two or three analyses at intervals of two or three months, remembering the fact that many wells are liable to periodical pollution, dependent on the height of the subterranean and ground or subsoil water, and other causes. I have heard of as many as nine samples of an intermittent public water supply having been taken at different times of the day (24 hours) by an analyst who felt convinced that some occasional pollution did occur. Eight samples proved on analysis to be pure. On making the ninth analysis he obtained proof of considerable organic contamination of the water. There is no evidence afforded that the samples of water, the analyses of which form the foregoing table, were all taken at the same time in perfectly clean vessels, as was very properly pointed out by the public analyst of Cornwall.

# CHAPTER XIV

## USEFUL MEMORANDA FOR MEDICAL OFFICERS OF HEALTH WHEN PERFORMING WATER ANALYSIS

1. THOROUGHLY wipe away all dust from the mouth of the sample bottle and stopper with a clean glass-cloth before commencing an analysis. Memoranda.

2. The hole at the upper extremity of the standard ammonia solution burette, for admitting air when the liquid is drawn off by the tap, should be closed by turning around the glass stopper, before leaving the laboratory for the day, otherwise evaporation will take place, and the remaining standard solution will become stronger than it should be when next employed. For the same reason it is undesirable to place more standard ammonia solution in the burette at a time than will be probably required. If, at the conclusion of one's work in the laboratory, a little solution only remains, it is as well to throw it away, and replace it by fresh from the stock bottle when next wanted.

3. On adding the caustic potash and permanganate of potash solution in the estimation of the albuminoid ammonia, it will be often noticed that on reapplying heat the steam that first passes off is not condensed, but escapes as such into the Nessler glass. It is wise to hold up the Nessler glass so that the steam issuing from the condenser tube may impinge on its cold base, and be thus condensed.

4. Sample bottles are exceedingly apt to fur, especially in warm weather, if waters are long kept in them, and difficulty is often experienced in cleansing them. Waters containing much free ammonia are especially liable to the growth of confervæ. It is desirable to wash out a sample bottle directly an analysis is completed. Bottles that have the slightest fur about them should be cleaned with strong impure hydrochloric acid and fragments of filter-paper. If this acid in a cold state fails to remove the fur, boiling acid must be employed. A most thorough washing with water is of course indispensable after the use of the acid.

5. Look narrowly for insect life in each sample of water submitted for examination. If a well water contains animal life of such a size as to be perceptible to the unaided eye, it is almost useless to analyze the water for organic matter, of which there is sure to be an excess. Animals will not exist in a fluid that does not possess organic matter on which they can feed. The presence of a distinct brown tinge in the water is often confirmatory in such a case of the presence of filth. Sometimes specimens of entomostraca may be seen along the edges of lakes and large reservoirs that supply towns with water. In such cases the volumes of water with which they are associated are so enormous that an analysis does not show any excess of organic matter in consequence of their presence.

6. Some of the ammonia found in rain water that falls near dwellings is derived from the soot, for ammonia is a product of combustion.

7. In the estimation of the solid residue it is advisable to examine the under surface of the platinum dish, after the evaporation to dryness, before the dish is weighed, and to carefully remove any saline matter derived from the water of the water bath. It is always best to employ distilled water in the bath.

8. The greater or less rapidity with which the solid residue increases in weight during weighing is an indication as to the amount of the deliquescent salts common to water residues, such as the chlorides of calcium and magnesium, the nitrite of potash, etc., which are present.

9. After the analysis of a very impure water, it is wise to distil a little distilled water through the retort and condenser tube, in order to be sure that the apparatus is perfectly free from any traces of ammonia.

10. Loosen the connection between the retort and the adapter or condenser tube after an analysis, to prevent a fracture, which will sometimes occur on cooling if this precaution is not taken.

11. The health officer should be prepared to deal with frauds with which the public occasionally amuses itself. Analysts have received, for example, samples of pure water into which a little soup or beef tea or mutton broth has been introduced; also samples of distilled water as obtained from druggists, and samples of rain water.

12. Nessler glasses are sometimes made of such thick glass, especially at their bases, as to give a distinct tinge of colour to colourless water. It is accordingly wise to select colourless and thin glasses, which should be all of exactly the same diameter.

13. Time is economized and accuracy is promoted if a separate graduated pipette be kept for each standard solution. A pipette should be filled by suction with the standard solution to which it is assigned, so as to moisten its interior before the solution is employed.

# CHAPTER XV

## FORMATION OF OPINION AND PREPARATION OF REPORT AS TO SAMPLE OF WATER SUBMITTED TO ANALYSIS

A FELLOW of the Chemical Society writes thus:[1]— "The facts in connection with water analysis are not a subject of dispute, but the deductions to be derived from the facts; and here we enter a region which is altogether outside the province of a chemist pure and simple, his usurpation to the contrary notwithstanding, and the question becomes one rather for the medical expert."

Mr. Simon rightly insists upon a high standard of purity for drinking water. In his second annual report to the city of London, he observes that "we cannot expect to find the effect of impure water always sudden and violent. The results of the continued imbibition of polluted water are indeed often gradual, and may elude ordinary observation, yet be not the less real and appreciable by close inquiry. In fact, it is only when striking and violent effects are produced that public attention is arrested; the minor and more insidious, but not less certain evils, are borne with the indifference and apathy of custom." Although no sickness may be produced during the life of a man by the habitual use of an impure water, yet there can be no question but that impure water, like impure air, affects the physique of individuals,

[1] "Potable Water," by Charles Ekin.

and tends to the degeneration of a race. Nearly every water contains some organic matter which, however, in exceedingly minute quantities is harmless, so far as our knowledge extends. When its amount in a water exceeds a certain limit, it is unwise to drink the water. If it is present in still larger quantities, the drinking of such water is attended with risk, or even with danger. Some may triumphantly observe that they have been endangering their health during a great many years, and are not, to their own knowledge, at all the worse for the filth that they have taken with their water. They conclude, therefore, that impure water, like tea against which the old woman of ninety was warned as a stealthy poison, must be exceedingly slow in its action. When will the public learn that what is apparently harmless to one is poison to another; that some constitutions are susceptible to a disease to which others are quite insusceptible;[1] that the susceptibility, when it exists, may only manifest itself at certain ages or periods in a life, or even times of the year; that a person may at one time be susceptible to a disease, and at another time be insusceptible? What a mistake then is it for a man to argue that, because he has drunk filthy pond water all his life, and fancies that he has never suffered thereby, therefore such water is not injurious to health, when we physicians can prove that it will often produce fatal diarrhœa. Because pond water does not *always* cause such disastrous results to *all*, such a man will argue that it can *never* do so to *any*. We know much, but we have yet much to learn as to the influence of impure water on the health of those in whom it does not produce disease.

Delusions of the public.

[1] Ample proof of the accuracy of this statement is obtainable. Witness, for example, the distressing symptoms produced in some people by the inhalation of the pollen of certain grasses, which form a complaint known by the name of hay fever, whilst the majority of persons are unaffected by the same.

The study of this subject forms part of the greater one, as to the *modus operandi* of various climates on the health and character of men and animals.

The question as to the suitability of peaty waters for the supply of individuals and communities often presents itself. The objections to such waters are twofold. (1) They are apt to produce diarrhœa in those unaccustomed to their use. Experiments made under the superintendence of Prof. Mallet showed that peaty waters, and waters containing an infusion of dead forest leaves, were distinctly injurious to rabbits. (2) Peaty waters are generally unpalatable and insufficiently aerated. Although they are soft and free from nitrogen as nitrates and nitrites, they are not properly oxygenated. They are accordingly unsuitable as public supplies where a non-peaty water can be procured.

The French chemists consider that all potable waters should contain 33 per cent of dissolved oxygen.

**Should pond water be condemned as unfit for drinking purposes?**

The minds of health officers have often been exercised as to the propriety of condemning pond water for domestic use. If the water be stored in clean vessels like the drinking ponds in the chalk districts, and as the "mist ponds," situated in high uncultivated hills in the north of England, which are said never to become dry, being replenished by the fogs which they condense; or if a pond is lined with cement, and so protected as to prevent the entrance of ditch water:—water will probably be furnished that is admissible. It will not, in fact, differ from the water of a lake or reservoir. Knowing, as we all do, that pond water as usually met with (1) is apt to create

**Its injurious effects.**

diarrhœa in summer; (2) that those who drink it are generally troubled with intestinal worms; (3) that these ponds are usually fed by ditches that drain fields which are often manured by town filth; and (4) that there is a strong suspicion of the existence of a connection between the employment of pond water and the prevalence of malarial diseases:[1]—we cannot, in the interests of the public health, approve of its adoption for drinking purposes. Families provided with this objectionable supply generally either strain the water through muslin, or boil the water, or pass it through a filter, or, if very turbid, a pinch of alum is added to clarify it. The father of a family drinks little else than beer, and the mother's beverage is tea. In summer and autumn, when there is a tendency to intestinal disorders, I have known entire families in rural districts, who have not taken the trouble thus to lessen the evil, thoroughly prostrate from severe diarrhœa; and if the pond water has been fouled by the excreta of cattle, a form of continued fever, resembling closely enteric fever, has been induced. If the excreta are of human origin, the danger is, of course, the greater. This summer or autumn diarrhœa is doubtless at times produced by direct mechanical irritation, and at others by the absorption into the blood of septic matters. We have most of us in our memories instances of persons who have employed no other water than that from a pond in summer full of insect life, for all domestic purposes, and whose health has not, to the eye of a casual observer, suffered. I have known a man who died at the ripe age of between 80 and 90 years, and who boasted that he had drunk nothing but pond water for between 30 and 40 years. I have also known a man who reached the age of 90, and who consistently led for about 50 years a most drunken and dissolute life.

Thames water collected below London Bridge, if allowed to stand in an open vessel for a few days in warm weather,

[1] Case of an outbreak of ague at Tilbury Fort in 1872. Case of an outbreak of malarious disease recorded by Boudin amongst certain soldiers in one ship supplied with marsh water during their voyage from Algiers to Marseilles, whilst their comrades in another ship which was furnished with good water were all well.

Thames water.

acquires a very offensive odour arising from the decomposition of the animal and vegetable matter. This water was formerly valued by sailors, and stored on board ship in wooden casks. When drunk, it was the custom to wipe away the solid matters that collected on the lips, after taking a draught, with the back of the hand. During the first week or fortnight of its storage in the hold, ship captains found that the water underwent a change described as a kind of fermentation, evolving a quantity of gas possessing a most offensive odour and depositing a copious brown sediment. The gases produced in the wooden casks were said to be slightly luminous in the dark and to be explosive. The coagulation of the albuminous constituents of the water by the tannic acid of the oaken casks probably occurred. The water gradually ceased to smell offensively, became bright and sparkling, and was said to keep fresh and sweet for an indefinite length of time, having lost the whole of its putrescent impurities. Pond water has been known to undergo a similar change on board ships. In our war vessels, etc., iron tanks are used instead of casks for storing. It is said that in iron tanks Thames water evolves no offensive gases, but becomes pure much quicker than when stored in wood, and deposits a more copious brown sediment which turns red on exposure to air. Iron possesses a wonderful power of causing the precipitation of the organic matter and some of the saline constituents of a water.

Information as to source, surroundings, etc., of water, a sample of which is to be analyzed.

It has been urged, as a serious objection to the Wanklyn, Chapman, and Smith process, by those who believe in the Frankland and Armstrong process, that an opinion of the smallest value cannot be formed of a water examined by the former process without the fullest information as to soil, situation of source of water, distance of possible centres of pollution depth of well, etc. Let any one read the printed instructions of Dr. Frankland,[1] sent out by him to those who collect samples of water to be analyzed in his laboratory, and it will be seen that he requires a similar amount of information for his own guidance. The reason of this is obvious. Every system of water analysis at present known has its weak points, some possessing more than others; accordingly, the best methods have to be fenced around with certain protections against error.

Golden rules in water analysis.

It is a golden rule in water analysis never to give an opinion unless the analyst knows (1) the nature of the source of a water—whether it comes from a spring, or well, or river, or rain reservoir, etc.; (2) the depth of the well, if it is withdrawn from one; (3) the geology of the district from which it is derived, together with the character of the soil and subsoil; (4) the distance from the source of the water of the nearest filth or drain. Another golden rule is never to give an opinion as to the character of a water from an estimation of one ingredient only in the water. A very serious mistake has often been made by those who practise the ammonia process of water analysis, which has thrown great discredit on the chemistry of the subject. This mistake has been to deliver an opinion on the quality of a water which has been *solely* formed from a determination of the amount of albuminoid ammonia contained in it. The practice of tabulating side by side with the *total amount of albuminoid ammonia* in a water, the fact of the appearance or otherwise of any pre-

[1] "At the time the samples are forwarded for analysis, give the following particulars:—(*a*) From what source—Wells, rivers, or streams? if from wells, (*b*) describe the soil and subsoil, and also the water-bearing stratum into which the well is sunk; (*c*) the diameter and depth of well; (*d*) the distance of the well from either cesspools or drains; if from rivers and streams, (*e*) the distance from the source to the point at which sample is collected; (*f*) whether sewage or other animal polluting matter is known to gain access to river or stream above the point of collection; if from springs, (*g*) describe the stratum from which the spring issues; (*h*) state whether the sample is taken direct from spring or otherwise," etc.

ventable disease amongst those who had been in the habit of employing it, an example of which may be seen in Table VII. of Dr. de Chaumont's *Lectures on State Medicine*, is apt to be misleading. The arrangement of a table, in which the valuation or *opinion of the analyst* as to each water (as formed from the observance of certain rules for guidance) is placed in juxtaposition to the name of the disease, if any, apparently produced by it, would be exceedingly interesting and of great practical value.

Sanitary authorities will sometimes present to a Medical Officer of Health a sample of very dirty water, which is reported to come from a well, and will ask him whether, if the well is cleaned out, the water will be good. This question can only be partially answered by an analysis. The hardness of the water can be roughly ascertained, and the presence or absence of objectionable ingredients, such as purgative salts, metals, etc., can be determined. A muddy water has often been sent to me derived from a new well recently dug, with a wish that I should ascertain whether there is any excess of organic matter in it. Such an inquiry is equivalent to the following:—"I have placed filth (for mud contains organic matter) in the water. When I cease to introduce filth, will the water be free from any?" Here are examples of turbid waters from new wells which have become pure after repeated removal of their contents by pumping:—

Turbid waters from recently dug wells.

| | Grains per Gallon. | | | Part per Million = Milligramme per Litre. | | Degrees. |
|---|---|---|---|---|---|---|
| | Solids. | Chlorine. | Nitrogen as Nitrates and Nitrites. | Free Ammonia. | Albuminoid Ammonia. | Hardness. |
| Well (25 ft.) in gravel | 51 | 7 | ... | ·01 | ·175 | 13 |
| Well (20 ft.) in sand and gravel. Sept. 16 (*a*). | ... | 2·1 | None | ·56 | ·24 | ... |
| Well (20 ft.) in sand and gravel. Sept. 25 (*b*). | ... | 2 | ,, | ·02 | ·09 | ... |
| Well (20 ft.) in sand and gravel. Oct. 15 (*c*). | 21 | ... | ,, | ·02 | ·04 | ... |

The estimation of the nitrates and nitrites is valuable in such cases as the above, for it often gives information respecting the surroundings of the well. The Medical Officer of Health can frequently clear up any obscurity that may exist, by himself visiting the well and noting its situation, etc.

## A. Summary of Data on which to base an Opinion.

Summary of data on which to form a judgment.

1. *Odour.*
2. *Colour through tube.*
3. *Free Ammonia*—Its amount.
4. *Albuminoid Ammonia*—Its amount and manner of distilling over.

   (3 and 4:) Smell of distillates?
5. *Oxygen absorbed* in 4 hours at 80° F.—Its amount.
6. *Nitrogen as Nitrates and Nitrites.*—Its amount. Nitrates *or* Nitrites?
7. *Solid Residue*—Its amount. Behaviour with Hydrochloric Acid. Appearance Before, During, and After incineration at a dull red heat. Amount of Volatile matters.

8. *Chlorine*—Its amount.
9. *Hardness*—Total, Temporary, Permanent.
10. *Microscopic Examination of Sediment*—Nature of objects observed.
11. *Biological Examination.*
12. *Metals.* { Lead, Copper, Iron } Existence or non-existence. If present, the amount.
13. *Mineral Matters objectionable if in excess.* { Magnesia, Salts of Sulphates, Phosphates. } Present or absent. If present, the amount.

In the great majority of cases that present themselves to the Medical Officer of Health a complete analysis of this sort is not wanted. In nine cases out of ten the question to which an answer is required is, as to whether a water is or is not polluted with filth. To reply to this query it is simply necessary to ascertain the amount of free and of albuminoid ammonia. If the applicant wishes to know if the filth is of animal origin or decayed vegetable matter, we must estimate the quantity of chlorine and nitrogen in the form of nitrates and nitrites. If the interrogation is submitted to us as to whether or not a water devoid of filth is in other respects wholesome, a calculation of the amount of solid residue, of the hardness, etc., is needful.

## B. Valuation Tables and District Standards.

Mr. Wigner's valuation table.

It would be a great convenience to the analyst if he were able to appraise each determination at its true value in a definite manner, which can be represented in figures. The late Mr. Wigner with this object in view, constructed a table[1] which gives the values in degrees of impurity of the several data on which an opinion is to be based.

*Appearance in two-foot tube.*

| | |
|---|---|
| C. Blue | 0 |
| C. Pale yellow | 2 |
| C. Green | 2 |
| C. Dark yellow | 4 |
| C. Dark green | 4 |

*Suspended matter to be added to the valuation of appearance.*

| | |
|---|---|
| For traces | 1 |
| „ heavy traces | 2 |
| „ turbidity | 4 |

*Smell when heated to 100° F.*

| | |
|---|---|
| Vegetable matter | 1 |
| Strong peaty | 2 |
| Offensive, of animal matter | 4 |

| | | |
|---|---|---|
| Chlorine in Chlorides | ·50 gr. per gall. | = 1 |
| Phosphoric acid as phosphates, traces = 2. h traces = 4. v h traces | | = 8 |
| Nitrogen in nitrates | ·100 gr. per gall. | = 1 |
| Ammonia | ·005 „ | = 1 |
| Alb. ammonia | ·001 „ | = 1 |
| Oxygen absorbed in 15 min. at 80° F. | ·002 gr. per gall. | = 1 |
| „ „ 4 hours „ | ·010 „ | = 1 |
| Hardness before and after boiling added together each 5° | | = 1 |
| Total solid matter | 5 grs. per gall. | = 1 |
| Heavy metals | s traces | = 6 |
| „ „ | h „ | = 12 |

*Microscopical Results.*

| | |
|---|---|
| Vegetable débris in small quantity | 4 |
| „ „ large „ | 8 |
| Diatoms and bacteria in small „ | 6 |
| „ „ large „ | 12 |
| Hair and animal débris (according to quantity observed) | 10 to 20 |

*Rules.*

| | |
|---|---|
| A valuation at or below 15. | = Exceptional purity. |
| „ „ „ 40. | = First class water. |
| „ „ „ 60. | = Second „ |

[1] *Analyst*, July 1881.

The metropolitan companies furnish waters that show a value on this scale varying between 20 and 40.

The foregoing table possesses three or four grave defects.

1. Some of the purest waters contain a large excess of free ammonia, and yet each ·005 gr. per gall. is valued at 1.

2. Good artesian well waters often contain a large quantity of chlorine, and yet each ·5 gr. per gall. is valued at 1.

3. Waters which cannot be condemned on account of the presence of peat absorb a large amount of oxygen, and yet each ·01 is valued at 1.

4. Artesian waters organically pure, although not of the best quality, contain large amounts of solids, and yet every 5 grs. per gall. are valued at 1.

Dr. Muter's amended valuation table.

Dr. Muter has suggested[1] the following amendment of the above valuation table.

| | | Gr. per gall. | | Valuation number. |
|---|---|---|---|---|
| Ammonia . . . . . | each | ·0015 | = | 1 |
| Alb. ammonia . . . | „ | ·0007 | = | 1 |
| Oxygen consumed in 15 min. . | „ | ·0040 | = | 1 |
| „ „ 4 hrs. . | „ | ·0100 | = | 1 |

He writes, "When any number exceeds 10, then all over 10 is to be doubled and added to the original number, and the total valuation is to be divided by 100 and noted as comparative degree of organic impurity.' Then *supposing no other consideration intervenes to modify the analyst's opinion of the sample*, I propose that the following limits should be observed:—

| | |
|---|---|
| First class water . . . . | up to ·25 degree. |
| Second „ „ . . . . . | up to ·40 degree. |
| Undrinkable „ . . . . . | over ·40 degree." |

[1] *Analyst*, June 1883.

The divergence in views as to the relative values might be minimized by excluding from the late Mr. Wigner's valuation table any values for microscopical results, leaving them to individual opinion,[1] and by omitting and diminishing the values of free ammonia, chlorine, oxygen absorbed, and total solids under certain conditions.

Some adjustment of the following kind might be thought feasible. Author's suggestions.

*Free ammonia* if in large excess is not to be valued, unless accompanied by an excess of albuminoid ammonia.

*Oxygen absorbed in 4 hours at 80° F.*, if in large excess is not to be valued beyond the value of the average of a water of medium purity, if an upland surface water, or water other than upland surface water, as the case may be (*vide* page 33), unless accompanied by an excess of nitrogen as nitrates and nitrites.

*Chlorine* if in large excess is not to be valued unless accompanied by an excess of ammonia and albuminoid ammonia, nitrogen as nitrates and nitrites, and oxygen absorbed in 4 hours at 80° F.

*Total Solids* if in large excess, as *e.g.* in artesian wells, are to be valued at 10 grains = 1, unless there is an excess of albuminoid ammonia, when the late Mr. Wigner's value, 5 grains = 1, may be employed. If some such qualified valuation were adopted, the total values in

[1] My own views as to the relative values of the several microscopic objects with which one is familiar, would lead me to place them in the following order, commencing with those of least and concluding with those of most importance :—

1. Vegetable matters.
2. Diatoms and desmids (*vide* p. 165 footnote).
3. Animal life.
4. Animal débris such as epithelial scales, human hairs, partially digested articles of food, fungi, etc.
5. Bacteria or bacilli so numerous as to be seen in each field of the microscope.

the rules as to the classification of waters in accordance with their valuation would have to be altered. Any valuation table that could be framed would be necessarily a mere rough guide, in which every one might find something to carp at. The history of a water, its surroundings, and the knowledge of the geological formation from which it is obtained, must be allowed to have a certain bearing on the judgment of the analyst.

District standards.

The author is disposed to agree with the opinion expressed by Dr. Dupré and Mr. Hehner,[1] that the establishment of "district standards" is preferable to the adoption of a general standard. They consider that the fitness of any given sample of water for drinking purposes is best judged "by its conformity to, or divergence from, the general character of the waters of the district from which it comes (or the geological formation from which it springs), which from their surroundings may fairly be taken as unpolluted."

The knowledge of the composition of the good well water of the locality from which the sample comes, which a Medical Officer of Health imperceptibly acquires after a time, often aids him in determining the nature of the water brought to him for analysis.

## C. Diagnosis and Formation of an Opinion.

The difficulties in judging as to the sanitary condition of a water from an estimation of the number of colonies developed by the employment of either of the biological methods are in the present state of our knowledge insuperable. It is undoubtedly true that the biological is the most delicate of all known tests, and that the purer the water, *cæteris paribus,* the smaller the number of colonies present. It is equally true, however, that micro-

[1] *Analyst,* April 1883.

organisms are to be found in nearly every water, and that length of storage, temperature, degree of aeration, etc. of a water, which have much to do with the number of colonies present, have, of course, no necessary connection with pollution. Prof. Bischof found:[1] (1) that New River water kept for six days compared unfavourably, as to number of colonies, both with New River water fresh from the mains, to which 1 per cent of sewage had been added, and with Thames water at London Bridge (*vide* page 213); (2) that the production of colonies is aided in a most marvellous way by increase of temperature from the freezing point where it is entirely stopped, up to from 86° to 104° F.; and (3) that a deficiency of oxygen in a water checked the development of microphytes. Until, therefore, it becomes possible to eliminate the effects produced by such influences, we have still to rely very much on our chemical and microscopical methods in the formation of an opinion, availing ourselves of any corroborative evidence which biological methods may afford.

1. The amount of organic matter in the best spring waters— Purest spring waters.

| | | Milligramme per litre. | | Milligramme per litre. |
|---|---|---|---|---|
| Spring water A. | Free ammonia | ·005. | Albuminoid ammonia | ·02. |
| ,, ,, B. | ,, ,, | ·000. | ,, ,, | ·01. |

2. A good water for drinking purposes should not contain more than Good waters.

| | Milligramme per litre. |
|---|---|
| Free ammonia . . . . . | ·01 or ·02. |
| Albuminoid ammonia . . . . | ·08 |

3. A water which possesses the following amounts of the two ammonias is classed amongst the suspicious waters. I have frequently noticed such waters as belonging to Suspicious waters.

[1] Paper on "Dr. Koch's Gelatine Peptone Water Test," read before the Socy. of Med. Officers of Health on April 16, 1886.

shallow wells surrounded by soil on which soapsuds, etc., are sometimes thrown.

| | Milligramme per litre. |
|---|---|
| Free ammonia . . . . | ·01 or ·02. |
| Albuminoid ammonia . . . | ·12. |

The suspicion of contamination is strengthened if the chlorides (in districts where these salts do not abound) and nitrates or nitrites (in non-chalky districts) are in excess. An excess or increase of the amount of saline residue is of unfavourable omen in the case of a doubtful water, for polluted waters generally contain a larger amount than pure waters coming from similar sources, although it cannot of course be said that a water which is highly saline is for that sole reason to be suspected.

Waters deserving condemnation.

4. A water, with or even without an excess of free ammonia, which displays a larger amount of albuminoid ammonia than ·15 milligramme per litre, should always be condemned if there is an excess of nitrogen as nitrates and nitrites (in non-chalky districts), and an excess over the average of the district of chlorides. If the nitrates and nitrites should not be in excess, but the chlorides be considerably above the average of the district, the water should still be denounced as unfit for drinking. If, with the above-mentioned excess of organic matter, the nitrates, nitrites, and chlorides should be insignificant in quantity, we should not form so unfavourable an opinion of the water, but would suspect the organic matter to be of vegetable origin—a view which would be strengthened or rebutted by other evidence, such as that derived from a microscopic examination of the deposit from the water, the colour of the water in a two-foot tube, etc.

| | Grains per Gallon. | | Milligramme per Litre. | |
|---|---|---|---|---|
| | Chlorine. | Nitrogen as Nitrates and Nitrites. | Free Ammonia. | Alb. Ammonia. |
| Water from spring pond situated in middle of a meadow. Water always running from pond. . . . | 4·5 | ·1 | ·08 | ·18 |

Waters fouled by surface impurities.

The amount of chlorine does not exceed that found in the purest waters of the district. Entomostraca noticed in it. Sediment consists of confervæ. Such a water cannot be condemned, but would simply be described as somewhat dirty. If the spring were enclosed by brick-work, so as to prevent the entrance of surface impurities, the water would be perfectly pure.

Here is the analysis of a water from a draw-well situated close to a dusty highway road, in a district where the purest waters contain an excess of chlorine :—

| | Grains per Gallon. | | Milligramme per Litre. | |
|---|---|---|---|---|
| | Chlorine. | Nitrogen as Nitrates and Nitrites. | Free Ammonia. | Alb. Ammonia. |
| B. | 6·3 | ·2 | ·01 | ·14 |

Such a water is simply fouled to some extent with surface impurities. If a pump were substituted for the bucket, etc., the water in all probability would be quite pure.

Waters polluted with animal matters.

5. If a water exhibits an excess of free ammonia and an excess of albuminoid ammonia, with an excess of nitrates and nitrites, and with an amount of chlorine above the average of neighbouring waters, that water is polluted with *animal* organic matter, *e.g.*—

| Samples. | Grains per Gallon. | | | Milligramme per Litre = Part per Million. | |
|---|---|---|---|---|---|
| | Solids. | Chlorine. | Nitrogen as Nitrates and Nitrites. | Free Ammonia. | Alb. Ammonia. |
| Waters from wells polluted by foul soil of churchyard— | | | | | |
| A . . . . | 94 | 11 | Abundant | ·12 | ·32 |
| B . . . . | ... | ... | Abundant | ·4 | ·52 |
| Water of well polluted by manure of garden | ... | ... | 2·4 | ·12 | ·20 |

Waters contaminated with vegetable organic matter

6. If a water possesses a large excess of albuminoid ammonia, and but little or no excess of free ammonia, and an insignificant amount of chlorides and nitrogen salts, there is strong presumptive evidence that the water is contaminated with *vegetable* organic matter. Such a water may be offensive, even after filtration through the best of filters.

| | | Milligramme per litre. | |
|---|---|---|---|
| *E.g.* Well water fouled with rotten leaves . . . . . | Free ammonia, | | ·05 |
| (A little rain water enters the well) | Alb. ammonia, | | ·30 |
| Well waters rendered impure by the | | A. | B. |
| decayed roots of trees . . . | Free ammonia, | ·01 | None. |
| | Alb. ,, | ·37 | ·25 |

No excess of nitrogen as nitrates and nitrites in either of these three waters.

Some peaty waters are an exception to this rule.

| | | Milligramme per litre. |
|---|---|---|
| *E.g.* Spring on Dartmoor, Devon (water very brown) . . | Free ammonia, | ·03 |
| | Alb. ,, | ·11 |
| Water from peaty well . . | Free ,, | ·06 |
| | Alb. ,, | ·08 |

Peaty waters often yield equal, or nearly equal, amounts of free ammonia and albuminoid ammonia. When equal, or nearly equal, amounts of albuminoid ammonia pass off in each distillate, strong evidence is afforded that the organic matter is of vegetable origin, although we must not conclude that when the albuminoid ammonia does not come over in that manner that the organic matter is *not* vegetable.

Prof. Wanklyn tells me that he found, on experimenting with the albumen of the egg and the gluten of wheat, this very important difference, as regards the manner in which the albuminoid ammonia often yields its ammonia.

Milligramme per litre.

| Vegetable Organic Matter. | Animal Organic Matter. |
|---|---|
| ·04 or ·03 | ·06 or ·07 |
| ·03 „ ·03 | ·03 „ ·025 |
| ·03 „ ·03 | ·01 „ ·005 |

Dr. Charles Smart thus discriminates[1] between fresh and decomposing organic matter of animal or vegetable origin:—

ORGANIC MATTER.

| RECENT. | | DECOMPOSING. | |
|---|---|---|---|
| Nitrogen as Alb. Amm. yielded slowly. | | Nitrogen as Alb. Amm. yielded more rapidly. | |
| Oxygen required by Drs. Letheby and Tidy's Permang. of Potash process. | | | |
| Animal. | Vegetable. | Animal. | Vegetable. |
| A small quantity. | A large quantity. | A small quantity. | A large quantity. |
| | | Colour interference. | |
| | | None. | Yellow colour on addition of soda carb. to water, and a greenish colour with Nesslerized distillates (*vide* p. 41). |

DIAGNOSIS OF A PEATY WATER.

Diagnosis of a peaty water.

*Colour.*—Generally, but not always, a shade of nutty brown.
*Saline Matters.*—Small in quantity.
*Chlorine.* Do.
*Free Ammonia.*—Very little } or Equal, or nearly equal, in
*Alb. Ammonia.*—Excess } amount.
*Hardness.*—Very little.

[1] *Op. cit.*

*Nitrogen as Nitrates and Nitrites.*—*Nil*, or almost *nil.*

*Volatile Matters.*—On burning solid residue, very little.

*Behaviour of Residue during Ignition.*—It blackens in patches or waves, which colour is very persistent.

*Oxygen Absorbed.*—Excess.

*N.B.*—Water often contains some *hydrogen sulphide.*

| Analyst. | Examples of Water. | Grains per Gallon. | | | | Part per Million = Milligramme per Litre. | |
|---|---|---|---|---|---|---|---|
| | | Solids. | Volatile Matters. | Chlorine. | Nitrogen as Nitrates and Nitrites. | Free Amm. | Alb. Amm. |
| Dr. Shea | 1. From peaty soil | 10·85 | ·95 | 1·85 | ·25 | ·065 | ·085 |
| Do. | 2. From peat in sand | 6·05 | ·85 | 1·4 | None. | ·04 | ·06 |
| Author | 3. Peat spring; hardness 2 or 2½ degrees | 5·00 | 1·40 | 1·1 | ·02 | ·03 | ·11 |
| Dr. Shea | 4 From peat; soil contained carbonate of iron, and consisted of a chalky marl. Water smelt strongly of hydrogen sulphide | 29·35 | 1·57 | 1·2 | | ·08 | ·06 |

Pollution by foul gases.

The pollution of a water by sewer gas or foul gaseous emanations from fæcal matter may be diagnosed by the absence of an excess of chlorine and nitrogen as nitrates and nitrites, whilst there is an excess of organic matter, and the microscope discloses an abundance of bacteria and micrococci.

The knowledge of the source of the water will prevent the possibility of making a mistake between a water vitiated with vegetable organic matter and one poisoned by sewer gases.

7. If a water contains an enormous excess of free

ammonia and an excess of albuminoid ammonia, the strongest evidence is afforded that a cesspool or urinal is delivering its contents into the well. Urine very rapidly decomposes, the micrococcus ureæ converting the urea into carbonate of ammonia, *e.g.*— Waters polluted by excremental matters, and their diagnosis.

Water from well polluted by urinal:—

| | Milligramme per Litre. |
|---|---|
| Free ammonia, above . . | 1·0 |
| Alb. " " . . | ·35 |

It is necessary to remember that rain water holds in solution a large amount of free ammonia, derived from the air which it washes as it descends, and from the soot with which it is generally mingled; and that, in consequence of the uncleanliness of the surfaces that collect it, which are often stained with the excreta of birds, it is apt to exhibit an excess of albuminoid ammonia. It is desirable not to confound the water of a well polluted with urine with water commingled with sooty rain water.

The manner in which the free ammonia comes over, and the collateral evidence, almost render such an accident impossible.

On distilling ½ litre of rain water collected on a slate roof in the country, which presented a slightly sooty appearance, I obtained the following result:—

| | |
|---|---|
| Free ammonia | ·35 |
| | ·25 |
| | ·12 |
| | ·09 |
| | ·09 |
| | ·04 |
| | ·03 |
| | ·97 |

I took off 7 distillates of 50 c. c. each, and did not come to the end of the free ammonia in this ½ litre of water.

In the case of a water polluted with urine, the free ammonia passes over in a wholly different fashion, *e.g.* in $\frac{1}{2}$ litre.

| | |
|---|---|
| Free ammonia | ·38 |
| | ·14 |
| | ·065 |
| | ·035 |
| | ·620 |

In litre above 1·0 part per million = milligramme per litre.

Rain water and well water polluted by urine.

There is one point of resemblance between the behaviour of rain water and urine polluted water under distillation, which is, that in both cases the evolution of ammonia cannot often be brought to an end.

Prof. Mallet even insists that "the value of the Wanklyn, Chapman, and Smith process depends more upon watching the *progress* and *rate* of evolution of the ammonia than upon determining its total amount." "*The gradual* evolution of albuminoid ammonia indicates the presence of organic matter, whether of vegetable or animal origin, in a fresh or comparatively fresh condition, whilst *rapid* evolution indicates that the organic matter is in a putrescent or decomposing state."

The following differences between rain water and urine polluted water should also be borne in mind:—

(*a*) Particles of soot may generally be seen in rain by the naked eye, or by the aid of the microscope, which are absent in the latter.

(*b*) The latter will probably contain an excess of nitrates unless actual sewage pollutes the water, whilst the former will probably exhibit only a trivial amount, or none.

(*c*) The latter will possess an excess of chlorine, whilst rain will not, unless it falls near the sea.

(*d*) The latter will display a greater or less degree of hardness, whilst the former will be soft.

## Diagnosis of Pollution by Urine or by Slop and Sink Water.

*Free Ammonia.*—Overwhelming amount, from ·50 to 2 milligrammes per litre. Diagnosis of Pollution by Slops, etc.

*Albuminoid Ammonia.*—Excessive. Often about ·3 or ·4, or even ·6 milligramme per litre.

*Chlorine.*—Generally in large excess.

*Nitrogen as Nitrates and Nitrites.*—In either minute amount, or in large excess.

*Oxygen absorbed.*—Excess.

| Analyst. | Examples. | Grains per Gallon. | | | Milligramme per Litre = Part per Million. | | Remarks. |
|---|---|---|---|---|---|---|---|
| | | Solids. | Volatile Matters. | Chlorine. | Alb. Amm. | Free Amm. | |
| Dr. Shea | Water from well close to broken sink pipe | 50 | 2 | 9 | Very abundant | ·35 | |
| Author | Water from artesian well into which drain conveying urine from stable leaked | ... | ... | 8·2 | ·51 | ·31 | The comparatively small proportion of free ammonia was due to the admixture of the urine with a vast quantity of water in this deep well. |
| Author | Same after diversion of drain | ... | ... | 7·3 | ·04 | ·08 | |
| | Water from a Shallow Well. | | Nitrogen as Nitrates and Nitrites. | | | | |
| Author | Before ... } Pollution by contents of Drain. | 75·6 | None | 12·3 | ·01 | ·07 | |
| | After ... | 103 | Abundant | 16 | ·69 | ·28 | Persistent uncontrollable diarrhœa produced. |

Dr. Shea has kindly sent me particulars of an interesting case where a new cesspool was constructed about thirty yards from a well, to receive slop water. Fourteen days after its completion the water of the well was noticed to taste unpleasantly. On analysis it proved to contain neither free nor albuminoid ammonia in excess, for the intervening earth acted as a filter. No less than 17·5 grains per gallon of chlorine were found in it, whilst neighbouring unpolluted wells possessed only 1·5 to 2·3 grains of chlorine per gallon.

### Diagnosis of Pollution by Contents of Cesspools and Sewers.

Diagnosis of Pollution by Sewage.

A glance at the following examples of waters polluted by a cesspool and drain, and by soil containing a large excess of decomposing animal matters, reveals immediately the difference in the results obtained.

| Samples. | Grains per Gallon. | | | Milligramme per Litre = Part per Million. | | Remarks. |
|---|---|---|---|---|---|---|
| | Solids. | Chlorine | Nitrogen as Nitrates and Nitrites. | Free Amm. | Alb. Amm. | |
| Water from shallow well near K. H. B. | 101 | 12·5 | excess | Above 1·0 | ·24 | Polluted by leaky cesspool. Typhoid fever and diphtheria amongst the owners. |
| Water from shallow well at A. L. B. | 50·4 | 6·9 | none | Above 1·0 | ·50 | Accidental overflow into well of cesspool contents which, having been the recipient of the specific poison of typhoid, spread the disease. |

*Free Ammonia.*—In large excess.

*Albuminoid Ammonia.*—In excess.

*Chlorine* somewhat in excess, but not so marked as when slop water is the polluting agent.

*Nitrogen as Nitrates and Nitrites.*—If sewage passes directly into a well—none. If sewage travels through some intermediate earth—generally an excess.

*Oxygen absorbed.*—Large excess.

8. Waters of shallow wells or springs in towns (the soil of which is, for the most part, more or less filthy) or near churchyards, if found to contain an excess of solid residue, in the form of nitrates and nitrites, chlorides, sulphates, and phosphates, should be pronounced as unsafe; although the amount of free and albuminoid ammonia may be insignificant, for we can never tell when the earth may cease to act as a filter by oxidizing the filth. Unsafe waters.

In forming an opinion as to the condition of a water, we should, in weighing the evidence afforded, adhere strictly to the standard of pure drinking water of the district from which the sample is collected. We should be extra-exacting as to purity in judging of a river water that has been polluted at some points of its course with the manure of fields and indescribable filth, for these river waters contain every now and then undigested portions of food excreted from the human intestinal canal, in addition to living organisms visible by the aid of the microscope, as well as the accompaniments of all life in water—namely, dissolved and suspended organic matter on which these same organisms feed. Septic poisons, or the poisons of the zymotic diseases, attach themselves to organic filth undergoing putrefactive decomposition, in which they find an appropriate nidus for development. It is questionable whether such rivers should ever be employed as public supplies, for, if the sewage of towns and villages on their banks be diverted and utilized on the land, the washings of manured fields cannot during periods of flood be altogether excluded. If such rivers are used for drinking purposes, an extra degree of purity should be demanded of the water companies that supply them.

## D. Preparation of Report.

Report of opinion.

The opinion of a water having been formed on a sound basis, its delivery is a very simple matter. In consequence of the severity of the criticisms that have been made as to the reliability of the several processes of water analysis, and as to the diagnosis with certainty between a small amount of vegetable and animal impurity in a water, certain analysts are very guarded in the choice of the language employed in the delivery of an opinion and express themselves thus:—"This *appears* to be a *pure* sample" and "*shows no evidence of contamination* from organic matter of animal origin"; "the polluting material is of a highly nitrogenous character," etc. The modes of statement of the results of water analysis are so various that they produce, even amongst medical men, endless confusion. "Chlorine calculated as chloride of sodium," "Loss on ignition after deducting combined carbonic acid," are samples of the most recent eccentricities. Why all chlorides in drinking water should be entered as common salt, and why combined carbonic acid should be alone excluded from the loss on incineration, are peculiarities for which it is quite impossible to find any valid reason. Some analysts express themselves in parts per 100, a few in 10,000, others in 70,000 or in 100,000, or in parts per million, whilst others make an estimate in grains per gallon or milligrammes per litre. Oxidized compounds of nitrogen are entered by some as nitric acid, by others as nitrates, and by the majority as nitrogen in the forms of nitrates and nitrites.[1] In order to prevent such differences in the modes

[1] *Vide* "Rules for Interchange of Different Expressions of Results of Analysis," in Appendix.

of expression of the results of an analysis which occasion so much annoyance amongst the public, one uniform plan of drawing up reports should be universally adopted. A form, of the accompanying description, is convenient for conveying a report to the sanitary authority or other applicant :—

____________________*Sanitary Authority.*

_______________188

ANALYTICAL REPORT.

| Date. | NAME AND DESCRIPTION OF THE SAMPLE OF WATER. | Grains per Gallon. | | | | Parts per Million.[1] | | Hardness. | Deposit under Microscope. |
|---|---|---|---|---|---|---|---|---|---|
| | | Solids. | Chlorine. | Nitrogen from Nitrates and Nitrites. | Oxygen absorbed in 4 hours at 80° F. | Free Ammonia. | Ammonia from Organic Matter. | Degrees. | |
| | *Mem.* | | | | | | | | |
| EXAMPLES. | LONDON WATER SUPPLY | | | | | | | | |
| | (Thames) . . . . . | 18·5 | 1·2 | ·15 | ·06 | 0·01 | 0·06 | 14 | |
| | (New River) . . . . . | 17·7 | 1·1 | ·17 | ·04 | 0·00 | 0·06 | 15 | |
| | (Kent Company) . . . . | 26·5 | 2·1 | ·30 | ·01 | 0·01 | 0·02 | 21 | |
| | Very bad Water. Thames Water at London Bridge . . . | .... | .. | 4·00 | .. | 1·02 | 0·59 | .. | |
| | Pure Spring Water which supplies village of Woodham Walter . . . . . . | 21 | 2·4 | ·20 | .. | 0·00 | 0·01 | 6 | |
| | Good Water from Shallow Well depth 25 feet . . . . . | 30 | 7 | ·07 | .. | 0·01 | 0·05 | 13 | |
| | Good Waters from Artesian | 106·4 | 37·7 | ·03 | | 0·01 | 0·02 | 9½ | |
| | Wells, of different depths, | | | | ·04 | | | | |
| | which supply a Village . . | 98·0 | 37·6 | ·00 | | 0·63 | 0·01 | 4½ | |

MEMORANDA AS TO WATER ANALYSIS.

1. Any one who wishes to have his or her drinking Water analyzed *at the Public Expense,* should apply to.............................Clerk of the...................... Sanitary Authority, for an order from this Authority, giving the reasons for his or her request. If the Authority considers that some grounds exist for thinking that the Water has produced disease, or is likely to be injurious to health, the Authority will issue instructions through its Clerk to the Medical Officer of Health, who will on receipt of the sample from the Inspector of Nuisances, analyze the water as soon as possible, and communicate the result to the applicant.
2. Any Member of either of the Combined Sanitary Authorities, and any qualified medical man practising in the Combined Districts who wishes to have *his own* drinking Water analyzed, should *communicate direct* with the Medical Officer of Health.
3. Any qualified medical man practising in the Combined Districts, who considers it expedient that the Drinking Water of a Patient on whom he is in attendance should be Analyzed *at the Public Expense,* should communicate *direct* with the Medical Officer of Health.

[1] As it is not easy to carry in the memory quantities smaller than are represented by the second point of decimals, it is undesirable to express

the amount of ammonia and albuminoid ammonia in fractions of a grain per gallon, which have not easy or ready significance, as has been adopted by the Society of Analysts whose form of certificate is here subjoined. This form is in other respects good, but is more adapted to the detailed requirements of the professional analyst than to the needs of the health officer.

SOCIETY OF PUBLIC ANALYSTS

REPORT OF ANALYSIS OF________________WATER, DRAWN ON______________188

All results are expressed in *Grains per Gallon.*

| Description of Sample. | Appearance in Two-foot Tube. | Smell when heated to 100° F. | Chlorine. | Phosphoric Acid. | Nitrogen as Nitrates. | Ammonia. | Albuminoid Ammonia. | Oxygen, Absorbed in | | Hardness, Clark's Scale, in degrees. | | Total Solid Matter, dried at 220° F. | Microscopical Examination of Deposit. | Remarks. | Valuation. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 15 minutes at 80° F. | 4 hours at 80° F. | Before Boiling. | After Boiling. | | | | |
| | | | | | | | | | | | | | | | |

*Analyst's Signature*________________

*Date of Report*________________

It may be remarked throughout this work that, at times grains per gallon are referred to, sometimes septems and deci-gallons, whilst at others the metrical system is employed. The object in view is to render the Medical Officer of Health perfectly *au fait* in the interchange of one into the other, as it is necessary for him to be conversant with all the methods of calculation in use.

## CHAPTER XVI

### CONCLUDING REMARKS ON SECTION I

Concluding remarks.

READERS of the foregoing pages will have perceived that I do not recommend the complicated and tedious process of Frankland and Armstrong, and that I cannot advise the sole unaided adoption of the beautiful process of Wanklyn, Chapman, and Smith, nor exclusive reliance on the quantitative Forchammer permanganate of potash process, which is often misleading. Whilst agreeing with the inventors of the first process as to the necessity of regarding the amount of nitrogen as nitrates and nitrites in a water, I totally disagree with Mr. Wanklyn in relying solely on the indications of the Nessler test, to the exclusion of an estimation of these products of oxidation and other valuable data on which an opinion should be based. Fallacies, undoubtedly, attend Dr. Frankland's lengthy method, and Mr. Wanklyn's rapid method; and errors are associated with the quantitative permanganate of potash processes, whatever those who are disciples of these several methods may think to the contrary. I am myself indebted to each process, more especially to Mr. Wanklyn's, in my studies of water analysis. The methods which I practise and recommend, and which I have in the foregoing pages attempted briefly to describe, are, it will be perceived, modified forms of the Wanklyn, Chapman, and Smith process and of the quantitative Forchammer or oxygen process. I am not conscious of ever having made a mistake in water analysis. This success is not attributable to any exceptional skill, but to the excellence of the process, which I designate the "Medical Officer of Health Method," because it is particularly suited to his wants.

## Recipes of Standard Solutions, etc.

### *Nessler Reagent.*

Standard Solutions.

Dissolve, by heating and stirring, 35 grammes of iodide of potassium and 13 grammes of corrosive sublimate in about 800 c. c. of distilled water. Add gradually a cold aqueous saturated solution of corrosive sublimate, until the red colour produced just begins to be permanent. Add 160 grammes of solid caustic potash to the mixture, which is then to be diluted with sufficient water to bring the whole to a litre. To render the test sensitive add a little more cold saturated solution of corrosive sublimate and allow it to settle.

This reagent is a rather troublesome one for the Medical Officer of Health to make, and that prepared by different persons varies somewhat. It is desirable that every one should obtain his Nessler test from one and the same source, but this arrangement seems very difficult of attainment. Very good is to be procured direct from Messrs. Sutton of Norwich, or indirectly through Messrs. Townson and Mercer of Bishopsgate Street, London.

### *Standard Soap Solution.*

10 grammes of Castile soap are dissolved in a litre of weak alcohol (35 per cent). If 35 per cent alcohol is not readily procurable, it may easily be prepared by mixing 29 ounces and 15 minims of distilled water with 17 ounces and 30 minims of rectified spirit (generally 84 per cent), which is everywhere obtainable.

One c. c. precipitates one milligramme of carbonate of lime.

This standard solution will not remain unchanged for an indefinite time. It loses strength. It is wise to make a small quantity of fresh solution every three or four months. One and the same water was recently examined by me for hardness with different standard soap solutions of various ages, and the following results were obtained :—

(*a*) 19½ degrees.
(*b*) 17 „
(*c*) 16 „
(*d*) 18 „
(*e*) 17 „

It is useful sometimes to verify the strength of a soap standard solution by the help of a solution of pure fused chloride of calcium, 1·11 gramme in a litre of water. One c. c. of the standard soap solution should precipitate 1 milligramme of carbonate of lime, which is the exact amount present in 1 c. c. of the chloride of calcium verifying solution.

*Dilute Standard Solution of Ammonia.*

Keep two solutions—a strong and a dilute. To prepare the strong solution dissolve 3·15 grammes of crystallized sal. ammoniac in 1 litre of distilled water. To prepare the dilute solution place 5 c. c. of the strong solution in a half-litre flask, and fill it up with distilled water.

Mingle very thoroughly by pouring the mixture several times from the flask into the bottle, and from the bottle back again into the flask. The dilute solution contains $\frac{1}{100}$ milligramme in each cub. cent.

These solutions should be perfectly limpid. They will not remain unaltered for an indefinite time. If any white filaments are visible in them, fresh solutions should be prepared.

*Permanganate of Potash and Caustic Potash Solution.*

Permanganate of potash crystallized, 8 grammes; solid caustic potash in sticks, 200 grammes; distilled water, 1 litre. Boil the above, so as to thoroughly dissolve the chemicals in the water, and until about $\frac{1}{4}$ of the solution has passed off as steam to dissipate all ammonia. Replace the water lost in boiling, as steam, by adding sufficient distilled water to bring it back to the litre.

This solution, notwithstanding the greatest precautions in its manufacture, invariably contains more or less ammonia. 50 c. c. of it should accordingly be distilled in $\frac{1}{2}$ litre of twice distilled water, and the ammonia that is estimated must be abstracted from the results of each analysis of a water. It is desirable to write the correction on the label of the bottle.

*Standard Solution of Nitrate of Silver.*

Dissolve 4·79 grammes of crystallized nitrate of silver in 1 litre of distilled water. One c. c. precipitates 1 milligramme of chlorine.

SECTION II

# SANITARY EXAMINATION

OF

# AIR.

## CHAPTER XVII

### THE PURITY OF AIR

THE examination of air for sanitary purposes by the Medical Officer of Health may be deemed by some as work that is needless, and which can be turned to no practical advantage. If preventive medicine and sanitation is ever to become an exact science, we must, as those who are laying its foundations, be able to state in precise language the boundary lines between wholesome air, air to which it is undesirable to be frequently exposed, and air which is so impure as to be quite unfit for breathing; and, again, between the latter and that which is poisonous. It is as desirable to know the composition of the air we breathe as of the water we drink. Indeed, it is more important to attend to the cleanliness of a medium in which we are always bathed, and which is continually passing into and out of our bodies, than of that which is only occasionally, and by some rarely, introduced into an organ which contains a fluid possessing a certain antiseptic and destructive power over substances injurious to health. The insidious and indistinctly recognizable deleterious effects on the health of a continued exposure of the human frame is often more marked in the case of impure air than of impure water. The train of evils is so slowly but surely laid as to even escape the observation often of an experienced medical man, who sees in a case of blood deterioration by impure air one of imperfect or defective assimilation, anæmia, dyspepsia, hysteria, disordered biliary functions, or one of those indefinite and chronic ailments which lead the way to the development of some visceral disease. What a contrast is afforded by placing a representative of the rebreathed and otherwise vitiated air trades, who perhaps rarely sees the sun, by the side of one whose daily occupations are such as to give him the fullest benefit of the purest air and the freest exposure to solar light! Bookbinders, or factory girls, or miners, from one of our towns and colliery districts, neither of whom are exposed to any distinctly poisonous influences, may, for example, be compared with sailors. The former are pallid, jaded, sallow, afraid of fresh air, with uncertain and capricious appetites, the normal functions of the body liable to continual disturbance, excitable, generally affected with a craving for stimulants—alcohol in the male, tea in the female—to temporarily alleviate their sensations of depression, whose lives are brief, their average duration being known by all insurance companies with mathematical precision; whilst the latter—namely the jack tars—present a *tout ensemble* indicative of the highest degree of health and buoyancy of spirits, which is so well known as not to need description. The sailor likes his occasional drinking bout when he goes on shore to enjoy freedom, after the confinement and tedium of a voyage, but is no "soaker." The moral condition of a class is intimately associated with its physical state, but a consideration of this connection would lead us too far away from the scope of these pages.

Density of population and mortality.

The late Registrar-General, Dr. Farr, drew the attention of the public some years ago to the recognized statistical law that the mean duration of life decreased as the proximity of one individual to another increased.

| Proximity. | | Mean Duration of Life. |
|---|---|---|
| 147 yards | | 51 years. |
| 139 ,, | | 45 ,, |
| 97 ,, | | 40 ,, |
| 46 ,, | | 35 ,, |
| 28 ,, | | 32 ,, |
| 17 ,, | | 29 ,, |
| 7 ,, | (Liverpool) | 26 ,, |

He stated that in 23 towns of this country there are 38 persons to an acre, and he suggested that the municipal bodies and local boards of our cities and towns should establish a bye-law, prohibiting the future building of houses which would render the density of population in excess of this limit.

Medical Officers of Health should be in a position to state accurately, when required, if any given air is or is not deleterious to the health of the body continually or frequently exposed to its influence. Provided that they could positively lay down the limit beyond which the organic matter and carbonic acid of our rooms, in which the majority of us spend the greater portion of our lives, should not pass, then architects and inventors would soon find out some simple, efficient, and economical mode of ventilating our houses and public buildings, which are nearly all afflicted with filthy air; and our mortality from diseases which we know now to be indirectly preventible, or capable of considerable reduction, such as consumption, bronchitis, and other pulmonary affections, would be materially lessened.

Pure air contains the following bodies:—

## Composition of Air.

Composition of pure Air.

| | | |
|---|---|---|
| *Oxygen* (Ozone, an active form of Oxygen, which varies in amount). . | 209·6 | in 1000. |
| *Nitrogen* . . . . . . . | 790· | |
| *Carbonic Acid* . . . . . . | ·4 | |

*Moisture* varying with temperature.

*Peroxide of Hydrogen*, *Nitrous and Nitric Acids* — occasional components.

*Organic Matter*, *Ammonia* — very minute traces.

The purest air is to be found on mountains, moors, or far away from contaminating and polluting agencies, such as aggregations of men and animals, manufactories, etc. There is an ample provision in nature for destroying the impurities of the air produced by man, especially the organic substances, some kinds of which become, when they decompose, injurious and often dangerous to him. Ozone, peroxide of hydrogen, and nitrous acid, are the three great purifying agents contained in the air, the first named being nearly always present in greater or less quantity, the two latter being the special productions of what the Germans call the "nieder-schlage," or the great cleansing operations of nature, such as the precipitation of the air-washer rain, storms, hail, dew, falls of snow, etc.

Oxygen.

*Oxygen.*—The following results of analyses made by M. Reynault and Dr. A. Smith show the deviation from a state of purity of air, as respects its life-supporting constituent, oxygen gas, in different situations and under different circumstances:—

## Oxygen in Air—Summary of Averages.

By Mons. Reynault.

| Specimens. | | | Volume per cent. |
|---|---|---|---|
| 100 | from Paris | from | 20·913 to 20·999 |
| 9 | „ Lyons and around | „ | 20·918 to 20·966 |
| 30 | „ Berlin | „ | 20·908 to 20·998 |
| 10 | „ Madrid | „ | 20·916 to 20·982 |
| 23 | „ Geneva and Switzerland | „ | 20·909 to 20·993 |
| 15 | „ Toulon and Mediterranean | „ | 20·912 to 20·982 |
| 5 | „ Atlantic Ocean | „ | 20·918 to 20·965 |
| 1 | „ Ecuador | „ | 20·960 |
| 2 | „ Pichincha, higher than Mont Blanc | „ | 20·949 to 20·981 |
| | Mean of all foregoing | „ | 20·949 to 20·988 |
| | „ the Paris specimens | „ | 20·96 |

By Dr. Angus Smith.

| | Volume per cent. |
|---|---|
| N.E., seashore and open heath (Scotland) | 20·999 |
| Atlantic, lat. 43° 5′, long. W. 17° 12′ | 20·99 |
| Top of hills (Scotland) | 20·98 |
| In a suburb of Manchester in wet weather | 20·98 |
| Do. do. do. | 20·96 |
| In the outer circle of Manchester, not raining | 20·947 |
| Low parts of Perth | 20·935 |
| Swampy places, favourable weather | 20·922 to 20·95 |
| In fog and frost in Manchester | 20·91 |
| In a sitting-room which felt close, but not excessively so | 20·89 |
| Best ventilated wards in three London hospitals— | |
| Day | 20·92 |
| Midnight | 20·886 |
| Morning | 20·884 |
| In a small room with petroleum lamp | 20·84 |
| Ditto, after six hours | 20·83 |
| Pit of theatre, 11.30 P.M. | 20·74 |
| Gallery, 10.30 P.M. | 20·86 |
| About backs of houses and closets | 20·70 |
| In large cavities in metalliferous mines (average of many) | 20·77 |
| In a schoolroom | 20·64 |
| Court of Queen's Bench, February 2, 1866 | 20·65 |

| | Volume per cent. |
|---|---|
| Court of Queen's Bench, at Lantern | 20·49 |
| Under shafts in metalliferous mines (average of many) | 20·424 |
| In sumps or depressions in do. | 20·14 |
| When candles go out | 18·5 |
| The worst specimen yet examined in a mine | 18·27 |
| Very difficult to remain in for many minutes | 17·2 |

By Various Scientific Chemists.

| | |
|---|---|
| Heidelberg (mean of 28 analyses) Bunsen | 20·92 |
| Paris. Dumas and Boussingault [1] | 20·86 |
| Faulhorn. Do. | 20·77 |
| Brussels. M. Stas | 20·85 |
| Geneva. M. Marignac | 20·78 |
| Bern. M. Brunner | 20·75 |
| Gröningen. Verver | 20·79 |
| Copenhagen | 20·81 |

Herr Von Jolly concludes from his experiments in the neighbourhood of Munich, that the variations in the amount of oxygen contained in pure air are influenced by the direction of the wind. He found the highest proportion of oxygen with a steady polar current and the lowest with currents from the equatorial regions where processes of oxidation preponderate. The remarks that accompany Dr. A. Smith's analyses, dealing as they do with a point that I have long wished to press on the attention of the sanitary public, are worthy of weighty consideration. Some people will probably inquire why we should give so much attention to such minute quantities—between 20·980 and 20·999—thinking these small differences can in no way influence us. A little more or less oxygen might not affect us; but supposing its place occupied by hurtful matter, we must not look on the amount as too small. Subtracting 0·980 from 0·999, we have a difference of 190 in a million. In a gallon of water there are 70,000 grains; let us put into it an impurity at the rate

[1] *Annales de Chimie* 1841.

of 190 in 1,000,000; it amounts to 13·3 grains in a gallon, or 0·19 gramme in a litre. This amount would be considered enormous if it consisted of putrefying matter, or any organic matter usually found in waters. But we drink only a comparatively small quantity of water, and the whole 13 grains would not be swallowed in a day, whereas we take into our lungs from 1000 to 2000 gallons of air daily. If, by inhalation, we took up at the rate of 13 grains of unwholesome matter per day—half a grain per hour—we need not be surprised if it hurt us. Such an amount is an enormous dose of some poisons, and yet this is not above one two-thousandth part of a grain at every inhalation. It is marvellous what small amounts may affect us, even when, by repeated action, they do not cumulate as certain poisons do. We commenced by assuming very small shades of difference—namely, 190 in a million; but if we examine the table we shall find much greater quantities. Take, for example, the pit of a theatre; we have, by subtracting 20·74 from 20·999, a difference of 2590 in a million, or 14 times more. And so on we may descend to the lowest in the series, where we have 17·2, which, taken from 20·999, leaves 3·799, or 37,990 in a million, or 200 times more than the first example.

*Carbonic Acid.*—The amount of carbonic acid in the air varies according to Boussingault, Farsky, Henneberg, Pettenkofer, and Cleasson, in different parts of the world from ·279 to ·060 per cent. It has been experimentally shown that its quantity in the air: (1) is greater in the night than by day on land, due doubtless to the large amount evolved by vegetation during the hours of darkness; (2) is slightly increased towards noon and after rain; (3) is greater in the air collected above the ocean by day (·05 per cent) than by night (·03 per cent). M. Méne[1] Carbonic Acid.

[1] *Comptes Rendus*, lvii. 155.

has found that the proportion of carbonic acid in the air varies at different seasons, being constant in December and January, increasing in February, March, April, and May, and decreasing from June to August, increasing again from September to November, and attaining its maximum for the whole year in October. Saussure discovered that the carbonic acid of mountain air is in larger amount than in that of plains. The remarkable uniformity and constancy in the amount of carbonic acid contained in the air of our parks and fields in the neighbourhood of cities, notwithstanding the universal pollution of the air rhat is unceasingly proceeding, shows the existence of tecuperative forces in nature of the greatest magnitude.

The observations made by M. Marié-Davy at the Montsouris Observatory, which is situated at the junction of Paris with the country, seem to furnish, as a rule, much lower results than were obtained by Mr. Dixon in, and in the vicinity of, Glasgow. Whilst the percentage ranges between ·02 and ·03 at the former station,[1] it somewhat

[1] In order to render the differences in the amount of carbonic acid in the air more apparent, he registers it as litres in 100 cubic metres of air, which can be easily changed into percentages by placing the figure 0 before the first figure and removing the decimal point to a position in front of that 0, *e.g.*

Monthly mean 29·7 = ·0297 per cent.

*Park of Montsouris.*

Average of nine years observations involving more than 3000 analyses.

*Annual.*

| | | | |
|---|---|---|---|
| 1877 | 28·4 | 1882 | 28·6 |
| 1878 | 34·5 | 1883 | 29·0 |
| 1879 | 32·9 | 1884 | 29·6 |
| 1880 | 27·0 | 1885 | 29·3 |
| 1881 | 27·7 | | |

Annual mean, 29·6.

*Monthly.*

| | | | |
|---|---|---|---|
| January | 30·4 | July | 29·9 |
| February | 29·7 | August | 29·5 |
| March | 29·6 | September | 29·7 |
| April | 29·8 | October | 29·0 |
| May | 29·9 | November | 28·7 |
| Juna | 30·3 | December | 29·4 |

Monthly mean, 29·7.

exceeds ·03 at the latter stations. Nor is this divergence wholly due to differences in the quality of the air around Paris and around Glasgow. There is a very strong probability, almost amounting to certainty, that it is partly owing to the greater speed at which the air is passed through the chemical reagent at Montsouris than at Glasgow. M. Marié-Davy transmitted air through his aspirator at the rate of about 10 cubic feet per hour, whilst Mr. Dixon sent 1 cubic foot of air through his absorbing solution in the same space of time. Chemical action consumes a certain definite time, and if we hurry air through a chemical solution, intended to withdraw from it any body which it contains, too rapidly, the air is not thoroughly deprived of the same.

Recent experimenters have found a larger amount of carbonic acid on the summits of high mountains than on their sides at a lower elevation. (*Vide* following Table.) The observations made by M. G. Tissandier in his late ascent in the balloon named the "Zenith," are confirmatory of their results, for he found at an altitude of from 800 to 890 metres that the amount of carbonic acid in the air was ·024 per cent, and at 1000 metres ·03 per cent.[1] Although many explanations of what must, I suppose, be admitted as a fact have been attempted, not one has as yet been offered which is altogether satisfactory.

As in the case of the amount of oxygen, so in that of the quantity of carbonic acid, in pure or moderately pure air, there is a remarkable absence of discrepancy in the analyses, made by different chemists by dissimilar processes, of air taken under similar conditions in various parts of the world.

[1] *Comptes Rendus*, April 12, 1875.

| | Per cent. |
|---|---|
| Mean of 18 analyses on Lake Geneva, by Saussure[1] . | ·0439 |
| Air of Madrid outside the walls. Mean of 12 analyses by Luna[2] . . . . . . . . . | ·045 |
| Air of Madrid inside the walls. Mean of 12 analyses by Luna . . . . . . . . . | ·051 |
| Air of Munich, by Pettenkofer[3] . . . . . . | ·050 |
| Air of summit of Mont Blanc, by Frankland[4] . . | ·060 |
| Air over Irish Sea, July and August (Dr. Thorpe)[5] . | ·030 |
| Air in Brazil (April and May) . . . . . . | ·032 |
| Hills above 3000 feet . . (A. Smith) . . | ·0336 |
| „ between 2000 and 3000 feet „ . . . . | ·0332 |
| „ „ 1000 and 2000 feet „ . . . . | ·0334 |
| „ below 1000 feet . . „ . . . . | ·0337 |
| At the bottom of the same hills . . . . . . | ·0341 |
| On hills in Scotland from 1000 to 4406 feet . . | ·0332 |
| In the streets of London (summer) . . . . . | ·0380 |
| In the London parks and open places . . . . . | ·0301 |
| On the Thames at London . . . . . . . | ·0343 |
| In the streets of Glasgow (E. M. Dixon). Mean of results for May and June 1877 . . . . . | ·0304 |
| Air of S.W. suburbs of Leicester (Weaver) . . . . | ·0460 |

[1] *Ann. de Chem. et de Phys.*, vol. xliv. 1830.

[2] *Estudios quimicos sobre et aire atmosférico de Madrid*, 1860.

[3] *Handwörterbuch der Chemie*—Ventilation.

[4] "On the Air of Mont Blanc;" *Journal of Chemical Society*, 1861.

[5] *Journal of Chemical Society*, 1867.

# PART I

## DIFFERENT KINDS OF IMPURITIES

Different modes whereby air is deteriorated in quality and defiled.

THE air is deteriorated in quality and defiled by—

1. Respiration[1] and Transpiration.
2. Combustion.
3. Putrefactive processes, sewage emanations, and excremental filth.
4. Gases, vapours, and suspended metallic, mineral, and vegetable matters given off by trades and manufactories.
5. Poisons of unknown nature evolved by damp and filthy soil.

[1] The changes that are found to have taken place in pure air that has been respired are roughly the following:—

(1) 100 parts of air contain only 13, instead of about 21, parts of oxygen, the missing 8 parts having been withdrawn by the blood corpuscles in the lungs.

(2) The ·03 or ·04 part per cent of carbonic acid is increased to between 4 and 5 per cent.

(3) An increase of watery vapour is noted, which is loaded with organic matter.

# CHAPTER XVIII

## ORGANIC MATTER

Organic matter.

ALL air contains some organic matter, which may be of different kinds. It has been divided into (*a*) the wholesome, (*b*) the neutral, (*c*) the putrid, and (*d*) the organized = dangerous form.

I apprehend that, in designating any particular kind of organic matter as wholesome, it is not intended to convey the idea that the presence in air of this variety is conducive to health, but rather that it does not influence health in one way or the other. It would be as well perhaps to combine the "wholesome" and "neutral" into one class, thus making only three varieties. It may be said at the outset that it is quite impossible by chemical means to distinguish one variety of organic matter from another.

Organic matter may be of an animal or of a vegetable nature, but the sum and substance of all the most recent observations on air is, that the bodies, the presence of which creates the difference between good or healthful air and bad or deleterious air, are mainly of a nitrogenous organic character.

Animal.

*Animal* organic matter is thrown off from the lungs in respiration, and from the skin by transpiration, in a state of invisible vapour and of epithelial dust. In 1870 Dr. Ransome read a paper[1] "On the Organic Matter of

[1] *Proc. of Manchester Philosph. Socy.*, February 22, 1870.

Human Breath in Health and Disease," in which he stated that the vapour of human breath in adults in a state of health, if condensed in a large glass flask, surrounded by ice and salt, and examined by the Wanklyn, Chapman, and Smith process, yielded about 3 grains of organic matter in 10 ounces of the condensed fluid, a quantity sufficient to make the fluid highly decomposable, and ready to foster the growth of those lowly organisms that we believe to be the intimate companions of the morbific ferments.

This animal organic matter decomposes and gives off various volatile nitrogenous compounds, which, although they may not themselves produce disease, undoubtedly lessen the power of the body to resist its attack. Moreover, putrefying animal matter is a favourite pasture for the development and dissemination of the animal poisons. It would seem to exert a distinctly poisonous action on one at least of the lower animals, if we are to accept the experience of Dr. Hammond, who placed a mouse under a bell glass, taking care to supply it with plenty of oxygen, and removing all carbonic acid and watery vapour, permitting the organic matter to remain. The mouse died in 45 minutes.

Excremental filth, in a condition of impalpable powder, is often present in the air, and is the most disgusting of all the impurities to which man is exposed. As many diseases propagate themselves by eliminating their poisons through the medium of the exhalations and excretions of the body, air thus polluted is often the bearer of the organic poisons by which maladies are disseminated.

Medical men and district visitors, who enter the dwellings of the poor in crowded courts and alleys, are perfectly familiar with the fœtid emanations that abound in such unwholesome styes. The peculiar sickening odour of organic matter is especially noticed in crowds of the great unwashed, and creates often, in those unaccustomed to such smells, a feeling of faintness, languor, and debility.

Vegetable. *Vegetable* organic matter, if excessive in the air, is associated with a poison productive of ague and other malarial affections.[1] Whether or not there exists any causative relation between the micro-organism named the bacillus malariæ and these diseases, is still a moot point.

The quantity of the nitrogenous material (ammonia and albuminoid ammonia) found in air varies, of course, and is a measure of its impurity, be it furnished by animal and vegetable decomposition, or by soot and imperfectly consumed organic impurities proceeding from manufactories. Dr. Angus Smith discovered ·066 milligramme of ammonia, and ·190 milligramme of albuminoid ammonia, in each cubic metre of air in a bedroom at 9 P.M., and ·095 milligramme of the former, and ·334 milligramme of the latter, per cubic metre, in the same room on the following morning at 7 A.M.[2] Mr. Moss[3] whilst finding as a mean of eight observations ·093 milligramme of ammonia and ·088, or roughly ·09 milligramme of albuminoid ammonia, in each cubic metre of the air of Portsmouth, estimated the proportions present at the same time in the Portsmouth Hospital, in the officers' quarters, etc. (*Vide* Table.)

Ammonia generally occurs in the air as a salt, such as the carbonate, chloride, nitrate or nitrite, derived from decomposing animal matters, such as manure, sewage, effete matters from the lungs and skins of men and other animals, from soot and manufacturing products.

Some express the amount of the ammonia, and the

[1] The answer of Dr. C. F. Oldham to the query which forms the title of his work, *What is Malaria?* namely that "Malaria is chill," and that ague and other malarial diseases are not produced by a specific poison, is not accepted by the medical profession.

[2] "Air and Rain."

[3] *Lancet*, November 2, 1872.

ammonia derived from albuminoid ammonia, which they detect in air, in terms of nitrogen, by multiplying by 14, and dividing the result by 17. The nitrogen from both kinds of ammonia being added together, is recorded as the total nitrogenous matter in the sample.

The old methods of estimating ammonia, in vogue before the discovery of the Nessler test, yielded most contradictory evidence. The invention of this re-agent, which can be worked with marvellous delicacy and precision, has inaugurated a new era in air and water analysis. The following observations have all been made by its assistance in different ways, which will be described, in connection with the names of the analysts, in the chapter on "The Chemical Examination of Air," page 310 :—

## Air-Washings.

### By Dr. Angus Smith, Mr. W. A. Moss, and Dr. C. B. Fox.

By Dr. A. Smith.

| Sample of Air. | Time and Weather. | Milligramme in One Cubic Metre of Air. | |
|---|---|---|---|
| | | Ammonia. | Albuminoid Ammonia. |
| *In Manchester.* | | | |
| Laboratory Office, 10 A.M. | . . . . . | ·106 | ·266 |
| ,, ,, 4 P.M. | . . . . . | ·133 | ·293 |
| Gas-room, 10 A.M. . | . . . . . | ·130 | ·213 |
| ,, ,, 4 P.M. . | . . . . . | ·190 | ·427 |
| Yard behind laboratory | Fine, Oct. 28, 1869 . | ·095 | ·095 |
| ,, ,, ,, | Freezing, snow on the ground, Dec. 28 . | ·106 | ·356 |
| ,, ,, ,, | Damp, Jan. 13, 1870 | ·059 | ·213 |
| ,, ,, ,, | Fine, Jan 25, 1870 . | ·190 | ·316 |
| ,, ,, ,, | Foggy, Jan. 26, 1870 | ·142 | ·221 |
| Street, open . . | Raining, and strong wind, Dec. . . | ·071 | ·261 |
| Average . . | . . . . . | ·122 | ·266 |
| Bedroom—Average of . | . . . . . | ·101 | ·238 |
| Midden—Average of . | . . . . . | ·336 | ·415 |
| *In London.* | | | |
| Average . . | . . . . . | ·061 | ·150 |
| Air of the Underground Railway (Metropolitan), 1869 | Nov. 11 and 12 (morning) . . . | ·109 | ·457 |
| Chelsea (three places) . | Nov. 4, windy . . | ·045 | ·110 |
| Brompton ,, ,, . | Nov. 4, windy, and a shower of rain . | ·047 | ·128 |
| *In Glasgow.* | | | |
| Average . . . . | . . . . . | ·078 | ·304 |
| Shore, Innellan, Firth of Clyde | March 3, N.N.E. wind . . . | ·052 | ·137 |

AIR-WASHINGS—*Continued.*

| Sample of Air. | Remarks. | Milligramme in One Cubic Metre of Air. Ammonia. | Albuminoid Ammonia. | |
|---|---|---|---|---|
| *In Portsmouth.* | | | | By Mr. W. A. Moss. |
| Mean of eight observations at different times in open air | Air obtained at elevation of 20 feet . | ·093 | ·088 | |
| Rooms (Officers' Quarters) | . . . . . | ·436 | ·462 | |
| No. 5 Ward of Hospital | . . . . . | ·428 | 1·307 | |
| ,, ,, | . . . . . | ·855 | 1·018 | |
| No. 7. ,, ,, [1] | . . . . . | ·520 | ·753 | |
| Variola Ward . . | Both were freely ventilated, and in both disinfectants were freely used . | ·309 | ·416 | |
| Rubeola Ward (children . . . | (as above) | ·226 | ·197 | |
| Respired air in health [2] | . . . . . | ·218 | ·545 | |
| ,, ,, . | . . . . . | ·122 | ·169 | |
| ,, ,, . | . . . . . | ·112 | ·099 | |
| ,, ,, . | . . . . . | ·144 | ·177 | |
| *In Essex.* | | | | By C. B. Fox, M.D. |
| Air on banks of Thames after passing over marshes | Wind flowing from river to shore . | ·03 | ·10 | |
| Air of sitting-room . | Occupied by one person for several hours. Good fire. Ventilation by draughts underneath door and windows, which open to ground . | ·066 | ·265 | |
| Air of bedroom, after being occupied by three persons for nine hours, at 7 A.M. | No ventilation of any kind . . . | ·264 | 1·367 | |
| Pure air of meadow . | . . . . . | ·066 | ·044 | |

[1] The amount of impurity found in the air of this ward gives, I should imagine, a fair example of the state of a fully occupied ward under ordinary conditions.—W. A. M.

[2] These analyses show a considerable variation in purity, even in the same individual. It appears probable that a far larger amount of organic matter passes into the air from the skin than from the lungs.

The observations at Glasgow.

The observations that were conducted some years ago on the air of several parts of the city of Glasgow by E. M. Dixon, B.Sc., and W. J. Dunnachie, show, as regards its organic impurities, two maxima—one towards the end of August, due to increased temperature which is the principal factor concerned in late summer in the greater activity of all putrefactive changes in nitrogenized material, and the other in winter. The winter maximum simply indicated the amount of tangible floating soot in the air, for no measures were taken for excluding from the absorbing solutions the particles of soot which in the air of such a smoky city as Glasgow are particularly abundant in the foggy days of winter when there is an extra consumption of coals. If a small particle of soot is shaken violently with some ammonia-free distilled water, and the mixture is analyzed by the Wanklyn, Chapman, and Smith process of water analysis, it will be found very difficult to extract all the ammonia. Particles of soot contain, in addition to a great deal of ammonia, imperfectly consumed organic matter derived from fires and manufactories, which, when decomposed by boiling with caustic soda and permanganate of potassium, yield ammonia freely.

Rain.

The proportion of organic matter in air is also estimated by making examinations of the amount contained in that great air-washer, rain. Rain dissipates the deleterious gases which accumulate and float over towns and cities. It brings down from the higher regions of the atmosphere a more salubrious air, and by the flushing of drains and cleansing of the surface of the country, aids in the prevention of the contamination of the air by the exhalations of animals, and by the decomposition of animal and vegetable matter which is incessantly proceeding. The following analyses, made by Dr. Angus Smith, evince very important differences :—

RAIN WATERS COLLECTED DURING 1869.

| | Albuminoid Ammonia. Part per Million = Milligr. per Litre. |
|---|---|
| Darmstadt, February | ·30 |
| Do. during a thunderstorm, May 26 | ·075 |
| Zwingenburg, near Heidelberg, July | ·15 |
| Heidelberg, June 15 | ·087 |
| Tyree, May[1] | ·30 |
| Kelly, Wemyss Bay, south-west wind, June 2 to 15 | ·075 |
| St. Helens, west wind, February 18 to March 11 | ·15 |
| Do. April 23 | ·20 |
| Manchester, during a thunderstorm. Rain had fallen heavily just before. Collected about 2 feet from the ground, September 10 | ·079 |
| Do. 2 feet from the ground, behind the Literary and Philosophical Society, September | ·25 |

The close agreement in chemical composition as regards the amount of organic matter of pure air, and of rain that falls through country air far away from animal and vegetable vitiating agencies, and of well water of average cleanliness, cannot but attract the attention of the analytical student of nature. About ·08 of one part per million appears to be the mean amount of albuminoid ammonia contained in air, in rain, and well water that has not received any extra impurities from organic life. The study of the compensatory forces of nature, as manifested in that universal tendency to a restoration to a state of equilibrium of everything that has to some extent departed from it, may well occupy the minds of those whose pursuits lead them to the contemplation of the laws by which this world is governed in special relation to the life and health of its inhabitants.

[1] A large kelp work exists on the island.

# CHAPTER XIX

## OXIDES OF CARBON

Carbonic Acid

A. *Carbonic Acid.*—The discomfort which we experience in badly ventilated rooms was formerly considered to be occasioned by the production of carbonic acid. We now know that it is caused mainly by organic matter, and that an excess of carbonic acid can be borne without ill effects, if the air be free from deleterious gases and an excess of organic impurity. Still the amount of carbonic acid is, as a rule, a measure of other accompanying impurities in the air, for it is almost always found in bad company.

A confidence in our powers of measuring very accurately the minutest quantities of carbonic acid is established by the harmony that has been already shown to exist on page 230, between the results obtained by analysts on air of varying degrees of purity, which is still further increased by our study of such an interesting series of observations of air, of various degrees of impurity, as are collected together in the following Table :—

## Carbonic Acid in Public and Private Buildings in Leicester, by R. Weaver, C.E., F.C.S.[1]

| Nature of Workroom or Building. | Carbonic acid per 100 of air. |
|---|---|
| 1. Boot and shoe finisher | ·528 |
| 2. Framework knitter | ·532 |
| 3. Ditto ditto | ·408 |
| 4. Boot and shoe finisher | ·460 |
| 5. Needlemaker | ·287 |
| 6. Tailor's workshop | ·306 |
| 7. Boot and shoe finisher | ·259 |
| 8. Tailor's workshop | ·217 |
| 9. Elastic web manufacturer | ·211 |
| 10. Fancy hosier | ·493 |
| 11. Boot and shoe riveter | ·172 |
| 12. Riveting-room of boot manufacturer | ·328 |
| 13. National school: Science class-room | ·241 |
| 14. Ditto Boys' day-room | ·116 |
| 15. Ditto Girls' day-room | ·164 |
| 16. Ditto Boys' day-room | ·309 |
| 17. Ditto Girls' day-room | ·204 |
| 18. Police Court: The Mayors' parlour | ·120 |
| 19. Ditto The Town Hall | ·098 |
| 20. Private house: sitting-room | ·304 |
| 21. Worsted spinner's preparing-room | ·106 |
| 22. Ditto doubling-room | ·174 |
| 23. Town Hall during Quarter Sessions | ·153 |
| 24. Prisoners' cell in police station | ·103 |
| 25. Police station: Sergeant's office | ·203 |
| 26. Prisoners' cell at Town Hall | ·081 |
| 27. Spring Assizes: Crown Court; body of hall | ·196 |
| 28. Ditto Ditto gallery | ·290 |
| 29. Ditto Nisi Prius Court; body of hall | ·134 |
| 30. Ditto Ditto gallery | ·169 |
| 31. Newspaper office; Compositors' room | ·111 |
| 32. Ditto Machine room | ·123 |
| 33. Ditto Compositors' room | ·149 |
| 34. Private house: One foot from floor of bedroom | ·102 |
| 35. Ditto One foot from ceiling of same room | ·150 |
| 36. Ditto One foot from floor of bedroom | ·116 |
| 37. Ditto One foot from ceiling of same room | ·164 |
| 38. National school: Infants' room | ·154 |
| 39. Ditto Girls' Room | ·139 |
| 40. Private school | ·120 |
| 41. Ditto | ·121 |
| 42. Elastic web manufactory: The lower or braid room | ·178 |
| 43. Ditto The upper or weaving room | ·328 |
| 44. Public library: Reading-room | ·206 |

[1] *Lancet*, July 6, August 3 and 17, 1872.

Mr. Weaver points out that the condition of the air in the sitting-room of a private house, No. 20, illustrates that of a great number of unventilated dwellings occupied by mechanics and clerks, where gas is burning.[1]

The higher percentage of carbonic acid in the galleries, as shown by the observations Nos. 27 to 30, testifies to the fact of its ascension with the aerial currents, and that there is no tendency towards accumulation in the lower strata of air from greater specific gravity, as has been sometimes stated.

## Carbonic Acid in London, Manchester, New York, Cornwall, Portsmouth, and elsewhere.

By Drs. Smith and Bernays, F. de Chaumont, and others.

| | Percentage by volume. |
|---|---|
| Chancery Court, closed doors, 7 feet from ground, March 3 | ·193 |
| Same, 3 feet from ground | ·203 |
| Strand Theatre, gallery, 10 P.M. | ·101 |
| Surrey Theatre, boxes, March 7, 1.03 P.M | ·111 |
| " " " March 7, 12 P.M. | ·218 |
| Olympic, 11.30 P.M. | ·0817 |
| " 11.55 P.M. | ·1014 |
| Victoria Theatre, boxes, March 24, 10 P.M. | ·126 |
| Haymarket Theatre, dress circle, March 18, 11.30 P.M. | ·0757 |
| Queen's Ward, St. Thomas' Hospital, 3.25 P.M. | ·040 |
| Edwards' " " " 3.30 P.M. | ·052 |

[1] All gas shareholders should welcome the advent of the electric light for domestic purposes when they consider the deteriorating effect on the air we breathe of our present illuminating agents.

| | Carbonic acid. |
|---|---|
| Argand gas burner | ·46 |
| Petroleum lamp | ·95 |
| Colza | 1·00 |
| Paraffin candle | 1·22 |
| Tallow | 1·45 |
| Electric light | 0 |

| | Percentage by volume. |
|---|---|
| Pavilion, 10.11 P.M., April 9 | ·152 |
| City of London Theatre, pit, 11.15 P.M., April 16 | ·252 |
| Standard Theatre, pit, 11 P.M., April 16 | ·320 |
| Stable for horses: École Militaire | ·700 |
| Crowded girls' schoolroom, seventy girls (Pettenkofer) | ·723 |
| Mean amount in a dwelling-house, during the day | ·068 |
| In a bedroom at night with closed windows | ·230 |
| ,, ,, ,, partly open | ·082 |
| Sleeping cabin of Dublin Canal boat (Cameron) | ·95 |
| Unventilated barracks in London (Roscoe) | ·124 |
| Tombs Prison (male department), New York (H. Endemann) | ·147 |
| Fulton Market, New York (H. Endemann) | ·084 |
| Manchester streets, ordinary weather | ·0403 |
| Where fields begin | ·0369 |
| About middens | ·0774 |
| In workshops | ·3000 |
| In theatres, worst part, as much as | ·3200 |
| In mines, largest amount found in Cornwall | 2·5000 |
| In mines, average of 339 specimens | ·7850 |

Dr. F. de Chaumont's estimations of the amount of carbonic acid in the air of barracks, hospitals, and prisons are interesting:—

*Barracks.*

| | Per cent. |
|---|---|
| Gosport New Barracks | ·06 |
| Anglesea Barracks | ·14 |
| Aldershot | ·049 |
| Chelsea | ·07 |
| Tower of London | ·13 |
| Fort Elson (Casemate) | ·12 |
| Fort Brockhurst (Casemate) | ·08 |

*Military and Civil Hospitals.*

| | |
|---|---|
| Portsmouth Garrison Hospital | ·097 |
| ,, Civil Infirmary | ·092 |
| Herbert Hospital | ·047 |
| Hilsea ,, | ·057 |

*Military and Civil Prisons.*

| | Per cent. |
|---|---|
| Aldershot Military Prison—Cells | ·165 |
| Gosport " " " | ·13 |
| Chatham Convict " " | ·169 |
| Pentonville Prison—Cells (Jebb's system) | ·09 |

Dr. Endemann obtained seventeen samples of air from the public schools of America, and found carbonic acid varying in amounts from ·09 to ·35 parts in 100; or, in other words, from more than twice to nearly nine times the normal quantity. He gives the following tabular results, obtained from some of the public schools in New York:—

| *Schools.* | Per cent. |
|---|---|
| Elm Street | ·146 |
| Roosevelt Street | ·195 |
| Thirteenth Street, near Sixth Avenue | ·281 |
| Thirteenth Street, near Seventh Avenue | ·213 |
| Greenwich Street | ·176 |
| Vandewater Street | ·147 |
| Madison Street, near Jackson | ·242 |

Dr. Breiting made a series of fourteen experiments on the quantity of carbonic acid contained in the air of some schoolrooms, commencing at 7.45 A.M., and continued to 4 P.M. in a room of 251·61 cubic metres capacity, and containing 64 children. The amount of carbonic acid was said to vary from 2·21 to 9·36 per cent (!).

Herr E. Schulz found in a clubroom ·37 per cent, and in a schoolroom an amount of carbonic acid varying from ·14 to ·35 per cent.

Dr. Snow has concluded from his experiments on animals "that 5 or 6 per cent by volume of carbonic acid cannot exist in the air without danger of life, and that less than half this amount will soon be fatal, when it is formed at the expense of the oxygen of the air."

My own determinations of the amount of carbonic acid in air of different degrees of purity teach no more than do the foregoing analyses, so that I will not trouble the reader at present with any more tabular matter.

The purest air—namely, that resting on the sea, and on the sides of the highest mountains—is thus seen to possess rather more than ·03 per cent of carbonic acid, which is often increased in the streets of cities to ·04, an amount which may be doubled in foggy weather. Much discussion has taken place at various times as to whether carbonic acid is a positive poison or simply an asphyxiating gas. It has now been pretty clearly established that this gas is a distinct poison when diluted with air, but that, in a pure or unmixed state, as it is sometimes found in a beer vat or old well, it extinguishes life in a mechanical manner, by immediately suffocating any one who may be immersed in it.

The presence or absence of injurious bodies in air (such as hydrogen sulphide, methyl hydride, hydrogen, organic matter, sulphurous acid, ammonia, ammonium sulphides), and the amount of oxygen it contains, must not be lost sight of in judging of the effects of carbonic acid on the human frame. It has been a subject of wonder that people have been but slightly inconvenienced by an exposure to the air of places where brewing is going on, or soda water is being manufactured, where, indeed, the air contains perhaps about ·20 per cent of carbonic acid. In such cases the gas diluted with air is unmingled with unwholesome accessories as organic matter, sulphur compounds, etc. Such air in a closed chamber will give to any one who exposes himself to it a severe headache. We all, indeed, avoid an atmosphere containing ·10 per cent of carbonic acid in crowded rooms. Animals can be kept alive for a long period in an atmosphere highly charged with it if oxygen be added.

The body, when exposed to air containing a large excess of carbonic acid (·30 per cent), suffers a reduction in the heart's action and an acceleration of respiration. These effects have been found to be produced when the influence of the organic matter and other foreign bodies is eliminated.

Continual pollution of the air.

Estimates of the enormous quantities of this gas that are daily and hourly poured forth by our cities would be alarming indeed were we not consoled by the knowledge of the rapid distribution of gases by diffusion,[1] which tends to maintain a state of equilibrium in the constitution of the air. Dr. Smith assures us that 15,066 tons of carbonic acid are daily passed by the city of Manchester into the air that envelopes it,[2] and Dr. F. de Chaumont

[1] The influence of condensed aqueous vapour in the air which interferes with this diffusion is well shown by the hourly experiments of Otto Hehner during a London fog. Percentage of Carbonic Acid by Volume.

·10
·08
·09
·04 obtained during the momentary lifting of the fog.
·07

It has been declared by Dr. Frankland and others that if London is to be freed from suffocating fogs, the importation of bituminous coal into the metropolis must be forbidden, and smokeless coal and coke be substituted. If that sweeping measure should ever be carried out, it would be necessary to make it compulsory that every room should have a chimney, as the consumption of smokeless fuel in the shape of coke, etc., in rooms without flues has produced so many fatal accidents. Smoke, however, is not the only cause of fog, for Prof. Dewar has shown that aqueous vapour has a tendency to condense into mist in the presence of a mere trace of sulphurous acid, which is an unavoidable product of the combustion of all kinds of coal and coke.

[2] M'Dougal (*Chemical News*, ix. 30), under Roscoe's direction, determined on two different days the amount of carbonic acid in the air of Manchester. As a mean of 46 analyses, the air from the centre of Manchester was found to contain ·039 per cent of carbonic acid (max. ·056, min. ·028), whilst the air four miles from the city exhibited as a mean of eight determinations ·04 per cent. Hence Roscoe concludes that in open places the influence of combustion and respiration processes is completely neutralized by the movements of the air.

states that 822,000,000 cubic feet of this gas are generated in London per day, or more than 9500 cubic feet every second. In consequence of the possession of most wonderful self-purifying properties, which are partly due to its powers of oxidation and partly to the physical changes that are unceasingly occurring in its condition, through the agency of currents, storms, rains, changes of temperature, etc., the vast aerial sea maintains a uniformity of composition so marvellous as to strike with awe the student of the mighty forces of nature.

B. *Carbonic Oxide*, which is a most poisonous gas, is a product of combustion, and is to be found in the air of towns, where it is so diluted as to do but slight injury. Carbonic Oxide.

Public buildings, churches, colleges, schools, barracks, etc., are very often heated by means of coke-burning iron stoves, some of which are provided with troughs and pans of water to counteract the aridity of the air which they are supposed to induce.

In the United States anthracite (called in Ireland "Kilkenny coal" and in Scotland "blind coal"), which bears a great resemblance to coke, and is equally objectionable as ordinarily consumed, is most extensively used. Dr Derby asserts[1] that "ninety-nine dwelling houses out of a hundred in Boston are, in whole or in part, warmed by this fuel, burned in iron stoves, or in the iron fire-pot of a furnace, which is but a stove in another form."

Many people of nervous and sanguine temperaments, especially the plethoric, most of those indeed who are sensitive to changes in atmospheric states and conditions, are affected injuriously if they remain for some time in a room or office warmed by an iron stove in which coke is consumed. They experience a languor and oppression; in fact, a sense of *malaise*, and sometimes a difficulty of breathing, slight dizziness, confusion of ideas, headache

[1] *Anthracite and Health.*

accompanied by a feeling as if a tight band encircled the forehead and temples, in one word, the symptoms of narcotic poisoning, which are speedily dissipated on removal to the fresh air.

Now, what poisonous gases are generated by the combustion of coke, coal, etc.? Carbonic oxide, carbonic acid, the carburetted hydrogen gases, and sulphurous acid.

The last named, which is so abundant in the air of coal and gas burning towns[1] (where it serves a useful purpose, being a powerful disinfectant), hardly deserves to be placed in juxtaposition with such deadly agents as carbonic oxide and carbonic acid.

The light and heavy carburetted hydrogen gases may be excluded from our consideration, for they pass off in comparatively minute quantities in an unconsumed state. As the carbonic acid, which is produced by the lower layer of burning matter forming the fire, rises through the heated mass above, it unites with more carbon and becomes changed into carbonic oxide. This latter gas may sometimes be seen burning on the surface, and yielding a pale blue flame. When it burns in contact with air, carbonic acid is reproduced. The presence of carbonic oxide is a sign of imperfect combustion. The loss of heating power when this gas escapes from a stove has been estimated at 67 per cent.

Carbonic oxide is believed by all to be a most virulent poison, even *in the smallest quantities.* It is, if quite pure, so free from odour and creates so little inconvenience that, when present in the air, it is apt to be breathed unconsciously until the effects of it are felt. It is said to be evolved by the common puff ball when burnt, the fumes

[1] One of the causes of the difficulty which is experienced in cultivating trees and shrubs in cities is to be found in the presence of this acid, which is highly destructive to certain kinds of plants.

from which have been employed for centuries to narcotize bees, before taking the honey from the hive.

As both carbonic acid and carbonic oxide gases are given off in the combustion of coke, anthracite, and charcoal; and as deleterious effects may be occasioned by either, and especially by the carbonic oxide, any escape of them into the air we breathe is to be carefully guarded against. Claude Bernard and M. Guerard both assure us that *a mixture of these gases is more hurtful than either respired alone.*

When coke or anthracite, which do not contain the illuminating gases, and which burn without flame and smoke, are used in our fire-grates, we can generally perceive an odour of sulphurous acid on the addition of fresh fuel, by placing the face close to the mantel-shelf. If this acid, which is detected by its irritating fumes, escapes then into our rooms, it may be fairly presumed that the inodorous gases, carbonic oxide and carbonic acid, which are simultaneously developed, are associated with it.

Coke as a fuel.

Some may inquire, "Is it then unadvisable to burn coke in open fire-grates?" I will answer this question by narrating an incident that once came under my notice. An extremely delicate child, afflicted with a pulmonary affection, was ordered, during the prevalence of the easterly winds, to be confined to a suite of rooms, all maintained at one temperature, during both day and night, by coal fires in open fire-grates. As coals were very expensive, the mother after a time adopted the economical measure of burning coke. On entering the sitting-room, after the introduction of the coke, to visit the little patient, I experienced a sense of general oppression, of weight about the head, and a difficulty in breathing air which seemed to have lost all freshness. The child was suffering from the symptoms of narcotic poisoning. She complained of great lassitude and of "a feeling as if a band was tightly bound around the forehead." The rooms were not again warmed by this fuel.

It is to be observed that those who are unaccustomed to remain in rooms warmed by iron coke-burning stoves are more liable to be unpleasantly affected than those who are frequently near them. There is a certain tolerance of the poison of carbonic oxide acquired in time by those who habitually breathe it in small amounts, such as is seen in the case of arsenic, opium, etc. With respect to the formation of carbonic oxide hæmoglobulin in the blood—a substance possessing a characteristic spectrum—I must refer to my paper on Coke written some years ago.[1]

Americans appear to be fully alive to the danger of the poisoning of the air they breathe with carbon monoxide, and now employ wrought-iron stoves, which are but slightly, if at all, permeable to gases. They are formed of plates riveted together as tightly as those of a steam boiler, so that the stove is practically of one piece. Stoves constructed of Russian sheet-iron (rolled iron covered with a silicious glaze) have also been employed. The Germans appear to be only partially aware of the injury attendant on the use of porous stoves.[2] As the majority of their earthenware stoves are covered with a silicious glaze, they suffer rather from the dryness of the air which they occasion than from the escape of poisonous gases.

Wrought *versus* cast-iron stoves.

The English seem perfectly insensible at present to this danger to health, although it has been pointed out by myself[3] and others for years.

[1] "Coke as a Fuel, in Relation to Hygiene," in *Disease Prevention.*

[2] *Vide* Haller's "Die Lüftung und Erwärmung der Kinderstube und des Kranken Zimmers."

[3] *Op. cit.*

The reader may imagine that, as stoves are furnished with flues, every provision is made for the removal of all the products of combustion into the outer air. Unfortunately these poisonous oxides of carbon do not all pass away by this outlet, but enter the rooms which the stove is designed to warm in three ways; (*a*) through the iron; (*b*) at the junctions of the separate pieces of which a stove is made; and (*c*) in consequence of downward currents of air.

The second and third modes of exit are readily intelligible, but the first requires some explanation. MM. St. Claire Deville and Troost have discovered that iron and several other metals permit, when heated, the passage through them of the gases of combustion. They write, "The porosity results from the dilatation induced by heat in the intermolecular spaces." The researches of Tyndall on the penetration of metals by gases, and of Graham on the absorption of carbonic oxide by iron, corroborate these experiments.

M. Dumas has distinctly shown [1] that a portion of the carbonic acid evolved during combustion is changed by heated iron into carbonic oxide. It is by virtue of the absorptive power possessed by iron that this metal is converted into steel. We learn from Dr. Derby's little work, before alluded to, that so long ago as 1865 Velpeau communicated to the French Academy some observations of Dr. Carret, as to the unhappy influences on the health which attend the use of cast-iron stoves. General Morin interested himself in the matter, and asked MM. St. Claire Deville and Troost to analyze the air encircling a heated stove.

These chemists found: (1) that tubes of cast iron are incapable of maintaining a vacuum; [2] (2) that carbonic

[1] *Comptes Rendus*, August 26, 1872.

[2] The soil in which pipes containing illuminating gas are embedded has often a powerful odour of it, and is frequently much discoloured. This

oxide, carbonic acid, and hydrogen gases pass through iron, and to a still greater degree through cast iron; and (3) that carbonic oxide, absorbed in our stoves by the internal surface of the cast iron, diffuses itself from the external surface into the atmosphere, and that this process goes on continuously. They have besides determined the quantity of the oxides of carbon present in the air surrounding heated stoves, and the proportion of carbonic oxide which permeates through a given surface of a cast-iron stove, as well as that which the metal absorbs and retains.[1] The passage of the comparatively harmless sulphurous acid through the crystalline structure of cast-iron stoves is often recognized by its pungent and peculiar smell.

Wolffhügel and Prof. Ira Remsen have expressed doubts[2] as to the permeability of cast iron to carbonic oxide. The latter did not find in the air around heated cast-iron stoves more than ·04 per cent of this gas. The Vogel-Hempel (which seems the most delicate known) method[3] of testing for its presence does not enable the

is, without doubt, partly occasioned by loss through the walls of the pipes; to guard against which, so far as is practicable, gas companies test their pipes by submitting them to a powerful pressure, and lay them in a concrete, composed of lime, etc., which adhering to them forms a protective coating that lessens the escape.

[1] The important experiments of these chemists are contained in *Comptes Rendus*, T. 57, 1863, and T. 59, 1864.

[2] "Carbonic Oxide as a source of Danger to Health in apartments heated by Cast-iron Furnaces or Stoves," in *National Board of Health Bulletin*, June 25, 1881.

[3] The Professor prefers this method to that of S. von Fodor, in which the blood of an animal exposed to carbonic oxide is shaken with ammonium sulphide—a test that reddens the blood if the poison be present and renders it violet if not present. This Vogel-Hempel method consists in allowing a mouse to breathe the suspected air, in killing the animal, in removing a little of its blood and diluting it with water, and in examining it with a spectroscope. The two bands characteristic of pure blood are replaced, in poisoning by carbonic oxide, by a broad indistinct shadow, not to be removed by ammonium sulphide, which causes the disappearance of the bands of pure blood.

chemist to detect a smaller quantity. Carbonic oxide probably exerts its action in the most minute doses. Whatever scientific chemists may or may not be able to discover, the fact remains that physicians occasionally encounter cases of poisoning from carbonic oxide when coke is burnt in open grates, and that cases with identical symptoms occur when cast-iron stoves are employed. (*Vide* cases of poisoning by coke fumes in *British Medical Journal,* March 6, 1875, and in *Lancet* of February 14, 1883.)

The most pleasant and grateful of all the *artificial* kinds of heat is obtained by the consumption of coal in open fireplaces, although as at present managed it is exceedingly wasteful. The quality of heat thus imparted is, according to my experience, more conducive to health than that supplied by any other fuel. Ventilation is also promoted by open fire-grates—an ordinary fire drawing about 150 cubic feet of air per minute. A brightly burning fire is an enlivening object, and tends much to render home attractive by its stimulating influence on the spirits. These beneficial impressions on the nervous system are denied us by the cheerless stoves.

Provided there is a powerful draught in a fireplace, coke may generally be burnt in it, *mixed in small proportions with coal,* without causing a disturbance of nervous functions. The draught in a chimney can of course be easily increased, if it is insufficient, by either lengthening the flue or diminishing the size of it near the fire.

# CHAPTER XX

## PUTREFACTIVE PROCESSES, SEWAGE EMANATIONS, AND EXCREMENTAL FILTH

Putrefactive processes.

THE putrefactive changes that occur in organic matter are always associated with micro-organisms, and are generally accompanied by the production of gases and vapours. Warmth and moisture favour, and cold and dryness retard, these putrid decompositions. "The ferments, so far as we know them," writes Mr. Simon,[1] "show no power of active diffusion in dry air; diffusing in it only as they are passively wafted, and then probably, if the air be freely open, not carrying their vitality far; but as moisture is their normal medium, currents of humid air (as from sewers and drains) can doubtless lift them in their full effectiveness, and if into houses or confined exterior spaces, then with their chief chances of remaining effective; and ill-ventilated, low-lying localities, if unclean as regards the removal of their refuse, may especially be expected to have these ferments present in their common atmosphere, as well as, of course, teeming in their soil and ground water." Pyæmia may probably be produced in the form of putrid infection or intoxication by a septic poison, which can be isolated by processes destructive of every living organism, and also by a septic poison which is the product of certain micro-organisms.

[1] Filth Diseases, in Report of Medical Officer of Privy Council and Local Government Board. New Series, No. II. 1874.

Sewer gas, which is one of the media for the conveyance of the poisons of the filth diseases, including erysipelas,[1] has been found on analysis to be somewhat variable in composition. The examinations of different analysts agree in noting a diminution of oxygen and increase of carbonic acid, with small proportions of hydrogen sulphide, carburetted hydrogen, and sulphide of ammonium. The characteristic fœtid odour of sewer gas is due to some organic vapour of carbo-ammoniacal origin, the precise composition of which has not yet been determined. Sewage and cesspool effluvia are well known to be injurious to the health of animal and vegetable life, even when mixed in small quantities with the air. The only forms of life that thrive in air thus polluted are certain of the bacteria and fungi, and other of the scavenging families of creation. Sewage emanations.

As to the fouling of the air we breathe with excremental filth, generally dried and wafted about as dust, and its connection with the spread of such diseases as cholera and typhoid and other of those loathsome filth diseases, the subject is too disgusting to treat of. I would simply refer my readers to two sources for information, if they require any:—first, to disclosures of Dr. Stevens as to the state of Over Darwen, when the terrible outbreak of fever occurred there in 1874, where the people were living with thousands of tons of excremental filth stored amongst their dwellings, exposing a surface of many acres, continually poisoning the air they breathed, and which enveloped them; secondly, to Mr. Simon's Report on Filth Diseases, in which he writes of enteric fever—"Of all the diseases which are attributable to filth, this, as an administrative scandal, may be proclaimed as the very type and quintessence; that though sometimes by covert processes which I will Excremental filth.

[1] *Sanitary Record*, June 6, 1879.

hereafter explain, yet far oftener in the most glaring way, it apparently has an invariable source in that which of filth is the filthiest; that apparently its infection runs its course, as with successive inoculations from man to man, by instrumentality of the molecules of excrement, which man's filthiness lets mingle in his air and food and drink."

# CHAPTER XXI

## POISONOUS GASES AND INJURIOUS VAPOURS

SUCH as hydrochloric acid gas from alkali works, arsenical vapours from copper-smelting works, hydrofluoric acid from superphosphate manufactories, etc., injure animal and vegetable life, sometimes destroying all trace of the latter for miles around. Then the air is vitiated by bisulphide of carbon from indiarubber works;[1] chlorine, sulphurous and sulphuric acids from bleaching works; hydrogen sulphide from chemical works where ammonia is manufactured. It is poisoned also by carbonic acid, carbonic oxide, and hydrogen sulphide, from brickfields and cement works; by organic vapours from glue refiners, bone burners, slaughter-houses, etc.,[2] and by the fumes of oxide of zinc, producing "brassfounders' ague."

[1] Paper on the injurious effects of vapour of bisulphide of carbon by M. Poincare in *Comptes Rendus*, December 2, 1878.

[2] *Vide* Dr. Ballard's Report on Effluvium Nuisances in Sixth Annual Report of Local Government Board, containing the Supplement of the Medical Officer, 1876.

# CHAPTER XXII

## SUSPENDED ANIMAL, VEGETABLE, AND METALLIC, AS WELL AS MINERAL IMPURITIES

Are the cause of an immense amount of suffering, the non-poisonous exciting lung disease by the irritation occasioned.

After the age of thirty-five the metal miners of Cornwall and Yorkshire are liable to a large mortality from a disease commonly spoken of as "miners' rot." The lungs of colliers become black with coal dust. The evil is aggravated by the imperfect ventilation and the laborious ascent and descent by long ladders in some mines. To these causes nearly two-thirds of the total mortality amongst Cornish miners can be referred.[1]

It may be well to enumerate a few of the trades which suffer in this way:[2]—

Potters suffer from the dust, and have what is called "potters' asthma,"[3] or a fibrosis of lung with consolidation.

Knife-grinders are injured by the fine particles of steel, and suffer from what is called "knife-grinders' rot."

Millers, sweeps, hairdressers, and snuff-grinders are liable to asthmatic affections.

[1] Report of the Inspectors of Mines in the United Kingdom for 1885.

[2] *Vide* Thackrah's work on the *Effects of Arts, Trades, and Professions on Health and Longevity*.

[3] It has been publicly declared that not less than 60 per cent of working potters die from diseases of the lungs.

Buttonmakers; pin-pointers; mother-of-pearl workers; cotton, wool, and silk spinners;[1] workers in flax factories;[2] cotton weavers;[3] stone masons; grinding and millstone makers[4] and glass makers; makers of sandpaper and Portland cement.

Apart from the very obvious injury to health induced by inhaling dust of various kinds, the circumstances which attend the performance of this injurious work are in many cases highly deleterious. The hot, stuffy, damp, rebreathed air in which large numbers of these artisans are bathed during their hours of labour is enough in itself to predispose strongly to the development of disease.

Some of the metallic dust to which some workmen are exposed is poisonous.

Lead miners, type-founders, glazed card manufacturers, and lacquerers, suffer from lead poisoning.

Manufacturers of white lead inhale the dust of this metallic compound. Plumbers and painters are very often poisoned by this metal in consequence generally of a want of sufficient cleanliness.

[1] *Vide* Dr. Greenhow's investigations in Reports of the Medical Officer of Privy Council for 1858-60 and 1861. Since the introduction of modern machinery the evils have been considerably reduced.

[2] Dr. Purdon of Belfast writes:—"The weavers suffer greatly from chest affections by inhaling the damp air, which has an average temperature of 75° F. Many of them being under 18 years of age, and being obliged to stoop constantly at the looms, get contracted chests, and this, with other circumstances, makes the death-rate very high. The rooms in which the dressing of the flax is carried on require to be kept at a temperature varying from 90° F. to 125° F. No one under 18 years old is employed in these rooms, and, as it is considered that their lives are shortened several years, they are paid very high wages."—*Lancet*, October 27, 1877.

[3] *Vide* Report of Dr. Buchanan's Inquiry at Todmorden, in Yorkshire.

[4] *Vide* French millstone-makers' phthisis, by Dr. T. B. Peacock, in *Brit. Med. Journal*, October 14, 1876.

Workers in brass suffer from copper poisoning, and workers in mercury (such as silverers of mirrors, quick-silver miners), and furriers, from mercurial poisoning. Workmen and women, who make arsenical wall papers, pigments, and artificial flowers, suffer from inhaling the poisonous dust of some compound of arsenic.[1] Many persons who do not gain a living by paper or flower making, but who are unwise enough to adorn the walls of their rooms with papers of gorgeous hues, suffer also, and know not what ails them.

Wall Papers.

Mr. Kerley found that a room, 16 feet square and 9 feet high, will have spread upon its walls, provided any of these arsenical papers are hung, from 52 grains to more than 8 ounces of poisonous green colouring matter.

It is a popular mistake to imagine that all green papers are coloured by arsenic, or that papers which are not green never contain arsenic, for yellow, blue, pink, mauve, red, brown, olive, sage green, drab, and white wall papers contain this metal. Cobalt blue is composed of 10 per cent of arsenic. Papers of the most brilliant green and other colours can be manufactured which are quite free from arsenic. This coloured powder being apt to be removed by trifling causes, is, of course, disseminated through the air, and well merits the epithet of "devil's dust." The researches of Fleck and Hamberg show that this metal is evolved as arseniuretted hydrogen, as these German chemists collected the gas. Lead papers and copper papers are not fanciful dangers. It seems that clothing and furnishing materials are also not exempted from the universal system of poisoning and adulteration that prevails. The above-mentioned analyst estimated the presence of $5\frac{1}{2}$ ounces of aceto-arsenite of copper or "Paris green" in a green tarletan dress of 16 yards.

Clothing.

[1] *Vide* Report on the Manufacture and Applications of Arsenical Green, by Dr. Guy, in Fifth Report of Medical Officer of Privy Council, 1862.

Every sample of tarletan examined contained it; the higher priced qualities of this material possessing more poison than the cheaper varieties. Some kinds of muslin are also coloured with this poisonous material. It has recently been discovered that the bright greens of certain furnishing materials, such as chintz curtains and linings, consist of the poisonous compounds—arsenate of iron and chromium. Mr. Foster, of the Middlesex Hospital, who has drawn public attention to this matter,[1] found in each square yard of bedroom chintz the metal arsenic, in the form of an arsenate, equal to $45\frac{1}{10}$ grains of white arsenic, and in each square yard of the chintz lining $20\frac{3}{10}$ grains of this deadly poison. On estimating the number of square yards of chintz and lining in the bedroom of a gentleman who had suffered for some time from nausea and nervous depression, it was proved that there was arsenicum present in his sleeping apartment equal in amount to 26 ounces of white arsenic.

**Furnishing Materials.**

These poisonous furnishing materials have been sold to the public for the last twenty years.

Children have been poisoned by white arsenic, with which "violet powder" has been found to be adulterated to the extent of 25 per cent, and by lead, from inhaling the dust that proceeds from inferior kinds of American cloth with which perambulators are lined.

The public is exposed to danger :—

*From Arsenic*

in the employment of packs of cards, enamelled cooking utensils, green lamp shades, green carpets, green venetian blinds, Berlin wools (green, blue, and rose), kindergarten toys, candles, water colour paints, gloves and stockings (aniline dyed), papers covering confectionery, glazed paper

[1] *Lancet*, August 11, 1877.

collars, and starched linen, artificial flowers and grass, anti-dry rot preparations, etc.

Arsenite of soda and arsenite of alumina are used in calico-printing and fixing the colours.

*From Lead*

in the use of soda-water, lemonade, beer, tinfoil around chocolate and other sweets, floor-cloths, snuff, tea, vermilion red flowers, wall paints, American imitation leather, and many other articles.

Many contrivances have been devised for the protection of the lungs of workmen who have to support "dear life" by engaging in the foregoing and other unhealthy callings; but there is in this field a great opportunity for those with talents for invention to exercise them in behalf of these suffering thousands.

In addition, the ventilation of workshops should be more attended to, for at present the admission of fresh, and the expulsion of foul, air is about the last thing thought of. Happily something has been done in this direction not only amongst the Sheffield knife-grinders,[1] but in the mines of Durham and Northumberland, and the greatly diminished death-rate of these poor mechanics

Knife-grinders.

[1] What distressing truths have been for years presented to the public by the late Dr. Hall, of Sheffield, respecting the average duration of life amongst the steel-grinding trades of that city! What fearful waste of life is disclosed in Dr. Wynter's summary of Dr. Hall's observations!—"Dry grinders of forks, 29 years: razors, 31 years; scissors, 32 years; edge tool and wool shears, 32 years; spring knives, 35 years; files, 35 years; saws, 38 years; sickles, 38 years." Some improvement has undoubtedly been effected of late years, as the report of the Medical Officer of Health, contained in Dr. Hall's last communication to the profession shows ("Remarks on the Effects of the Trades of Sheffield," *Brit. Med. Journal*, October 14, 1876), through the introduction of fans, but much still remains to be done.

In 1874, 92 grinders died; average age at death, 46 years.
In 1875, 111 ,, ,, ,, ,, 42·5 ,,

and colliers from pulmonary disease proves the advantage of free ventilation.

Sufficient evidence has been adduced to show the magnitude and enormous importance of the subject. Medical literature and the columns of the medical press have for years been teeming with instances of the wholesale destruction of health and life by these terribly dangerous occupations. In brief, the mortality induced by impure air charged with poisonous and non-poisonous dusts is simply an ignorant waste of human life.

The air that we breathe, we who are not engaged in these unwholesome avocations, is full of dust—a heterogeneous mixture of particles of organic and inorganic origin.

From the amount of spores (250,000) in a single drop of fluid, Mr. Dancer calculated[1] "that 37½ millions of these bodies, exclusive of other substances, were collected from 2495 litres = 88 cubic feet of the 'air of Manchester,' a quantity which would be respired in about ten hours by a man of ordinary size when actively employed." It may well be said, "Surely this dust that we all of us breathe must be hurtful. Is there no provision in nature for counteracting its baneful influence?" There is no doubt but that the less of it we have the better for us. We are taught in every possible way, if we will but be guided by the teachings of nature, to be clean. If people will but admit an abundance of Nature's great disinfectant, pure fresh air, into their houses, and at the same time keep themselves and their houses clean, they will not be injuriously influenced by the dust of the air.

[1] "Microscopic Examination of the Solid Particles of the Air of Manchester." *Proc. Lit. and Philosoph. Socy. of Manchester*, vol. iv. series 3, 1867-68.

# CHAPTER XXIII

## EMANATIONS FROM GROUND HAVING DAMP AND FILTHY SUBSOIL—SUBSOIL AIR, CHURCHYARD AIR, MARSH AIR

THE air of towns, and also that of houses, is often deteriorated by emanations from wet and filthy subsoil. It has been distinctly proved both in this country and in America that the death-rate of consumption is diminished very considerably by drying the subsoil.

Rheumatism, and heart-disease which is so frequent a concomitant of rheumatic affections, are lessened by the same beneficial measure. Emanations from filthy soil produce diarrhœa in that part of the year, namely autumn, when there is a predisposition to intestinal disorders. It is very unwise to allow the soil close to houses to be defiled by filth, for the fires of a house, creating a force of suction, draw into the house the air contained in the surrounding soil, as well as of that on which it is built. The popular impression that the atmosphere ends where the ground begins is a very widely spread delusion. Most soils are more or less porous. A house built on a gravelly soil stands on a foundation composed of a mixture of two parts of small stones, and one part of air. The air may give place to any gas or to water. The porosity of soils may be well illustrated by the following experiment devised by Pettenkofer.[1]

[1] *Cholera: How to Prevent and Resist it*, by Dr. Max von Pettenkofer. Translated by Dr. Hime.

"If a person blows, as represented in the figure, on the surface of the gravel, the water in the U-shaped tube will be seen to alter its position, the level of the side next the person who is blowing becoming lowered, and the other proportionately elevated. The depression of the fluid is caused by the force of the air blown through the gravel. This air ascends from the bottom of the

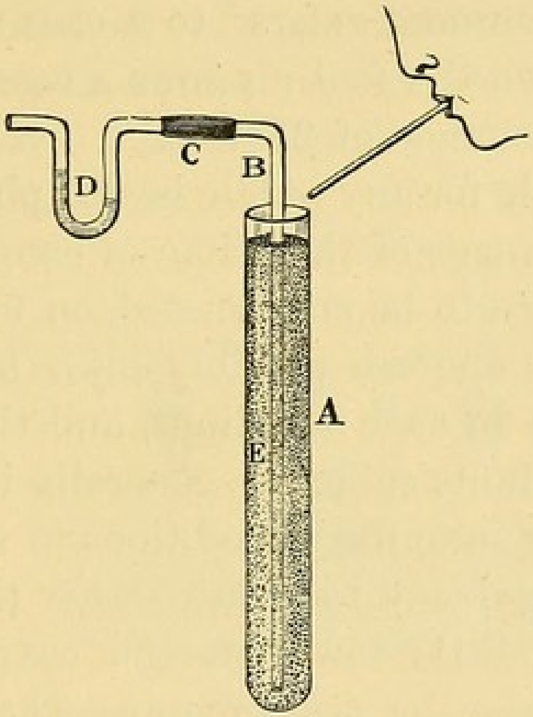



Fig. 17.

A, a tall and large glass tube filled with fine gravel, in the axis of which stands a very small tube, B, open at both extremities, the upper being curved, and connected by a piece of indiarubber tubing, C, to a U-shaped tube, D, containing water. E, fine gravel.

gravel through the small glass tube, passes through the indiarubber tube, and thus reaches the water."

Remembering the force with which the wind often strikes the surface of the ground, with a pressure during a hurricane, amounting, according to some, to 36, and to others, of 50 pounds on every square foot, it cannot be a matter of surprise, in the light of the above experiment, that foul and pestiferous air from the filthy earth beneath, and close to our habitations, should be introduced into them, aided, as this driving force is, by the suction power created by the fires and lamps, etc. I have encountered instances in which foul air from drains, cesspools, and from leaky gaspipes, has been drawn into houses great distances, and has caused ill-health and death from the continued poisonous condition of the air. Pettenkofer, of Munich, relates a case [1] where gas was found to have travelled a space of 20 feet from the street main into the house.

Dr. F. de Chaumont refers [2] to a case that occurred to Dr. Fyffe, in which the foul air from a cesspool was sucked into a house a distance of 27 feet.

It is impossible for any public health physician to speak in temperate language of the crime of erecting houses, and of allowing houses to be constructed, on filthy and sodden foundations. No one can possibly enjoy for any length of time good health in such buildings, and the diseases from which the inhabitants suffer are generally influenced so unfavourably by the insanitary conditions in which they exist, as to have a tendency to death rather than to recovery. I once visited a little town on the coast, swept by the purest of breezes—the sea breeze—where scarlet fever was prevalent. In one part of the town, where the cottages were kept in a cleanly and wholesome state, and were built on virgin soil, the disease showed itself in a mild form, and not a death occurred. In another part of the town nearly every family lost one or more children, killed almost immediately by the poison. I went into one of the cottages where all the children, five in number, were destroyed, and talked to the poor afflicted parents. The father, pointing to a loose plank of the floor, moved a portion of it aside. I pushed my walking stick down, and stirred up the soil over which this family had been living. It was fluid filth. The cottages in which these fatal cases occurred had been erected on ground made up

[1] *Op. cit.* [2] *Lectures on State Medicine.*

of stinking fish, brickbats, earth, and every kind of decomposing débris.

*Subsoil Air.*—The chemical composition of the air contained in soils[1] has been investigated by many chemists, such as Boussingault and Lewy, Pettenkofer, Fleck of Dresden, Nichols of Massachusetts, and others. A large excess of carbonic acid, a little carburetted hydrogen, a trace of ammonia and hydrogen sulphide (when the ground water possesses sulphates), have been discovered. They all seem to be unanimous as to the much greater quantity of carbonic acid in ground air than in atmospheric Subsoil air.

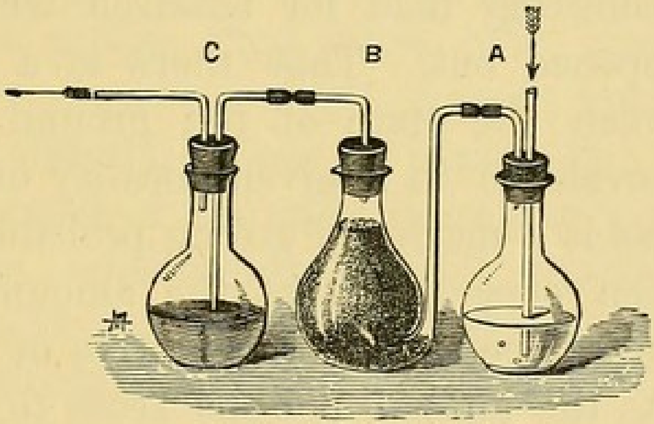



FIG. 18.

air, and as to its great variability in amount. The former fact is well demonstrated by an experiment and illustration, contained in Mr. W. N. Hartley's *Air and its Relation to Life.*

A flask full of clear baryta water is connected by tubes to a vessel filled with earth, and again attached to this is another flask of baryta solution. By drawing air through the whole system of bottles the amount of insoluble carbonate of baryta, formed in the first flask by the carbonic acid in the air, may be compared with that in the second flask, produced by the carbonic acid in the soil.

[1] *Vide* Fodor's *Hygienische Untersuchungen über Luft, Boden und Wasser*, 2e Abtheilung Boden und Wasser, p. 99, *et seq.*

Pettenkofer discovered that the amount of carbonic acid in ground air varies in different seasons of the year, that it reaches its minimum from January to May, and then rises steadily to its maximum from July to November. The occurrence of the maximum in autumn, is probably the result of high temperature and excess of decomposing organic matter. The exact period of the minimum has not been so clearly determined. The analyses of the air of soils of various kinds that rest on different formations, the degree of porosity of soils, and the connection, if any, of the same with such diseases as diarrhœa and certain forms of continued fever, is an extremely interesting field for research which has been but barely opened out. That there is a very decided relation between the state of the ground air and the continued prevalence in a given locality of diarrhœa at certain seasons is a matter of strong probability.

It has been suggested that the amount of carbonic acid in ground air be taken as indicative of the degree of impurity. As the animal poisons seem to attach themselves always to minute particles of animal and vegetable organic matter in a state of decomposition, a study of the comparative amount of organic matter in the ground air of soils cannot well be omitted.

Churchyard air.

*The Air of Churchyards and Vaults* is richer in carbonic acid than ground air, and contains often a putrid organic vapour, hydrogen sulphide, carbonate of ammonia and sulphide of ammonium, and elementary forms of animal and vegetable life.

Marsh air.

*The Air of Marshes* contains also a large excess of carbonic acid and organic matter. The experimental evidence which at present exists as to the presence of a bacillus malariæ (Klebs) in the air of marshes where ague abounds, and as to its existence in the blood of those suffering from this disease, is insufficient and unconvincing.[1] Great quantities of living organisms and organic débris, carried upward for a certain distance by the ascensional force afforded by the evaporation of water, are discernible on microscopic examination. Carburetted and phosphuretted hydrogen gases are evolved by marsh land, and sometimes hydrogen and ammonia. The time to be selected for making observations on the composition of marsh air is in the early morning or evening, when the density of the air and the deposition of dew prevents a free admixture of the impure with the higher strata of pure air, or during a hot, sultry noon when no breeze keeps the air in motion. I have made analyses of the air of marshes that are hotbeds of ague, taken on a fine day, whilst a gentle wind blew over them, and have found no more organic matter in such air than in pure air collected simultaneously on high hills. This fact is only another proof of the marvellous purifying properties of air, and the tendency throughout nature, not only in the air, but in the earth and in water, to self-purification, and to the restoration of an equilibrium.

[1] *Vide* information on this subject in Dr. H. Gradle's work on Bacteria and Tourmasi-Crudeli's illustrations, in *Journal d'Hygiène* of March 31, 1881.

## CHAPTER XXIV

### THE DELETERIOUS EFFECTS ON HEALTH OF THE AIR OF OUR HOUSES

The air of our houses.

To dilate on such a subject would be indeed needless to students of preventive medicine, if a general recognition existed of the fundamental principles on which the relations between a state of health and disease, and between a condition of health and the circumstances which tend to promote and deteriorate it, rest. The old notion that disease is a sort of malignant demon that takes possession of the body, and requires to be combated and expelled by some violent means, is still a very widespread one, even amongst some of the rural rank and file of the medical profession, and any modern ideas as to the relations of health to the conditions of those surroundings of life, namely, the air we breathe, the water we drink, and the food we eat, which so seriously influence it for good or evil, are often received with a smile of incredulity. The public surely ought not to require a skilful physician to teach them what common-sense inculcates, that perfect bodily and mental health cannot be enjoyed by those who are inattentive to the cleanliness of the body, and of that which enters it. There is, unhappily, an increasingly exaggerated importance attached at the present time, by great numbers of people, to the injurious effects of impure water. It is the fashion to ascribe almost every indisposition to the condition of the water supply. The tendency to run into extremes about most matters, and to ride hobbies, is but too frequently observed. On the other hand, there does not yet exist in the public mind an adequate conception of the extent of the danger to the health which is induced by a continual immersion of the body in impure air, notwithstanding the efforts that have been made in this direction for the enlightenment of the public mind. For a quarter of a century I have been preaching on this subject, pretty much in the language of my First Annual Report as Medical Officer of Health for 1874, which contains the following passages:— "It should not be necessary to point out the blessings of pure air, and the evils resulting from the inhalation of a vitiated atmosphere. Excluding from consideration the effects of an exposure to the fœtid gases of organic decomposition, which act like other poisonous chemical agents, it may be said that offensive smells, the products of putrefaction, are not only injurious in themselves, but serve as danger signals bidding men to beware. By acting as depressants, and as reducers of bodily vigour, they tend to make the system more prone to be attacked by disease. As the smell of gas in a house warns men of the presence of a body dangerous when diffused through it, so an offensive smell is a signal of the possibility of the presence of the poison of a disease. A stench may or may not be associated with a disease poison, and no one knows when it is and when it is not thus accompanied. As a means of warning to those exposed, an offensive smell is useful, but we must remember that agents which destroy the stink of filth may yet leave all its powers of disease-production undiminished. Disease poisons or ferments, although not always in the companionship of stinks, are often so, and it behoves every one to remove the cause of stinks, and prevent

The teaching by health officers.

their recurrence. Disease ferments may fatally assail the human body in doses quite unappreciable to the most acute sense of smell. All unpleasant smells are to a certain extent deleterious, although infinitesimally so perhaps. Pleasant odours, if in excess, become injurious to some persons. Those who visit the farms devoted to the cultivation on a large scale of the rose and jessamine in France, for the manufacture of scents, experience, after being exposed to these perfumes for a little time, severe frontal headache and lassitude, symptoms which speedily pass away when they emerge from these odoriferous tracts of country. It should always be remembered, then, that smells which offend the senses, even when not accompanied by disease poisons, act deleteriously on the health of those frequently exposed to them, by depressing the system, thereby lessening the resistance of the frame to the approach of disease, and by diminishing the bodily vigour, rendering the vis medicatrix naturæ a less chance of success in preventing disease from destroying those attacked."

Result of the same amongst the public.

The effect of all the exertions of that class who have been called sanitary reformers is, that large numbers of people tacitly acknowledge that the constant inhalation of air rendered impure to the senses of sight and smell is likely to injure. It seems very difficult for the public to go a step further and cease to offer opposition to the belief which is rooted in the mind of every public health physician, that frequent exposure of the body to air that is deteriorated in quality either by having been rebreathed without purification, or devitalised, tends to a reduction of the vital powers, a state which is favourable to the development of a perversion of healthy action, the precursor of disease.

Dr. Richardson has, in his attractive style, most candidly spoken out on this subject in his *Diseases of*

*Modern Life.* "It is this devitalised air in our over-crowded towns and cities, where there is no vegetation to revivify it, which we distinguish as something so different from the fresh country air that streams over forest and meadow. It is the breathing of this air that makes the child of the close town so pale and lax and feeble, as compared with the child of the country. It is this air that renders the atmosphere of the crowded hospital so deficient in sustaining power. It is this air that gives to many of our public institutions, in which large numbers of our poorer, ill-clad, uncleansed masses are herded together, that 'poor smell,' as it is called, which is so depressing both to the senses and to the animal power.

Dr. Richardson's sketch of the universal system of air deterioration.

"In many private houses, houses even of the well-to-do and wealthy, streams of devitalised air are nursed with the utmost care. There is the lumber-room of the house, in which all kinds of incongruous things are huddled away, and excluded from light and fresh air. There are dark understairs closets, in which cast-off clothes, charged with organic débris of the body, are let rest for days, or even weeks, together. There are bedrooms overstocked with furniture, the floors covered with heavy carpets, in which are collected pounds upon pounds of organic dust. There are dressing-rooms, in which are stowed away old shoes and well-packed drawers of well-worn clothing. There are dining-rooms, in which the odour of the latest meal is never absent, and from the cupboards of which the smell of decomposing fruit or cheese is always emanating. There are drawing-rooms, in which the scent of decayed roses, or of the varnish from the furniture, or of the dye from the table-covers, is always present. There are kitchens in which there is the odorous indication of perpetual cooking. There are sculleries where the process of 'washing up' seems to be in permanent action, and where the products of change from stored bones, potato parings, recent vegetable green food, and other similar refuse, are abiding. There are water-closets in which there is at every time of day or night a persistent, faint ammoniacal organic odour.

"The process of devitalisation of the air is again effected, locally, in human habitations, by the presence in it of the lower forms of life. When in the dwelling-house dogs, cats, tame mice, birds, squirrels, are kept in such numbers that the odours of the animals are perceptible; when flies cover the ceilings, and a mould collects on the walls, then the air teems with myriads of minute living forms, and with organic dust. Every particle of this matter induces deterioration of the air that feeds the lungs."

Although many may smile on reading the foregoing extract, every one with any experience of life must admit the truthfulness and fidelity of the sketch. The principles that should be firmly implanted in our minds are involved in the consideration of such golden rules as the following:—

Principles with which the public mind should be imbued.

1. The exposure of the body continually to a smell, be it a pleasant or an unpleasant one, is deleterious to health.
2. An odour that is at first pleasant, generally soon becomes objectionable. The little is grateful, but a constant excess of the perfume is hurtful.
3. An unpleasant odour may or may not be in the companionship of a disease ferment, and no one knows when it is or when it is not so accompanied. The putrid gases of decomposition will not in themselves give rise to the development of either of the zymotic diseases.
4. When an unpleasant odour is not associated with a poison of a disease, it is nevertheless deleterious to the health of those constantly subjected to its in-

fluence. I know that this statement will be doubted by some. Several instances of its truth have occurred to me. For example, a man in good health took a house close to one of those public trade nuisances where the smell of melted tallow taints the air, and suffered in consequence severely from nausea and diarrhœa. Here no septic ferment could have existed, such, for example, as is supposed, with good reason, to be mingled with the odours of the dissecting-room.

5. The healthy human body often becomes inured, after long exposure, to unpleasant odours, and at length hardly notices them, if always immersed in them. Those actively injurious effects of impure air, such as nausea, diarrhœa, etc., often gradually pass away. If a man is possessed of exceptional powers of vigour, which enable him to maintain a successful warfare with those depressing influences that surround him, he may live for a great many years in tolerable health, although defying the laws of nature. The large majority become affected in course of time, if not suddenly attacked by a passing epidemic (to which a person living under unhealthy conditions is especially prone), by the insidious progress of a chronic disease.
6. Air, which is not defiled by the offensive productions of decomposition, may contain organic matter in the form of dust or vaporous emanations, as carriers of the specific poisons.

A cursory examination of these dicta may lead some one who is indisposed to remove a nuisance from his premises to urge that the whole question as to whether an odour is or is not injurious to health, rests on the point as to whether it does or does not annoy the person continually exposed to it. Anything which persistently worries, disturbs, and irritates, is undoubtedly deleterious to health, although the injury may be so infinitesimal that it cannot perhaps be measured or demonstrated. It will probably scarcely incommode the resilient disposition of the young and healthy animal that is naturally cheerful, and disposed to look on everything with a *couleur de rose* hue. The human body by acclimatization can adapt itself to wondrously different circumstances, although a certain injury is received by so doing, but it never reaches the period of old age if continually bathed in impure air, although that air may have long ago ceased to offend the olfactory nerves. The comparative freedom of the sewer men of Paris from cholera and other zymotic diseases, the absence of any marked injury to health during the year that the Thames was so odoriferous, and of any excess of zymotic disease in the neighbourhood of Montfaucon, in Paris, where much of the filth of that city is stored preparatory to its conversion into manure for agricultural purposes—assertions which have encouraged the opinion that a constant exposure to morbific ferments or contagia diminishes the risk of being injured by them—will perhaps be urged as contradicting these views. It is a well-established rule, however, notwithstanding the existence of certain much-talked-of supposed exceptions, which is recognised by the whole of the medical profession, that there is a greater mortality amongst those who are exposed continually to impure air than with others who are not so circumstanced, and that the diseases from which the former suffer are of an asthenic type tending to death rather than to recovery.

Air of the streets of towns and cities is not

The amount of oxygen in the air is diminished, and that of the carbonic acid is increased by respiration, and combustion and decay of organic matter, the former, to speak in popular language, being the lifegiving and purifying principle, and the latter its noxious substitute. Thanks to the diffusive powers of gases, and the effects of wind, and to the currents produced by the fires of large towns, and last, but not least, to the wonderful cleansing properties of fresh air, the air of the streets of our towns is not so impure as might be expected. The air of our houses, on the other hand, is generally very impure, because the continuous admission into them of pure air, and expulsion of that which has been used up, is rarely thought of, or if so, is seldom efficiently managed. In respiration we deteriorate an enormous quantity of air (about a gallon a minute), and we are continually throwing off carbonic acid and organic matter. Every time we breathe, and we breathe about eighteen times per minute, we expel 30 cubic inches of air, which amount contains 1·29 cubic inch of carbonic acid, or 16·1 cubic feet in the 24 hours. In the 16 cubic feet of carbonic acid, there are about $7\frac{1}{2}$ ounces by weight of charcoal. Others say that the amount of charcoal is 160 grains per hour = 8 ounces in 24 hours. Air which has been once breathed should never be breathed again until it has been mingled with fresh air, in order that the impurity which it has acquired may be removed from it, and that it may regain a wholesome amount of moisture. The overcrowding of schoolrooms is a subject respecting which much has been said in the way of protest for years. It has been shown by Roscoe in his experiments on the air of schoolrooms that 10 cubic feet of air per minute per head is insufficient to remove completely the organic putrescent matter, and yet schoolrooms are to be found where there is even less than 4 cubic feet for each child.

so impure as has been generally thought.

Air of our dwellings exhibits the presence of large amounts of defiling agents.

Architects design houses, local boards pass the plans, builders erect places which are totally devoid of all provision for the admission of fresh air, and may be likened to Holes of Calcutta on the small scale. As for arranging for a change of air by the passage through a room of warmed fresh air in winter, and cooled fresh air in summer of a healthful degree of humidity, such a proceeding is never dreamt of. The drowsiness which often oppresses our congregations may frequently be more correctly ascribed to the absence of any attempt at ventilation than to the cause to which it is generally attributed. Who is there not acquainted with the unwholesome atmosphere to be met with in nearly every public building? whilst our drawing-rooms, dining-rooms, and bedrooms, even in the best houses, are too often in a most disagreeable state of what is termed "closeness." On once remonstrating with the verger of a church in a suburb of London with respect to the oppressive state of the air during the Sunday afternoon, and on suggesting to him the propriety of opening freely the windows during the interval between the first and second services, he expressed his disapproval of my proposition by informing me that if he followed my advice "the church would catch a chill."

Absence of any attempt to ventilate buildings except in the crudest manner.

I have always maintained, and increased experience has only confirmed my previous conviction, that the impure condition of the air of our houses, be they factories, public buildings, or dwelling-houses, has much to do with the great prevalence of such diseases as phthisis pulmonalis, bronchitis, and pneumonia, which together make up nearly one quarter of the total mortality; and if we could strike a telling blow at that great universal evil—namely, poisoning by impure air—we should do much to save life. Unventilated and overcrowded workshops and schools are, moreover, the nurseries of strumous diseases in general, which sap the strength of the community.

During the decennial period 1865 to 1874, not less than half a million individuals died of phthisis, and three-quarters of a million of people were destroyed by other diseases of the lungs in England. The dependence of these diseases on vitiated air was maintained by Dr. Alison[1] as long ago as 1824, by Baudelocque in 1834,[2] and very likely long before those years.

Phthisis pulmonalis.

The facts that an increase of phthisis pulmonalis occurs *pari passu* with an increase in the density of a population; that in manufacturing centres, where the males are the chief workers at indoor employment, the male death-rate is the highest; and in others, where females are principally required at indoor work, they suffer most; that in agricultural districts, where the men spend nearly all their lives in the open air, and the women scarcely ever leave their cottages, the female death-rate from this disease is higher than the male:—all point to this inevitable conclusion.

Dr. Parkes mentions a remarkable circumstance illustrative of this connection as having occurred in Vienna. In the badly-ventilated prison of Leopoldstadt, 51·4 per 1000, whilst in the well-ventilated House of Correction of this city, 7·9 per 1000 died of consumption.

Dr. Guy's evidence before the Health of Towns Commission contained most striking statements as to the journeymen printers of London. He divided them into three classes:—

The 1*st Class* consisted of men who worked in rooms where they had less than 500 cubic feet of air per head. Of these 12½ per cent had spat blood, and a like proportion had been subject to catarrh.

The 2*d Class* comprised men who had between 500 and 600 cubic feet of breathing space per

[1] *Edinburgh Medico-Chirurgical Transactions*, vol. i.

[2] *Etudes sur la maladie scrophuleuse.*

individual, and amongst them intermediate effects were noticed.

The *3d Class* was composed of men who worked in shops where they had more than 600 cubic feet per individual, and amongst these only 4 per cent had suffered from spitting blood, and only 2 per cent from catarrh.

The published opinions of Dr. Farr, Dr. Marcet, Mr. Welch,[1] Dr. Ransome,[2] Dr. Parkes, Dr. Austin Flint, and Sir James Clark, are all to the same effect.

The continued employment of rebreathed air for respiratory purposes, and its bearing on the development of that terribly fatal strumous disease, pulmonary consumption, has been vigorously brought before the world by the late Dr. MacCormack, of Belfast,[3] who, to show his enmity to used-up air, was said to sleep always, during winter and summer, as did also his family, with the windows of their bedrooms widely opened.

The testimony of the most able physicians of this and other countries; the results of inquiries as to the prevalence of this disease amongst the picked men of the armies and navies of the world; the reports of hospitals for consumption, and of commissions and committees appointed to make special investigations as to jails, workhouses, and schools: all, in various degrees, corroborate this opinion. There are one or two apparent exceptions to this rule in Iceland and the Hebrides, which are worthy of attentive consideration.[4] The beneficial effects

[1] "On the Nature and Variations of Destructive Lung Disease, as seen amongst Soldiers, and the hygienic conditions under which they occur."

[2] "Foul Air and Lung Disease."

[3] "Consumption, as engendered by rebreathed air."

[4] *Vide* Dr. Morgan, on the "Non-prevalence of Phthisis in the Hebrides and along the N.W. Coast of Scotland."—*Brit. and Foreign Medico-Chirurgical Review*, 1860, vol. xxvi. p. 483.

*Vide* controversy in Medical Periodicals, during 1868 and 1869, between on this disease of sea air, the air of high latitudes and elevated regions, furnish an indication as to its cause.

That impure air vitiated by respiration is the one great cause of pulmonary consumption, which may be transmitted from parents to children for generations, needs no proof, as it rests on such a mass of evidence. It is probable that foul air, by impairing the appetite and thus hindering nutrition, may render the body susceptible to the development of the virus peculiar to the disease.

If it should ultimately be shown that the bacillus tuberculosis (*vide* page 306) is the agent contained therein, through which the poison of phthisis pulmonalis is communicated from one individual to another, still further confirmation would be afforded as to its causation. Pathogenic micro-organisms, whilst influenced by temperature and other circumstances, flourish in media containing organic matter, accordingly a pure air is not so likely as an impure one, either to contain nourishment for any elementary forms of life productive of disease, or to be the carriers of the same. Dr. Fuller writes[1] "the more closely human beings are congregated together the more abundant will be that wonderful micro-organic life which goes on unseen, and often unheeded, around us and about us, exerting its baneful influence on the crowded millions packed away in our great cities insidiously eating away their lives with consumption."

Some animals that are kept for a long time in confinement are affected in a manner similar to man. The monkeys of our Zoological Gardens are well known to die in great numbers from this disease. Dairy cows that

the late Dr. MacCormack, Dr. Leared, Dr. Hjaltelin, and others, as to whether Phthisis is or is not indigenous in Iceland.

[1] *South Africa as a Health Resort.*

are kept immured in close, ill-ventilated sheds in cities and towns also suffer from a form of tuberculosis.[1]

Strumous diseases and overcrowding.

As regards the connection between the other strumous diseases and overcrowding, abundant proof is to be found if looked for. Scrofula once prevailed to such an extent in the Asylum of the house of Industry, Dublin (so Carmichael affirms), that it was regarded as a contagious complaint. The air was so impure in consequence of the excessive overcrowding as to be unendurable when the wards were first opened in the morning, and to be "but little better" during the day time.

The communicable eye disease, so common in asylums and schools for children, is another of the legacies of our overcrowding. The injurious effects of rebreathed air, and the want of any provision for ventilation, is not only seen in the public schools for the poor, but in private schools for middle classes. I once visited a "College for Young Ladies," which contained rooms 12 ft. × 9 ft. × 8 ft. high, in each of which slept six girls, between the ages of 10 and 17, in two beds. Not a fireplace or other means of ventilation existed. This school, which was a popular one, had, like a concertina, a wonderful power of expansion—those who could not be accommodated with beds being stowed away on floors and in day rooms. That young women, at the most delicate period of their lives, should be thus injured by thoughtless parents, who care more for the cheap purchase of a smattering of accomplishments than a healthy frame, is a great evil. Every school should be under the supervision of the Health Authority of the district in which it is situated, so that a guarantee may be afforded to the State that the young be not subjected to the cruelty of slow poisoning by foul air.

The relation between such lung diseases as bronchitis

[1] Vide *Annales d'Hygiène*, vol. ii. p. 447.

and pneumonia, and the unwholesome condition of the air of our dwellings, has not been sufficiently recognized by the medical profession and the public. One of the most common causes of an attack of bronchitis is a sudden exposure of the bronchial mucous membrane to extreme meteorological conditions of air. A man who breathes for some hours the hot and dry vitiated air of an unventilated room is prone to be thus affected on passing out into cold damp night air. If debilitated from any cause, the inflammation may affect the substance of the lung, and the man will have pneumonia.

Diseases of respiratory organs and impure air.

Rapid alternations of temperature and moisture are apt to be attended with risk to health to those who have passed the period of youth during which the body quickly adapts itself to altered atmospheric conditions. The body, in the middle-aged and old, always experiences a difficulty in suddenly accommodating itself to extreme ranges of temperature. By substituting for the overheated and impure air of our houses and public buildings a pure wholesome air, of a temperature adapted to our sensations of comfort, by the establishment of an efficient system of ventilation, we shall avoid the danger of sudden and extreme changes which continually menaces those organs in which the blood and air meet.

A Fellow of the Royal Society has recently publicly declared that there is not a perfectly healthy dwelling-house in the country. Although that at first sight seems an exaggerated view, yet it is not far short of the truth. I only know of one room in this country in which there is any good ventilation, namely, the House of Commons. All the patents that have ever yet been devised are inefficient and faulty, although some very elaborate ventilating and warming arrangements for the comfort of guests have of late been established in some of the continental health resorts, notably at the large Kursaal on

One well-ventilated room in the country.

Uselessness of the numberless popular ventilators.

the Maloja plateau of the Upper Engadine. Amongst the dozens of contrivances that are described and figured in F. Edwards' book, entitled *Ventilation and Heat*, not one fulfils the requirements of a good ventilator, namely, the constant passage into each room of pure air of a healthful degree of humidity—warmed in winter and cooled in summer—with an accompanying provision for the immediate removal of that which has been breathed, in such a manner that no draught is created. The most modern are Tobin's tubes, Fischer and Stiehl's tubes buried 9 or 10 feet in the ground, whereby air is warmed 8° or 9° F. in winter and cooled 1·2° or 13° F. in summer. Motive power for the circulation of air has of late been obtained by gas jets, by a jet of water (Messrs. Verity's plan), and by *exhausting* cowls and other devices.

To intercept the fuliginous particles of the air by gauze curtains; to pass the inflowing air through an atmosphere of spray; to artificially warm it in winter, and cool it in summer with ice: all this preparation of the air can be carried out in public buildings like the Houses of Parliament, but such arrangements are quite impossible in the case of the majority of private houses. As regards cottages, the mere hint at such a project is absurd in the extreme.

An American architect has expressed the opinion [1] that a building cannot be supplied with cool air of a pleasant degree of humidity when the external air is hot and damp, for the cooling would be attended by the condensation of the moisture and the formation of a mist. This change cannot, I admit, be produced without a preparation of the air in underground chambers adapted for the purpose, such as are available beneath public buildings or large houses. In the case of the majority of

[1] "On the Relation of Moisture in Air to Health and Comfort," by Robert Briggs, C.E., in *Quarterly Journal of Science*, April 1878.

houses, air, when hot and moist, can be passed through a room with greater rapidity than usual, and the occupants will experience the cooling effects produced by the more frequent renewal of air. The establishment of a comfortable uniform loss of heat by the body is the point to be arrived at in our efforts to determine the requisite speed for the passage of the air.

Rôle of physicians is to excite the demand for efficient ventilating contrivances.

Physicians are waiting for inventors to deal with this difficult subject of providing the habitations of the people, poor as well as rich, with some efficient and simple ventilating methods, remembering the above indispensable requisites. There is no difficulty as regards public buildings, such as churches, meeting halls, concert rooms, theatres, ball rooms, etc. They can all be ventilated and lighted in the same manner as the House of Commons. An exposure of the body, and especially of that part of it named the pulmonary surface, to sudden and extreme ranges of temperature, as in coming out into the cold air from a hot, ill-ventilated church or other public building, should be regarded as attended with a certain amount of risk to all, and a positive danger to the aged and weakly.

The rôle to be played by the Medical Officer of Health and other sanitarians in the public interest, is to urge Local Boards of Health to refuse to pass the plans of houses in which there is no efficient provision for the removal of used-up air, as well as of other effete and noxious matters. When a great demand is in this way excited, a vigorous attempt will be made by those who devote their energies to the invention of contrivances for our health and comfort to supply that want.

The standard of pure air for our dwellings and for all places of public resort, which we should endeavour to reach, may be considered to be thus constituted :—

Standard of pure air.

*Active Oxygen, Ozone, and other air purifiers,* in recognizable quantities.

*Organic Matter, as Albuminoid Ammonia,* as near ·08 milligram. per cubic metre as possible.

*Carbonic Acid*—Not more than ·06 per cent.

*Temperature* to be determined by the sensations of the majority as to comfort.[1]

*Moisture*—Relative humidity 70 to 75 per cent. A difference between the dry and wet bulbs of about 5 or 6 degrees.

To approach this standard as closely as possible should be the aim of all who study the construction of healthy homes for the people.

The practical question arises—How are we to make an attempt to arrive at any point on the road to this standard amongst the cottages of the poor? The difficulties are enormous in many cases. In the rural districts, where the houses are surrounded generally by pure air we insist on every inmate (age not considered) having at least 200 cubic feet of air by night. In tramps' lodging-houses 300 cubic feet of air in a sleeping-room, and 400 cubic feet in a room used for sleeping and as a day room, are the minimum quantities sanctioned by the Local Government Board. In towns, where the air is more or less impure, a larger quantity of air per individual should be insisted on. We should gradually aim at obtaining not only the largest amount of breathing space that is practicable, but some efficient provision for the change of air to the extent of from 2000 to 3000 cubic feet per hour, or about 10,000 gallons of air per head, per hour.

[1] The temperature of comfort of air indoors has been variously stated:—
55° to 58° F. Hood's *Treatise on Warming Buildings.* 59° F. Peclet's *Traité de la Chaleur.* 56° to 62° F. Tredgold's *Principles of Warming and Ventilation.* 60° F. Dr. Richardson. 62° F. Box's *Practical Treatise on Heat.* 65° F. Reed's *Illustrations of the Theory and Practice of Ventilation.* 48° to 60° F. Parkes' *Manual of Hygiene.* 59° F. Nurseries; 66° F. German Schools; 61° to 64° F. Hospitals; 66° to 68° F. Theatres and Assembly Halls.—Morin's *Etudes sur la Ventilation.*

How is this to be accomplished? Happily, for the sake of ventilation, the majority of our cottages have an abundance of chinks and crevices that admit air from without. Fortunately, also, a considerable change of air is effected through the walls of our dwellings, if they are composed of brick, or mud, or tufacious limestone or wood.

Permeability of walls.

Professor Pettenkofer has, by experiments, shown[1] that through a room made of brick walls, of the capacity of 2650 cubic feet, every crack and hole in which was thoroughly plugged up, 1060 cubic feet of fresh air passed per hour, by virtue of the difference of temperature (30° F.) between the outer (32° F.) and the inner (62° F.) air. He found that, with a difference of temperature of 9½° F. between the outside and the inside of a room, the spontaneous ventilation through each square yard of the free wall amounted to about 7 cubic feet, or 43 gallons per hour.

Märker's and Schultze's experiments on the spontaneous ventilation of stables confirm these observations. They discovered that with a difference of temperature of 9½ F., the passage of air through each square yard of free wall was—

| | | | | |
|---|---|---|---|---|
| With walls of | Sandstone . . | 4·7 | cubic feet | per hour. |
| ,, | ,, Quarried Limestone | 6·5 | ,, | ,, |
| ,, | ,, Brick . . | 7·9 | ,, | ,, |
| ,, | ,, Tufacious Limestone | 10·1 | ,, | ,, |
| ,, | ,, Mud . . | 14·4 | ,, | ,, |

All the ordinary building materials, such as plaster, wood, cement, etc., are more or less porous, and admit the passage of air through them in such a manner that we are not conscious of the movement. We are insensible to the passage of air if the velocity of the same is less than 19 inches per second.

It will, perhaps, be considered by some that to change the air of a cottage at the rate of between 2000 to 3000

[1] *The Air, in relation to Clothing, Dwelling, and Soil.*

cubic feet per hour per individual, at a velocity, to avoid draught, of less than 19 inches per second, is to supply an enormous and unnecessary amount of fresh air, and is, moreover, a thoroughly impracticable project. Our continental neighbours do not consider this amount excessive, if we may judge from the following table, given by Pettenkofer and Morin, of their demands as to change of air in their buildings per hour per person :—

| | | |
|---|---|---|
| Hospitals for ordinary cases | 2120—2470 | cubic feet. |
| ,, for wounded | 3530 | ,, |
| ,, for epidemics | 5300 | ,, |
| Prisons | 1766 | ,, |
| Workshops—ordinary | 2120 | ,, |
| ,, unhealthy | 3530 | ,, |
| Barracks—day | 1060 | ,, |
| ,, night | 1410—1765 | ,, |
| Theatres | 1410— ,, | ,, |
| Large rooms for long meetings | 2120 | ,, |
| ,, for shorter ,, | 1060 | ,, |
| Schools for adults | 880—1060 | ,, |
| ,, for children | 424— 530 | ,, |

Provided we keep our walls dry, for then we maintain them in a porous condition, as moisture renders them impermeable, so long we can draw a very large quantity of air through our walls, with but little difference of temperature between the inside and outside of the house.

Ventilation. If this spontaneous ventilation is supplemented by some simple contrivance, such as a Tobin's tube, a Chowne's tube or Hinckes Bird arrangement, which cannot be interfered with, for admitting fresh air in so broken-up and divided a state as that its flow shall be unfelt by the occupants, all that can be done will have been accomplished for the majority of our old isolated cottages in the country districts, the repairs of which often consume the whole of the yearly rental. Pettenkofer rightly says, "It is a waste of ventilation if it is directed against avoidable pollutions of the air . . . the proper domain of ventilation begins when cleanliness has done its best." We ought not, however, to let matters rest here as regards the rows of cottages in our towns and cities, which have but little free wall surface, and are often merely foul caves with no opening at the back to allow of the free passage of air. Thousands and thousands of these urban dwellings of the poor are caricatures of what cottage homes should be, namely, a healthful place for rest, refreshment, and cheerful intercourse after toil, and would be more truthfully designated human piggeries. Who is there amongst medical men that is not familiar with the appalling infanticide that prevails amongst these districts which have been designated "Herodian," mainly due to the foul air (for young lives are the most sensitive tests of the existence of an infraction of sanitary laws), and partly, no doubt, to improper feeding and neglect. That noble appeal of Charles Dickens for legislation for the poor cannot but be remembered in thinking of this sad subject: "If those who rule the destinies of nations would but think how hard it is for the very poor to have engendered in their hearts that love of home from which all domestic virtues spring, when they live in dense and squalid masses, where social decency is lost, or rather never found,—if they would but turn aside from the wide thoroughfares, and great houses, and strive to improve the wretched dwellings in byeways, where only poverty may walk—many low roofs would point more truly to the sky than the loftiest steeple that now rears proudly up from the midst of guilt and crime and horrible disease, to mock them by its contrast." What a picture was sketched of these dreadful places by Dr. Buchanan, when he was one of the travelling inspectors of the Local Government Board! "In small closed courts, surrounded by high buildings, and approached by narrow and perhaps winding gangways, houses of the meanest sort stand, acre after acre of them, with but privies and dust bins to look upon. And surely such cannot be accounted fit for human habitation, while the standard of that humanity is low. Nothing short of a tornado can effectually ventilate these courts; in still weather the atmosphere in them is unchanged and unchangeable. Can it be a matter of surprise that such regions should be the favourite pastures or hunting-grounds of filth diseases, and that moral as well as material deterioration should be invariable accompaniments? It may be truly said of many evil things, that 'like goes to like.' Happily the Artisans' Dwellings Bill, *alias* the Rookeries Bill, has been passed, which aims at the demolition of these nests of disease and crime; and which will, it is to be hoped, gradually diminish the most depraved and unhealthy modes of life."

# PART II

## THE DETECTION AND ESTIMATION OF THE AMOUNT OF THE MOST IMPORTANT IMPURITIES FOUND IN THE AIR

TWO methods of discovering the condition of the air, as to purity, a direct and an indirect one, have been in vogue: the direct which is either (*a*) chemical, having for its object the detection and estimation of the quantity of impurities, such as the organic and other solid bodies, and the carbonic acid present in the air, or (*b*) biological, which is concerned in the estimation of the number of germs present in a known quantity of air; and the indirect one being to ascertain its departure from a state of purity by the estimation of the amount of ozone and other purifying agents which have not been used up by the organic matter and by the various noxious gases with which the air is contaminated.

# CHAPTER XXV

## MODES OF OBSERVING SOLID BODIES IN THE AIR, AND OF SEPARATING THEM FOR EXAMINATION

Solid bodies in the air.

As far back as 1830, Ehrenberg worked and published on this subject. He showed the actual existence of an atmospheric kingdom of life, animal and vegetable. He was followed by M. Gaultier de Claubry, who passed air from various localities through water that had been exposed to a high temperature.

During the cholera epidemic in England of 1849, the dust of air was much examined, in consequence of the supposed discovery of certain bodies termed cholera fungi in infected air. M. Quatrefages, Pouchet, Pasteur, N. Joly, and Charles Musset, Boussingault, Baudrimont, and Gigot, are foreigners who have all severally laboured at this subject from different points, the first five being especially interested in it in relation to the doctrine of spontaneous generation.

Devergie examined the air in the vicinity of a case of hospital gangrene, and detected an enormous quantity of organic matter in it. Bits of wool, cotton, particles of hair, and epithelial cells and starch, were most common.

In the Army Medical Report for 1867, is an account of an experimental investigation made by Dr. F. de Chaumont into the ventilation of the new barracks at

Chelsea. He passed 120 cubic feet of air through a freezing mixture, and 4·7 c. c. of fluid condensed from it contained epithelium in large amount, hair and various fibres, sand, soot, crystalline substances, and chloride of sodium, together with sporangia of fungi, and monads in considerable quantity. In the air of a back yard of a London Hospital he found considerable quantities of epithelium; and in the "dirty linen area," where the foul linen was kept in crates until washed, pus globules and a quantity of fatty crystals apparently from dressings, bacteria both free and in the zooglæal form. In the Accident Ward of St. Mary's Hospital, Paddington, he discovered pus cells in the air near some beds which had a bad reputation for erysipelas.[1]

The Army Medical Report for 1868 contains similar observations by Dr. R. T. Wright on the air of the barrack-room, Royal Victoria Hospital, Netley.

In 1861 MM. Eiselt and Bechi published the result of some experiments. In the same year an investigation was undertaken on behalf of the *Lancet* on the dust of town houses in dry weather. The result of this inquiry showed that it consisted of pulverized horse dung, and the grindings of shoe leather, and starch corpuscles.

In 1862 Reveil and Chalvet made some observations on the air of the surgical wards of the Hospital of St. Louis.

Dr. Jefferies Wyman and Dr. Salisbury were the earliest of American workers on atmospheric dust.

Samuelson and Balbiani have also made experiments on this subject.

Dr. Salisbury's observations especially related to the air of the low marshy valleys of the Ohio and Mississippi in connection with the causation of intermittent and

[1] "Three Reports on the Sanitary Condition of St. Mary's Hospital, 1875-76."

remittent fevers[1] in which he found palmelloid growths. M. Lemaire's researches, communicated to the French Academy in 1863, partly related to marsh air in the neighbourhood of Sologne, which was a highly malarious district. Selmi and Balestra have both made observations on the air of swamps, and both describe the presence of myriads of spores of algæ. The experiments of the latter were made on the air of the Pontine marshes.

A great many examinations were made of the dust of the air during the cattle plague epidemic of 1866. It was collected in most cases by passing it through cotton wool. In 1867, M. Poulet reported that he found a number of bacteria in the condensed vapour of the breath in whooping cough.

Tissandier found that atmospheric dust contains from 25 to 34 per cent of combustible, and from 66 to 75 per cent of incombustible matter. He passed a measured volume of air through distilled water which he evaporated, and then weighed the residue. In this manner, 1 c. c. of air yielded—

| | | Gramme. |
|---|---|---|
| In Paris | After heavy rain | ·006 |
| | After 8 days of dry weather | ·023 |
| | Under normal conditions | ·007 |
| In the country | Under normal conditions | ·00025 |
| | After lengthened drought | ·003 |

A rough-and-ready way of observing the dust of air is by admitting a ray of sunlight into a darkened room, when the "motes in the sunbeam," as the particles of dust have been popularly called, are visible to us.

Professor Tyndall's experiments.

Professor Tyndall has employed the very powerful beam of the electric light for the purpose of rendering the dust of air more apparent, with which he associated the flame of a spirit lamp that created an appearance, when applied to the beam, of the ascent of dark wreaths of

[1] *American Journal of Medical Sciences*, April 1866.

intensely black smoke. A large hydrogen flame produced the same effect. The blackness proved to be due to the absence from the track of the beam of all matter capable of scattering its light, which had in fact been burnt. He said, in his lecture, delivered in the Royal Institution at the end of 1869 or commencement of 1870:—

"Nobody can without repugnance place his mouth at the illuminated focus of the electric beam, and inhale the dirt revealed there. Nor is the disgust abolished by the reflection, that, although we do not see the nastiness, we are churning it in our lungs every hour and minute of our lives. If, after inspiring a quantity of common air, a long expiration is made through a glass tube across the electric beam, the luminous track is at first uninterrupted. The breath impresses on the floating matter a transverse motion, but the dust from the lungs makes good the particles displaced. After a time, however, an obscure disc appears upon the beam, and at the end of expiration the beam is, as it were, pierced by an intensely black hole, in which no particles whatever can be discerned. The air in fact has lodged its dirt in the lungs. A handful of cotton wool placed over the nose and mouth during inspiration makes the dark hole in the beam of light appear from the beginning of expiration. A silk handkerchief[1] answers nearly as well."

[1] The old-fashioned practice amongst the public, often witnessed by medical men, of holding a handkerchief to the mouth and nose on approaching the bedside of a person suffering from an infectious disease, may, in the light of recent investigations, have been a wise proceeding, and was doubtless intuitively arrived at and found by experience to be protective to the health. Sometimes scents were employed, not only in the handkerchief but in the sick-room (*vide* "Perfumes and Ozone," in *Ozone and Antozone*, pp. 121, 122). People very commonly apply a handkerchief also to the nose and mouth when they come into contact with a stench, to prevent the offensive odour from annoying them. The linen or cotton fabric no doubt acts as an imperfect filter, which strains off the solid particles floating in the air, with which that unpleasant odour is associated

Mr. C. Tichborne communicated to the British Association, in 1870, an account of his experiments on the air of Dublin. Street dust he said, was mainly composed of stable manure and triturated stones.

The dust of New York has been examined by the New York Officers of Health by exposing glass plates to the air. The same substances were present in all of the specimens; street dust, particles of sand and carbon, fibres of cotton, fragments of vegetable tissues, granules of starch, three different kinds of pollen grains, micro-organisms, and fungal elements. The latter were abundant, ranging in character from a micrococcus to mycelial filaments. When water was added to the specimens, bacteria and vibriones invariably made their appearance within a few hours.

Dust of Paris.

M. Miquel furnishes the following estimate of these micro-organisms, which, as will be seen, vary in number in the dust of different localities:—

| | No. of Bacteria in 1 gramme of dust. |
|---|---|
| Observatory of Montsouris near Paris . | 750,000 |
| Rue de Rennes, Paris . . . | 1,300,000 |
| Rue Monge, Paris . . . . | 2,100,000 |

Mr. Blackley[1] has devoted his attention to that particular kind of air dust that produces hay fever, namely, the pollen of certain kinds of grasses.[2]

A good account of the great variety of particles of which atmospheric dust is composed is contained in Charles Robin's *Traité du Microscope.*

The space at my disposal will not permit me to enter

[1] *Experimental Researches on the Causes and Nature of Catarrhus Œstivus*, by C. H. Blackley, 1872.

[2] He refers to one species, the pollen of which is so small that it would require 37 millions to make a grain; whilst 6 millions are required of the particles of pollen of the English meadow grasses. He considers that $\frac{1}{760}$, or the 3427th part of a grain, is capable of producing the severest form of hay fever.

on that very large field as to the presence of those organic substances in air which have in past times fallen in showers, giving rise to the belief that blood and sulphur have descended from heaven. I must refer my readers to a little book, named *Odd Showers*, which is published by Kerby and Son, of Oxford Street, for much interesting information as to these records.

The observations of Messrs. Tichborne, Blackley, and others, would lead one to think that the spores of fungi and other light bodies are to be detected in the air at very great heights, and that they are conveyed by aerial currents and storms from one part of the earth to another over vast tracts of country.

The air dust, such as we breathe, may be conveniently collected, for either microscopical or chemical examination, in several ways :—

Pouchet's aeroscope.

1. By means of Pouchet's aeroscope,[1] which consists of a glass tube hermetically closed at either extremity by a copper ferule. The upper ferule is fixed to the glass, and is connected with a tube of copper, terminating externally in a small funnel, and internally in the inside of the glass tube, in a very finely drawn point, not more than ·5 m. m. in diameter. The other ferule is removable, and allows of the introduction of a circular glass plate into the interior of the instrument, which is placed at 1 m. m. from the point of the tube connected with the upper ferule. This plate is covered with adhesive matter; and, if necessary, the point of the tube is made to terminate in a minute perforated diaphragm like the rose of a watering pot, so as to secure the dispersion of the atmospheric particles over the surface of the plate.

[1] Moyen de rassembler dans un espace infiniment petit tous les corpuscles normalement invisibles contenus dans un volume d'air déterminé.—*Comptes Rendus*, T. i. p. 748.

Cunningham's apparatus.

The apparatus employed by Dr. D. D. Cunningham,[1] in his numerous observations on atmospheric dust, consists of three thin brass tubes (A), two of which slip over the third central one, and come into contact with the opposite sides of a projecting rim on its circumference. This rim is formed by the margin of a diaphragm, which divides the centre tube into two chambers. It is of sufficient thickness to allow of a spindle passing up through it (B).

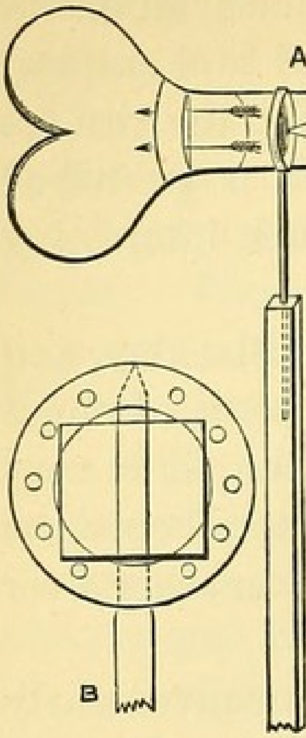



FIG. 19.

Dr. Maddox's Aeroscope Pump

Dr. Maddox's Aeroscope Pump[2] is an improvement on his aeroconiscope. It consists of two metallic chambers A and B screwed together, the chamber A being

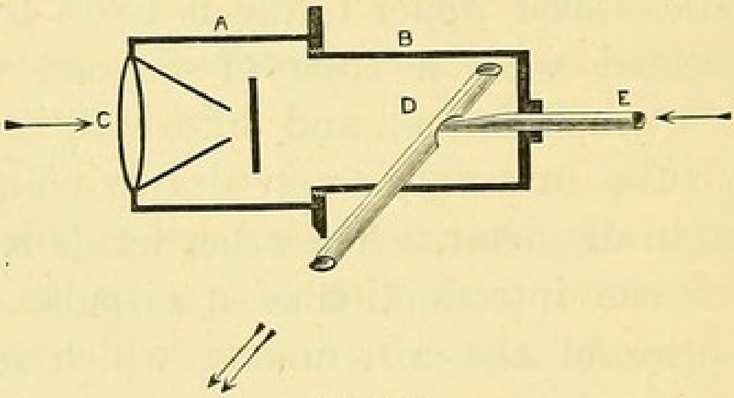



FIG. 20.
Aeroscope Pump.

furnished with a perforated cone intended to project the dust of the air on a slip of glass covered with glycerine. This chamber is in direct communication with the chamber B, which contains an aspirator. The water passes drop by drop by the tube E into the tube D which is in-

[1] *Microscopic Examination of Air*, by Dr. D. D. Cunningham, Surgeon, H. M. Indian Med. Service. Published by Government, 1874.

[2] *Journal Microscop. Socy.*, 2d series, vol. i. p. 338.

clined at an angle of 45° with the axis of the instrument. The tube D is open at its upper end, and has a flute-like aperture laterally below the entrance of E. A litre of water is sufficient to pass 66 litres of air over the glass slip.

The great objection to the three foregoing varieties of the same method is, that it is difficult to obtain glycerine perfectly free from foreign bodies.

2. A glass tube is heated to redness, and, when it has cooled, is surrounded by a freezing mixture. Air is then drawn by an aspirator through the tube. The great cold condenses the moisture of the air, and arrests its solid particles which is in both cases collected and examined for nitrogenized compounds.

3. Dr. Watson employs fine glass threads soaked in glycerine or powdered glass, as traps for catching the solid substances which he afterwards washes with pure water. Perhaps the substance known as glass wool would prove a still more effectual air filter.

4. I use a mineral named asbestos, which is a fibrous and woolly substance, composed of a silicate and aluminate of magnesia and lime, for arresting the dust of the air. A U-shaped platinum tube about $\frac{1}{4}$ inch in diameter, and 7 inches long, having been filled at the bend with this inorganic wool, and little caps of fine platinum gauze being inserted at each end of the asbestos to prevent the loss of any of its particles, a known volume of air is drawn through the tube by means of an aspirator. The tube loaded with asbestos is weighed in a delicate balance, both before and after the air is passed through it. The increase in weight, after the experiment, of course indicates the amount of solid particles contained in the quantity of air drawn through the tube by the aspirator. The platinum tube is then exposed to the flame of a Bunsen's burner, in which it soon becomes red hot. When all the volatile solid bodies, such as organic matter, nitrates, etc.,

have been burnt off, the tube having been again weighed is ready for a fresh experiment.

5. By taking the rain, which is *the* great air washer, and removing, by means of a pipette, the solid particles that subside in it after a few hours' rest.

6. M. Pasteur filtered a certain quantity of air through perfectly pure pyroxyline, which is soluble in a mixture of strong alcohol and ether. A tube containing a plug of this material was attached to a water aspirator, from the exit portion of which the amount of air drawn by the instrument per minute, can be easily collected and measured. The cotton plug, on removal, was treated with its solvents, and the dust then allowed to subside. The complete removal of the pyroxyline was effected by adding, and after a time removing, fresh quantities of alcohol and ether. The dust is then transferred to the microscope slide for examination.

7. M. Marié-Davy of the Montsouris Observatory collected the dust of the air in a receiver which was connected with an aspirator such as is represented in Fig. 21. The receiver was composed of a bell glass, the roughened lower edge of the large opening of which rests on a piece of plate glass also roughened. The upper and small opening is closed by a cork, which is perforated by two glass tubes: one of them, marked *c*, is connected with the aspirator; the other, *h*, terminates at one extremity in the air, and at the opposite, within the bell glass, in a tapered point, a short distance from a glass plate covered with glycerine or syrup.

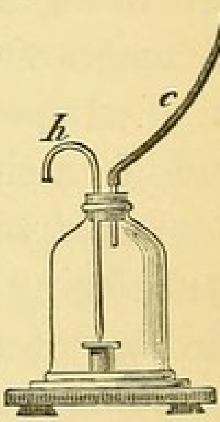


Fig. 21.

The arrangements carried out by M. Miquel in this Observatory for the collection of the schizomycetes, such as the micrococci, bacilli, bacteria, etc., are most elaborate and ingenious. The latest and most improved forms of apparatus will be referred to in the chapter on "The Biological Examination of Air."

## CHAPTER XXVI

### MICROSCOPICAL EXAMINATION OF THE DUST OF THE AIR

Dust derived from animal, vegetable, and mineral kingdoms.

THE air contains such an immense variety of substances in the form of dust, invisible to the naked eye, that their bare enumeration, without entering into any description of them, would occupy a considerable space. Minute particles of anything and everything that exists on the earth, are liable to be mingled with the air that rests on it. Such minute organisms as micrococci, bacteria, and bacilli, are omnipresent except in the pure air of the highest mountains and far away at sea. As the air, in which we are always plunged, invariably contains more or less of these minute objects, our bodies [1] are naturally invaded by the same. These suspended matters are furnished by the animal, vegetable, and mineral kingdoms.

From the animal kingdom is derived the débris of little creatures who have been born and have lived and died in the atmosphere, germs and small eggs.

From the vegetable kingdom, spores of fungi, the pollen of plants and seeds of all kinds, particles of finely pulverized straw, minute fragments of rags, etc., are obtained.

From the soil, dust of inorganic composition, such as sand, oxide of iron, lime, etc.; from volcanoes, sand and

[1] M. Lemaire finds not only in the air that passes from the lungs, but also in the perspiratory fluid, abundant indications of animal and vegetable life.—*Comptes Rendus*, October 14, 1867.

mud, and small particles of carbon; from the sea, chloride of sodium which is lifted by the spray and conveyed by the wind vast distances:—are contributed.

It is in respect to the dust and impurities in the air, created by man and animals, and by vegetation, in which we are at present most interested, as they relate more especially to public health. Excluding, then, a consideration of the solid particles diffused through the air in manufactories, and mines, to the injurious influence of which so many of our fellow-creatures are unhappily exposed, let us ask ourselves the question "What appearances do the minute solid impurities contained in the air of our dwellings and public buildings, and of our streets, present under the microscope?" Air dust has been divided into the light, which floats and is wafted about by currents, and the heavier particles that settle. The dust of our houses consists largely of light organic matter, either living or dead, whilst that of public buildings would appear to contain a larger proportion of the heavier kinds. Dr. Percy found that the dust on the walls of the British Museum consisted of 50 per cent of incombustible matter. The principal objects which we see in the dust of rooms and hospitals with high powers are little portions of (1) scaly epithelium (the dust of the skin), (2) particles of soot, (3) small round and oval cells, which, when multiplying, have an appearance like the number 8. These little bodies have been named "putrefaction cells," and by some microzymes, and have been described by Trautman, Lemaire, and Béchamp. Their growth is accelerated by hydrogen sulphide and other vile-smelling gases, and is arrested by carbolic acid, which is one of our most valuable disinfectants. Lemaire found them in immense quantities in the air of dirty prison cells. They belong to that border land which is midway between the animal and vegetable kingdoms. We know not whether they are animals

Dust of the British Museum.

or vegetables. They bear a strong resemblance to certain kinds of bacteria found in impure air and water. These organic impurities in air are favourite pastures for the growth and development of the animal poisons that produce the zymotic diseases, such as typhoid fever, scarlet fever, etc. The poisons of these diseases rejoice and luxuriate in filth of all kinds, especially in filthy air. The spores of tricophyton have been collected in the wards of hospitals devoted to skin diseases, and those of achorion schönleinii in wards containing cases of favus.

The organic impurities furnished by different diseases.

The air of sick rooms and hospitals that are not ventilated efficiently, is loaded with organic impurities, which, in certain diseases, furnish different odours,—for example, a medical man usually recognizes the presence of small-pox or rheumatic fever in a house by their characteristic odours. The smell of a room occupied by a person who is suffering from abscesses is almost distinctive of this class of malady. In smallpox wards minute scales and dust of dried pustules, which, if introduced into the system of one unprotected by vaccination, would reproduce the disease, are found floating in the air. In hospitals devoted to skin diseases, that contain patients suffering from favus, ringworm, etc., which depend on the growth in the skin of little parasitic plants or fungi, the spores or seeds of these plants may be found suspended in the air.

The air of the streets and gardens of our towns and cities contains soot, crystals of certain salts, starch granules, linen, cotton and wool fibres, bits of wood, and particles of food, the hairs of man and animals (dogs and cats).

The character of the dust of the air that is found between the pure air of the country and the impure air of a large city has been well observed by M. Marié-Davy and his associates at the Montsouris Observatory, in the neighbourhood of Paris.

Bodies collected on glycerine from December 30, 1875, to January 2, 1876, × 1000 :—

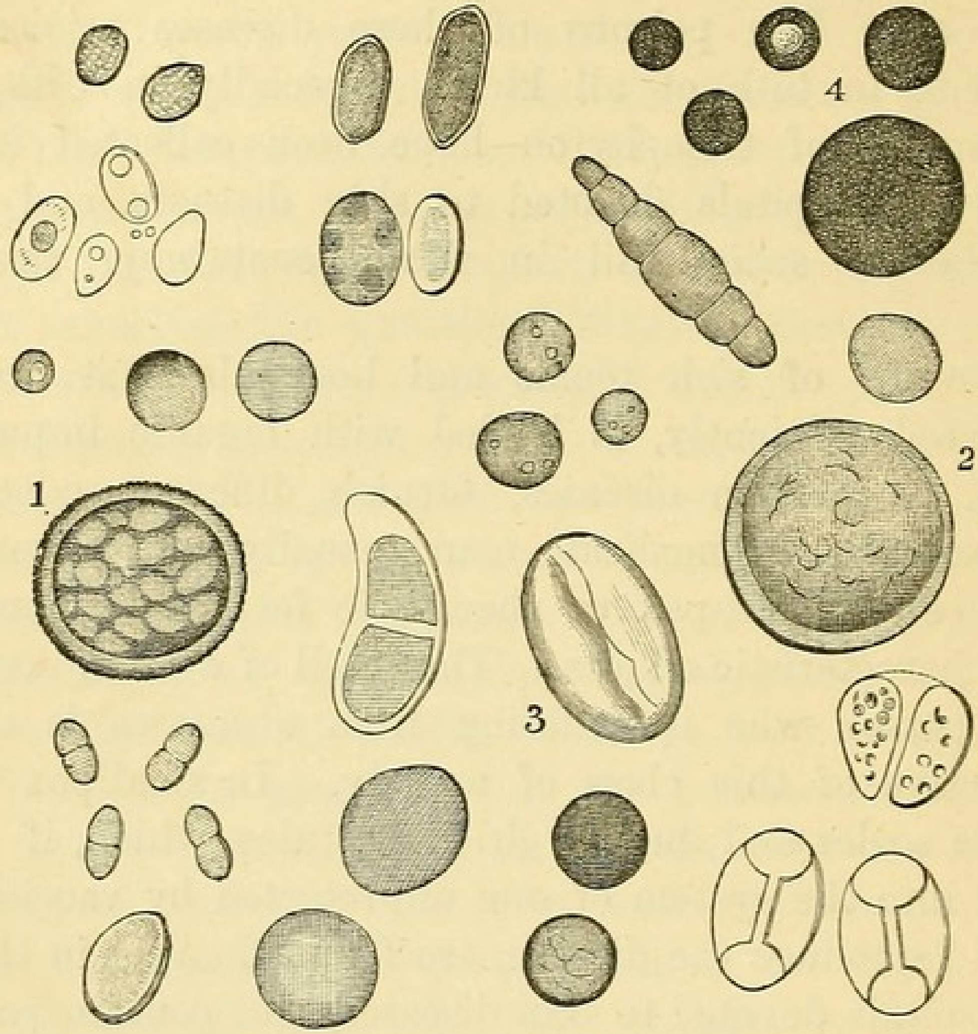



FIG. 22.

1 and 2, Pollen ; 3, Starch ; 4, Three of these reddish black bodies were attracted by the magnet, and are gran-

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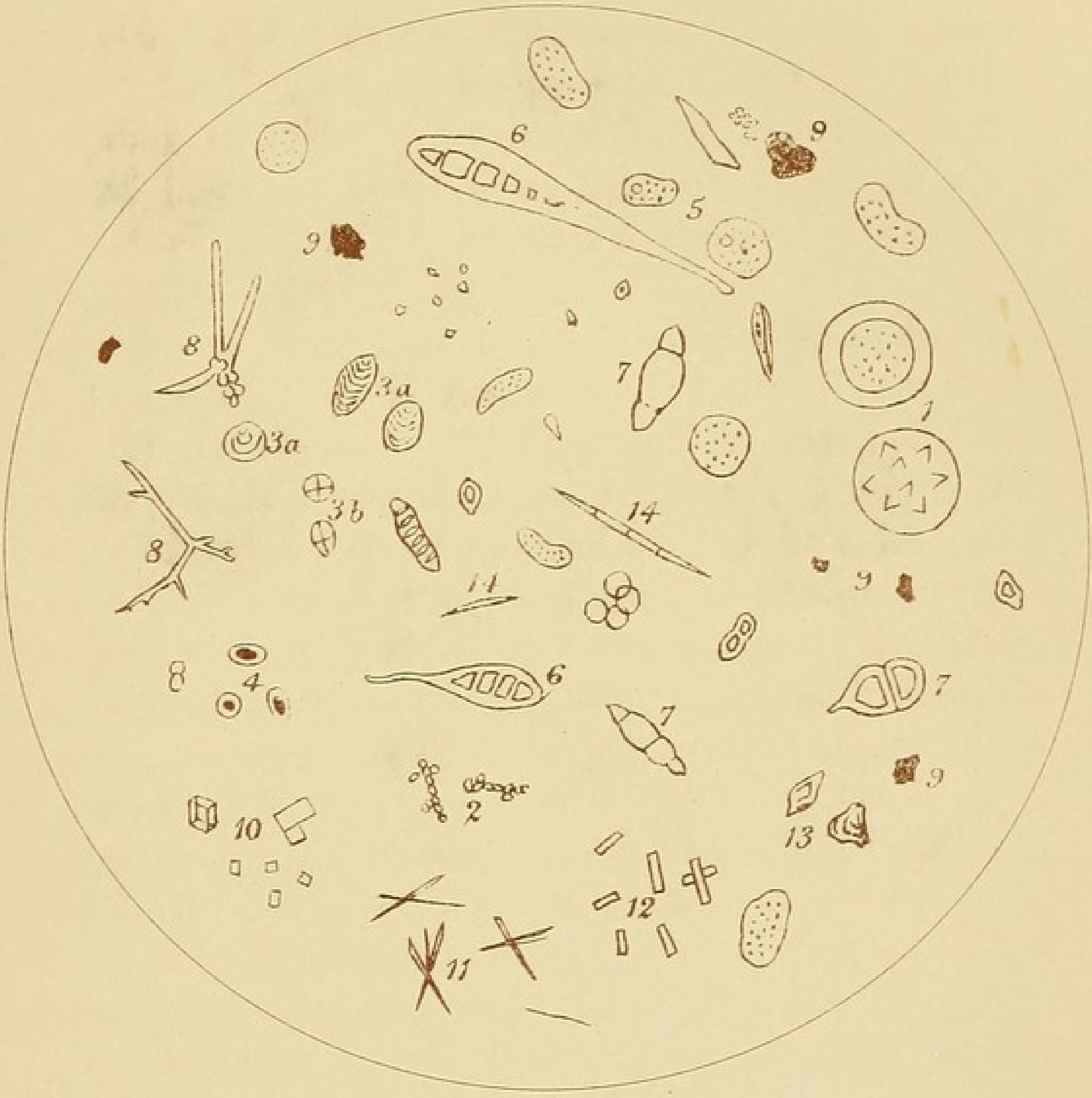
DESCRIPTION OF PLATE OF MICROSCOPIC OBJECTS FOUND IN AIR.

1. Pollen.
2. Fungi.
3*a*. Starch granules.
3*b*. Starch granules polarized.
4. Protococcus pluvialis.
5. Epithelium.
6. Vegetable spores.
7. Spores?
8. Fungi?
9. Particles of soot.
10. Crystals of chloride of sodium.
11. Crystals of chloride of ammonium?
12. Crystals of sulphate of soda.
13. Mineral particles.
14. Desmids?




SOLID BODIES IN AIR.

To face page 304

ules of meteoric iron, which have been described by M. Tissandier. The fourth is a spore: it is uninfluenced by dilute sulphuric acid which dissolves starch granules.

M. Pasteur suggests the institution of comparisons between the kind and quantity of organized corpuscles disseminated in the air at one place during the several seasons of the year before and after rain, etc., and at different places at the same time, with the object of increasing our knowledge of the zymotic diseases, especially when epidemics are prevalent. He found in the winter months, during a period of very low temperature, ranging from 15·8° to 6·8° F., that a very small number of germs could be collected from the air.

Micro-organisms.

Of late years much attention has been devoted by Koch, Klein, Lister, Klebs, Sanderson, and a host of others, to those constituents of the dust of the air which have been denominated micro-organisms, and between one and two thousand publications have appeared in different languages on various branches of this subject. Into one comparatively so new, with a bibliography so imposing, and which is in a state of transition from month to month as new facts are elicited, it would be unprofitable in the interests of the health officer to plunge. It will be sufficient to give: (1) an idea of the appearance[1] under the microscope of the more important of these bodies; (2) some information as to the number present at different times in pure and impure air; and (3) the reason for prosecuting researches into their life history and the conditions indispensable for the proof of the existence of a causative relation between some of them and certain communicable diseases.

The most approved and recent classification of these

[1] A good description of them is to be found in the Supplement of the Eleventh Annual Report of the Local Government Board for 1881, from the pen of Dr. Victor Horsley.

schizomycetes or fission-fungi, named also microbes, microphytes, and micro-organisms, is that of Zopf[1] who arranges them in four groups.

Group 1. COCCACEÆ—*Genera.* Micrococcus, Streptococcus (chain coccus), Sarcina (packet coccus) Merismopedia and Ascococcus.

Group 2. BACTERIACEÆ—*Genera.* Bacterium, Spirillum, Bacillus, Vibrio, Leuconostoc and Clostridium.

Group 3. LEPTOTRICHEÆ — *Genera.* Leptothrix, Beggiatoa, Crenothrix and Phragmidiothrix.

Group 4. CLADOTRICHEÆ—*Genus.* Cladothrix.

The most interesting group is that entitled the Bacteriaceæ which contains the largest number of micro-organ-

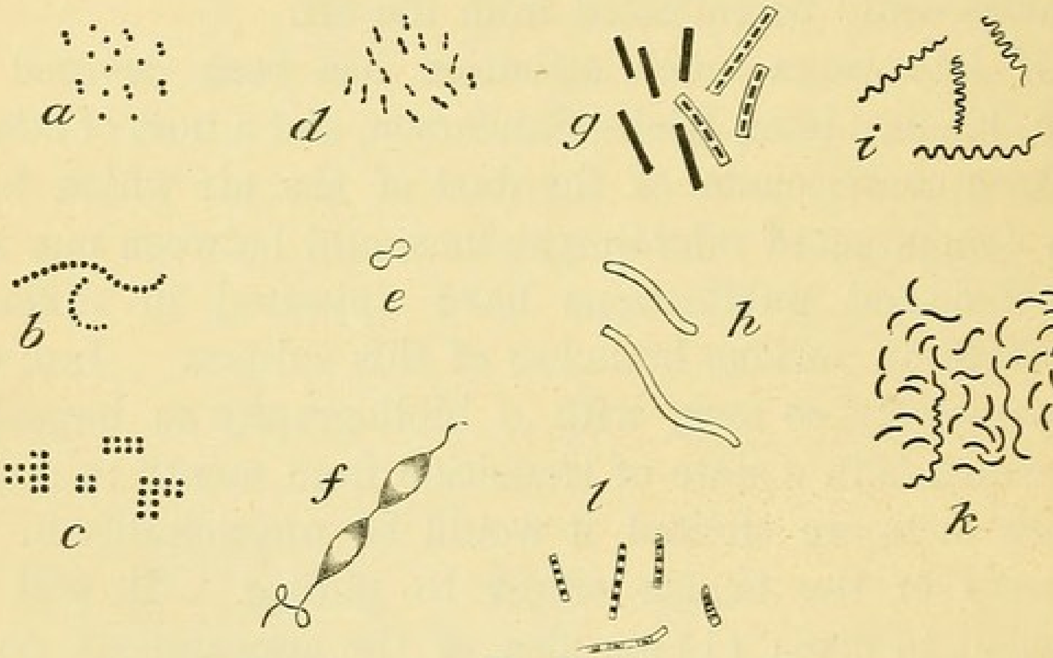


FIG. 23.

*a.* Micrococci × 600.
*b.* Streptococci × 600.
*c.* Sarcinæ (packet cocci) × 600.
*d.* Bacterium termo.
*e.* Bacterium termo, diagram of outline under higher power.
*f.* Bacterium termo, × 4000 (Dallinger and Drysdale in Crookshank's *Bacteriology*) with flagella.
*g.* Bacillus anthracis with and without spores × 700.
*h.* Vibrio serpens (after Cohn).
*i.* Spirillum Obermeieri (of relapsing fever).
*k.* Comma-shaped bacilli[2] (after Crookshank).
*l.* Bacillus tuberculosis with spores × 700.

[1] Dr. Crookshank's *Bacteriology*.

[2] There are several varieties of comma-shaped bacilli, one kind being found in the mouth in connection with caries of the teeth and another in old cheese. The cholera comma-bacillus is stated to be distinguishable from other comma-shaped micro-organisms by its behaviour under cultivation.

isms. Examples of the most important of its genera are here depicted.

These micro-organisms multiply either by division or spore formation with marvellous rapidity. Cohn has pointed out that one bacterium placed in an organic medium suitable for its growth will in 24 hours have developed 16,777,216 bacteria and in three days 47 trillions, but, that as soon as they have exhausted the nourishment on which they live, they will soon cease to exist. Although spores are more resisting than the bacilli to extremes of cold and heat and chemical agents, it is reassuring to learn that pathogenic organisms are less resistant to perchloride of mercury (our chief microbe destroyer) than non-pathogenic ones.

M. Miquel has found[1] that the number of bacteria varies much in the air at the different hours of the day,

[1] Averages in a cubic metre of air from observations during 6 years.

| Months. | Park of Montsouris. | Rue de Rivoli, Paris. |
|---|---|---|
| January | 225 | 1880 |
| February | 155 | 2480 |
| March | 495 | 3710 |
| April | 420 | 4905 |
| May | 575 | 5750 |
| June | 495 | 5535 |
| July | 740 | 5205 |
| August | 685 | 4405 |
| September | 605 | 4615 |
| October | 500 | 3825 |
| November | 335 | 2650 |
| December | 225 | 2015 |
| Annual Mean | 455 | 3910 |

| Seasons. | Park of Montsouris. | Rue de Rivoli, Paris. |
|---|---|---|
| Winter | 290 | 2690 |
| Spring | 495 | 5395 |
| Summer | 675 | 4705 |
| Autumn | 355 | 2830 |

months and seasons of the year, and in the air of different localities.[1] He noticed at Montsouris, near Paris, two minima between 2 and 3 A.M. and between 2 and 3 P.M., and two maxima between 7 and 8 A.M. and between 7 and 8 P.M. They are present in the air in diminished numbers during those atmospheric states that accompany currents from the south and south-west, viz., low barometric pressure, an excess of moisture and purifying storms.

| | No. of Bacteria per cub. metre. |
|---|---|
| [1] Sea air, Atlantic Ocean | 6 |
| Air of high mountains | 1 |
| ,, the saloons of ships | 60 |
| Air at the summit of the Pantheon, Paris | 200 |
| Air of the city of Berne | 580 |
| ,, new houses in Paris | 4,500 |
| ,, the sewers of Paris | 6,000 |
| ,, the Laboratory of Montsouris | 7,420 |
| ,, old Parisian houses | 36,000 |
| ,, the new Hôtel de Dieu, Paris | 40,000 |
| ,, the Hôpital de la Pitié | 79,000 |

*Bacteria collected from 1 cubic metre of air.*

| 1881. | Hôpital de la Pitié. Ward Michon (men) | Hôpital de la Pitié. Ward Lisfranc (women) | Rue de Rivoli |
|---|---|---|---|
| March | 11,100 | 10,700 | 750 |
| April | 10,000 | 10,200 | 970 |
| May | 10,000 | 11,400 | 1,000 |
| June | 4,500 | 5,700 | 1,540 |
| July | 5,800 | 7,000 | 1,400 |
| August | 5,540 | 6,600 | 960 |
| September | 10,500 | 8,400 | 990 |
| October | 12,400 | 12,700 | 1,070 |
| November | 15,000 | 15,600 | 810 |

Although the number of bacteria in the air outside the hospital was nearly double as much in summer as in winter, the number in the wards was not more than half so numerous in the former as during the latter season, showing the influence of open windows and *à fortiori* the necessity of efficient ventilation without draughts in the wards of an hospital at all seasons of the year.

Koch of Berlin [1] and Klein of London are assiduous in the prosecution of researches having for their object the discovery as to whether a given micro-organism can be demonstrated to be the cause of a given disease in the bodies of man and animals. To obtain proof it is necessary to fulfil the following four conditions: (1) the micro-organism in question should be found in the blood or diseased tissues; (2) successive cultivations of the micro-organism should be obtained in artificial media until its purity is undoubted; (3) its reintroduction into the body of a healthy susceptible animal should result in the production of the same disease as that from which the original organism was primarily derived; and (4) this same organism should be found in the animal thus intentionally infected. As regards the diseases of man, each of these desiderata has been supplied in the case of anthrax, and accordingly ample proof has been afforded of the existence of an etiological relation between the bacillus anthracis and woolsorters' disease.

[1] Die Milzbrand-impfung, 1883.

# CHAPTER XXVII

## THE CHEMICAL EXAMINATION OF AIR

Chemical sanitary analysis of air.

THE description of the *modus operandi* in making sanitary estimates of the degree of impurity or purity of the air must necessarily be restricted to those bodies which are the principal and universally observed injurious agents, to the exclusion of others, such as sulphuric and hydrochloric acids, arsenic, etc., that are the local and special products of certain manufacturing industries.

Organic matter and carbonic acid stand prominently forward beyond all others as the bodies which require our attention: the former because it is, if in excess, the pabulum on which animal poisons feed, amongst which they increase, and through the medium of which they spread; the latter because, whilst itself being noxious if in any large amount, it is nearly always in bad company. Dr. A. Carpenter, in his *Lectures on Preventive Medicine and Public Health*, writes, "Wherever you have excess of carbonic acid from the action of animal life, there you have also an excess of other débris, such as the organic matters which pass off from the respiratory organs; septic matters given off from the pulmonary membrane, very manifest in some diseases to the sense of smell; impure matters in the insensible perspiration; ammoniacal compounds from retrocedent decompositions—all of which are the most injurious of such impurities."

The presence of sulphurous acid from the combustion of coal in an overcrowded city, and free chlorine in the air of a manufacturing centre, may certainly tend to purify to some extent the atmosphere, which is so heavily laden with animal emanations. As the existence in air of an excess of organic matter keeps the oxygen, or its active form ozone, low—for it is always being used up in oxidizing it—so the presence of such intruders as sulphur or chlorine compounds, takes the place of this vitalizing gas. The purification of air by disinfectants after defilement reminds one of the purification by filtration of the water supply of a town that receives sewage—which is at the best an imperfect proceeding, and, moreover, a great waste of power. Far better and wiser is it to keep both these media pure, rather than, after permitting them to become impure, to then expend force (money) in endeavouring to restore them to a state of purity.

Dr. Ballard and other eminent men have diligently collected information as to the fearful pollution of air that is unceasingly proceeding, and valuable materials have been accumulated by a Royal Commission, which, after devoting two years to its work, issued in 1878 its recommendations, in which were embodied suggestions for the extension of the Alkali Acts. Seven years have passed and matters are *in statu quo* as to air pollution, so that the future presents a gloomy outlook. The scientific chemist is at length in a position to represent on paper, in the form of figures, the differences in the degree of impurity of various kinds of polluted air. This first step towards the definite and precise having been gained, it then devolves on the health officer to clearly lay down, with exactitude, the connection that exists between these degrees of impurity and certain forms of disease or ill health. If the scientific chemist and Medical Officer of Health can push our knowledge so far as to be able to prove to demonstration that, if the human body is persistently exposed to air contaminated by a polluting agent to a degree represented by a certain figure, it will be, in the majority of instances, injuriously affected, then the Legislature will have some basis on which to work. A Government would, whether in accordance or not with its own wish, be compelled to act consistently with the principles of past sanitary legislation, the burden of which is that a man shall do nothing which is injurious to the health of his neighbour or to the public welfare. But the obstacles to advancement are twofold: first, an indisposition exists to place further restrictions on trade which is already depressed; and, secondly, the legal mind seems quite unable to assimilate the fact that anything obnoxious is "a nuisance injurious to health" unless it creates a definite disease. Mr. Simon has tersely adverted to the point thus:—"To be free from bodily discomfort is a condition of health. If a man gets up with a headache, *pro tanto* he is not in good health; if a man gets up unable to eat his breakfast, *pro tanto* he is not in good health. When a man is living in an atmosphere which keeps him constantly below par, as many of these trade nuisances do, all that is an injury to health, though not a production of what at present could be called a definite disease." Those who govern cannot avoid deploring, as do the governed, that great manufactories that defile the air exist, which sustain in their vicinity hundreds and thousands of work-people, whose vital energies are lowered (thus rendering them a more ready prey to disease), and whose offspring are stunted and depraved by the medium which the industry that supports them is always and needlessly rendering unwholesome.

### *A. Organic Matter.*

Organic Matter.

Organic matter which is given off from the skins and lungs of all animals, and gives that peculiar, indescribable odour noticeable in ill-ventilated bedrooms occupied by many or by dirty people, is very easily detected in the air, but there has always been a considerable difficulty in estimating its amount, by reason of the interference of other substances contained in air, which is a mixture of so many different extraneous bodies.

Of the chemical composition of organic emanations we know very little. Dr. Odling found that the vapours arising from sewage were of a carbo-ammoniacal nature, similar to such bodies as methylamine, or trimethylamine and ethylamine. Beyond this point there is nothing but a *terra incognita* as to this very interesting subject.

**Permanganate of Potash Method.**

One of the first processes adopted for the estimation of the amount of organic matter was to expose a solution of permanganate of potash to the air, as the oyxgen of the salt has a powerful oxidizing effect on organic matters. A burette was filled with a very weak solution, and an attempt was then made to ascertain how much of it was necessary to drop into a bottle of a certain capacity, before it arrived at the point when it was no longer *de*colorized by the air of the bottle. The amount necessary to reach this point having been found, it was a matter of easy calculation to ascertain how much of the permanganate of potash salt was expended.

Another plan was the following:—The test solution is placed in a bottle of known size, attached to an aspirator, and is violently shaken with the air in the bottle. This air having been washed, the bottle is refilled by the aspirator, and a fresh quantity of air is washed, etc., the object being to discover how much of any given sample of air is necessary to *de*colorize the pink solution. It will be seen that in both modes of applying this permanganate of potash test the aim is the same, namely, to remove the pink colour of a solution of known strength by a known quantity of air shaken with it. It was ascertained, however, that the nitrous acid often present in the purest air; that the sulphurous acid, which is very abundant, and the hydrogen sulphide gas, which is generally found in minute quantities, in town air; and the chlorine compounds, which often exist in the air of our manufacturing cities:—also decolourize permanganate of potash. This process, therefore, never unquestionably proves the presence of any organic matter, but merely indicates the relative quantities of oxidizable matter contained in different samples of air.

Better modes have since been devised, having for their object the conversion of the organic matter of air into ammonia, the amount of which can easily be calculated.

Dr. A. Smith's method of air-washing.

Water is prepared of great purity by distilling it twice in perfectly clean vessels. A definite quantity, generally 50 c. c., is placed in a Winchester quart bottle, or any other of known capacity. A little bellows,[1] the capacity of which is ascertained, with a vulcanized indiarubber tube, is employed for pumping fresh supplies of air into the bottle, or for withdrawing the air contained in the bottle, so that fresh air may rush in and take its place (fig. 24).

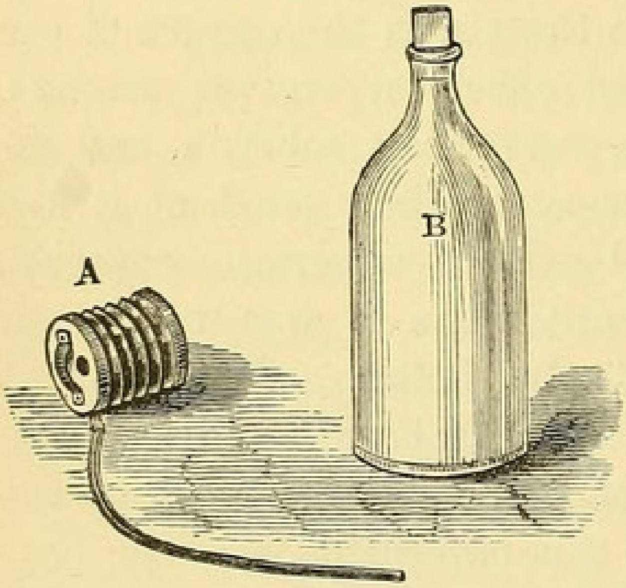



FIG. 24.

A. Small hand-bellows, with indiarubber tube attached. It possesses a valve at one extremity, which admits air when air is pumped into a vessel. If it is wished to withdraw air from a vessel this aperture is closed by a large cork.
B. A Winchester quart bottle.

The bottle and bellows are taken to the place, the air of which it is proposed to analyze, and the washing of

[1] Mine was procured at a surgical instrument maker's, such as is employed for inflating air-beds.

the air is proceeded with by blowing air thrice into, or sucking air three times out of, the bottle, replacing the stopper, and violently shaking the bottle. This performance has to be repeated 100 times, and is, as may be supposed, sufficiently laborious. In order to refill the bottle with air, an air-pump is sometimes used until the required point is obtained on a mercury gauge, this being found to indicate a known amount of air, which is then allowed to enter in order that it may be washed. Some few, such as Dr. Angus Smith, have gone through a series of these air-washings, and the results arrived at have been found satisfactory. The cumbrousness of the apparatus, and the labour involved, have been great obstacles to the general adoption of this process. Mr. A. Moss' experiments on the nitrogenous organic matter in air, referred to on page 237, were made by passing a certain quantity of air, by means of "an accurately graduated aspirator," through four wash bottles, each being of a capacity of 100 c. c., and each containing 50 c. c. of *pure* distilled water. In the first bottle of the series, 50 c. c. of pure hydrochloric acid were also poured.

The air-washings are distilled with the caustic potash and permanganate of potash solution, and the distillates are treated with Nessler reagent. Although all the organic nitrogen of the air is not in this manner converted into ammonia, that which is most easily decomposed, such as is theoretically capable of producing disease, is secured.

A fourth method, which has been suggested as applicable to the detection and estimation of atmospheric impurities, is to pass a known quantity of air by means of a swivel aspirator, graduated into cubic centimetres or cubic inches, through distilled water to catch the organic matter, and through standard solutions of nitrate of silver and chloride of barium, to retain respectively the chlorine and sulphur compounds. This plan is perfectly useless, for the amounts of these bodies secured in this way are too small for estimation.

If success is to be achieved in air analysis, it is absolutely essential that a very large quantity of air be washed in a very small quantity of water, so large indeed as to be able to obtain results which are altogether beyond the reach of being affected by the experimental errors that are inseparable from all delicate analytical operations.

A fifth method, already mentioned as adopted for extracting the solid particles contained in air for microscopical examination, consists in drawing a measured quantity of air by means of an aspirator through a clean curved tube (which has been previously heated and cooled), surrounded by a freezing mixture. The moisture contained in the air is condensed, and with it much of the organic matter. The tube is then washed out with pure water and the washings are analyzed.

The elaborate series of analytical observations on the impurity of air that have been in progress for some years at the Montsouris Observatory, near Paris, under the superintendence of M. Marié-Davy, and the valuable analytical work on the air of Glasgow, that was for a short period carried out by Mr. Dixon, B.Sc., and Mr. Wm. Dunnachie, with the co-operation of the Medical Officer of Health, are the most complete and perfect that have yet been attempted on a large scale.

The arrangements of the latter gentlemen are in many respects precisely the same as those conducted by M. Marié-Davy, with some improvements that they have, through the light of English methods of analysis, made.

The apparatus which is used at the Montsouris Observatory, not only for the estimation of the amount of organic matter, but of that of carbonic acid, ozone, etc., consists essentially of two distinct parts, one being a pump or aspirator, of a peculiar construction, which draws a known quantity of the air operated upon through a certain solution, and the other being an arrangement for holding the absorbing solution and exposing it fully to the influence of the air.

The Montsouris Aspirator.

The aspirator is composed of a glass tube, about 2 centimetres in diameter, and 10 centimetres long. This tube is tapered at its lower extremity, which is connected with a vertical india-rubber or glass tube B, about 5 millimetres in diameter and 2 or 3 metres in length. The glass tube A is closed at its upper extremity by a cork, through which two tubes D and C pass. The tube D communicates with a water service pipe; a stopcock at the junction serves to regulate the flow of liquid which, running into A, descends through the ringed portion (*b*) of the tube B, carrying bubbles of air derived from the tube C, similar in appearance to the manner in which the mercury of a Sprengel's pump draws the air (fig. 25).

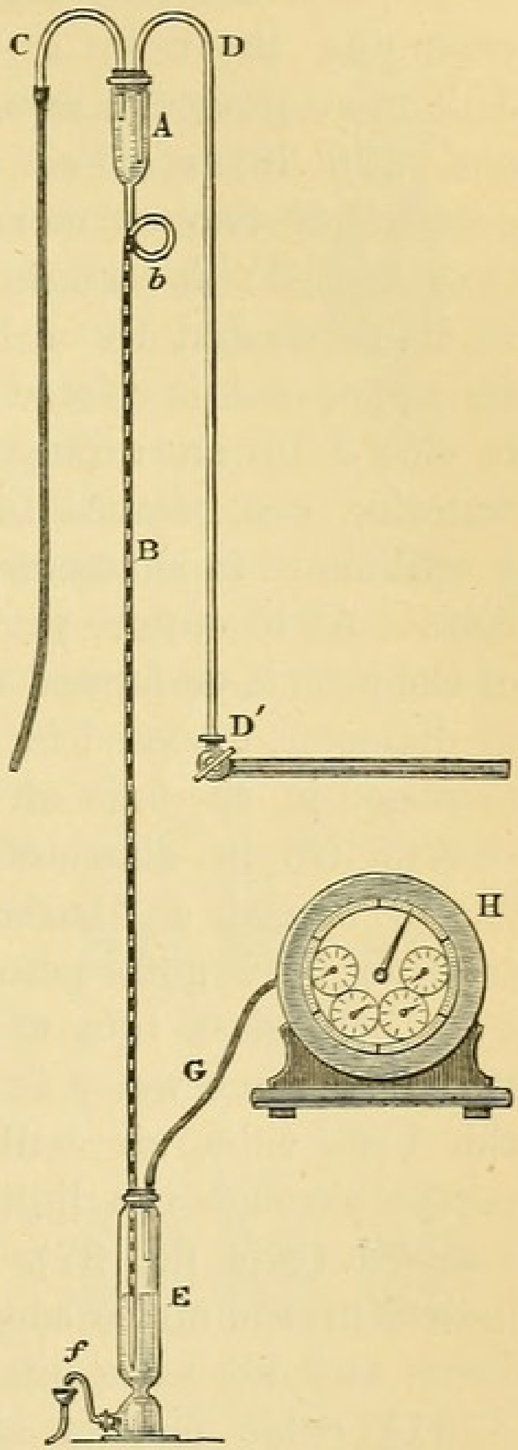


Fig. 25.

The water and air both enter the displacement gauge E, where they separate. The water flows away by the curved spout F, and the air escapes by the tube G, which terminates in an air meter that measures its volume. The "aspiration pipe," C, is attached to the set of absorbents intended to remove the body to be collected from the air. Where, in other analytical experiments, a larger quantity of air is required, the observers at Montsouris combine together 8 of these twisted tubes, arranging them in a parallel manner (*vide* fig. 28). This more powerful aspirator delivers 80 litres of water and 200 litres of air per hour. A set of absorbers consists of two or more elements, each element being thus formed: A straight tube of platinum, 1 centimetre in diameter, and 14 or 15 centimetres in length, open at its upper end, is dilated at its lower extremity, where it is closed by an arrangement resembling the rose of a watering can, pierced in its centre by 5 or 6 holes of $\frac{1}{2}$ millimetre in diameter, to facilitate the washing of the tube. At the upper part of the rose the enlarged portion of the tube is perforated with 20 holes of $\frac{2}{3}$ of a millimetre in diameter, disposed in two circular rows. This tube is arranged in the axis of a deep cylindrical glass, about 4 centimetres in diameter, and 11 or 12 centimetres in depth, named a "barboteur." Here it is retained in position by a gutta-percha cork, which is also traversed by a bent glass tube of a diameter of 1 centimetre. If we place some water in the glass and draw air through the bent tube, air will enter the platinum tube and escape through the liquid in the form of numerous fine bubbles (*vide* fig. 27). When the amount of organic matter in the air is sought to be determined, M. Marié-Davy and his assistants pass 100 cubic metres = about $3531\frac{1}{2}$ cubic feet of air, through distilled water, and examine it by the permanganate process.

Air examinations at Glasgow.

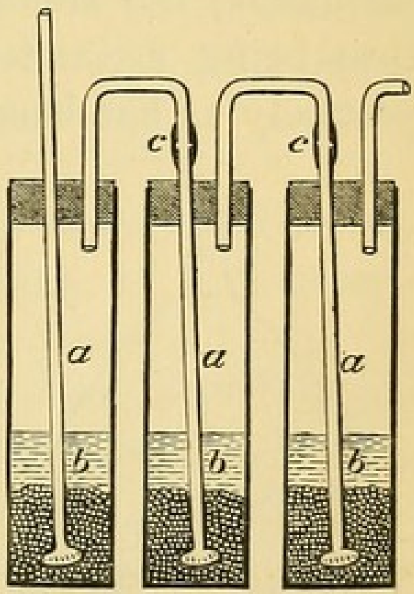
In Glasgow, which is well known to be a city of smoke and manufactories, 6 or 7 stations were established in its various parts, and one was organized in pure air at Eaglesham, which is 12 miles distant; at all of which the amount of ammonia and albuminoid ammonia, carbonic acid, sulphuric acid, and chlorine, coupled with certain meteorological phenomena, such as rainfall, temperature, etc., were observed.

Every station in the city was provided with (1) sets of "absorbers," each "set" or "series" being furnished with a distinct solution containing glass beads, adapted to withdraw one of the above named substances from the current of air that passes through it; (2) a water injection aspirator (*vide* fig. 26); (3) a gas meter to measure the amount of air passing through the aspirator; and (4) a water-gauge to keep the aspirators at all the stations as nearly as possible at one and the same speed.

Water Injection Aspirator, adapted for constant and high pressure water service.

FIG. 26.

A set of absorbers for free ammonia and albuminoid ammonia (*i.e.* the ammonia which we obtain by decomposing nitrogenous matter), which were estimated together as nitrogen, was thus prepared. The glasses having been thoroughly washed, about three ounces of glass beads (*vide* fig. 27) and some twice distilled water were placed in each. They were allowed to remain in the water for a short time in order that any impurities adhering to the beads might be removed by the water. The distilled water having been poured off, 10 c. c. of diluted sulphuric acid, and 70 c. c. of distilled water, free from ammonia, were introduced in the following proportions:—



A set of Absorbers

FIG. 27.

A SET OF ABSORBERS.

*a a a.* Tubes with roses at their extremities.

*b b b.* Absorbing solutions.

*c c.* Indiarubber tube connections.

| Dilute Sulphuric Acid. | | Distilled Water. | | Glass. |
|---|---|---|---|---|
| 5 c. c. | . . | 30 c. c. | in | No. 1 |
| 3 c. c. | . . | 30 c. c. | ,, | ,, 2 |
| 2 c. c. | . . | 10 c. c. | ,, | ,, 3 |

The roses being inserted, the set of absorbers was attached to an aspirator for 48 hours, in which space of time about 200 cubic feet of air had passed through this dilute sulphuric acid. At the end of this time the contents of the glasses, beads included, were poured into a copper flask made out of a very large ball-cock, into which 15 c. c. of a solution of carbonate of potash (240 grammes in a litre of distilled water) had been previously poured. The washings with twice distilled water of the glasses and tubes were added, so as altogether to just exceed ½ litre. The copper flask was then attached to a condenser, and distillation was performed exactly as has been described on pages 40 to 48, in the analysis of water, the first ¼ litre yielding the ammonia, and the remaining ¼ litre, after the addition of 50 c. c. of the caustic potash and permanganate of potash solution, furnishing the albuminoid ammonia; the amount in each case being estimated by a standard ammonia solution precisely as has been there indicated.

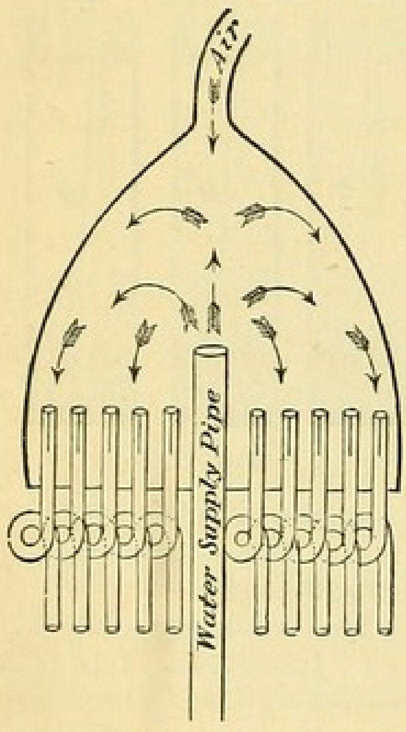


Fig. 28.

I am not aware that beads are employed at the Montsouris Observatory for minutely subdividing the streams of air. This addition has been made, I believe, by Mr. Dixon (*vide* fig. 27). And to it is partly, in all probability, to be ascribed the higher results which he obtains.

At the station at Eaglesham he used an aspirator formed of a combination of twisted tubes, the internal orifice of each having a slit (*vide* fig. 28).

There are a great variety of aspirators, and it is difficult to decide as to which is the best form. Some are more adapted for certain purposes than for others. Descriptions and sketches of many of the favourite kinds are to be found in *Ozone and Antozone*, pp. 250-259.

The improvements effected by Mr. Dunnachie on the retirement of Mr. Dixon consisted in employing more "absorbers" in each "series," in substituting glass retorts for the copper flasks, and in abolishing the error attendant on the changes in the water pressure by adapting Borradaile's governors for street lamps to the meters.

There would seem to be some divergence in the results as derived by the bellows pump and shaking (described on page 314) when compared with those procured by aspiration with rose-ended tubes.[1]

| | By Shaking. | | Aspiration, 3 bottles. | |
|---|---|---|---|---|
| | Milligramme in 1 Cubic Metre of Air. | | | |
| | Free Ammonia. | Alb. Ammonia. | Free Ammonia. | Alb. Ammonia. |
| Manchester, Dec. 2, 1876, dull, damp morning . | ·093 | ·160 | ·070 | ·053 |
| Ditto, Dec. 4, raining . | ... | ·159 | ... | ·124 |

Prof. Ira Remsen has adopted[2] as a collector of the organic matter of air a modification of Chapman's arrangement of a funnel filled with pumice stone. A tube of $\frac{3}{8}$th inch internal diameter and from 5 to 7 inches long is drawn out at the lower end, so as to accommodate a small piece of rubber tubing. Having been carefully washed it is filled with ignited pumice stone. A piece of platinum gauze having first been dropped into the tube, a layer of coarsely powdered pumice stone is introduced, and finally a layer of the finely powdered material is placed on the coarse layer. 10 litres of the air to be examined are drawn through this tube of pumice stone by an

Prof. Remsen's Collector.

[1] *Proc. of Royal Society*, December 13, 1877.

[2] "Organic matter in the Air," in *National Board of Health Bulletin*, January 31, 1880.

aspirator. The organic matter obtained is examined by the Wanklyn, Chapman, and Smith process, and its amount is determined by means of the Nessler reagent. No ammonia is obtainable from absorbents placed between the pumice stone tube and the aspirator. The pumice stone requires to be freshly ignited after each experiment.

Mr. A. H. Smee's Method.

The organic matter has been obtained for examination from air, by collecting the moisture that is seen to attach itself to the walls and windows of crowded, ill-ventilated halls, which has been condensed by the cold air outside. Mr. A. H. Smee[1] employs a glass funnel drawn to a point, and filled with fragments of ice. The aqueous vapour in the air is deposited as a dew on the sides of the funnel, which runs down and is received in a vessel underneath. This air moisture, in whatever way procured, is examined for nitrogenous compounds.

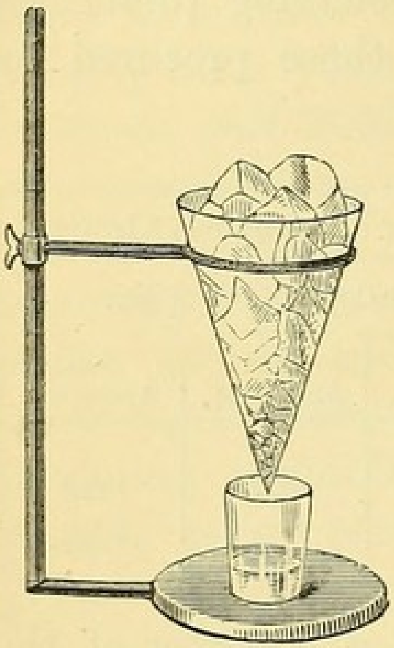


Fig. 29.

Pulverization of water Method.

The process, which will now be described, is preferred by me to all that have yet been adverted to :—

1. Because it is the most rapid and reliable one that has been devised.
2. Because the air-washing apparatus required is portable, and can be readily carried in the hand by any one in a small box.

It consists in bringing continually fresh quantities of air into intimate contact with a small quantity of very pure water, which is reduced to a minute state of subdivision by pulverization. The tools required are the following :—

[1] *Soc. Science Transactions*, 1875, p. 486.

1. A glass cylinder about $7\frac{1}{2}$ or 8 inches long and 2 inches in diameter, furnished with a large black india-rubber stopper, perforated with two holes, into one of which the air-pipe of a Bergson's spray producer is fitted, the other being intended for the passage of a straight glass tube about 12 inches long and $\frac{1}{4}$ inch in diameter.

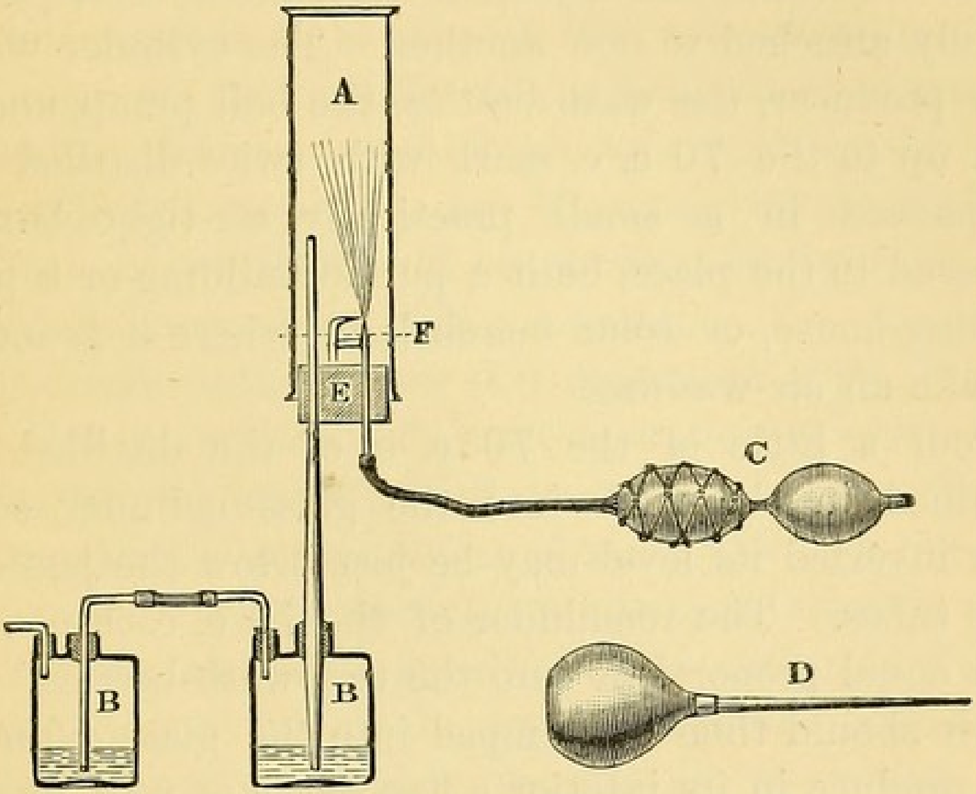



FIG. 30.

A. Cylinder.
B B. Wash-bottles.
C. Black indiarubber ball pump.
D. Black indiarubber $\frac{1}{2}$ oz. ball, to which a glass tube, tapered to a fine point, is attached.
E. Black indiarubber cork, through which passes the air-pipe of a Bergson's spray producer and a straight glass tube, one end of which stoppers into a wash-bottle.
F. Level of fluid in cylinder.

2. Two stoppered Woulff's wash-bottles, of a capacity of about 130 c. c.

No corks should be employed for connections. The tubes are stoppered into the necks of the wash-bottles.

3. A stoppered flask, of the capacity of 100 c. c., with a mark at about 70 c. c.

4. A black $\frac{1}{2}$ oz. indiarubber ball, to which a glass tube, drawn to a fine point at its extremity, is fitted.

The point is protected by a cap formed of an inch of the smallest black indiarubber tubing, sealed at one end.

The steps of the process are as follows :—

The several parts of the apparatus having been thoroughly cleansed in the laboratory with twice-distilled water, which gives no colour whatever with Nessler test, by the aid of the ball injection tube, the several parts are securely attached to one another. The cylinder with its spray producer, the wash-bottles, the ball pump, and flask filled up to the 70 c. c. mark with twice-distilled water, are packed in a small practically air-tight box, and conveyed to the place, be it a public building or a private dwelling-house, or some marsh land, where it is intended to make an air-washing.

Pour a little of the 70 c. c. of the distilled water contained in the flask into the glass cylinder, so that when inverted its level may be just below the jets of the spray tubes. The remainder of the 70 c. c. is poured in about equal proportions into the two wash-bottles.

Air should then be pumped into the glass cylinder so as to produce in its interior a fine spray or mist by means of the indiarubber pump, the capacity of which should have been previously ascertained by the help of an air or gas meter. The greater part of the spray returns to the water at the bottom of the cylinder to be reconverted into spray with fresh portions of air, but a small quantity passes downwards through the straight tube into the wash-bottle to which it is attached, and a still smaller portion reaches the other wash-bottle. At the exit tube of the latter no spray can be perceived. The indiarubber pump which I employ delivers 3·2 cubic inches of air every time its sides are approximated by the pressure of the hand, so that if it is emptied 540 times, an operation which altogether consumes about a quarter of an hour, 1 cubic foot of air is injected into the glass cylinder. At the termination of the stage of air-washing, the distilled water in the cylinder and in the wash-bottles should be immediately poured back into the flask, and the apparatus having been restored to the box is returned to the laboratory; where the interior of the cylinder, and wash-bottles, and glass tubes, should be at once washed out, by the aid of the ball injection tube, with twice distilled water. The great point to be aimed at is to wash the several parts of the apparatus most thoroughly with as little distilled water as possible, as if indeed this fluid was most costly. The washing of the apparatus can efficiently be accomplished with 30 c. c., which should be poured also into the flask, thus filling it up to its 100 c. c. mark.

The mere washing of the apparatus with distilled water both before and after the operation is sufficient to heighten the experimental error, which is inseparable from all these delicate experiments. Accordingly, it is necessary to know the average amount of nitrogen, whether in the form of free ammonia or albuminoid ammonia (*i.e.* the ammonia which we obtain by decomposing nitrogenous matters), which is present in the air in which these cleansings are made. If we know the average experimental error which occurs when blank experiments are made in our laboratory, there is nothing easier than to make the necessary deduction from the results furnished by an air-washing. The average experimental error of manipulation when the preliminary and terminal cleansings of the apparatus are made in my laboratory is about ·006 of albuminoid ammonia for a cubic foot of air, a quantity which is consequently always deducted by me from any result obtained from an air analysis.

The contents of the flask, namely, the air-washings and the cleansings of the cylinder and wash-bottles, are analyzed for ammonia and albuminoid ammonia in a manner precisely similar to the mode adopted in a water analysis.

A small stoppered retort, of a capacity of 200 c. c. connected with a glass Liebig's condenser, about 18 inches long, is necessary.

By means of a little copper basin, containing sand or oil, placed on a large ring of a retort stand, heat can be applied more gently than with a naked flame. I often, however, use the naked flame with the chimney, as figured on page 115. The retort, condenser, etc., should, after copious ablutions with tap water, be first thoroughly washed internally by distilling through the apparatus some twice-distilled water. The 100 c. c. of air-washings contained in the flask should then be introduced into the retort, and distillation begun.

A dozen test glasses that will stand without support, about 4 inches long, and $\frac{5}{8}$th inch in diameter, the bases of

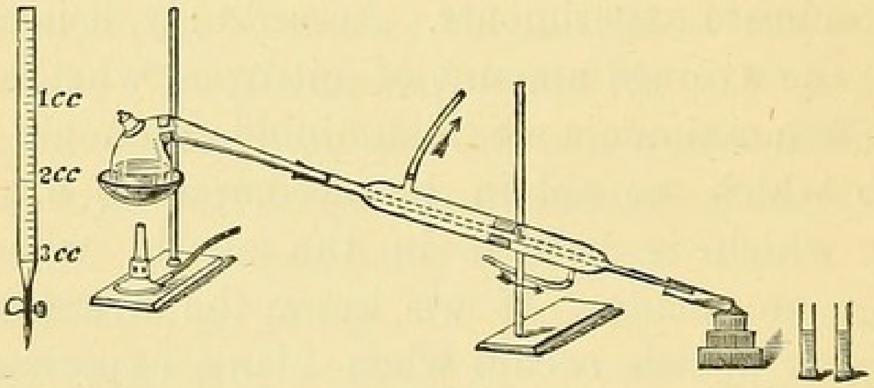



FIG. 31.

which have no colour, should have been previously marked with a file at the height which is reached by 10 c. c. of fluid. No corks should be used. The retort and condenser can be united by a packing made of a strip of common writing-paper. The first distillate of 10 c. c. that passes over should be Nesslerized by introducing into it $\frac{1}{2}$ c. c. of Nessler reagent, and shaking the mixture. We should not blow into the pipette so as to mingle the contents of the Nessler glass, as is not uncommon in water analysis. The second, third, and fourth distillates, each of 10 c. c., may be thrown away, and a third of the quantity of ammonia found in the first distillate be added as in water analysis, page 42. The contents of the retort are then to be allowed to cool. After it has become reduced to a state of tepidity, 10 c. c. of the solution of permanganate of potash and caustic potash are added, and the distillation again proceeded with. Each of the three distillates should be tested with $\frac{1}{2}$ c. c. of Nessler reagent, and then the estimation of the coloration of the single ammonia distillate, and the three albuminoid ammonia distillates, should be made.

A burette with the subdivisions of each cubic centimetre widely apart is necessary. Mine is 1 foot long and $\frac{3}{10}$th inch in diameter, and with it $\frac{1}{10}$ths of a c. c. can easily be read.

The very dilute standard ammonia solution used is half the strength of that found most convenient in water analysis, and is prepared by mixing 5 c c. of the strong standard solution of ammonia (1 milligramme of ammonia in 1 c. c.) with 995 c. c. of twice-distilled water. Accordingly

| | | | | |
|---|---|---|---|---|
| 1 c. c. of it | contains | ·005 | milligramme | of ammonia. |
| $\frac{1}{2}$ c. c. | ,, | ·0025 | ,, | ,, |
| $\frac{3}{10}$ c. c. | ,, | ·0015 | ,, | ,, |
| $\frac{1}{10}$ c. c. | ,, | ·0005 | ,, | ,, |

It is necessary to make up standards exactly as in water analysis. The test glasses should be cleansed with twice-distilled water by the aid of the pipette before they are employed. If Gmelin's wash-bottle is used, organic impurities from the breath may be introduced.

The test glasses containing the standards and the distillates, the colour of which it is necessary to imitate, are placed on a sheet of white paper. It is often very convenient to stand them in a common test tube rack. The differences between the tints of each $\frac{1}{10}$th of a c. c.

of the very dilute standard ammonia solution are distinguished with great precision by one who has had some practice with these delicate analytical operations.

The great objection to the employment of so small a quantity of air as 1 cubic foot is, that the experimental error falls so heavily on the results. This difficulty can be overcome by practice and the greatest attention to cleanliness, and the minute details with which every practical scientific chemist is conversant. Blank experiments on pure air, or on the twice-distilled water with which the apparatus is washed, will give confidence to the operator in his tools, and by affording him practice will help him to obtain reliable results from air of different degrees of impurity.

Whichever of the foregoing plans be adopted for extracting the organic matter from the air, its washings are treated in the same way. These washings are examined by the Wanklyn, Chapman, and Smith process, in a manner precisely similar to the mode in which the organic matter contained in water is detected and estimated, which has already been described (*vide* page 39).

## B. *Carbonic Acid.*

Carbonic Acid.

As I before stated, carbonic acid is not the worst impurity in the air of our houses, for it stands second to the organic matter in its evil effects, yet an estimation of its amount is an index of the foulness of air of a very valuable kind. There are several modes of detecting its presence and calculating its amount in any given sample of air.

Pettenkofer's Method.

The method known as Pettenkofer's is a good one, but requires the expenditure of much time and labour. It consists essentially in washing a certain measured quantity of air with a definite quantity of lime water or baryta water, and noting the loss of causticity that either of these waters has undergone; in other words, the amount of lime or baryta that has united with the carbonic acid. The causticity of the lime water to be used in the experiment is first ascertained by mixing with a certain measured quantity of it a known amount of a solution of oxalic acid to neutralize it. The oxalic acid solution is made of such a strength, 2·25 grammes in 1 litre of water, that 1 c. c. will exactly neutralize 1 milligramme of lime. Turmeric paper is employed for noting the exact point of neutralization. The same quantity of lime water is placed in the bottle of air to be examined, is shaken with it, and is allowed to remain in it for not less than six or eight hours, at the end of which time the causticity of the lime water is again determined by means of the oxalic acid solution. The difference will furnish us with the amount of lime that has become united with carbonic acid in the measured amount of air under examination. From this datum the percentage of carbonic acid is easily calculated. Corrections have to be made for temperature and barometric pressure. This process is fully described in Parkes' *Hygiene* (fifth edition).

The Montsouris Observatory Method.

The determinations of the amount of carbonic acid in the air are thus made at the Montsouris Observatory. A set of absorbers, consisting of four elements or "barboteurs," each of course furnished with its platinum rose, is charged with a 20 per cent solution of potash, coloured blue with a few drops of litmus. The elements are connected with one another, all being in communication with the aspirator depicted in Fig. 25.

The last element serves to show if all the carbonic acid has been extracted by the preceding ones. After the passage of 100 cubic metres of air the contents of each element is submitted to analysis. The platinum tube through which the air has entered is attached to a graduated burette containing hydrochloric acid. The glass tube through which the air has passed out is connected with a cylindrical displacement receiver full of water, covered with a layer of petroleum oil, to prevent the water from dissolving the gas, and furnished with an

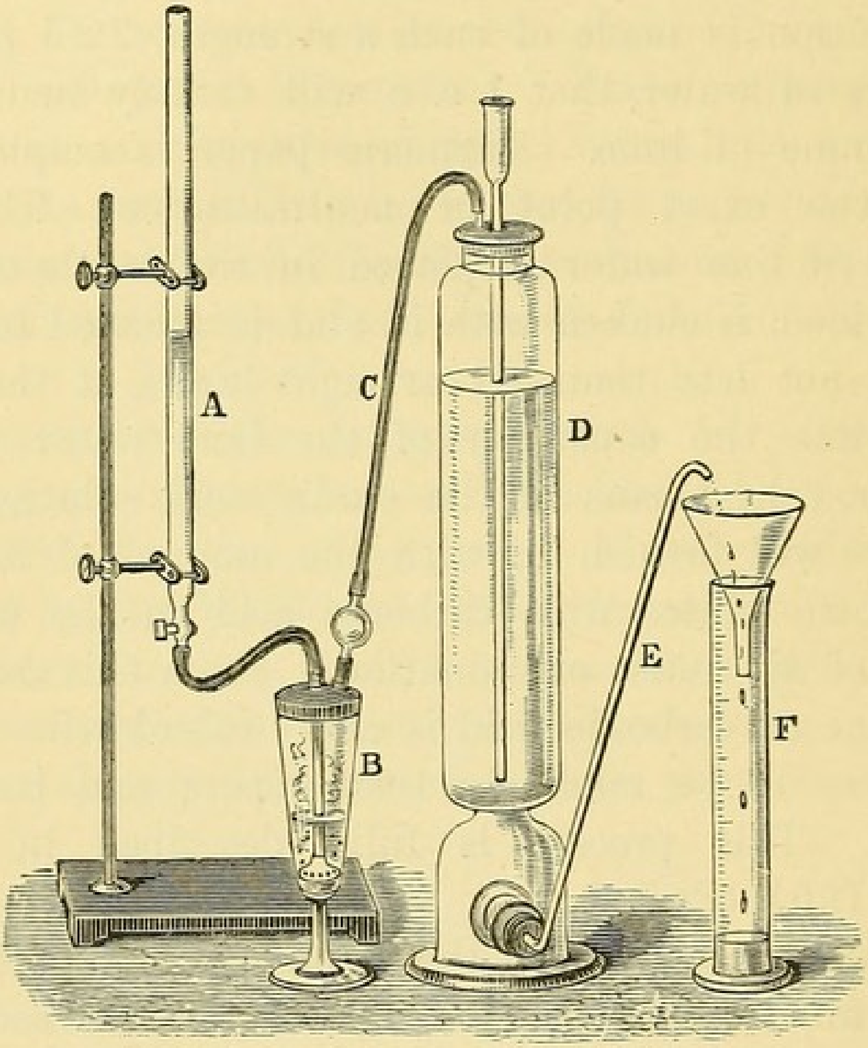



FIG. 32.

A. Graduated burette.
B. An element or "barboteur."
C. Indiarubber tube.
D. Displacement vessel.
E. Bent tube.
F. Measure.

exit tube. This exit tube E may be inclined on one side in such a manner that its upper end shall be on a level with the liquid in D. A definite quantity of hydrochloric acid is allowed to flow into the solution of potash, sufficient, indeed, to convert the blue colour of the litmus to a red tint. The carbonic acid evolved displaces a volume of the water equal to itself. This water is received into a burette graduated into cubic centimetres.

The method pursued at Glasgow by Mr. Dixon, consisted of the passage of 1 cubic foot of air per hour, for 48 hours, through solutions of caustic potash (320 grammes per litre) contained in three wash-bottles (a set of absorbers). On their removal to the laboratory, the carbonic acid was precipitated as carbonate of baryta, which was allowed to subside in well-stoppered bottles, and the amount of carbonic acid was estimated by the sp. gr. process. Dr. A. Smith has found[1] that three washing-bottles containing a solution of barium hydrate, were insufficient to absorb all of the carbonic acid from the air aspirated through them.

Volumes, $CO_2$ per million volumes of air.

| | Exp. 5. | Exp. 6. |
|---|---|---|
| 1st bottle gave | 80 | 115 |
| 2d " " | 62 | 71 |
| 3d " " | 62 | 66 |
| 4th " " | 53 | 62 |
| 5th " " | 18 | 62 |
| 6th " " | 45 | 62 |
| Total . | 320 | 438 in series of 6 bottles. |

Another good method, proposed by Wanklyn, based on the same principle, is to make a standard by dissolving 4·74 grammes of dried carbonate of soda in 1 litre of water—a solution which contains a cubic centimetre of carbonic acid (= 1·97 milligrammes of carbonic acid) in every cub. cent. of liquid. Wanklyn's Method.

A bottle capable of holding 2000 cubic centimetres of air, or, failing one of exactly the right capacity, a stoppered Winchester quart bottle, having been washed clean, is rinsed with distilled water and allowed to drain. It is filled with the air to be tested by sucking

[1] *Proc. of Royal Society*, December 13, 1877.

out the air of the bottle with a glass tube, or with a bellows, like that in Fig. 24, when air from without immediately takes its place. 100 c. c. of baryta water are introduced, and the bottle is shaken for two or three minutes. The baryta water, on being poured out into a glass cylinder, is found to be more or less turbid, being slightly so if the air is good, and like milk if it is very impure. We then proceed to imitate the degree of turbidity in the following manner:—The standard soda solution is measured by drawing out the number of cub. cents. required from a burette graduated to deliver tenths of a cubic cent. of solution. We take 100 c. c. of baryta water and introduce into it 1 c. c. of soda solution. If the turbidity thus occasioned is about equal to the turbidity produced in the 100 c. c. of baryta water by the air under examination, we know that the air contains ·05 vol. of carbonic acid per cent. If 2 c. c., or more than 2, are required to imitate the turbidity occasioned by the air, the air is bad and ventilation is defective.

Captain Abney's Method.

Dr. Notter advocates the trial of the delicate process of Capt. Abney, which is described in the *Sanitary Record*, September 9, 1876:—To a Florence flask of known capacity is adapted a U-tube half filled with coloured spirit and to which is fitted a scale of half an inch. A small glass bulb is filled with a saturated solution of caustic potash and sealed by the flame of a gas jet. The bulb is broken by violently shaking the flask, and the caustic potash set free combines with the carbonic acid contained in the air of the flask. The production of a partial vacuum depresses the spirit in one of the limbs of the U-tube, the amount of which being measured furnishes the datum from which a calculation is made of the quantity of carbonic acid in the flask.

Simpler, but somewhat less accurate, modes, called the household and minimetric processes, which are sufficiently exact for all practical purposes, have been proposed by Dr. Angus Smith.[1]

**Household Method.**

The outside air contains an amount of carbonic acid, varying between ·03 and ·06 per cent, but is most frequently ·04 per cent, which rises in crowded buildings and other close, ill-ventilated places to ·25 per cent.

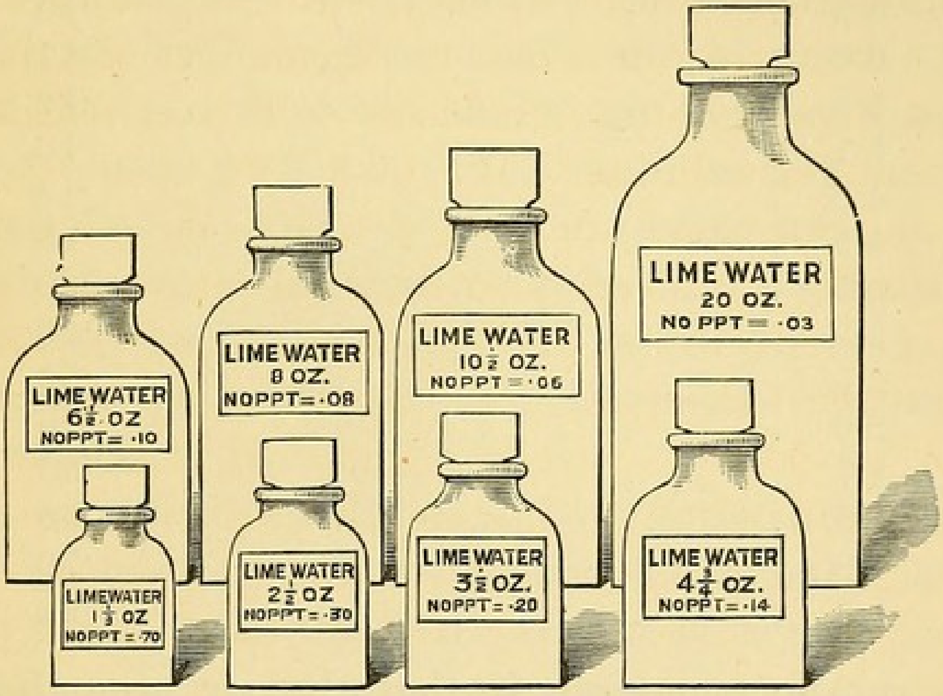



FIG. 33.

The way to estimate the amount roughly is to wash different measured quantities of air with $\frac{1}{2}$ oz. of lime water in such bottles as are here depicted. The lime water is prepared by slaking lime with water, stirring the slaked lime with the water, and then allowing the lime to subside. The clear fluid is, after 12 or 24 hours, poured off, and is ready for use. A table has been prepared to facilitate the use of this plan :—

[1] *Op. cit.*

| Size of Bottle. Ounces. | Lime Water. Point of observation is *no precipitate.* Carbonic Acid in air per cent. |
|---|---|
| 20·6 | ·03 |
| 15·6 | ·04 |
| 12·5 | ·05 |
| 10·5 | ·06 |
| 9·1 | ·07 |
| 8·0 | ·08 |
| 7·2 | ·09 |
| 6·5 | ·10 |
| 6·0 | ·11 |
| 5·5 | ·12 |
| 5·1 | ·13 |
| 4·8 | ·14 |
| 4·5 | ·15 |
| 3·5 | ·20 |
| 2·9 | ·25 |
| 2·5 | ·30 |
| 2·0 | ·40 |
| 1·7 | ·50 |
| 1·5 | ·60 |
| 1·3 | ·70 |
| 1·2 | ·80 |

The rule to remember is that the air around houses generally contains about ·04 per cent of carbonic acid, and that our rooms should always be kept so that a $10\frac{1}{2}$ oz. bottle full of air, when shaken with $\frac{1}{2}$ oz. of lime water, gives no precipitate. We then know that the air does not contain more than ·06 per cent. It is often difficult to keep the air of a room below ·07. If a precipitate is observed, we know that the air does contain more than ·06 per cent, and we take a smaller bottle, say a 9 oz. bottle, the air of which, when shaken with $\frac{1}{2}$ oz. of lime water, gives, perhaps, no precipitate. We then say the air is worse than ·06, and not worse than ·07; accordingly, the amount must roughly be ·07. If we wish to test the air as expeditiously as possible, and are not particular to ascertain the exact percentage, we may take a bottle of a size indicative of alternate hundredths. Instead of taking a 9 oz. bottle we may take an 8 oz., and treat 8 oz. of air in the same manner. If we obtain no precipitate we know that the air is not worse than ·08 per cent. Having already ascertained that the air is worse than ·06 we conclude that the air is contaminated with ·07 or ·08 per cent of carbonic acid.

If no turbidity is occasioned on commencing with our $10\frac{1}{2}$ oz. bottle, and we would like to know whether the air contains as much as ·06 per cent, we must take a larger quantity of air, for example a $12\frac{1}{2}$ oz. bottle. If, when this quantity of air is shaken with $\frac{1}{2}$ oz. of lime water, no precipitate is procured, we know that the air does not possess more than ·05 per cent, and if a precipitate is occasioned, we know that ·06 per cent is the amount.

The air to be examined is best introduced into the bottles by sucking out the air already contained in them with a glass tube. Fresh air enters to supply the void we create. The greatest care should be taken not to breathe into the bottle, for our breath is full of carbonic acid. The bottles should be wide-mouthed, so that the sides can be wiped dry and clean. If the lime cannot be readily removed, they should be rinsed out with strong hydrochloric acid, followed by an abundance of water. There is great difficulty in obtaining bottles of exactly the capacity required, but this could be overcome if there was any demand for such measures, by the special manufacture of bottles to hold accurately the quantities of air indicated.

*Minimetric Method.*—This method is more accurate, and involving the use of but few tools, which can be conveniently disposed of in one's pocket, is more handy. It consists essentially in ascertaining the smallest or

Minimetric Method.

minimum amount of air required to produce a precipitate of given density—hence the name. Baryta water, which is very poisonous, is employed, because it is more sensitive than lime water. A standard precipitate is obtained by shaking ½ ounce of baryta water in a 23 oz. bottle in pure air, which generally contains ·04 per cent of carbonic acid. The liquid is turbid and still translucent, but so that you cannot read through it. The endeavour is to ascertain the smallest amount of the air to be tested which is necessary to produce this standard degree of turbidity. We take a bottle which holds exactly 2½ oz., and place in it ½ oz. of baryta water, having first changed the air in the bottle by a few strokes of the finger-pump; we then shake the 2 oz. of air contained in the bottle with the ½ oz. of baryta water, and count one (*vide* fig. 34).

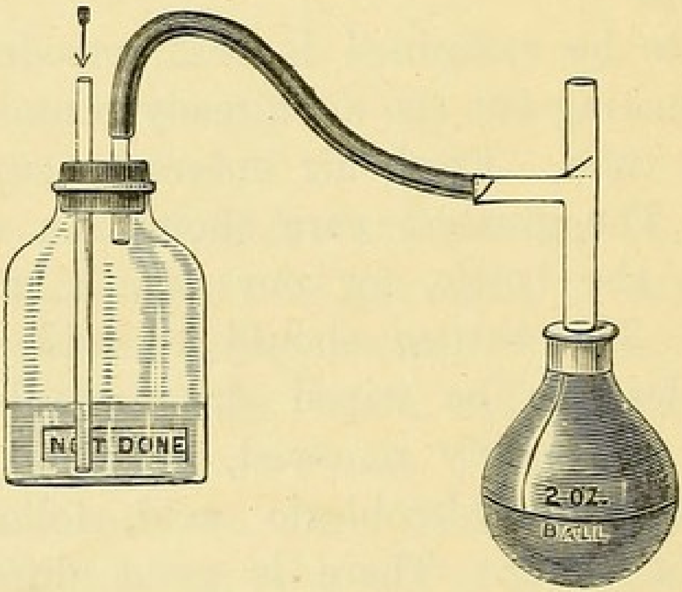



FIG. 34.

We then pump 2 oz. of air through the liquid and again shake violently and count two. When the turbidity is such that the words written on the slip of paper[1] affixed to the outside of the bottle become indistinguish-

[1] The words written with a lead-pencil on the label must be of such a depth of shade that the turbidity of the standard liquid just prevents them from being seen.

able, we stop, and refer to a table that has been prepared to economize the labour of calculation.

| Number of ballfuls of air. | Volumes of Carbonic Acid in 100 of air. | |
|---|---|---|
| | With 2 oz. ball. | With ½ oz. ball. |
| 1 | ·44 | |
| 2 | ·22 | |
| 3 | ·14 | |
| 4 | ·11 | |
| 5 | ·088 | |
| 6 | ·074 | |
| 7 | ·063 | |
| 8 | ·055 | |
| 9 | ·049 | |
| 10 | ·044 | ·17 |
| 11 | ·040 | ·16 |
| 12 | ·037 | ·14 |
| 13 | ·034 | ·13 |
| 14 | ·032 | ·12 |
| 15 | ·029 | ·116 |
| 16 | ... | ·11 |
| 17 | ... | ·10 |
| 18 | ... | ·098 |
| 19 | ... | ·093 |
| 20 | ... | ·088 |
| 21 | ... | ·084 |
| 22 | ... | ·08 |
| 23 | ... | ·077 |
| 24 | ... | ·074 |

The ½ oz. ball enables us to estimate greater degrees of impurity than the 2 oz. one.

When the air of a place, which it is wished to test, feels close on first entering, I use the 2 oz. bottle, and if very close I employ the ½ oz. ball and bottle.

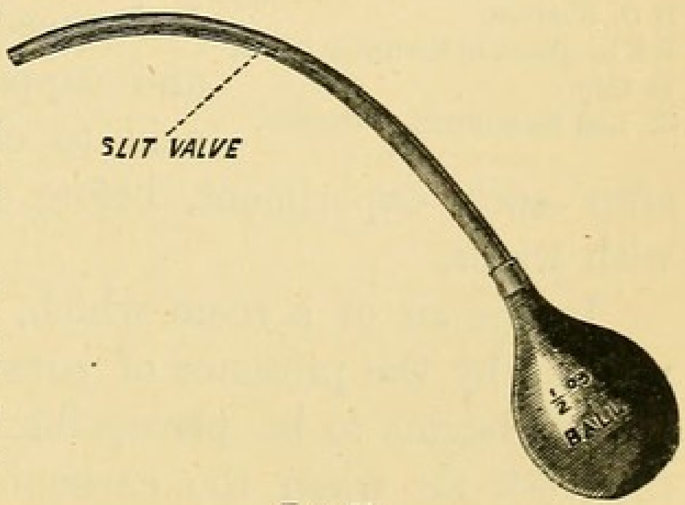


FIG. 35.

As the silk valves are rather liable to get out of order, I dispense with them, and simply make a slit in the tube connecting the ball and bottle, which allows of the expulsion of air, but prevents its ingress (*vide* fig. 35).

Store Bottle.

A weak solution of baryta (·1 to ·5 per cent, the exact strength being unimportant) is employed, which is made by dissolving caustic baryta in distilled water. It must be stored in such a way that, on removing portions of it, air undeprived of carbonic acid shall not enter the store bottle. The arrangement here sketched, which was in constant use in the Board of Health Laboratory, Glasgow, and is to be found in Sutton's *Volumetric Analysis*, is a most convenient one for withdrawing any quantities that are required of baryta water, or, indeed, of other standard solutions, in such a manner that air entering is freed from whatever body the contained solution is designed to extract from it (*vide* fig. 36).

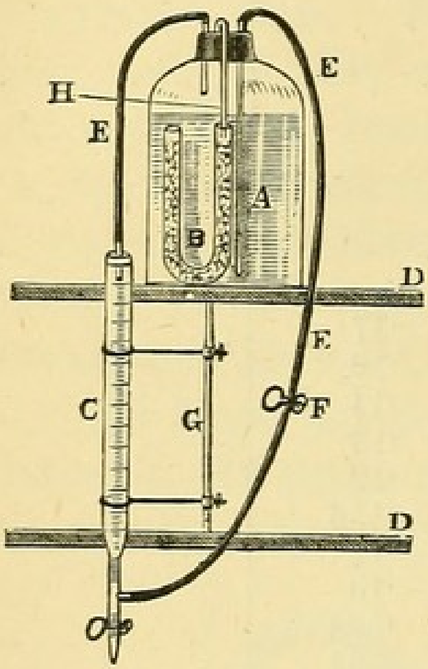



FIG. 36.

A. Store bottle containing solution of caustic baryta.
B. U tube filled with fragments of pumice stone moistened with caustic potash, through which air passes in order to enter the store bottle.
C. Burette graduated in any manner that is required.
D D. Shelves.
E E E. Black indiarubber tubes.
F. Clip.
G. Rod for support of burette.

It will be found very handy to have a dozen ½ oz. stoppered bottles with wide mouths, and to fill them from this store bottle. It is needful to carry a stoppered and capped bottle of hydrochloric acid to clean the little apparatus after each experiment, before it is washed thoroughly with water.

In the air of a room which, at first pure, is gradually vitiated by the presence of persons, the smell of organic matter begins to be perceptible to one entering it from the fresh air when the carbonic acid reaches ·06 or ·07 per cent. When the carbonic acid amounts to ·09 or ·1 per cent, the air is termed "close" or "stuffy." The fœtid odour of organic matter becomes very disagreeable when the carbonic acid exceeds ·1 per cent.

When the carbonic acid is as much as from ·15 to ·3 per cent, headache and vertigo are experienced, as the result of the vitiation of the air by this gas and its accompanying impurities.

When people speak of good ventilation, they mean air with less than ·07 per cent.

Detection of hydrogen sulphide, ammonium sulphide, and ammonia.

A rough-and-ready mode of detecting the presence of hydrogen sulphide in the air, which is a gas produced in the decay of organic matter—for example, in some marshes, in sewer gas, etc.—is by means of acetate of lead papers.

Ammonium sulphide, which, with hydrogen sulphide, is a constituent of sewer gas, is detected by nitro-prusside of sodium tests. Ammonia, a product of putrefaction and decomposition, is, if in large amount, observed by means of logwood papers.

# CHAPTER XXVIII

## THE BIOLOGICAL EXAMINATION OF AIR

Collectors of micro-organisms.

THE examination of air biologically resembles closely that of water. The difference consists in the arrangements for collecting from the air the micro-organisms or germs contained in it. A glass jar about 6 inches high plugged with a stopper of cotton wool, containing at its bottom a shallow glass capsule, which can be easily removed by the help of a brass lifter and charged with sterile jelly, is opened to the access of the air under examination for a certain number of seconds or minutes. Cohn and Miflet employ Wolff's bottles (in which the sterile jelly is placed) and an aspirator or a Sprengel pump to draw a definite amount of air through the same. Hesse substitutes a long horizontal fixed-glass cylinder for the Wolff's bottles, along the floor of which the liquefied nutrient jelly is allowed to solidify. Dr. Maddox's combined aeroscope and aspirator has been employed as a collector (*vide* page 298). A shallow watch glass filled with a nutrient jelly may be placed on the glass plate in the bell jar receiver depicted in Fig. 21 (page 300), in the mouth of which is an indiarubber cork perforated with two holes for entrance and exit glass tubes, the latter being connected with a Dancer's aspirator, by the help of which a known number of cubic inches of air can be transmitted over the sterile jelly. For the composition and mode of preparation of Koch's nutrient jelly *vide* page 75. The nutrient jelly in whatever manner it is inoculated is placed in the "damp chamber" (*vide* fig. 9, page 83), or is maintained in the incubator at a temperature of from 68° F. to 77° F., and daily inspected. The number of colonies or foci of growth which appear on the jelly can be counted or calculated approximatively as described on page 84. After the trial of many different kinds of collectors, the form of apparatus at length adopted by M. Pierre Miquel at the Montsouris Observatory and its mode of employment is thus described.[1] It consists of a glass flask with a long neck, which extends downwards into its interior and terminates in a minute aperture. The mouth of the flask is protected by a hood A furnished with a plug of sterilized cotton wool (*vide* fig. 37). The flask possesses two lateral tubes; the one marked C being provided with two plugs of cotton wool, and the other B being attached by a piece of rubber tube to a sealed up point of glass tube.

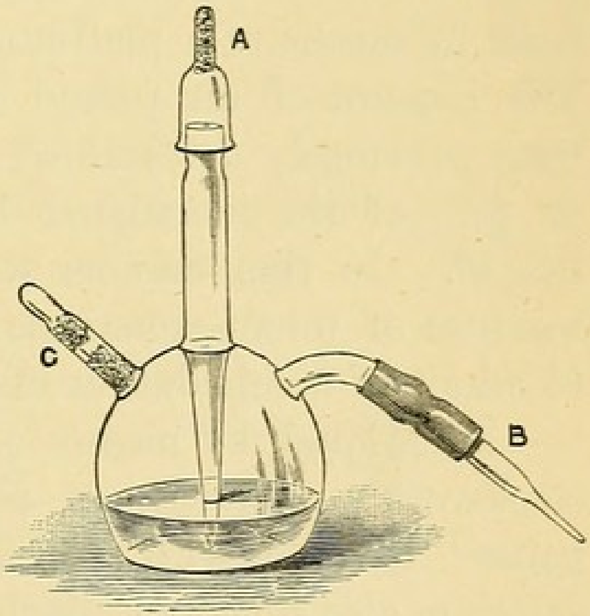


FIG. 37.

*Preparation for Experiment.*—From 30 to 40 c. c. of distilled water are introduced into the flask, which is then heated for two hours at 230° F. in a steam bath. After cooling it is placed in the incubator ready for use. 20 or 30 little glass flasks, each containing beef broth, are then sterilized, so as to be fit for inoculation.

*Experiment.*—A caoutchouc tube is fitted to C and an aspirator (after the removal of the hood) being attached, a certain known amount of air is drawn through

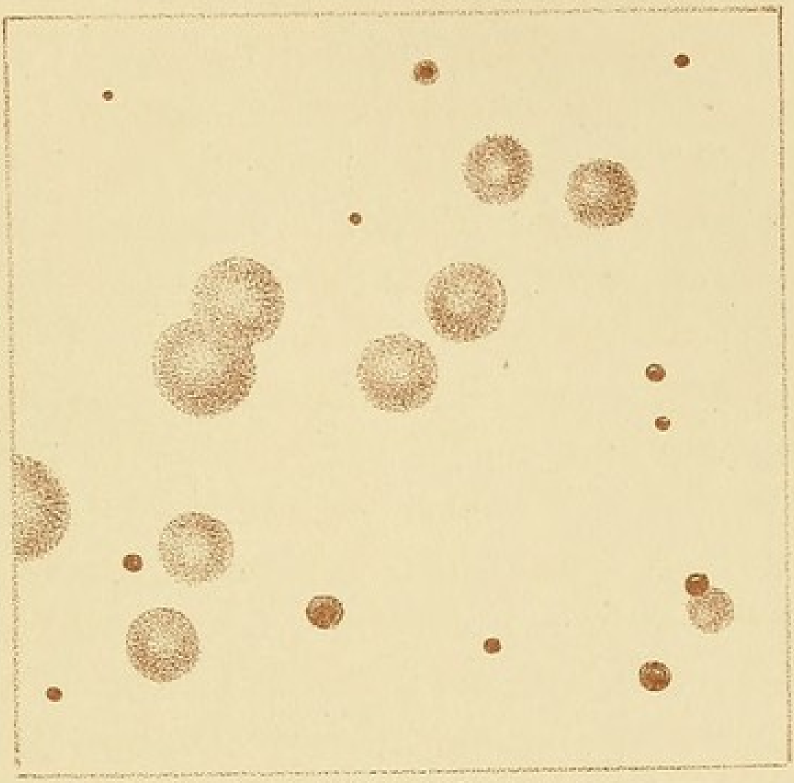
[1] *Annuaire de l'Observatoire de Montsouris* for 1886.

the fluid. The hood having been strongly heated during its time of withdrawal is replaced.

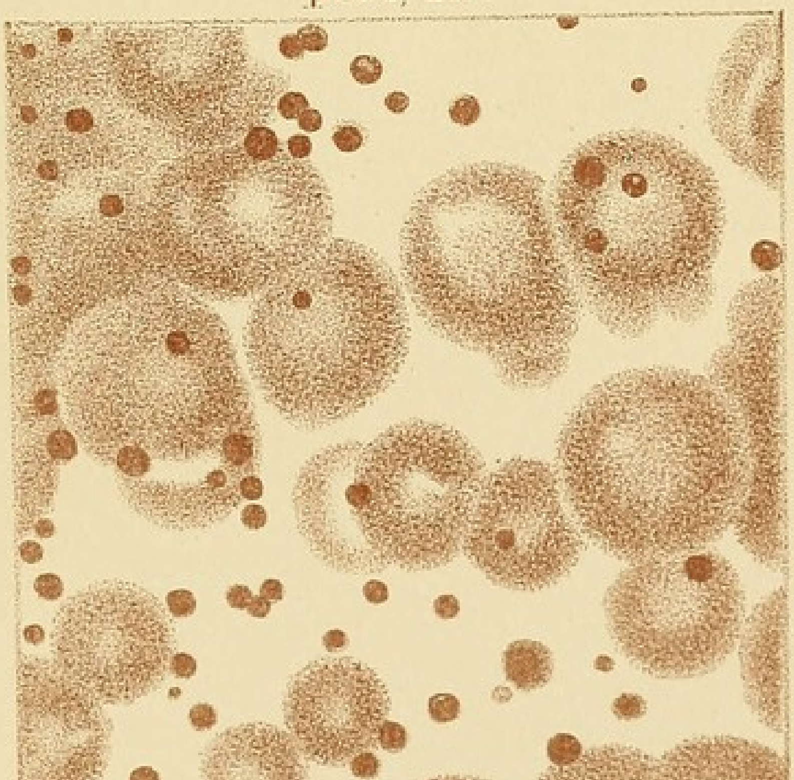
*End of Experiment.*—By alternate pressure and removal of pressure on the caoutchouc tube attached to C, the liquid is raised up and down the tubular neck 10 or 12 times in order to wash its interior. After having broken off the sealed point B, we distribute the liquid in fractional proportions amongst the glass flasks containing sterilized beef broth. Finally 25 c. c. of this broth are introduced into the glass collector itself, and the internal plug of cotton wool in the tube C is projected into the flask by means of a platinum wire which has been heated. The amount of air passed by the aspirator should have been previously determined and proportioned, so that $\frac{3}{4}$th or $\frac{4}{5}$ths of the inoculated broths shall remain perfectly limpid. In this manner we are enabled to operate on a mixture of micro-organisms and water sufficiently dilute to admit of a calculation of their number.

M. Miquel, by means of an aspirator attached to a clockwork apparatus, on which is exposed a nutritive paper[1] covered with a thick layer of freshly sterilized gelatine, also registers hourly the quantity of bacteria and germs contained in air by the enumeration of the number of colonies subsequently developed on it. He gives the accompanying records thus taken of pure and impure air.

[1] Mode of preparation described in *Annuaire de l'Observatoire de Montsouris* for 1886.



pure air.



impure air.

To face page 342.

## CHAPTER XXIX

### METALLIC POISONS:—ARSENIC, COPPER, AND LEAD

ARSENIC, copper, and lead are sometimes found in the air in the neighbourhood of smelting works, etc. The determination of the amount of these metals, which, when diffused through the air, exercise injurious effects on animal and vegetable life, fall rather within the scope of those legislative enactments that concern the contamination of the air by manufactories, such as the Alkali and Works Regulation Act of 1881, under which scientific chemists are appointed as inspectors. The human system itself, when continually exposed to the poisonous influences of copper and lead, affords an excellent test of an exposure to an injurious amount in the case of those who work with these metals, such for instance as miners in copper mines, or painters. The effects on the body of these metals, even in the smallest doses, are so well known to every physician, that he requires but little chemical aid. Arsenic, copper, and lead.

It is different in the case of arsenic, for the effects of this metal give rise in minute doses to such obscure and incomprehensible symptoms of such great variety, that they often cannot be assigned to their rightful cause without chemical assistance.

A description of the several poisonous colours used to tint the cheeks, the hair, etc., to avert the appearance of old age and to dye articles of wearing apparel, will not fall within the province of this work, because they exert their poisonous effects by coming into contact with the skin. Arsenic, mercury, lead in the form of magenta, coraline,[1] and other of the new dyes, are some of the most common poisons thus used (*vide* page 261).

rsenical wall paper.

Instances of the terrible suffering, misery, and even death, that have occurred from the use of arsenical wall papers, from the preparation for sale of feathers, artificial flowers, leaves, fruit, etc., swarm in medical publications. The poisonous greens, such as Scheele's, Schweinfurth's, Brunswick, Emerald, Paris, which are all confounded together by work-people, are used in enormous quantities, partly because they are very attractive in appearance and partly because they are cheap. Not less than 700 tons of these deadly greens are consumed in trade annually in this country. Many wall papers that are not green are loaded with arsenic, especially pale or white drawing-room papers, with an enamelled or opal white ground, which have yielded 15 to 25 grains of arsenic per square foot. The late Mr. Wigner, on examining samples some years ago of all the papers in a ten-roomed house, none of which were green, discovered that five of them contained arsenic in such quantity as to be injurious to health.

The Medical Officer of Health, in his inquiries after the causes of vague and obscure forms of illness, may often have occasion to examine the air of rooms poisoned by arsenic papers and furnishing materials. The public will not unfrequently bring him portions of wall paper with which their rooms are adorned, in order that he may examine them and express an opinion thereon. It is as well, therefore, for him to be acquainted with a simple means of testing for arsenic, not only to aid him in his own investigations, but to assist the public and their medical attendants. If it is wished to ascertain whether

[1] *Bulletin de l'Academie Imperiale de Medicine,* February and March 1869.

a paper does or does not contain arsenic, the paper is scraped with a penknife, and the dust that is removed is tested. If we desire to find out whether particles of dust have detached themselves from the paper, and poisoned the air of the room, the dust that lies on the articles of furniture may be collected for examination. The dust of the paper, in whatever way obtained, is mixed with an equal bulk of bicarbonate of soda (dried over a spirit lamp) and a little powdered charcoal. The mixture is placed in a dry test tube and heated. If arsenic is present, the characteristic odour of garlic is perceived, and a mirror of metallic arsenic is obtained as a ring on the sides of the tube. If the test tube is large, so as to allow of free access of air, octahedral crystals of arsenious acid, easily recognized by the microscope, will be found instead of the mirror. Reinsch's test may be employed to show the presence of arsenite of copper in a paper. The paper having been soaked in a solution of ammonia, which will dissolve the arsenite of copper forming a blue liquid, is acidified with hydrochloric acid and then boiled in a test tube with one or two strips of brilliant untarnished[1] copper. If arsenic be present the polished metal acquires a steel-gray coating. The

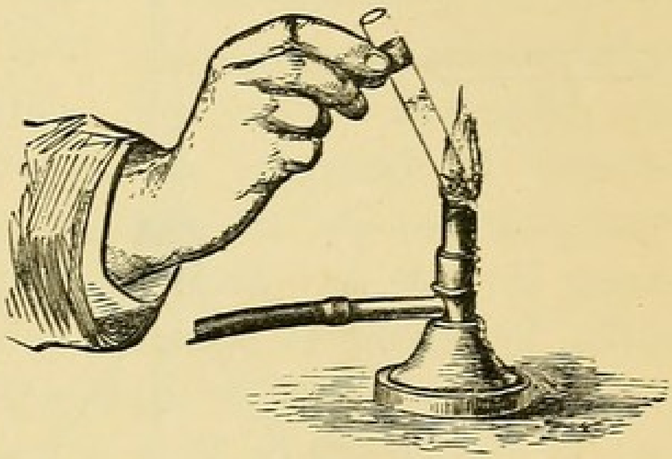


FIG. 38.

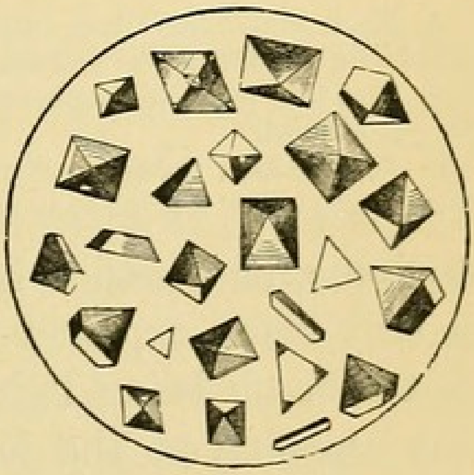


FIG. 39.

[1] Copper may be cleaned by heating it in a flame, by then applying a little nitric acid to it, and lastly washing it in water.

copper is washed, dried on filter paper, and heated in a small test tube over a Bunsen's burner or spirit lamp, when arsenious acid in octahedral crystals, readily diagnosed by the microscope (*vide* fig. 39), will be deposited in the cool part of the tube, if the paper contains arsenic.

Marsh's test.

Or the green colouring matter may be scraped off the paper and dissolved in pure hydrochloric acid and water, and examined by Marsh's test. Granulated zinc, or zinc foil in fragments, is introduced into a flask with some water, and a little pure sulphuric acid is poured down the funnel. A few minutes should be allowed to elapse for the removal of all the air from the flask. The gas evolved should then be collected in a test tube, and a lighted match be applied to the test tube to ascertain whether a mixture of hydrogen and atmospheric air is escaping, or whether hydrogen is alone given off. If air is still being expelled from the apparatus the gas in the test tube on being lighted will explode harmlessly. The gas escaping at the jet should on no account be ignited until two or three of these trials have been made. When the gas collected in the test tube does not explode, it is safe to light the jet. Having ascertained the purity of the chemicals employed, by depressing a piece of

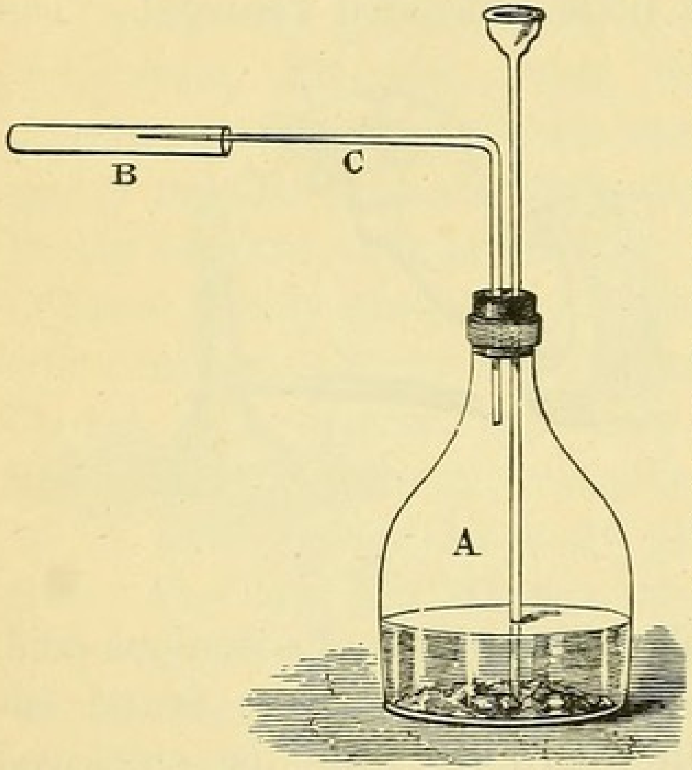



FIG. 40.—MARSH'S TEST.

A. Flask containing dilute sulphuric acid and zinc free from all traces of arsenic.

B. Test tube for collecting small quantities of the gas evolved.

C. Tube of hard Bohemian glass that will not fuse, drawn out to a point so as to form a jet.

porcelain on the flame, the solution of the green colouring matter may be passed down the tube funnel and the flame again tested. If it consists of arsenic there will be a dark mirror of arsenic deposited on the porcelain.

If there is any doubt as to the purity of the chemicals, Dr. E. Davy's sodium amalgam test, which finds so much favour in the United States, may be substituted, since sodium and mercury, of which the sodium amalgam is formed, are generally free from arsenic. This amalgam is prepared by adding 1 part of sodium to 8 or 10 of mercury, and supplies us with a ready means of obtaining hydrogen free from arsenic. It evolves hydrogen gas when water is added to it. A fragment of sodium amalgam is dropped into a flask and the solution supposed to contain arsenic is introduced. A strip of paper moistened with an acidified solution of nitrate of silver (·25 gramme arg. nit., 5 grammes of water, and 2 drops of nitric acid) is blackened if held at the mouth of the flask. To verify the result, it is as well to treat the blackened paper with ammonium sulphide. The sulphide formed is insoluble in hydrochloric acid if arsenic be present, and is soluble in hydrochloric acid if antimony be present.

Dr. Davy's sodium amalgam test.

If it is wished to ascertain the amount of arsenious acid (the common white arsenic of commerce) contained in a paper, a rough estimate may be easily formed. If the pattern of the paper consists of groups of green leaves, as is often the case, scrape off all the green arsenite from a single leaf and weigh it. The number of leaves in each square foot of surface of the paper having been counted, and the dimensions of the room having been taken, the number of leaves in the room is easily ascertained. If the green colouring matter is equally distributed over the surface of the paper a square inch of the paper should be operated on in place of a single leaf. A measurement of the room will readily give the number of square inches of surface. Two or three green leaves of a wall paper were recently sent to me with the request that I would ascertain whether the green pigment contained arsenic, and, if so, the quantity of the same. It had been estimated by the applicant that there were about 22,800 leaves in the room.

All the green colour having been scraped off from a single leaf, by the help of a penknife, was found to weigh 16 milligrammes.

| Arsenite of Copper. | | Arsenious Acid. |
|---|---|---|
| $2\ Cu.\ O.,\ H\ O.,\ As_2\ O_3$ | | $As_2\ O_3$ |
| 375 | : 16 : : | 198 |

$$\begin{array}{r} 198 \\ 16 \\ \hline 1188 \\ 198 \\ \hline 375)\,3168\,(8 \text{ Arsenious Acid.} \\ 3000 \\ \hline\hline \end{array}$$

To convert the 8 milligrammes of arsenious acid into fractions of a grain, a weight that is more readily understood by the public, it is simply necessary to multiply by 15·5 and divide by 1000.

| Milligram. | Milligram. | Grs. in 1 gramme. |
|---|---|---|
| 1000 | : 8 | : : 15·5 |

$$\begin{array}{r} 15{\cdot}5 \\ 8 \\ \hline 1000)\,124{\cdot}0\,({\cdot}124 \end{array}$$

Ans. One leaf contains ·124 of a grain, which is equivalent to 124 grains of white arsenic in every 1000 leaves, or nearly 6 ounces in the room.

Some wall papers contain compounds of lead and copper (non-arsenical), but, although their employment is undesirable, we have but little evidence at present which would forbid their use.

# *INDIRECT METHOD*

## CHAPTER XXX

### ESTIMATION OF OZONE AND OTHER AIR PURIFIERS

THE whole subject is so vast that it is extremely difficult to know how to concentrate it without omitting salient points of great interest.

*Ozone.*—Ozone is *condensed* oxygen, or a very active, lively, and energetic form of this life-giving gas. Its object in nature is to destroy, or, to speak more correctly, to render harmless by oxidation all offensive noxious products that, if permitted to accumulate, would produce disease and extinguish life. Ozone

Take, for example, a little blood, and keep it in a warm place for months, until it putrefies. When the odour is something horrible, sufficient indeed to create nausea, or sickness, send a stream of ozone over it, and its freshness, purity, and sweetness will be restored. Neither ozone nor the other air purifiers are to be found in the air of unventilated inhabited rooms or hospitals unless the windows are open, being speedily used up, and not replaced as they should be by the admission of fresh air, which nearly always contains them in greater or less quantity.

Ozone can be prepared in a great variety of ways. It is perhaps most conveniently made by mixing three parts of sulphuric acid with two parts of permanganate of potash.[1] This mixture will continue to give off ozone for several months. It is associated in the air with other purifying agents, such as peroxide of hydrogen and acids of nitrogen. Peroxide of hydrogen, called also oxygenated water, is produced by a combination of the oxygen of the air with water. It is found sometimes in rain and snow. It also is a powerful oxidizing agent, for it very freely parts with its excess of oxygen. Its oxidizing powers render it useful for bleaching, as it attacks vegetable colours vigorously. Young ladies used to purchase it for bleaching their hair, under the name of "auricomus," when it was the fashion for every one to exhibit flaxen locks. It so readily parts with its oxygen that a temperature of 68° F. is sufficient to disengage it, the warmth of the hand to the bottle which holds it being often dangerous when it is quite pure. Nitrous acid is produced whenever an electric spark passes through the air. It is one of the most valuable gaseous disinfectants and deodorizers known. It acts most energetically on organic impurities, removing the unpleasant odours of the dead-house more readily (so it is said) than any other gas. This rapid action arises from the facility with which it gives up its oxygen. For deodorizing purposes, it is made by mixing nitric acid and water with copper turnings. It is used more on the Continent than in this country. The amount of ozone, peroxide of hydrogen, and nitrous acid, which are *all*

[1] Dr. Leeds states that when permanganate of potash is exposed to the action of sulphuric acid, chlorine is evolved in consequence of the presence of an impurity in the shape of a chlorate. Apart from the ease with which chemistry enables us to distinguish ozone from chlorine, the smell of these two bodies is so different that there can be no difficulty in diagnosing the one from the other. Moreover on the fact that permanganate of potash emits oxygen when under the influence of sulphuric acid, rests the excellent process for the estimation of peroxide of hydrogen in which the oxygen produced is measured.

powerful air purifiers, are measured by exposing to the air paper dipped in a solution of iodide of potassium. They all have the property of breaking up this salt and setting free the iodine, which gives the paper a reddish brown colour, of greater or less depth, according to the amount of these disinfectants present in the air during the time of its exposure. Sometimes, instead of all the iodine being set free, some of it goes to form an oxide of potassium, called the iodate which is a colourless salt. It is therefore always necessary to spray these tests after exposure with a solution of tartaric acid which sets free the iodine from the iodate, but does not interfere with the unacted upon iodide of potassium. We are then sure of obtaining *all* of the iodine set at liberty by the air purifiers. If we wish to ascertain the amount of ozone present in the air to the exclusion of the other air purifiers, we employ a paper which is *alone* acted upon by ozone, such as the iodized litmus paper. With this test we do not take any notice of the amount of iodine set free, but we observe the amount of potash formed by the union of the ozone with the potassium. Potash, being an alkali, of course has the property of turning red litmus blue, whilst an acid turns blue litmus of a red colour. The greater or less conversion of the red litmus into blue, shows a greater or less quantity of ozone in the air.

Scales have been prepared for estimating the depth of colour of the iodine papers in testing the amount of the three air purifiers, and of the iodized litmus papers for showing the amount of ozone.

**Iodized starch tests.**

It was formerly the practice to employ starch tests, which are composed of a mixture of iodide of potassium and boiled starch, which became blue on exposure to the air from the formation of the blue iodide of starch. There are many different kinds, which may be looked upon now as curiosities; for example, Schönbein's, Lowe's, Jame de Sedan's, Lender's, Moffat's, etc. They are all more or less disposed to behave in an eccentric fashion; now they colour, then they bleach; sometimes they tint in a uniform manner; at other times they become marked with lines like a Scotch plaid, or with spots; whilst they very frequently fade. Hence the records of observations appear most contradictory, forming a mass of almost inextricable confusion. In support of this assertion, the opinions of a few who have made ozone a subject of study may be quoted:—

"At the present time the modes of determining ozone, and the tests for ozone in the external air are very unsatisfactory."—*Dr. Richardson.*

"The greater part of the countless observations on the amount of ozone in the air are worthless."—*Prof. Heaton.*

"The determinations which have hitherto been made are very vague and unsatisfactory."—*Dr. Wetherill.*

"Tests prepared from the same recipe, by different persons, give varied results."—*Boehm.*

"If we expose the tests of Schönbein and Moffat together we do not get the same result, and even tests made by the same persons at two different times will not read alike."—*Mr. Lowe, of Nottingham.*

"All the methods employed are more or less defective."—*Dr. Scoresby-Jackson.*

"Until more certain means are discovered for estimating ozone, present observations must be received with great caution."—*Davies.*

"The estimation of ozone is in a very unsatisfactory state. The great imperfection in the tests make it desirable to avoid all conclusions at present."—*Prof. Parkes.*

"No clear and consistent results have yet been obtained. Variations of light, wind, time, and paper, may cause changes attributed only to ozone, and there are no reliable means of checking them."—*Admiral Fitzroy.*

"No trustworthy observations on ozone are made in the United States of America."—*Dr. Henry of the Smithsonian Institution.*

These views refer to the antiquated practice of estimating atmospheric ozone with the iodized starch test, by suspension in a cage or box, and subsequent comparison with a scale containing gradations of colour.

The exposure of any kind of test papers in cages is a most fallacious mode of observation, for they are measurers of the velocity of the wind, and may be called anemometers rather than ozonometers. The higher the wind the deeper the colours they assume, for the simple reason that more air passes over them.

There is a special fallacy attendant on the employment of starch tests in ozonometry, because there is every reason to believe that the iodide of starch is not a true chemical compound. M. Duclaux declares that its formation is purely physical, and results from the adhesion of the molecules of its constituents. It appears that M. Personne and M. Guichard expressed the same opinion some years ago. The latter chemist, who examined the iodide of starch by the aid of the dialyser, writes—"The so-called iodide of starch is simply starch tinted with iodine." Watts considers that "the blue coloration is due to the formation of a loose combination of starch and iodine, or perhaps to the mere mechanical precipitation of the iodine upon the starch." The various circumstances which affect and modify the colour of the iodide of starch have been pointed out by Gmelin.[1]

Then, again, all of the iodine set free in the starch test does not sometimes combine with the starch. Some of the iodine set free occasionally forms a colourless iodate.

[1] *Handbook of Chemistry*, xv. 97 (German edition).

It is, moreover, very difficult to obtain pure starch, and samples of the same kind of starch often vary much in strength. The errors associated with the employment of iodide of starch tests are indeed legion.

Notwithstanding the existence of these irremediable defects inherent to the employment of iodide of starch in atmospheric ozonometry, which were brought by me before the scientific world in a prominent manner in 1873, the officials at the Montsouris Observatory have been throwing away their time and labour by employing cotton wool impregnated with iodide of potassium and starch. They have at length, it seems, discovered that what I told them years ago is but too true—namely, that the iodide of starch test is wholly unreliable. M. Marié-Davy writes:—"La difficulté de la methode consiste en ce que l'iodure d'amidon manque de stabilité, qu'il se décolore à l'air, et qu'en présence de la potasse formée une partie de l'iode mis en liberté peut se transformer en iodate. D'un autre côté, l'amidon s'altére au contact de l'air et des produits pyrogénés qu'on rencontre toujours dans l'atmosphére des grandes villes." They have now forsaken this untrustworthy iodide of starch reaction, and estimate the quantity of oxygen employed in the conversion of an arsenite into an arsenate,[1] and efforts have been made to bolster up the belief in the starch tests of Schönbein, by making it appear that Schönbein's starch tests—plus certain corrections—agree in their indications with the results determined by the oxidation of an arsenite. Having had such an immense

[1] The average amount of ozone furnished by this process for the eight years 1877-1884 shows a remarkable constancy in the composition of the air.

Ozone in 100 cubic metres of air in the Park of Montsouris, near Paris.

Milligrammes.

| 1877 | 1878 | 1879 | 1880 | 1881 | 1882 | 1883 | 1884 |
|---|---|---|---|---|---|---|---|
| 1·9 | 1·5 | ·8 | ·6 | 1· | ·7 | 1·1 | 1·7 |

experience with starch tests, my intimate acquaintance with their comic behaviour would incline me to think that if there is any harmony between them and the process with the compound of arsenic, the latter must be worthless also.

According to the most approved recent mode of observing ozone, and of estimating the amount of the air purifiers (ozone, peroxide of hydrogen, and nitrous acid), it is necessary to pass a *known* quantity of air over test papers of two different kinds at a *known* and *unvarying* velocity by means of aspirators, of which there is a great variety, such as Mitchell's aspirator, the tube aspirator, Dancer's aspirator, the injection aspirator, Andrews' aspirator, the Montsouris aspirator, and the clockwork fan aspirator. The test papers are exposed in a box of a peculiar form, where they are protected from dust, light, and moisture.

It would be impossible to give the reader in this handbook an adequate description of the mode in which ozone and the other air purifiers should be estimated. The fullest information as to how these bodies should be observed has already been published by me in my work on *Ozone and Antozone*, in which it occupies 136 pages. The errors associated with the old ozonometric method of exposing starch tests may be here summarized.

**Errors connected with old method.**

1. Impurity of chemicals } employed in the manufacture of the tests.
2. „ „ paper }
3. Formation of the iodate of potash.
4. Non-union with the starch of the whole of the liberated iodine.
5. Changes in the force of the wind.
6. Bleaching and fading of coloured tests from—
    - A. Formation of the iodate of potash.
    - B. Excess of moisture in the air.
    - C. A high temperature of „

D. A great velocity of the air.
E. A long exposure to „
F. Sulphurous acid in „

7. Light.
8. Ozonometers ( = chromatic scales) faulty in construction.
9. Differences of aspect and elevation.

I must refer to that work for the blue and red chromatic scales, the ozone register and diagram, which in like manner cannot possibly be copied into this publication. After a thoroughly accurate estimation of the amount of ozone present in the pure air of different climates, and during the various atmospheric changes of each climate, we shall be in a position to attempt an elucidation of the following and many other questions which are of immense interest and importance to the human race :—

1. What are *all* the sources of atmospheric ozone ?
2. How is it formed, and in what circumstances does it arise ?
3. What is its precise action on animals and plants ?
4. Has an excess or deficiency of ozone any effect on the public health ?
5. If so, what is the nature of that influence ?
6. What is the effect of the presence of epidemics on its amount, as calculated by the improved ozonometric method ?
7. Does ozone oxidize one only, or all of the different kinds of organic matter found in the air ?

The elucidation of that very interesting mystery respecting the supposed relationship between an excess of atmospheric ozone and an epidemic of influenza is one which demands special attention, because of the fact that an excess of ozone artificially prepared will originate a catarrh.

*Peroxide of hydrogen.*—The best method for the estimation of this, apart from the other air-purifiers, involves much labour in its performance and cannot therefore be here described. Peroxide of hydrogen.

*Nitrous acid* is recognised in so ready a manner when present in the air, that a few lines must be devoted to a consideration of its mode of detection. Nitrous acid.

Griess, who recommended the employment of metaphenylene diamine as a delicate test for nitrous acid (*vide* page 110), has described a far more sensitive test for this air purifier. His later test, in which naphthylamine is used, renders it possible to distinguish 1 part of nitrogen in 1,000,000,000 parts of water. Mr. Robert Warrington recommends[1] that this remarkably delicate reaction be applied in the following manner:—To the water in a test tube suspected to contain nitrous acid are added, successively, one drop of dilute hydrochloric acid (1-4), one drop of a nearly saturated solution of sulphanilic acid, and one drop of a saturated solution of hydrochloride of naphthylamine. Nitrous acid forms with the sulphanilic acid a diazo-compound, which is further converted by the naphthylamine into a body of a rose or ruby colour. A mixture of freshly-distilled water and these reagents remains colourless when left in a half-filled stoppered bottle, but when exposed to the air in an open vessel may be observed to deepen in tint from day to day as the absorption of nitrous acid proceeds. Test papers are easily prepared by soaking small strips of Swedish filtering paper in a solution, made by dropping a drop of each of the reagents into about two fluid drachms of distilled water, and then drying them by suspending them in a cupboard.

[1] "Note on the appearance of nitrous acid during the evaporation of water."—*Journal Chemical Society*, 1881, p. 229.

# PART III

## SKETCH OF RELATION BETWEEN CERTAIN METEOROLOGICAL VARIATIONS IN THE CONDITION OF THE AIR, AND STATES OF HEALTH AND DISEASE

In the consideration of "all influences affecting, or threatening to affect, the public health within his district," the medical officer of health should not only note all sudden and great changes of barometric pressure and heavy falls of rain, which are important factors in the production of those atmospheric conditions on which movements of underground air and water depend, but should make observations on those climatic and topographical peculiarities which are likely to exert any action on health. The value of his observations will be increased by a comparison with published readings taken simultaneously over large neighbouring areas and by a study of the laws that govern the movements of the air. The variations in the temperature, humidity, pressure, and electric state of the atmosphere, as well as the effects of these changes on the moral and physical condition of nations and individuals, form a most extensive field of study, and one, moreover, of the highest possible interest. The influence of climate on the sanitary condition of all animals, and especially of the most highly organized being in the scale of creation, has occupied for more than 2000 years, and still engages, the attention of scientific men.

The great subject of weather and disease has been worked at ever since the times of Pythagoras, whose doctrines were supported by Hippocrates,[1] the father of medicine. These distinguished philosophers divided nature into four qualities—viz. cold and warmth, dryness and moisture. They considered cold with moisture to be hurtful, and warmth with dryness to be beneficial qualities.

The three following rules have been accepted by the few, and unrecognized by the many, for hundreds of years :—

1. A preternaturally dry air, with a high temperature, predisposes to the development of fevers and intestinal disorders.

2. A very moist atmosphere, accompanied by a low temperature, is apt to induce bronchial and rheumatic affections.

3. A very dry atmosphere, when associated with a low temperature, has a tendency to excite inflammations of the respiratory organs.

The labour of the past has borne, however, some little fruit, for we are obtaining an increased knowledge of the influence of meteorological conditions on health. The bearings on health of the disturbances of the atmospheric sea above and around us, occasioned by the great cyclonic and anti-cyclonic changes throughout the world, are better understood, thanks to the telegraphic system of reporting the approach, direction, and rate of progress of storms, and the elucidation of the laws that govern their motions. As to cyclones in which the winds circulate with great Cyclones.
rapidity around and towards the centre or point of *lowest* barometric pressure, from which rises a vast ascending current, physicians with meteorological tastes cannot fail to have noticed that attacks of neuralgia in the form of

[1] *Vide* "περι αερων, υδατων, τοπων."

migraine and other nervous maladies seem often to recur at the approach of a considerable fall of the barometer, especially when this culminates in rain. Dr. Weir Mitchell gives the following result of his observations on this connection in the case of a Captain Catlin, U.S.A.,[1] who suffered from attacks of neuralgia in a painful stump:—"It was rather the fact of a storm, or the disturbance of pressure, that induced, or at least accompanied pain, than its depth, duration, or extent." Dr. Mitchell adds, "Every storm as it sweeps across the continent of America consists of a vast rain area, at the centre of which is a moving space of greatest barometric depression, known as the storm centre, along which the storm moves like a bead on a thread. The rain usually precedes this by 550 to 600 miles, but before and around the rain lies a belt which may be called the neuralgic margin of the storm, which precedes the rain about 150 miles. This fact is very deceptive, because the sufferer may be on the far edge of the storm basin of barometric depression, and seeing nothing of the rain, yet may have pain due to the storm. It is somewhat interesting to figure to oneself thus a moving area of rain girdled by a neuralgic belt 150 miles wide, within which, as it sweeps along in advance of the storm, there prevail in the hurt and maimed limbs of men and in tender nerves and rheumatic joints renewed torments called into existence by the stir and perturbation of the elements."

Anti-cyclones.

Anti-cyclones, or periods of high barometric readings, in which the winds circulate very slowly around and out from the centre or point of *highest* pressure of the barometer, which is filled by a slowly descending current from the upper regions, last longer than cyclones, often continuing for many days. In summer they are characterized by hot sultry weather without a breeze, and in winter by cold

[1] *American Journal of the Medical Sciences*, April 1877.

fogs. The former climatic condition is often accompanied by diarrhœa and cholera, whilst the latter in winter is notorious for bronchial and catarrhal affections.

To descend from the general to the particular, we know that, as regards the commencement of life, the offspring of man and the other animals born in the cold season of the year has a higher probability of life during the first year than if born in the hot season, although an exposure to excess of cold is highly destructive to infancy; and as regards the close of life, that the mortality by cold due to age doubles every nine years from the age of twenty, so rapidly does the power of resistance to cold decline with age.

It will be useful to consider: *first,* the effects of differences of temperature, solar radiation, moisture, and barometric pressure, direction of the wind, etc., on health; and, *secondly,* the meteorological conditions which appear to favour or retard the development of those diseases that seem to be influenced most by climatic variations.

# CHAPTER XXXI

## 1.—THE INFLUENCE OF DIFFERENCES OF TEMPERATURE, SOLAR RADIATION, MOISTURE, AND BAROMETRIC PRESSURE OF THE AIR, DIRECTION OF THE WIND, ETC., ON HEALTH

### A. *The Temperature of the Air = Air Warmth.*

The Temperature of the Air.

THE average mean temperature of the capitals of England, Scotland, and Ireland, deduced for long periods, which have been published by Messrs. Glaisher and Buchan, are valuable, and they give at a glance a general idea of the differences between the temperature of these countries.

| | No. of years. | Jan. | Feb. | Mar. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Greenwich | 60 | 37·1 | 39·0 | 41·5 | 46·6 | 52·9 | 59·1 | 62·1 | 61·3 | 56·8 | 50·1 | 43·0 | 39·9 | 49·1 |
| Edinburgh | 30 | 36·6 | 37·9 | 40·6 | 44·8 | 50·3 | 55·6 | 58·3 | 57·5 | 53·7 | 47·5 | 41·2 | 38·6 | 46·9 |
| Dublin | 36 | 40·5 | 41·2 | 42·7 | 47·2 | 52·0 | 57·1 | 59·4 | 58·9 | 55·1 | 50·3 | 44·1 | 42·7 | 49·3 |

The following dicta may be regarded as aphorisms :—

In *summer*, during which season there is a tendency to intestinal affections, a rise of mean temperature above the average increases the number of cases and the mortality from them.

In *winter*, during which season there is a predisposition to lung diseases, a fall of mean temperature below the average increases the number of cases of, and the mortality from, these affections.

When the temperature in London falls from 45° to 27°, the Registrar-General calculates that about 400 persons perish of *bronchitis.*

The valuable reports of the Registrar-General contain much information as to the connection of mortality from various diseases with temperature. As his reports are quite accessible to sanitarians, I shall not make any further quotation from his calculations.

Dr. Ballard concludes,[1] from a comparative study of the meteorological observations made at Greenwich for the six years from 1860-65, and on the amount of parochial sickness in the parish of Islington and in two large metropolitan dispensaries, and in the Pentonville convict prison, that—(1) "Comparative warm weather is more deleterious to public health in the colder than in the warmer half of the year," which is certainly opposed to the general opinion; (2) "In the *colder* months of the year the mean temperature is, on the whole, much more important as a condition determining the absolute quantity of sickness than the extent of the diurnal range, and that in these months the higher the mean temperature the more important is the influence of the range; (3) In these *colder* months a low range is more injurious to public health than a high range, whether the mean temperature be comparatively high or comparatively low," which is a conclusion contrary to the received opinion that an equable temperature is the most favourable to health; (4) "That in the *warmer* months of the year the diurnal range of temperature is, on the whole, more important as a condition determining the absolute quantity of sickness than the mean temperature; and (5) That, in these warmer months, a high diurnal range of tempera-

[1] "On the influence of some of the more important elements of weather upon the absolute amount of sickness."—*British Medical Journal*, June 12, 1869.

ture is much more injurious to public health than a low range."

Low temperatures.

Health is deleteriously influenced by extreme degrees of cold, unless the body has by long acclimatization become inured to such exposure. In the Arctic Expedition of Sir G. Nares, the crew of the *Alert* suffered much from the extremely low temperature, the thermometer being in March 1876 so low that –73·7° F. was registered. Dr. Lansdell states[1] that Yakutsk in North Siberia has the credit of being the coldest town in the world. Its mean temperature is 18·5° F. Between December 17 and February 18 of each year the cold exceeds –58° F. Mercury is frozen for one-sixth of the year. So accustomed do natives become to the cold that, with the thermometer at "unheard of" degrees below the freezing point, the Yakute women with bare arms stand in the open-air markets as if in genial spring. A man wrapped up in his pelisse can lie without inconvenience on the snow, under a thin tent, when the temperature of the air is –30° F. He also states that the maximum temperature of 1877 at Tomsk, Siberia, rose at 1 P.M. on August 6 to 106·9°, and the minimum temperature reached on Christmas Day 83·2° below zero, and that at Barnaul, which lies some 200 miles to the south, the maximum was 107·8°, and the minimum 84·8° below zero. He adds that small birds sometimes drop dead in the streets from cold.

Extreme ranges of temperature.

The very sensible discomfort and illness in some, induced by sudden and extreme ranges of temperature, as much at times as 30° F. or 40° F. in a few minutes, must often press itself on the notice of the health officer. The *healthy* body in the prime of life shows a wonderful ability to adapt itself, not only to great differences of temperature to which its opposed surfaces or extremities may be subjected, but to extraordinary ranges of tempera-

[1] *Through Siberia*, 1883.

ture, as extensive even as 72 degrees. Aldrich, in the Western Sledge journey from the *Alert* in April 1876, wrote, "The air is very cold, and the sun is very warm. The thermometer hanging on my chest registered −12° F., when on my back −30° F." The very young, the aged, the feeble, the sickly and diseased, are generally more or less disturbed by the sudden variations of our fickle climate, and it is sometimes found almost impossible to provide against the rapid alternations of heat and cold, moisture and dryness, etc., with suitable clothing. It is not only desirable, then, to observe extreme ranges of temperature, but the differences between the temperature of the earth and of the air 4 feet above it. Catarrhal affections are sometimes noticed when the rays of the sun are powerfully felt, whilst the earth is at the same time exceedingly cold.

"Cold spells."

It is wise to bear in mind the occurrence of exceptionally cold weather on certain days in the spring months, and to be prepared for it with clothing of an extra warmth. These "cold spells" have been noticed over all parts of the world, and were pointed out long ago by Kaemtz in his book on Meteorology. Periods of "treacherous weather" at this season of the year have been recognized by the people of all countries in their old sayings. They occur on or about February 7 to 12, April 10 to 14, and May 10 to 14. Mr. Glaisher, in his estimation of the mean daily range of temperature at the Royal Observatory, Greenwich, during the sixty years from 1814 to 1873, found[1] the February "spell" to be distinctly visible, but the April and May "spells" to be situated more at the commencement of those months. The cold "snap" of February was even noted by the pupils of Galileo. The three cold days of April are called in Scotland and the

[1] *Quarterly Journal of Meteorological Society*, vol. iii., New Series, No. 20, October 1876.

North of England "the borrowing days," as they are supposed to be lent by the colder month of March.

Mädler[1] examined the mean temperature of May in Berlin for eighty-six years, and found a retrogression of temperature amounting to 2·2° F. from May 11 to 13.

Cool rainy summers are generally periods of low mortality. Cold winters and hot summers, although agreeable to the strong and healthy, are fatal in their effects on the general population. Intestinal disorders kill in hot summers, whilst pulmonary affections destroy life in cold winters. Dr. Richardson states:[2] "that, (1) the phenomena of catarrhs or colds are confined within a range of temperature extending from a mean of 41° F. to the extreme cold of the Arctic climate; (2) yellow fever can only continue in parts of the earth where there is a mean temperature above 68° F.; (3) typhus fever flourishes only in regions having a range of temperature lying between 40° F. and 62° F.; and (4) the phenomena of phthisis pulmonalis are so limited by a given degree of cold that they cannot exist in the Hebrides, Faroe Isles, Iceland, and the Arctic Regions." Some years ago a considerable discussion took place in the medical journals as to whether phthisis pulmonalis *did or did not* occur in Iceland, the result of which terminated in the production of evidence which showed that it is found there, and that the hilly tablelands of Mexico are the only parts of the civilized (?) world where the disease is unknown (*vide* page 280). Is it not probable, in view of recent bacteriological researches, that isolation has much to do with the immunity enjoyed by the inhabitants of these islands and out-of-the-way places?

As regards the climate of this country it has been recommended:[3]—

[1] *Verhandlung des Vereins zur Beförd des Gartenbanes,* 1834.

[2] *Diseases of Modern Life.*

[3] "The effect of cold on children."—*Brit. Med. Journal,* Dec. 25, 1875.

1. That no child too young to walk or run should be taken out of doors when the external temperature is below 50° F.[1]
2. That the rooms in which children live and sleep should never be below 58° F.; and
3. That the dayroom should be three or four degrees warmer than the bedroom.

The relation between certain varieties of *coup de soleil* or heat apoplexy, as well as other affections, and the indications of solar and terrestrial radiation thermometers, is a subject that, if worked at, will probably yield valuable results.

B. *The Solar Radiation.*

The sun-warmth is a factor in the production of climate of considerable importance to health, and is estimated by the means of a solar radiation thermometer (*vide* page 414). The space at my disposal will not permit me to dwell on its relation to the duration of sunshine, as registered by the several ingenious arrangements for its measurement, but will only allow me to direct attention *en passant* to the very suggestive influence on life and growth, shown by the relation between the amount of sunshine and the yield of hay and other vegetable crops, the abundance during years of little sunshine being compensated for by a deficiency in weight. Sun-warmth.

Dr. Frankland has pointed out[2] that the sun-warmth is influenced: (1) by the *colour* of the soil, and our other surroundings and their consequent absorbent power;

[1] The No. 1 recommendation is too stringent, and requires the addition of the words, "unless carried in the arms of an adult, so as to derive warmth from an external source." On several occasions have young children come under my charge who have been exposed in perambulators to great cold, in whom a complete cessation of the flow of bile into the intestinal canal has occurred.

[2] "The Climate of Town and Country," in *Nineteenth Century*. July 1882.

(2) By reflection from land (snowfields or chalk-pits) or water; and (3) by the amount of watery vapour in the air. "The nearer the colour of the ground approaches to white, the greater will be the sun's warmth and the cooler the air; whilst the darker the colour, the warmer will be the air, and the less will the heat of solar radiation be felt. The darker the colour of our houses the cooler the streets, and the hotter the rooms during sunshine. The lighter the colour of the houses, the hotter the streets and the cooler the rooms." The dark, distinguished from the luminous, heat rays are sifted out of the air by the watery vapour in its lower strata, hence the higher we ascend into the air the greater is the sun's warmth.

He points out that the sun's warmth, unlike the air temperature, is greater in Norway than at the equator, because the air is colder, and therefore drier, in the Arctic than in the hot regions of the world.

| Dry bulb. | Wet bulb. | Vapour in a cubic foot of air. Grains. |
|---|---|---|
| 36 | 33 | 1·8 |
| 96 | 93 | 15·2 |

Arctic voyagers have stated that, with the temperature in the shade far below freezing-point, the pitch will boil in the seams of the vessel where it is exposed to the sun.

Dr. Frankland has drawn a strong contrast between the sensations experienced when he was exposed to the following opposite climatic conditions:—

| | Sun Warmth. | Air Warmth. | Remarks. |
|---|---|---|---|
| Bellaggio . . | 72° | 83° | Heat most oppressive. |
| Summit of the Diavolezza Pass | 107° | 43° | Delicious sensation of coolness. |

He omits all reference, however, to the influence of the hygrometric condition of the air, which was probably four or five times greater at the former than at the latter station, and which has much to do with the *sultry* character of heat.

### C. *The Hygrometric State of the Air.*

Whilst the air is never without *some* moisture, the amount present in the air is largely due to its temperature, the capacity for retaining moisture in an invisible gaseous form being greater when the temperature is high than when it is low. The moisture of the air.

The aching of rheumatic joints and of corns, the extraordinary noises that sometimes proceed from chairs and tables, and the condition of certain epithelial structures, such as the hair and skin, are often signs to the public of the approach of rain, all being the result of an excess of humidity in the air, due to the great alterations in size which fibrous, epithelial, and ligneous bodies undergo by the addition or subtraction of moisture. How cleverly did the great Jenner embody in a few lines of verse, "On the Signs of Rain," the effects of this atmospheric change—

> "Hark! how the chairs and tables crack,
> Old Betty's joints are on the rack."

The decrease of the pressure of the air which generally accompanies an excessive hygrometric condition has doubtless, however, much to do with the painful condition of that old lady's joints. We know but little of the influences of varying degrees of humidity of the air on animal life. It is unquestionable that an excess or deficiency of the normal amount of moisture in the air exerts a very decided action on the state of the public health. People in health merely feel slightly depressed when the air is rather damp, and somewhat irritable when it is unusually dry, but to invalids even a change of two or three per cent in the humidity is perceptible. An excess is the more prejudicial, because aqueous vapour possesses a powerful affinity for organic matter, and serves both to preserve and diffuse it. We all of us have frequently experienced the enervating effects of a fog, which has been termed " half an air and half a water," and the return of our usual mental and bodily vigour on its removal. When we remember that all depressing agents predispose to disease, the subject of humidity in relation to hygiene, connected as it is so intimately with that of climate, cannot be too diligently examined.

Insular climates, in the temperate latitudes, are necessarily humid to a certain extent, especially if the temperature is low. When there is in addition an excessive rainfall, a damp, foggy, and relaxing climate is produced, which often exercises an injurious influence on the health of those unacclimatized to it. The voice of Grassini was reduced nearly an octave by the relaxing effect of the air of this country. Her vocal organs were restored, however, to their normal condition on her return to the drier climate of Italy.

Female beauty.

The view has been expressed that the degree of moisture of the air is intimately associated with the degree of beauty in the human female, and especially with its duration. The average hygrometric state of the air is but one of the many factors concerned, which, by their union, form the climate of a country, by which the female body is undoubtedly influenced to a considerable extent in its development. Temperature indubitably exerts an effect which is perhaps scarcely if at all inferior. Warm moist climates, in the temperate regions of the earth, have been considered to produce more beautiful women, whose beauty endures longer than countries possessing different qualities of climate. As we leave the temperate climes for the sunny south, where development is more rapid, and the period of puberty earlier, we notice that female beauty is very evanescent, and is soon on the wane. As the temperate latitudes are left for the northern, colder, and drier climates, there is a coarseness, and want of the softness and delicacy so characteristic of the women of the south. Modes of life, differences of race and character, as well as the kind of climate, have, of course, some considerable action on the grace and loveliness of the female. This subject is one of great magnitude, on which there will necessarily be a divergence of opinion, as the question of taste is very much involved. I only allude to it as one deserving of thought.

An excess of aqueous vapour in the atmosphere has not only a depressing effect on the nervous system, but it interferes with the cutaneous and pulmonary exhalations. If the temperature is high (65° to 80° F.), saturated air is sultry and oppressive. If low (*e.g.*, a Scotch mist of 36° F.), its chilling influence penetrates all clothing. At least one half of the patients who apply for relief during the winter months to the physicians of the metropolitan and provincial hospitals of this country are afflicted with colds, coughs, bronchial and rheumatic affections. The prevalence of these disorders at this season is, without a doubt, due partly to the *coldness* in association with *the excessive moisture* of our very changeable climate. Above 80° F., air of excessive humidity becomes injurious; and it has been doubted as to whether life can be prolonged in such air at a temperature between 90° F. and 100° F. An excess.

A very dry air is considered by some as less deleterious to health than a very moist air. Assistant-Surgeons Lauderdale and Ross, in a report relative to Fort Yuma, California, write:[1]—"With the thermometer at 105° F., the skin becomes dry and hard, and the hair crisp, and furniture falls to pieces. Newspapers, if roughly handled, A deficiency.

[1] *Quarterly Journal of Science*, April 1878.

break. Eggs that have been on hand for a few weeks lose their watery contents by evaporation, and the remainder is tough and hard. A temperature of 100° F. may exist for weeks in succession, and there will be no additional cases of sickness in consequence. We have none of the malarial diseases."

Dr. Ballard's[1] inferences as to the effect of variations in atmospheric moisture, as represented by the readings of the hygrometer, and the estimation of the rainfall on the public health of a portion of London, are thus given by him :—

"1. That in the *colder* months of the year the mean temperature is, on the whole, more important as a condition determining the absolute quantity of sickness than the amount of accompanying atmospheric moisture. 2. That in the *warmer* months of the year, on the other hand, the amount of atmospheric moisture is more important as a condition determining the absolute quantity of sickness than the mean temperature. 3. That, both in the colder and warmer seasons of the year, a comparatively dry condition (for the season) of the atmosphere is more damaging to public health than a comparatively moist condition of the atmosphere. The amount of rainfall is more important at comparatively low than at comparatively high temperatures, in regulating the absolute quantity of sickness."

Writers on cholera in India have pointed out the coincidence of maximal rainfall and minimal cholera.

The artificial climates which we manufacture in our houses and public buildings are far more deleterious to health than any atmospheric vicissitudes as to moisture.

The air of our rooms.

The air of our rooms has a tendency to be preternaturally dry, and when so is often oppressive and unwholesome. The degree of moisture of air is shown by the hygrometer,

[1] *Op. cit.*

which consists of two thermometers, one the dry bulb, and the other (covered with muslin and attached by a lamp wick to a feeder of water) the wet bulb. The difference between these bulbs is about five or six degrees in a healthful atmosphere. In rooms warmed by radiant heat it reaches often eight degrees; whilst in rooms heated by hot air a difference of fifteen to seventeen degrees is often noticed, which is unwholesome and unpleasant. Although so many different kinds of stoves and other appliances, such as hot water pipes, etc., for heating rooms have been devised, that important point seems nearly always to have been overlooked, namely, the maintenance of a healthful amount of moisture in the air.

I have seen pans of water placed on iron stoves to counteract the unpleasant effects caused by the dryness of the air, and have seen the water steaming, and even boiling. In such an apartment there was an excess of moisture in the air which made me feel very uncomfortable, creating the disagreeable sensation which one experiences on entering the house of a laundress; the hygrometer in such a case giving a difference of only one or two degrees, showing that the air was almost saturated with watery vapour in an invisible form.

The air sometimes becomes almost saturated with the aqueous vapour that proceeds from the pulmonary and cutaneous surfaces in crowded halls or rooms. Prof. Sanders relates[1] an anecdote, narrated to him by a Russian officer, of the production of a shower of snow that fell on the audience in a concert-room by the sudden opening, in very cold weather, of a window, for purposes of ventilation.

Even now, when the study of health and the influences which deteriorate and promote it, coupled with the prevention of disease, are the great subjects of the day, rivalling in interest the kindred one of the cure of disease,

[1] *Handbuch der öffentlichen Gesundheitspflege.*

there seems a complete ignorance or apathy in regard to this subject amongst physicians and leading architects.

The modern pattern hospital.

On visiting some years ago the completed portion of the New Edinburgh Royal Infirmary, which is fitted with all the most approved and recent appliances for heating, ventilation, etc., and which is considered to take the place, previously occupied in turn by St. Thomas' Hospital, London, and the Lariboisière and Hôpital de Ménilmontant in Paris, of the modern pattern hospital, I was astonished to find that no provision whatever existed for supplying moisture to the air dried by the coils of hot water pipes that are seen in so many places. If gardeners were to treat their greenhouse plants thus, healthy life and growth would be impossible. Horticulturists always furnish their hot water pipes with long troughs, filled with water, that rest on the pipes, and thus maintain an artificial climate, closely resembling that to which the plants have been accustomed, in which air is enabled to lick up as much water as its temperature will permit.

## D. *The Pressure of the Air.*

The Pressure of the Air.

There is a strong popular belief that old wounds, injuries, diseased bones, and rheumatic joints are the seat of discomfort, or even pain, on the approach of a storm, which, speaking generally, means in this country a sudden decrease of at least $\frac{1}{2}$ inch of the mercurial column. Richardson and others tell us that when the body is exposed to low barometric pressure there is a tendency to exudation of fluid from wounded surfaces, a feebleness in the healing of wounds, a susceptibility to disturbance in the body generally, and a proneness to the production of secondary fever by the absorption of discharges which have undergone some decomposition. The outcome of these facts has been the establishment of the law that no important surgical operation should be performed when the barometer is low, or when it is steadily falling. The principal effect of diminished pressure of the atmosphere is distension of the capillaries. We all recognize, as one of the exciting causes of apoplectic seizures, a rapid diminution of atmospheric pressure producing a sudden capillary engorgement. Dr. M. A. Veeder, of Lyons, New York, suggests that there is a difficulty in the adjustment of the volume and rate of the circulation of the blood to the varying atmospheric pressure upon the surface of the body, and consequent unusual strain on the weakened bloodvessels. Dr. Murray, of Forfar, is in the habit of advising his elderly patients who have weak hearts and degenerated arteries to observe the strictest moderation in eating, drinking, and in mental and physical exertion, when the barometer suddenly rises and falls. Mr. Wood, of King's College Hospital, introduced the question in the *British Medical Journal* in the spring of 1872, as to why cases of joint disease are invariably worse during the warm, moist days of winter? It was curious that his attention should have just at that time been particularly called to the connection, for the pressure of the air in London had been less early in that year than had been noted for nearly thirty years. Indeed, it was stated, on the authority of the editor of the *Meteorological Magazine*, that only on two occasions during the present century had the barometer been so low as on January 24, 1872. An exacerbation of the symptoms in cases of joint disease may be due to low barometric pressure, acting in a manner which may be thus explained:—In the solid, inelastic articular expansions of the bones, which are surrounded by firm inextensile textures, forming the joints, the minute nerves, shown by Kölliker and others to permeate the cancellous and compact structures in company with vessels, are pressed by these vessels, when enlarged, against the unyielding walls of the channels through which they pass. Although the nerves of bones do not generally afford healthy individuals any conscious sensations, yet, in diseases of the joints, the bones, when congested or the seat of inflammation, become painful. Tissues, not supplied with rigid canals like bone, yield to pressure during any temporary increase in the size of the minute vessels. In such tissues, vascular distension, from a diminution of the pressure of the air, is unassociated with pain, because the nerves accompanying the vessels are uninterfered with. Low barometric pressure and an excess of humidity of the air offer conditions most unfavourable for the removal of heat by evaporation and radiation from a congested or an inflamed joint. Teeth, which have a nutrient system very similar to that possessed by bone, become painful when the pressure of the air is suddenly lessened, for the same reason. The nerves of the tooth being in a morbid condition from caries, are temporarily irritated by the capillary enlargement. How is it that joints which are not diseased ache when the barometer is low? I am not aware that this occurs in the young and healthy. Experience teaches us that old rheumatic people often complain of this symptom. Such persons, whose joints are not in a perfectly healthy state, are generally worse during damp weather, in consequence, I presume, of imperfect elimination by the skin, and of the lowering of the vitality of parts (whereby the action of a morbid condition is favoured),—changes undoubtedly induced by the meteorological conditions, the effects of which we have been considering. It has for a long time been held that increased atmospheric pressure artificially applied exercises an anœmiating and compressing action in the peripheric tissues; that it diminishes the frequency of the pulse and the calibre of the small vessels generally, thus increasing the obstacles which the vascular walls oppose to the current of blood from the heart. M. Vivenot states that this diminution in the size of the vessels may be seen on the conjunctiva, on the ear of the rabbit, and on the vessels of the retina, and that rarified air produces contrary effects (*Virchow's Archiv.* 1866). The hæmorrhages and peripheric congestions observed in aeronauts, and in divers and miners, are in this mechanical manner accounted for. M. Bert[1] and Forlanini[2] have impugned the correctness of this view, and state that the calibre of the capillaries does not undergo change under the action of compressed air. The therapeutic employment of compressed air, which is given at a pressure of from 1 to 10 atmospheres, in bronchitis, asthma, and other affections, is now a recognized mode of treatment, as, for example, at Ben Rhydding, in Yorkshire, and at some establishments in France and Germany. The physiological effects are said to be the following:—1. Augmentation in the amplitude of the inspirations; 2. Diminution in the number of respirations in a given time; 3. Prolongation of the expiratory act; 4. Gradual augmentation of the capacity of the lungs; 5. Superoxygenation of the blood, increased activity of the organic combustion, and elevation of temperature.

The effects of diminished pressure of the air are an increase in frequency of the respiratory and circulatory acts, and a reduction of the activity of the nutritive processes, as shown by the amount of urea eliminated.

The treatment of certain pulmonary diseases by compressed and rarified air as a substitute for change of climate has been introduced into the United States by Dr. H. F. Williams under the somewhat ponderous title of "Pneumatic Differentiation," as a new method.[3]

The subject of the effects on health of changes in

[1] *Comptes Rendus*, August 19 and August 26, 1872.

[2] *Gazzetta Medica Italiana*, Lombardi, March 31, 1877.

[3] *New York Medical Record*, January 17, 1885.

atmospheric pressure[1] should be more clearly ascertained, and it offers a wide and encouraging field for exploration.

Meteorological vicissitudes appear to exert an influence on nervous maladies. Persons whose stumps of amputated limbs are painful sometimes get into a morbid and hysterical state of mind; and in their prospective study of their discomforts, this hyperæsthetic condition gives rise to fanciful imaginary ideas.

It is the experience of those who have the care of the insane that a sudden and great decrease in atmospheric pressure is generally accompanied by an increased excitability, more apparent amongst some forms of mental disease than others. The late Dr. Day, of Geelong, connected[2] an epidemic of suicide which prevailed in Australia in 1872 with a period of low barometric pressure. Dr. Ransome has observed[3] that a high degree of atmospheric pressure is favourable to the production of neuralgias.

## E. *The Direction of the Wind.*

The Direction of the Wind.

West and north-west winds are considered more favourable to health than south and south-west winds, which are generally warm and soothing to invalids, and others with an irritated pulmonary surface. North and north-east are not considered unfavourable to health, and are generally enjoyed by those who are robust. The east winds of spring are proverbially deleterious, except to the strong and healthy, by reason of their coldness and dryness.

The heat of the sun is greater when the air is dry

[1] Vide *Effets Physiologiques et Applications Thérapeutiques de l'Air Comprimé*, by Dr. J. A. Fontaine, 1877.

[2] *Australian Medical Journal*, November 1872.

[3] "On Atmospheric Pressure and the Direction of the Wind in relation to Disease," read before the Manchester Philosophical Society.

than when it is moist, for the humidity of the air acts as a screen to the sun's rays. A sudden exposure of the body to extremes of temperature, such as are experienced when passing out of the oppressively hot sunshine into the icy cold shade, is injurious to the weakly, for it is unable to accommodate itself readily to the rapid transition.

The dry east winds are not complained of so much if they blow in February as in March or April, because we do not receive so much heat from the sun in the former as in the latter months, and are not therefore exposed to the same extremes of temperature.

East winds have been especially connected with the production of neuralgic affections, and the moist warm relaxing winds from the south-west have to a less extent been blamed.

Dr. W. Mitchell found that of 50 cases of amputation of limbs less than half felt unusual sensations upon the coming of or during an east wind. Of the rest, two-thirds insisted on their power to predict such a change of weather, but said they were unaffected by a thunderstorm or by rain coming from the south.

Dr. Ballard's observations, to which allusion has already been made,[1] lead him to believe that westerly, southerly, and south-westerly winds are associated with a larger amount of sickness than northerly and north-easterly winds.

| | No. of Weeks. | Sum of Sickness in new cases. | Mean. |
|---|---|---|---|
| W.S.S. | 2 | 984 | 497 |
| S.W. | 103 | 48,550 | 471 |
| W. | 7 | 3273 | 467 |
| N.W. | 5 | 2312 | 462 |
| N. | 3 | 1382 | 460 |
| Var. | 47 | 21,660 | 460 |
| N.E. | 33 | 14,952 | 453 |
| N.N.E. | 4 | 1790 | 447 |

[1] *Op. cit.*

# CHAPTER XXXII

## 2.—THE METEOROLOGICAL CONDITIONS WHICH APPEAR TO FAVOUR OR RETARD THE DEVELOPMENT OF CERTAIN DISEASES

THE influence of season is recognized by physicians in the treatment of disease, and by surgeons in the repair of injuries. When all animal and vegetable life exhibits evidence of growth in spring, the most intractable forms of disease will sometimes yield to treatment. This vis medicatrix naturæ is especially seen in the young, but is also frequently noticed in the aged.

It will be useful to dwell briefly on the relative prevalence of certain diseases during the several months and seasons of the year, in order to ascertain the influence exerted on them by meteorological changes.

1. Surgical fever and shock after operations.
2. Smallpox.
3. Measles.
4. Whooping cough.
5. Scarlet fever.
6. Fever.
7. Diarrhœa. / Dysentery. / Cholera.
8. Bronchitis, pneumonia, and asthma.

9. Phthisis.
10. Diphtheria.
11. Hydrophobia.
12. Erysipelas and puerperal fever.
13. Insanity.
14. Rheumatism.

1. *Surgical Fever after operations.*—Dr. Richardson shows[1] that there are differences in the mortality of certain diseases which are attended by fever or increment of animal heat during the several seasons of the year. He found, from an analysis of 139,318 deaths from all diseases, during the years between 1838 and 1853, that the mortality from three of the diseases of this class, held the following proportions :— Surgical Fever and shock.

| | First Quarter. Jan. Feb. March. | Second Quarter. April, May, June. | Third Quarter. July, Aug. Sept. | Fourth Quarter. Oct. Nov. Dec. |
|---|---|---|---|---|
| Scarlet Fever . . | 20·809 | 18·978 | 26·234 | 33·976 |
| Erysipelas . . | 25·144 | 23·444 | 22·337 | 29·174 |
| Carbuncle . . | 29·771 | 19·685 | 24·409 | 29·133 |

He points out that the last quarter is the central quarter of the year in which these diseases are most fatal, and that December is the centre of a period of seven months which commences in September, during which there is occurring in the animal organism a marked modification in the nutrition, as compared with the five remaining months from April to August.

Admitting that whenever there is any considerable increase of the animal temperature, there is danger, unless there be established a compensation by radiation and specially by evaporation of water from the body, we find that the fourth quarter of the year is more distinguished than the other quarters for those meteorological conditions

[1] "On Meteorological Readings in relation to Surgical Practice."—*Medical Times and Gazette*, January 29 and February 5, 1870.

which are most unfavourable to equalization of heat by evaporation and radiation, namely, low barometric pressure, excess of humidity of air, and a temperature low, but not low enough to compensate for increase of heat by arrest of oxidation or by abstraction of heat.

Dr. Richardson has accordingly drawn up certain rules for the guidance of surgeons in the performance of operations which will admit of delay, until natural conditions arise favourable to operative work, whereby surgical fever, which often creates such fatality, may be prevented.

*The time is favourable for operations*—

(*a*) When the barometer is steadily rising.
(*b*) When the barometer is steadily high.
(*c*) When the wet bulb thermometer shows a reading of five degrees lower than the dry bulb.
(*d*) When, with a high barometer, and a difference of five degrees in the two thermometers, there is a mean temperature at or above 55° F.
(*e*) When the wind is west or north-west.

*The time is unfavourable for operations*—

(*a*) When the barometer is steadily falling.
(*b*) When the barometer is steadily low.
(*c*) When the wet bulb thermometer approaches the dry bulb within two or three degrees.
(*d*) When, with a low barometrical pressure and approach to unity of reading of the two thermometers, there is a mean temperature above 45° and under 55° F.
(*e*) When the wind is south or south-west.

Dr. A Hewson has published[1] the results of the observations made in the Pennsylvanian Hospital by the surgeons, on the relation between certain meteorological

[1] *Pennsylvanian Hospital Reports*, vol. ii. 1869.

conditions and the mortality after surgical operations. They agree in the main with the conclusions of Dr. Richardson, and elicit the additional fact that death from surgical "shock" is associated with a high barometrical pressure and a dry air, conditions opposite to those accompanying fatal pyæmia. Dr. Hewson writes, "We obtained a mortality, when the operation was performed with the barometer ascending, of 10·7 per cent, of 20·6 per cent with it stationary, and 28·4 per cent with it descending."

French surgeons seem disinclined to operate during the *hot* and *sultry* days of summer, fearing secondary hæmorrhage and septicæmia. Roux, who operated on a large number of cataracts, reserved the operations until spring.

2. *Smallpox* has been found by Dr. Ballard[1] in London, Smallpox.
and by Dr. Wistrand in Sweden (in which country there is a registration of disease), to prevail more from November to May than from May to November. The former physician noticed that it has assumed an epidemic form soon after the mean temperature of the air has persistently fallen below 50° for the winter season, and has begun to decline in May, when the mean temperature of the air begins to rise above this line, and gives place to higher temperatures.

The curve for smallpox in London for a period of

*Smallpox—for all Ages and both Sexes.*

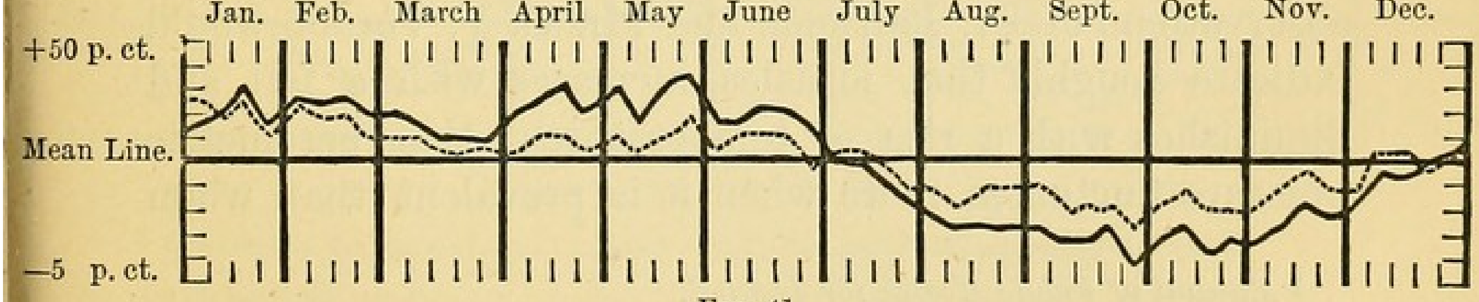



Fig. 41.

[1] *Medical Times and Gazette*, March 11 and 13, 1871.

thirty years (1845 to 1874), represented in Mr. Alexander Buchan's and Dr. A. Mitchell's interesting research on *The Influence of Weather on Mortality from Different Diseases and at Different Ages,* endorses these views.

The dotted line represents the mortality from which that of the abnormally high epidemic of 1870-72 has been withdrawn. This abstraction has simply reduced the sensitiveness of the curve. The straight black line in this and in the following figures containing curves, indicates the mean weekly death-rate on an average of 52 weeks. The curve, as it rises above and falls below the straight black line, represents the average death-rate of each week, calculated in percentages of the mean weekly death-rate for the whole year.

Dr. Moore has confirmed these observations in Dublin, where a well-marked tendency to an epidemic was noticed in March 1871; but the disease appeared to be kept in check by the increasing temperature, notwithstanding the importation from England of many cases, until, with the advancing autumn it blazed into an epidemic. He has also noticed[1] that abundant rainfalls seemed to be followed by remissions in the severity of the epidemic, and that the acme of the epidemic closely followed a period of comparatively dry weather and lower humidity.

Measles. 3. *Measles.*—Sydenham, in his medical observations, states that cases of measles are generally most numerous towards the end of March, and that they then gradually decline in number and disappear by midsummer. The observations of Dr. Ransome and Mr. G. V. Vernon would indicate roughly that measles increases with a fall and diminishes with a rise of temperature;[2] that barometric pressure fluctuates more when it is prevalent than when

[1] *Manual of Public Health for Ireland.*

[2] "On the Influence of Atmospheric Changes upon Disease."—*Proc. Lit. Phil. Soc.*, Manchester, vol. i. Series 3, 1859 to 1860.

it is not rife; and that the period of its recurrence is about every five or six years.[1]

This disease, which prevails especially during the spring and summer quarters of the year, would seem, according to the observations of Drs. Moore,[2] Ballard,[3] and others, to be unfavourably influenced by a temperature of the air above 60° in summer, and to be checked by a fall of temperature during winter below 42°.

Its mortality is governed by other influences than those of a meteorological nature. *Cæteris paribus,* measles would seem to be more destructive amongst those who live in total disregard of all hygienic rules than amongst those who obey the laws of health, and to be more fatal to native tribes amongst whom the disease has been previously unknown. The severe epidemic in the Fiji Islands, when the disease was introduced by Europeans, affords a fresh proof of the truth of this last-mentioned statement.

The measles curve, representing the fatality in London from this disease, is remarkable, according to Mr. Buchan and Dr. A. Mitchell, in showing a double maximum and minimum during the year, a rapid fluctuation taking place from Christmas to the

*Measles—for all Ages and both Sexes.*

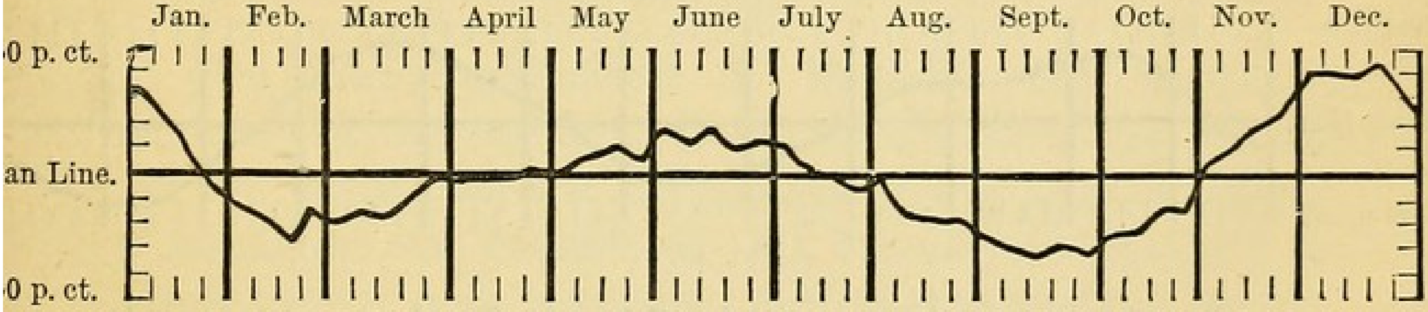



FIG. 42.

[1] "Epidemic Cycles."—*Brit. Med. Journal,* September 1, 1877.

[2] *Op. cit.*

[3] Eleventh Report of the Medical Officer of the Privy Council, 1868, No. 3, pp. 54-62.

middle of February, when the weekly deaths fall from 42 to 21.

Whooping-Cough.

4. *Whooping-Cough.*—Extremes of heat and cold appear to affect not only the prevalence of this disease, but much more so its mortality. It generally seems to progress hand in hand with measles, increasing with a falling and diminishing with a rising temperature. During the hot weather of summer it is rarely heard of; and during the period when the cold, dry, east winds blow in spring, it is generally most fatal amongst the insufficiently clothed and ill-fed. We usually regard it as a winter and early spring disease.

Dr. Moore thinks that intense cold checks the disease, whilst moderate cold favours its spread.

The London curve for thirty years agrees pretty closely with these views.

*Whooping-Cough—for all Ages and both Sexes.*

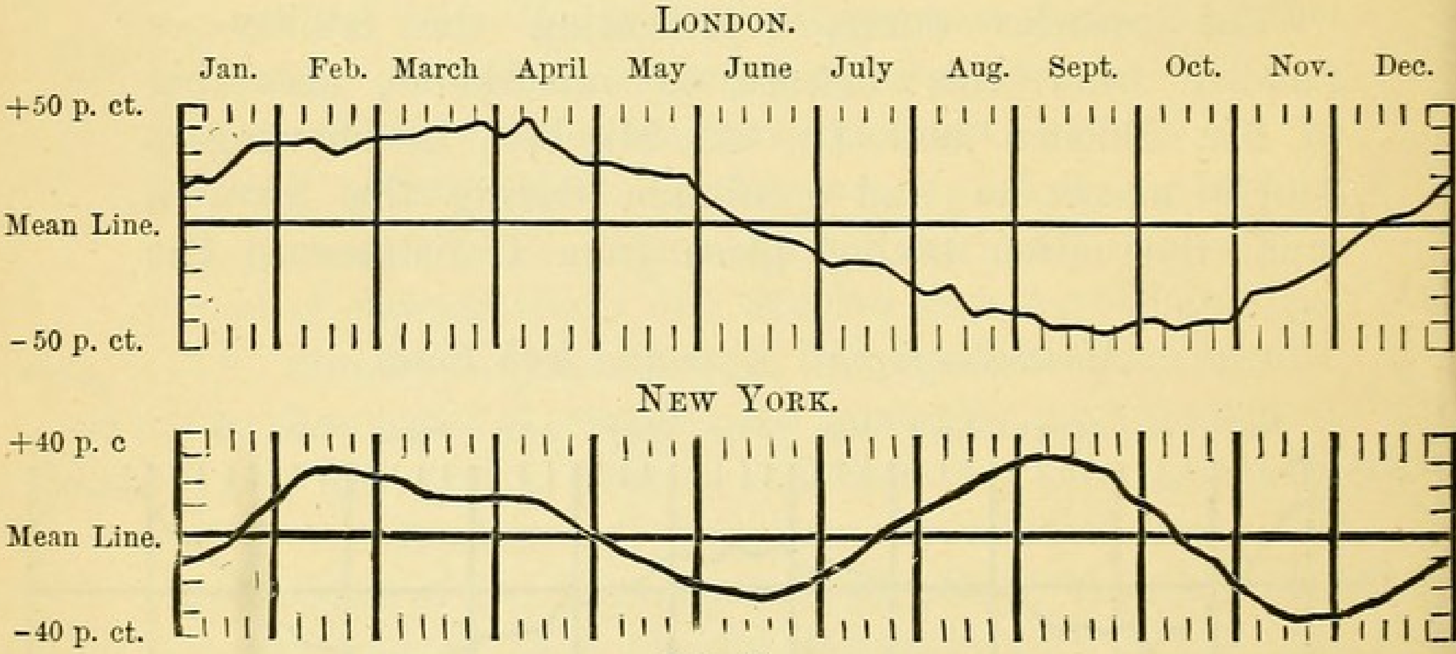



FIG. 43.

The investigation made by Mr. A. Buchan and Dr. A. Mitchell into the mortality of New York,[1] conducted on

[1] "The Influence of Weather on Mortality of New York from different diseases and at different ages."—*Journal Scottish Meteorological Society*, New Series, vol. v., Nos. xlix-lxiii., p. 171, 1880.

the same lines as that respecting London, shows that the chief maximum of the curve of New York is almost coincident with the minimum of London.

5. *Scarlet Fever.*—Sydenham considered that this disease appears most frequently towards the end of summer. Scarlet Fever.

F. Favourable, U. Unfavourable, to the development of the disease.

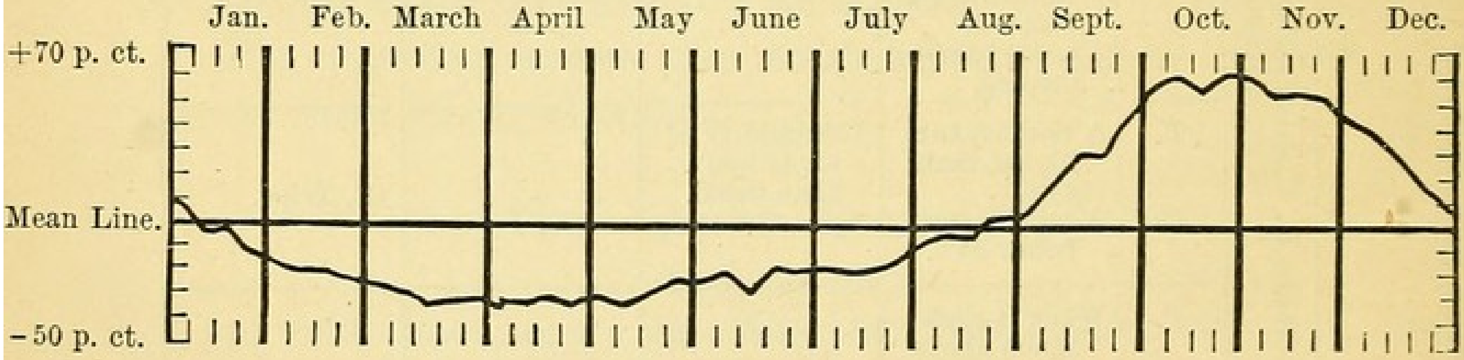
| | Temperature. | Humidity. | Pressure. | Authority. |
|---|---|---|---|---|
| F. | Moderately low. | Excessive. | Sudden fluctuations. Diminished pressure. | Dr. Ransome. |
| U. | Above the average. | | | |
| F. | Between 56° and 60°. | Not above 86, or much less than 74. | | Dr. Ballard. |
| U. | Fall of mean temperature below 53° tends to arrest disease. | | | |
| F. | A temperature higher than 44·6. | If humidity of air is less than usual. | | Dr. Tripe. |
| U. | A temperature below 44·6. | | | |
| F. | When it rises much above 50°. | | | Dr. Moore. |
| U. | A fall of mean temperature below 50° in autumn. | | | |
| F. | | Mortality greater in dry than wet season. | | Dr. Longstaff. |

The Registrar-General of England has noted a tendency in the mortality from this disease to increase in London during the last six months of the year, attaining a maximum in December. Dr. Moore has observed it always to be most prevalent and fatal in Dublin during the last quarter of the year. Dr. Wistrand considers that this disease is most abundant in Sweden in November, and least so in August.

The habits of the people have much to do, doubtless, with the particular time of the year when the maximum of the disease appears. My own experience teaches me that it increases with a rising temperature, spreading like wild-fire in very hot weather in agricultural villages, during the times when children congregate together, as, for example, during hay-making, pea-picking, gleaning, hop-picking, and school fêtes; and that this highly infectious disease spreads in towns and cities in very cold weather amongst the poor, who with their scanty supplies of fuel, huddle together for mutual warmth, diligently closing every chink whereby fresh air might possibly enter their overcrowded dwellings.

*Scarlatina—for all Ages and both Sexes.*

LONDON.




The curve of New York may be roughly described as the opposite of that of London :—

NEW YORK.

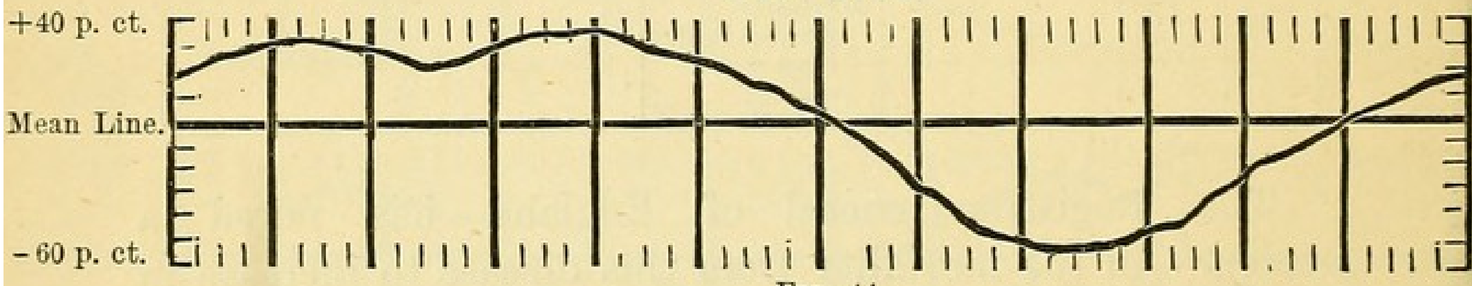



FIG. 44.

The thirty years' curve for London would, according to Mr. A. Buchan and Dr. A. Mitchell, show the maximum death-rate to occur from the beginning of October to the end of November (when the mean temperature of the air of London is 48·2, and its relative humidity is 85), and the minimum to be in March, April, and May (during which months the mean temperature of the air of London is 47·3, and its relative humidity is 77).

The curves of whooping-cough and scarlet fever form striking contrasts in the case of London, the maximum for whooping-cough and the minimum for scarlet fever both occurring in spring; whilst whooping-cough reaches its minimum in autumn, when scarlet fever is at its maximum. This conspicuous difference does not, however, obtain in the case of New York. As to the cycle of scarlet fever, Dr. Ransome has noted[1] that a small wave has appeared about every five years, and a great wave every fifteen or twenty years.

6. *Fever.*— { Typhus. / Enteric. / Intermittent and continued.

*Typhus*, according to most observers, is only indirectly influenced in its prevalence by temperature. When the weather is very cold cases are generally more numerous, Typhus Fever.

*Typhus—for all Ages and both Sexes.*

(*Bloxam's Method.*)[2]

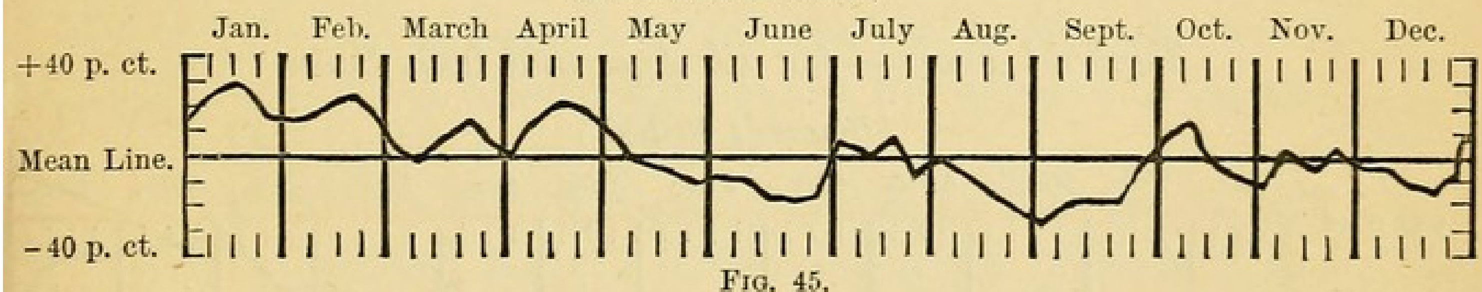



FIG. 45.

[1] *Op. cit.*

[2] This method of dealing with the percentages in laying down the curves is convenient in arriving at an approximately true average when a small number of years are available, as in the case of typhus and typhoid figures (for which diseases figures extending over six years only are obtainable), or when few deaths occur from any particular disease, such as gout or ague. The method consists in assuming the average, for instance, of the second week of January, to be not the actual average of that week, but the average of the first, second, and third weeks; the average of the third week is assumed to be the average of the second, third and fourth weeks, and so on.

because the overcrowding and the defective ventilation of the dwellings of the poor is worse than usual. The height of an epidemic has occurred in some instances during hot weather (as, for example, in Glasgow during July 1847).

Mr. Buchan and Dr. A. Mitchell remark respecting the London curve, "It is probable that this curve has two maxima, the larger in the early months of the year, and the smaller in the height of summer."

Enteric or Typhoid Fever.

*Enteric.*—Autumn is generally considered the season *par excellence* for the development of this disease, hence it has been called in America "autumnal or fall fever." It would be more correct to call it a late autumn or winter-autumn fever, and diarrhœa a summer-autumn complaint. It has been noticed to be more prevalent after dry and hot summers than after those which are cool and wet. Warm, damp weather, in autumn and winter, when there is much decomposition of vegetable matters, is favourable to an outbreak. Heavy rains, by cleansing the air and the drains, is unfavourable to its appearance, except when filth is washed by these downfalls into the wells.

The London curve for typhoid fever resembles that

*Typhoid Fever—for all Ages and both Sexes.*

(*Bloxam's Method.*)

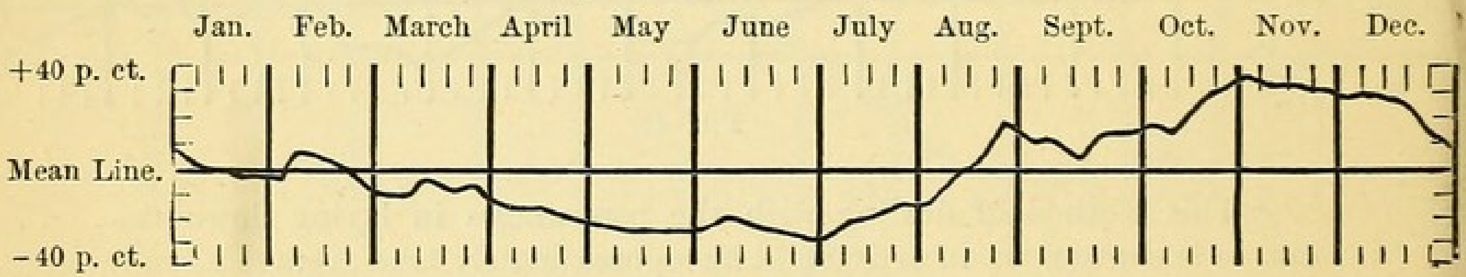



Fig. 46.

for scarlet fever as to the period of its maximum death-rate, but the minima of these two diseases widely differ in character from one another.

The curve of New York closely resembles that of London, but rises two months earlier to its absolute maximum.

| | Temperature—Degrees Fahr. July | | Aug. | | Sept. | | Oct. | | Nov. |
|---|---|---|---|---|---|---|---|---|---|
| | | 1·8 | | 8·7 | | 10·7 | | 12·9 | |
| New York . . . | 75·4 | | 73·6 | | 64·9 | | 54·2 | | 41·3 |
| London (Greenwich) . | 63·8 | | 63·0 | | 59·2 | | 51·9 | | 42·6 |
| | | ·8 | | 3·8 | | 7·3 | | 9·3 | |

When the fall of temperature from one month to another is about 9 degrees in both cities, then we have the absolute maxima of "Fall Fever."

*Intermittent Fever*=*Ague.*—The popular idea in aguish districts that outbursts of this disease generally occur when sudden changes of weather, from hot to cold or the reverse, take place, and especially during the prevalence of a dry east wind with a scorching hot sun, is interpreted by the knowledge that we at present possess, as to the tendency of such meteorological influences, to conduce to the congestion of the liver, the spleen, and other internal organs. Ague.

7. { Diarrhœa.
Dysentery.
Cholera.

*Diarrhœa.*[1]—Dr Ransome writes:—"A mean temperature above 60 predisposes to diarrhœa when continuous, causing a rapid increase in the number of cases. A temperature below 60 appears to be unfavourable to its progress." Diarrhœa.

Dr. Moffat has expressed the opinion that, as regards simple diarrhœa, there is a decrease in the pressure of the

[1] Great efforts have of late years been made to ascertain the mode of causation of the autumnal form of this disease, especially in children, amongst whom it produces such a large mortality, and much interest has been excited on this subject in Leicester, which seems to suffer in proportion to its population more than other towns in this country. Many different views prevail in the profession as to its origin. One of the most interesting is that propounded by Dr. John Shea in his Annual Report for Reading for 1880. He holds "that, when a hot and comparatively dry summer month follows a decidedly wet month, diarrhœa prevails, due to soil (telluric) and other exhalations, and that under such conditions these exhalations affect human beings, children chiefly, possibly by inducing

air and an increase in the force of the wind on the days on which diarrhœa occurs, and to a less extent on the days after its occurrence.

fermentive changes in the food and milk used by them, stored, as such foods and milk often are, in unventilated cupboards and exposed to foul effluvia." In both 1875 and 1880, when there was much mortality from autumnal diarrhœa amongst children in and around Reading, which could not be ascribed to the increased vegetable matter in and temperature of the Reading water supply, since it occurred partly in the rural districts outside its distribution, and which could not be due to hand feeding, which goes on much the same one year as another, there occurred the sequence above described. Dr. Shea adds, "The natural tendency that is created in hot weather and hot climates to throw an extra stress of elimination of bile on to the liver, and so induce bilious diarrhœa, must not be forgotten." Dr. V. C. Vaughan, Professor of Physiological Chemistry to the University of Michigan, seems disposed to connect infantile diarrhœa with the production, by the growth of some micro-organism, of a poisonous alkaloid or ptomaine named tyrotoxicon, along the seam of the milk-pail, or in the rubber nipple, tube or nursing bottle. Drs. Guy and Harley say in their work on medicine: "The functions of the liver and lungs are, to a considerable extent, vicarious. The digestion and assimilation of animal diet is attended by the separation of a large quantity of hydrocarbon from the blood. If the respiratory function be sufficiently active, this is consumed in the lungs and excreted as carbonic acid and water; but if, as in tropical climates, or in very hot weather, the respiratory function be insufficient, the hydrocarbon is separated by the liver in the form of fatty acids of the bile. Now, in very hot weather the air per cubic foot contains necessarily less oxygen than at a lower temperature, hence for each cubic foot breathed less carbon is burnt off from the lungs in hot weather than in a cooler atmosphere. Again, if with heat, the air is charged with moisture and is "steamy," the exhalation of watery vapour from both the lungs and skin is checked and thrown on to the kidneys and bowels. Both influences, excessive heat and moisture, therefore, favour diarrhœa, independently of other causes."

There is a very strong popular belief in a connection between a state of weather termed "thunder weather," which is most common in autumn, and the presence of diarrhœa. The air being humid as well as hot, drains and cesspools unpleasantly obtrude themselves on the attention, because the moisture acts as a medium of conveyance to the nerves of smell of the sewage emanations that are raised by the heat. Such weather is not only sultry and hot, but the clouds are at the same time laden with electricity. Absence of sunlight and the presence of haze generally combine to form the kind of weather thus christened. The employment of fruit and vegetables, even if fresh, during the prevalence of such weather is likely to

The mortality from diarrhœa in New York is greater than in London, doubtless in consequence of its greater summer heat. The commencement of its increase is two months earlier in New York, due to the increased temperature of summer beginning sooner than in London. Of

induce this complaint, although such a result does not usually follow a sudden invasion of a high temperature during other seasons of the year.

It is probable that such evidence will soon be forthcoming for the use of the profession as will conduce to a settlement of this question which has been so long *sub judice*. Dr. Ballard, in the inquiry with which he has been entrusted into the causes of autumnal diarrhœa, is engaged in investigating the temperature of the earth at 1 foot and at 4 feet in depth, and has, I learn, ascertained some curious facts with reference to the prevalence of the disease being coincident with the periods between the crossing of the readings of these earth thermometers, which I am not authorized to disclose, but which he will doubtless in due time publish. The fact, pointed out by Drs. Lewis and Cunningham ("Cholera in relation to certain Physical Phenomena") with reference to cholera in India, that the great maximum of prevalence in April and the minimum in November both occur when the soil temperature at 6 feet from the surface is between 78° and 79° F., would seem to have a bearing on this question. Dr. Ballard will not, I trust, fall back upon the conclusion that this disease is attributable to earth emanations, without a rigorous exclusion of the evidence showing the influence of temperature and alternations of temperature in its production under certain conditions of the human body and of climate. The compensatory interchanges between the skin and the mucous membrane of the intestinal tract are well known, but perhaps hardly sufficiently borne in mind. Sudden heat or sudden cold will produce diarrhœa, and young children, amongst whom the mortality is greatest, are more influenced by such changes and are less able to withstand the impact of a severe drain on their resources of strength than adults and middle-aged individuals. When the skin is acting freely during the hot summer months, when, as the public say, "the pores are open," any sudden chill or cessation of perspiration may, as every medical man knows, produce a determination of blood to the biliary organs (exciting an increased flow of bile) and to the intestinal tract, probably at the time irritated by decomposing milky food, or decomposing and half-digested fruit, such as plums, etc., and a flux results. On the other hand, a sudden check to the action of the skin by cold, unless followed by the glow of a reaction, may induce an attack of diarrhœa, and this flow is often welcomed as an easy way of getting rid of a catarrh. I have never, since the publication of Dr. C. F. Oldham's book, entitled *What is Malaria?* referred to on p. 234, *been allowed* by facts, that have every now and then come to my knowledge, *to forget it.*

*Dysentery, Diarrhœa, and Cholera—for all Ages and both Sexes.*

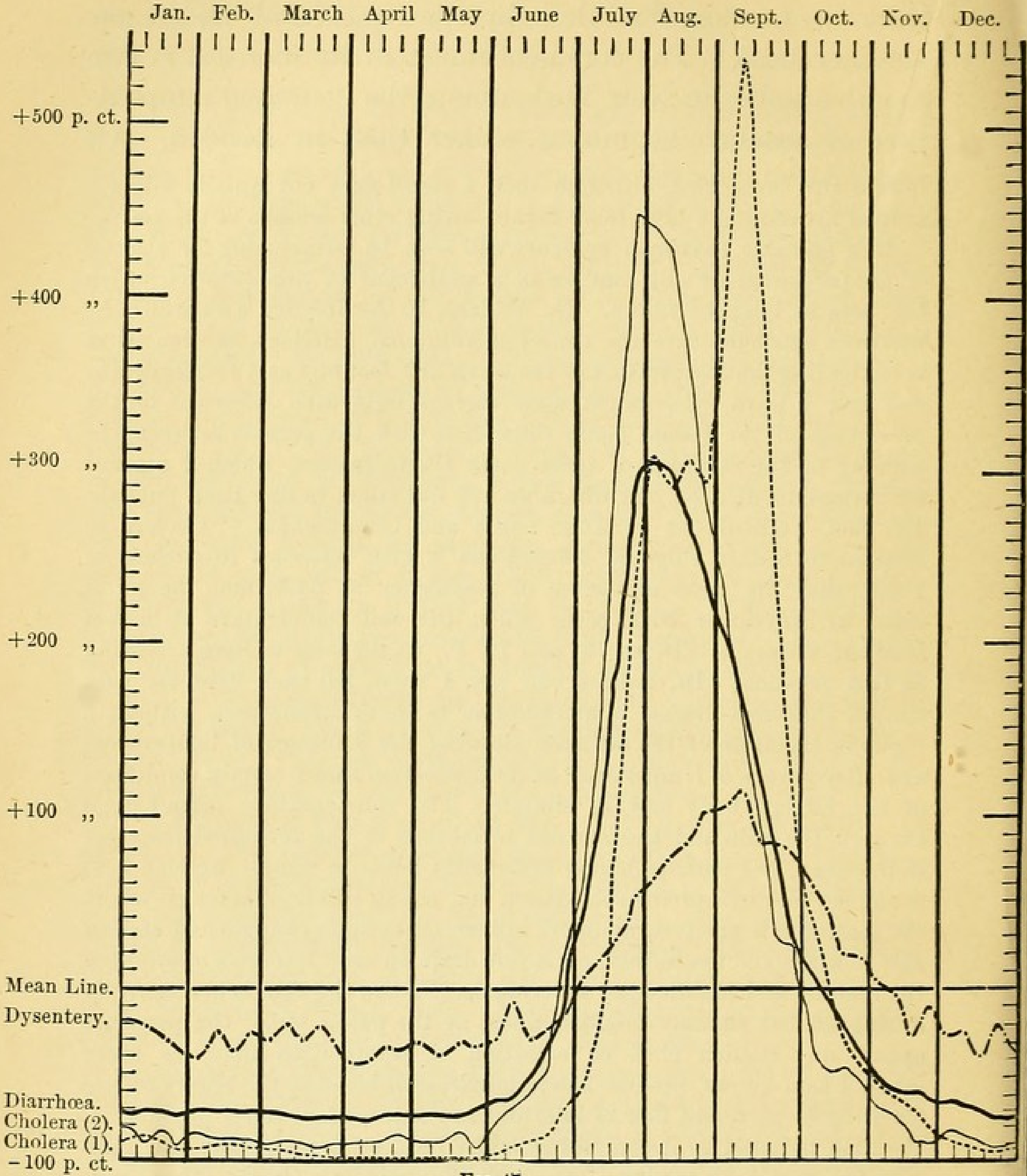



FIG 47.

all the deaths in New York from diarrhœal affections, 69 per cent occur amongst infants under one year, 18 per cent between 1 and 2 years, and ·06 per cent from 10 to 20 years. How strongly does this enormous fatality amongst infants point to the want of *good* milk, which should be the sole food of infancy.

*Dysentery.*—"Dysentery," writes Dr. Ransome,[1] "seems to be increased by a high mean temperature and diminished by a low mean temperature, but to be influenced by variations of temperature to a less extent than diarrhœa. High readings of the barometer are nearly always accompanied by a diminished prevalence of dysentery." Dysentery.

*Cholera.*—The history of past epidemics has generally taught us, with but two or three exceptions, that the mortality from this disease usually increases until September, when it reaches its maximum, after which it begins to decline. A sudden diminution in the extent of its ravages is often ushered in by some great natural cleansing process, such as a storm of wind, or heavy downfall of rain, or sudden descent of temperature diminishing decomposition of organic matters. Cholera.

The London curves for these diseases show the close relationship that the progress of mortality from them bears to temperature.[2] The speed at which they suddenly increase during the hottest weeks of the year, and rapidly decline on the fall of the thermometer, is very striking.

The dotted line, Cholera, No. 1, indicates the fatality from *Asiatic* Cholera. The line not dotted, Cholera, No. 2, represents simple or English cholera.

The maximum and minimum of diarrhœa is seen to be a month earlier than the maximum and minimum of dysentery.

Mr. Buchan and Dr. A. Mitchell point out that the four curves seem to group themselves in pairs—diarrhœa and English cholera on the one side, and dysentery and

[1] *Op cit.*

[2] It is stated in the *Annuaire de l'Observatoire de Montsouris* for 1886 that, during the last epidemic of cholera in Paris in 1884, the increase in the number of deaths was not accompanied by an increase of the temperature; but that the micro-organisms in the air of Paris and its neighbourhood

Asiatic cholera which pass through their annual phases a month later, on the other.

Bronchitis, Pneumonia, and Asthma.

8. *Bronchitis, Pneumonia, and Asthma.*—These diseases are greatly influenced by mean temperature. They increase in prevalence as the temperature falls, and diminish as it rises. The London curves strikingly exemplify this fact.

The percentages of the mean weekly death-rate at different ages are—

*From Bronchitis.*

AGES.

| 1-5 | 5-20 | 20-40 | 40-60 | 60-80 | Above 80 | Total. |
|---|---|---|---|---|---|---|
| 38 | 1 | 4 | 17 | 34 | 6 | 100 |

*From Pneumonia.*

| | | | | | | |
|---|---|---|---|---|---|---|
| 61 | 6 | 10 | 13 | 9 | 1 | 100 |

Bronchitis is thus seen to be most fatal to children under 5 years, and to the old; whilst pneumonia, although specially fatal to children below this age, is of rare occurrence amongst the aged.

The principal maximum of pneumonia in November-December, is chiefly determined by the large number of deaths amongst children under five years, whilst the secondary maximum occurs in March. Dr. William Squire does not apparently recognize the existence of two maxima, but contends that the annual maximum

were much more abundant than usual during the days when the deaths were most numerous.

| Dates. | Bacteria per Cub. Metre. | | Deaths from Cholera. |
|---|---|---|---|
| November 1884. | Montsouris Park. | Rue de Rivoli. | |
| From 1- 4 | 110 | 1200 | 2 |
| ,, 5- 8 | 190 | 1150 | 63 |
| ,, 9-12 | 245 | 2120 | 349 |
| ,, 13-16 | 340 | 1360 | 268 |
| ,, 17-20 | 255 | 880 | 150 |
| ,, 21-24 | 185 | 1120 | 76 |
| ,, 25-28 | 50 | 220 | 40 |

*Bronchitis, Pneumonia, and Asthma—for all Ages and both Sexes.*

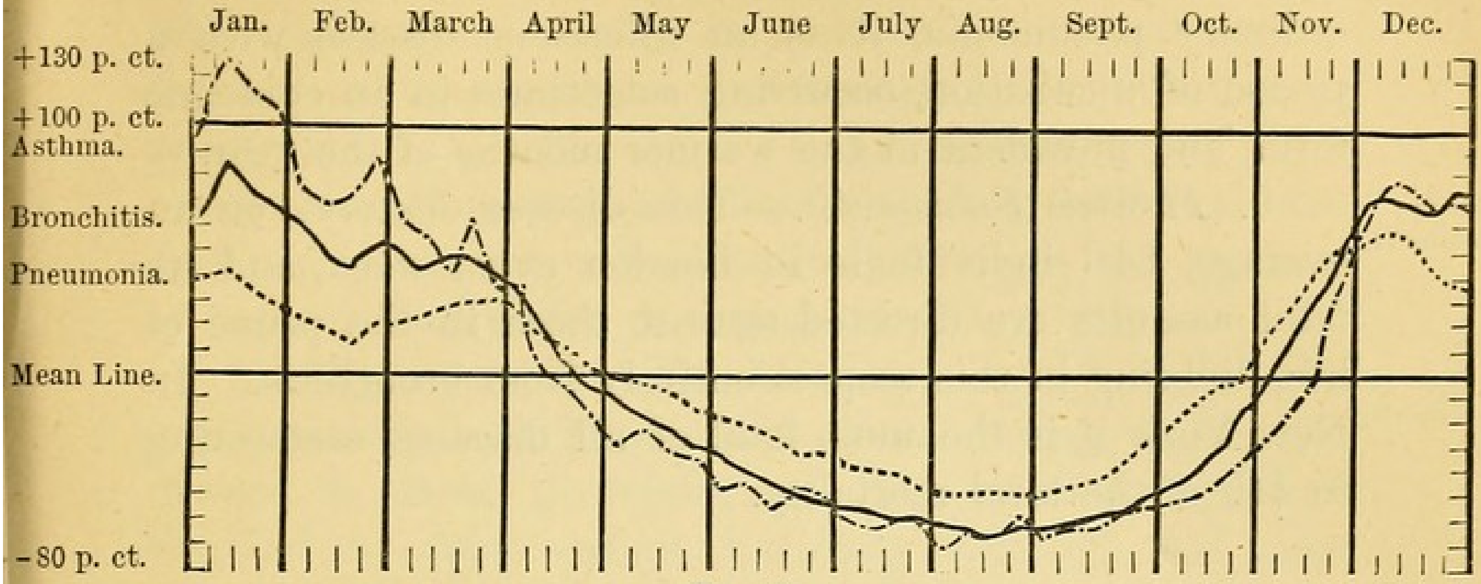



FIG. 48.

of pneumonia, unlike that of bronchitis, is always in spring.

It is unwise to associate closely bronchitis and pneumonia in their causative relations with temperature, or by so doing we become oblivious to the fact to which Dr. Longstaff has directed attention,[1] that, whereas 1104 males die from bronchitis to every 1000 females, but as many as 1460 males die from pneumonia to every 1000 females, the cause of the two diseases is somewhat different. The catarrhal form of pneumonia should be distinguished from its specific form. Dr. Seibert[2] has established a close relationship between the prevalence of catarrhal pneumonia and those meteorological conditions which favour catarrh, such as a concurrence of any two of the following factors—a low and falling temperature, an excessive and increasing humidity and high winds. The existence of an infectious form of pneumonia,[3] named also "pneumonic fever," "sewer gas and pythogenic pneu-

[1] "Phthisis, Bronchitis, and Pneumonia: Are they Epidemic Diseases?"—Contribution to Epidemiological Society of London.

[2] *Berl. Klin. Wochenschr.*, 1886, No. 17.

[3] *Vide* "Pythogenic Pneumonia," by Drs. Grimshaw and Moore, in *Dublin Journal of Medical Science*, May 1875, and *Dictionary of Hygiene*, p. 452.

monia," is now no longer a matter of doubt. Unlike ordinary pneumonia, it is an infectious disease with a period of incubation, occurring sometimes in an epidemic form, and prevalent in the warmer months of the year.

Phthisis Pulmonalis.

9. *Phthisis Pulmonalis.*—This disease destroys, on an average, 148 individuals in London every week, and its fatal assaults are directed against those in the prime of life, differing in this respect entirely from bronchitis. In New York it is the most fatal of all diseases, amounting to $\frac{1}{7}$th of the total mortality.

*Phthisis—for all Ages and both Sexes.*

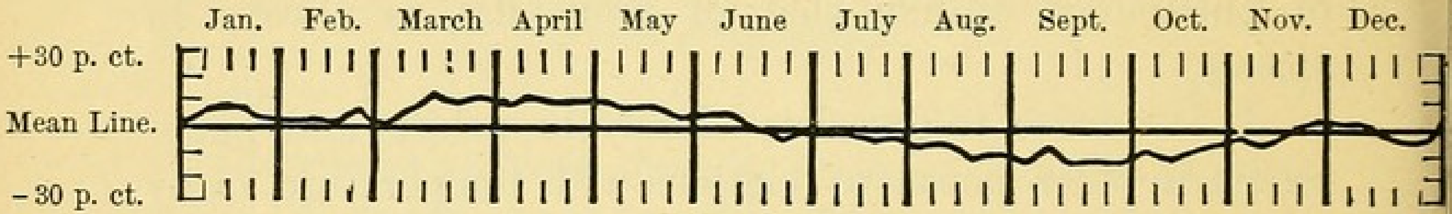



FIG. 49.

Diphtheria.

10. *Diphtheria.*—There is a close correspondence between the diphtheria curves of London and New York, and between both of these curves and the scarlatina curve of London. The influence of cold and the season of the year on diphtheria is recognized by medical practitioners. According to my experience, which extends back to 1856, the damp, cold days of November, and the dry, cold days of the early months of the year, have been most prolific in cases. Dr. Thursfield's "Table of Deaths,"[1] from 1870 to 1877 inclusive, yields the following averages :—

| Quarter of the Year. | Deaths. | Mean Temperature. | Rainfall in inches. |
|---|---|---|---|
| First . . . | 735 | 40·5 | 5·0 |
| Second . . . | 578 | 52·5 | 4·5 |
| Third . . . | 547 | 60·6 | 7·0 |
| Fourth . . . | 750 | 43·7 | 7·5 |

[1] *Lancet*, August 3, 1878.

The question which requires elucidation is, as to what influence (if any) is exerted by the amount of moisture in the air on the development of the diphtheritic micro-organism. The virus of this disease seems to be communicated from one to another, if not by actual contact (as by kissing and otherwise), through the medium of foul air, foul water, or foul milk.

Hydrophobia.

11. *Hydrophobia.*—The hot "dog days" of summer are generally considered to be those during which this disease is most prevalent, and this ancient belief is justified to some extent by facts, although we must remember that it shows itself to be independent in its spread of a high temperature, as the following curve of the mortality in London during 30 years proves:—

*Hydrophobia—for all Ages and both Sexes.*

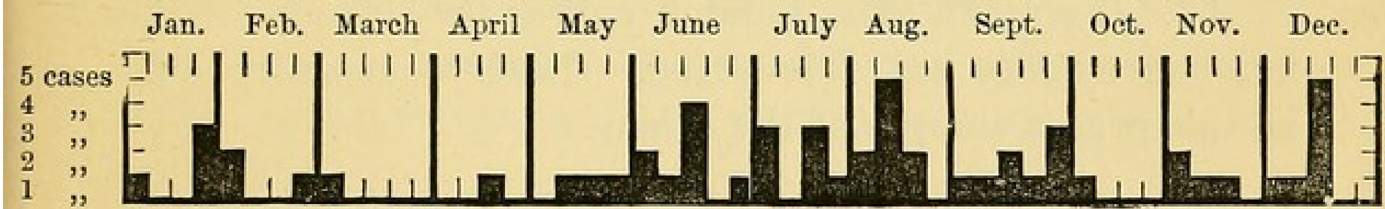



FIG. 50.

The number of cases in December is there seen to be as numerous as those in August. More persons are doubtless bitten by dogs in hot weather, because dogs are more irritable during this season. We want an answer to the query as to the percentage of cases of hydrophobia in those who are bitten in each month of the year, before we can determine with certainty the influence of meteorological conditions on the disease.

Erysipelas.

12. *Erysipelas and Puerperal Fever.*—The curves of mortality for 30 years in London from these two diseases wonderfully resemble each other, and are highly suggestive of a more intimate relationship between them than is generally conceded.

*Erysipelas—for all Ages and both Sexes.*

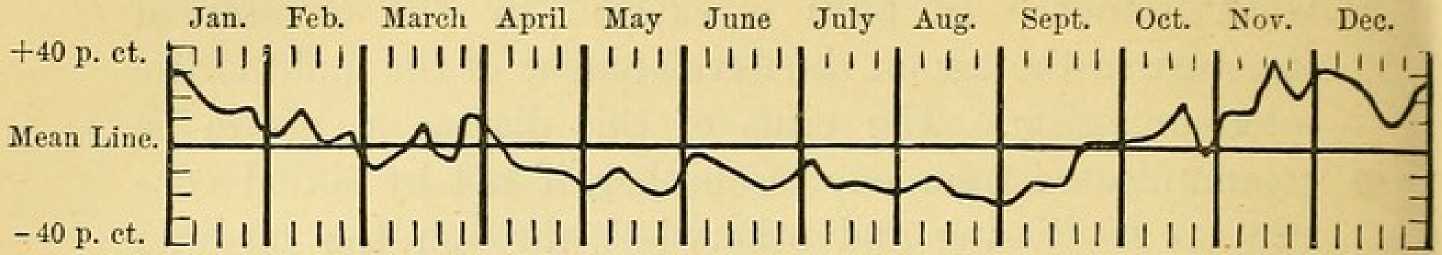



Fig. 51.

Puerperal Fever.

*Puerperal Fever or Metria—for all Ages.*

(*Bloxam's Method.*)

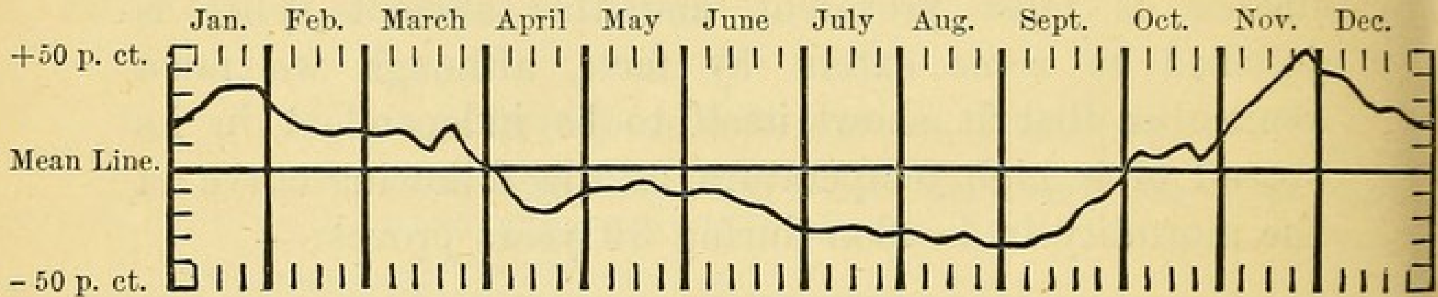



Fig. 52.

Insanity.

13. *Insanity.*—The London curves for diseases of the nervous system are interesting. That of insanity may be taken as a sample of the others.

*Insanity—for all Ages and both Sexes.*

(*Bloxam's Method.*)

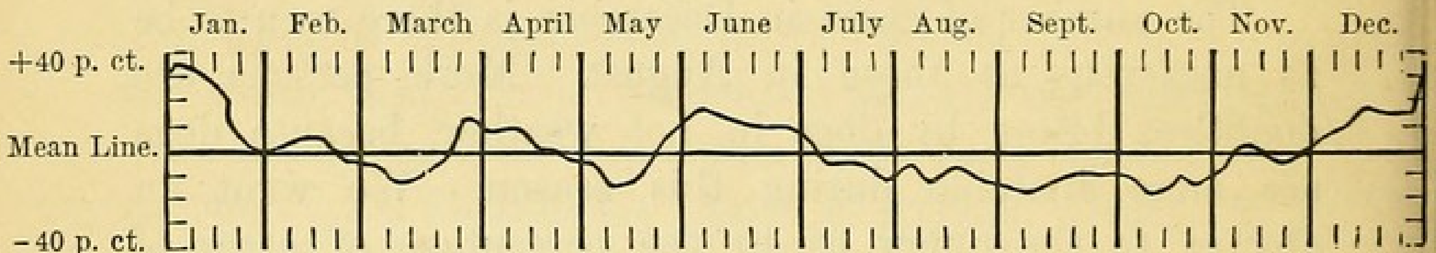



Fig. 53.

This curve shows three maxima, the largest being in December and January, the next in June, and the least marked in March and April.

The New York curve for "All nervous diseases" exhibits a considerable maximum in July—the hottest month of the year—owing no doubt to fatal cases of sunstroke.

14. *Rheumatism.*—Rheumatic fever was said by Sydenham to be most common during the autumn. The London curve does not confirm his view.

Rheum-tism.

*Rheumatism—for all Ages and both Sexes.*

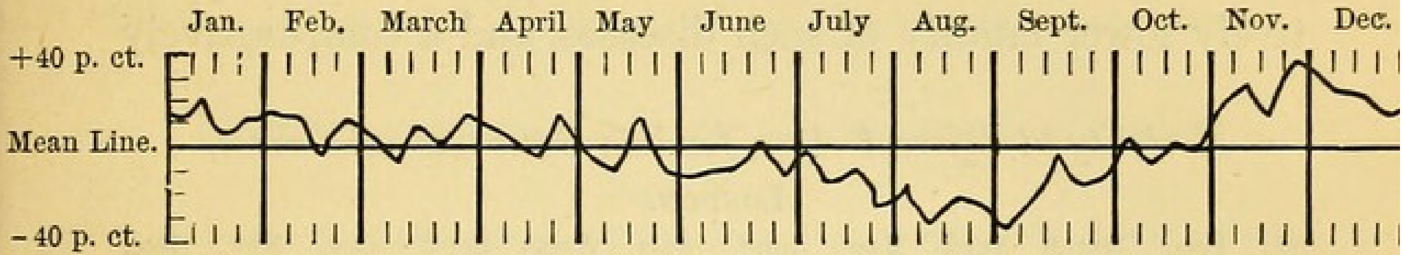



Fig. 54.

Sub-acute rheumatic affections of joints would seem to be more uncomfortable to their possessors when the barometer is low, and the air is warm and moist, and chronic cold rheumatic affections of the aged, in whom the skin is inactive, are apparently benefited by this "muggy" condition of the air. Both kinds of rheumatic joints are incommoded by a sudden diminution of pressure and perhaps by a low atmospheric pressure (*vide* page 374).

The curve of pericarditis is very similar to that of rheumatism, as every medical man would of course conjecture. Dr. Longstaff and Messrs. Buchan and Mitchell all state that the curve of pleurisy resembles more closely that of rheumatism than that of the respiratory diseases—a circumstance which strengthens my belief in the existence of an etiological relation between rheumatism and pleurisy.

Pericar-ditis.

Before concluding this sketch of the influence of meteorological conditions on mortality, it would be instructive to consider briefly:—(1) The influence of weather on the mortality at different ages; and (2) The influence of weather on the mortality of the two sexes.

"The broad fact which the following diagrams (fig. 55 and fig. 56) disclose is," as has been stated by Mr. Buchan

Mortal at diffe ages.

and Dr. A. Mitchell, "that the New York curve receives its leading characteristics from a great fatality there of diseases which have their maxima as causes of death in the hot months (diseases of the abdominal organs), and that the London curve receives its form from a comparatively lower fatality of such diseases, and a comparatively

*Mortality at different Ages, for both Sexes and all Causes.*

LONDON.

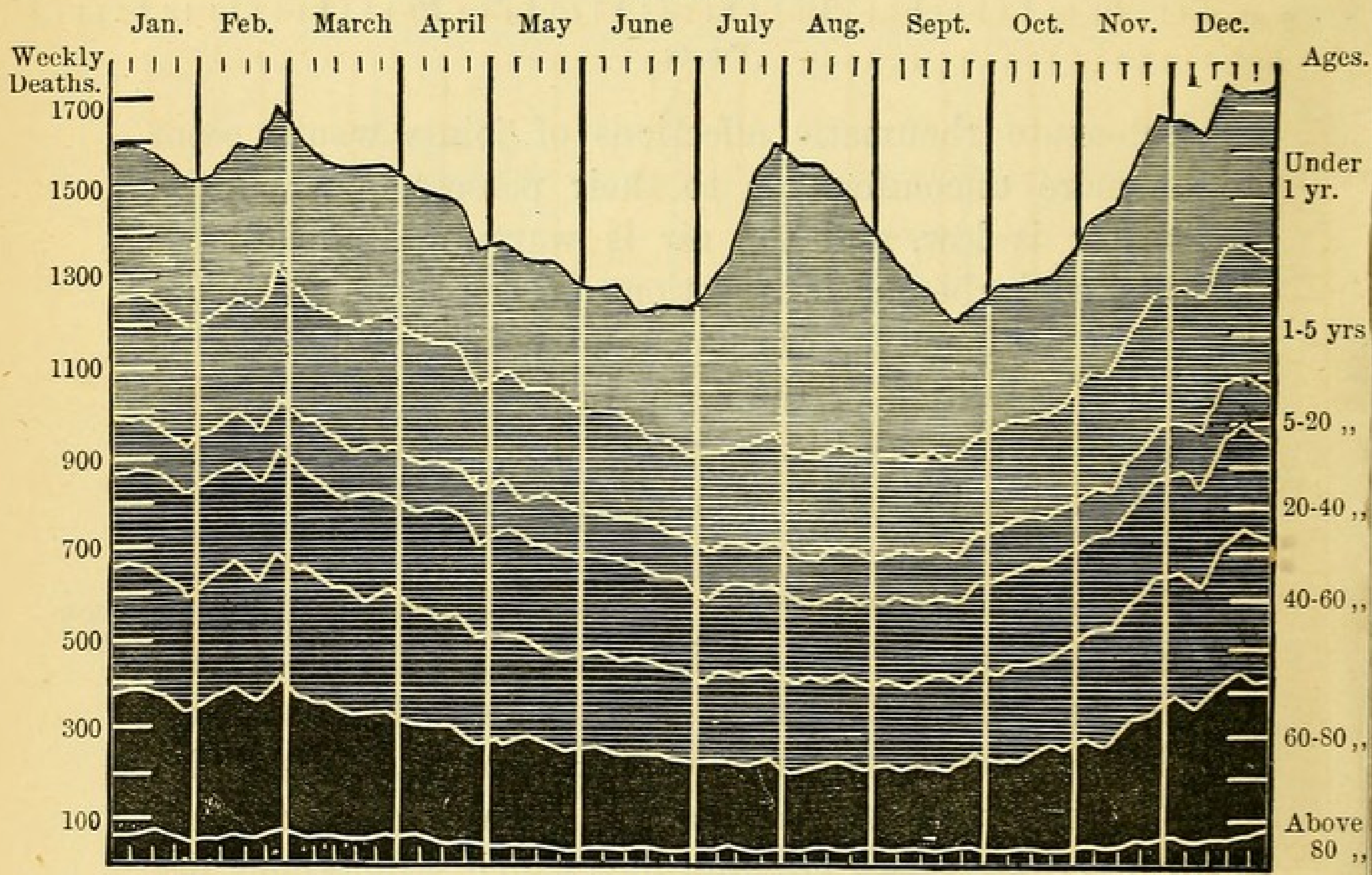



FIG. 55.

higher fatality of the diseases which have their maxima as causes of death in the winter and spring months (diseases of the respiratory organs and of the nervous centres)." The deaths from respiratory diseases during the winter and spring months in London are shown, by the maintained excessive height of the respiratory diseases curve at those seasons, to be enormous in young children. The major part of this winter mortality arises from diseases of the respiratory organs. This excess in our insular climate over that of the much drier continental climate of New York must be ascribed to the greater dampness associated with the cold, and to the greater vicissitudes of weather which we islanders experience. In December and January, when the air is most humid,

*Mortality at different Ages, for both Sexes and all Causes.*

NEW YORK.

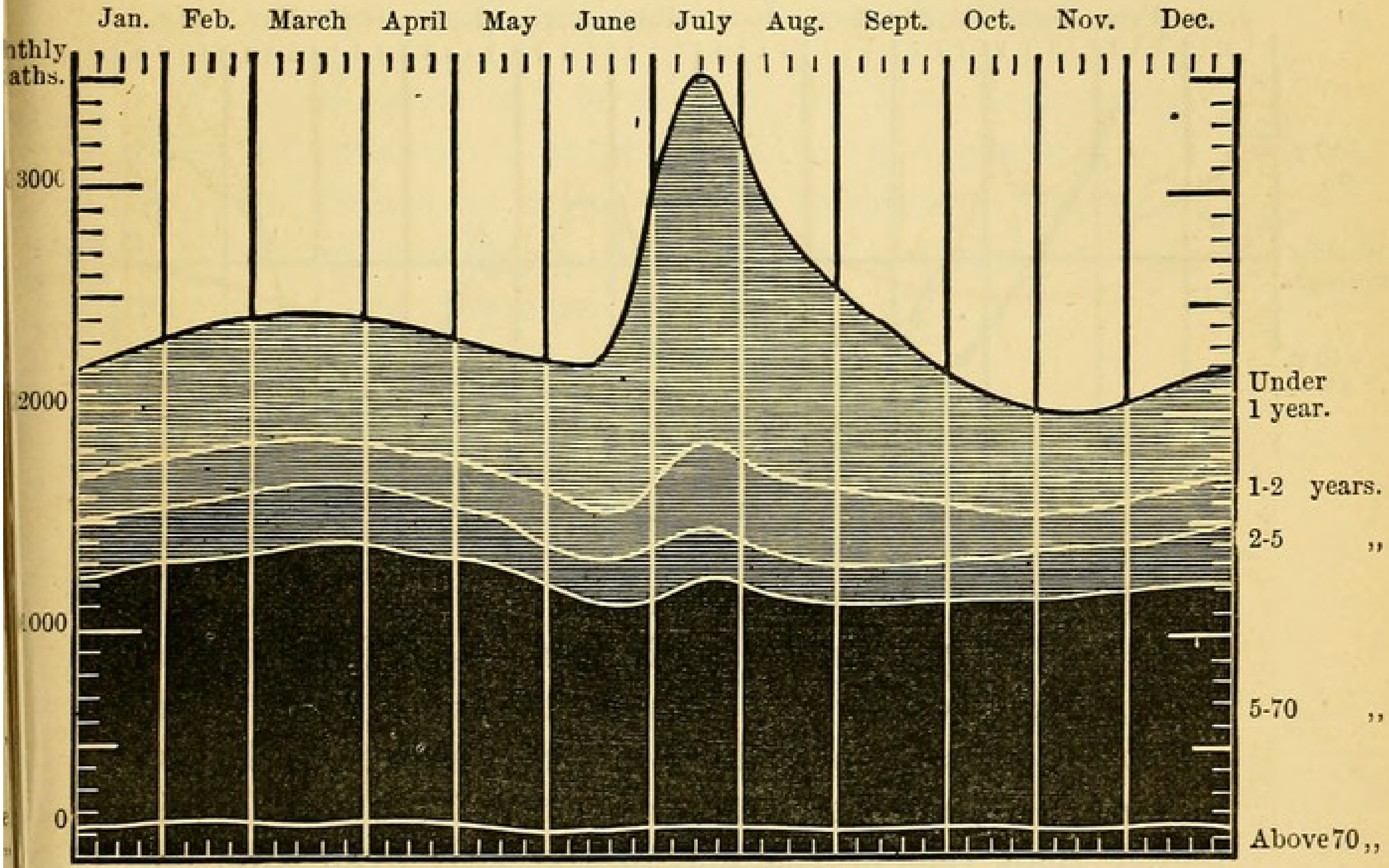



FIG. 56.

the relative humidity of New York is 79, and of London 87. The annual minimum of New York is 62, and of London 72. The mortality curve at the opposite end of life, in persons upwards of 80, appears to be a very simple one, having its maximum in cold and its minimum in warm weather. The curve indicative of summer mortality from diarrhœa is seen to be somewhat affected in adults in the hotter climate of New York.

Mortality of each sex.

The period of the year when females have a higher death-rate than males is when diseases of the respiratory organs are most fatal, and the period when females have a lower death-rate than males is when diseases of the nervous system are most fatal.

*Deaths of each Sex from all Causes—Males being represented by the solid line, and Females by the dotted line.*

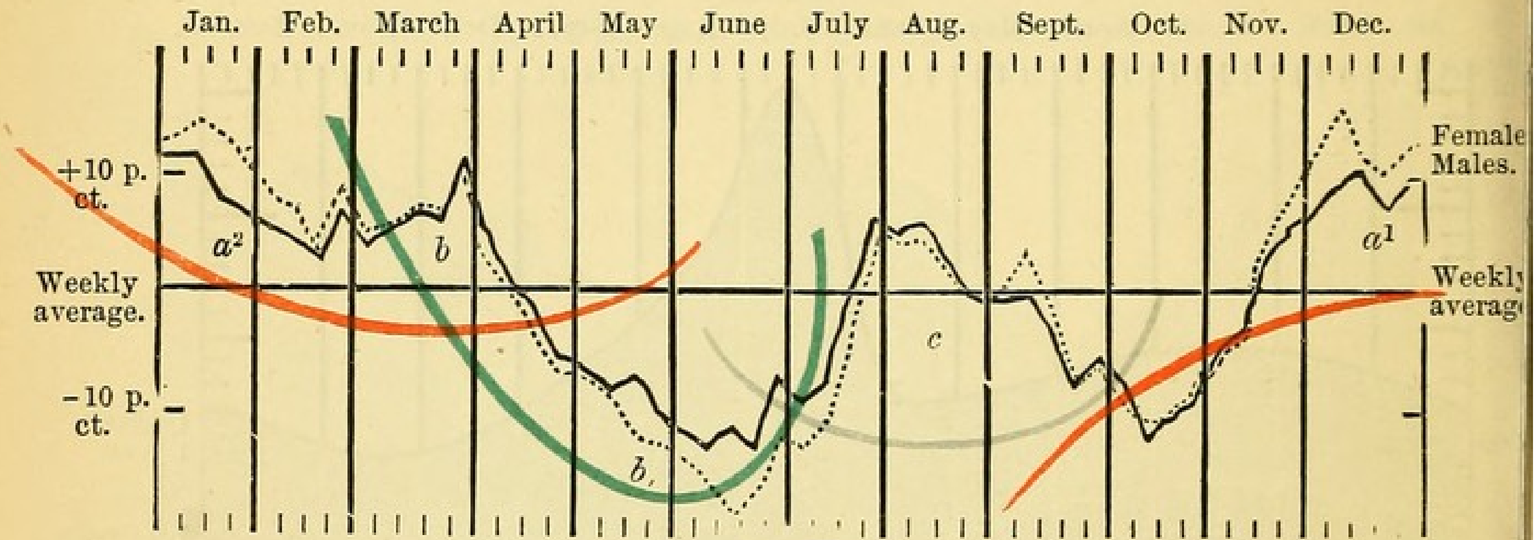



FIG. 57.

The curve of the mortality of each sex consists of three distinct portions, $a^1$ $a^2$ the respiratory disease mortality, $b$ $b$ the nervous disease mortality, and $c$ the intestinal disease mortality. The respiratory disease mortality during the commencement of the year, $a^2$, is higher than that of the end of the year, even after an allowance is made for the support afforded by the two maxima of the nervous disease mortality. Nearly the whole of the intestinal affection mortality is created by the death of infants under one year. If we could diminish the mortality to any considerable extent from these three kinds of disease, namely, the respiratory, the nervous, and the intestinal, the curve of mortality would become very much flattened and approach in appearance the curve of old age. Here the end generally comes, it would seem, from some respiratory affection (fig. 58).

*Old Age—for both Sexes.*

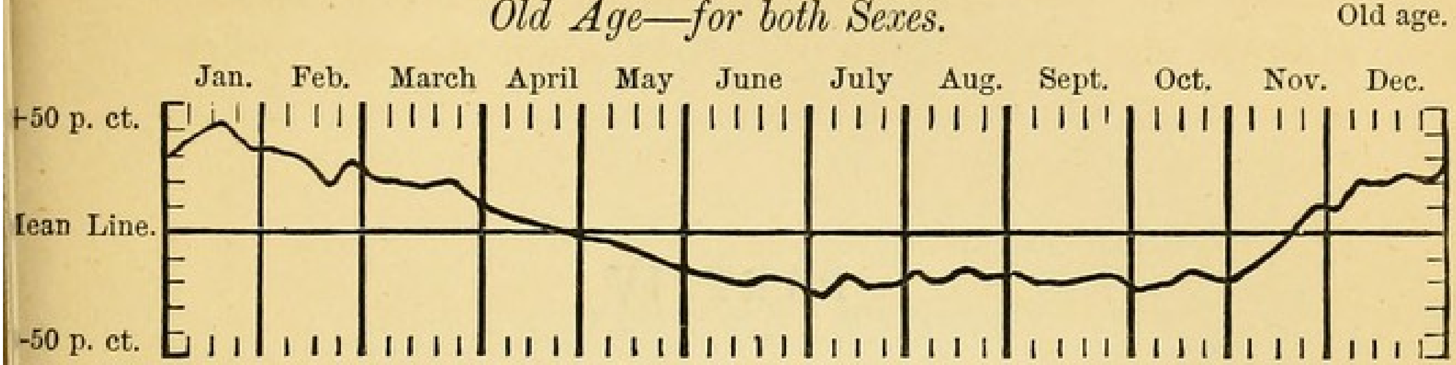



Fig. 58.

No more space can be allotted for the consideration of the relations of atmospheric states and conditions of the air to disease, as it is necessary to describe the mode of observing meteorological variations according to the most recent and approved methods.

# PART IV

## MODE OF OBSERVING THE METEOROLOGICAL STATES AND VARIATIONS IN THE CONDITION OF THE AIR

IN commencing a series of meteorological observations it is necessary to know the height above the sea of the place of observation.

This is readily found by making a search for the nearest bench mark of the Ordnance Survey, and

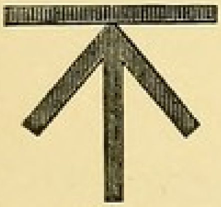


FIG. 59.

ascertaining by a rough estimation, or by the help of a surveyor and his spirit level, the difference between the level of that bench mark and the station where our instruments are exposed. As the publications of the Ordnance Survey are not readily accessible, it will afford me much pleasure to give any applicant the height of any bench mark.

The hours of observation that are best, if two observations are taken daily, are 9 A.M. and 9 P.M.

## CHAPTER XXXIII

### 1.—THE ATMOSPHERIC PRESSURE

THERE are three principal classes of barometers—the syphon, the aneroid, and the cistern. The wheel barometer, so common in the passages and halls of houses, is an example of the first class, and is useless for all scientific purposes. The aneroid is not a thoroughly reliable instrument, unless checked frequently by means of a good mercurial barometer. It varies very much in excellence according to the skill and delicacy of workmanship bestowed on it. Fortin's cistern barometer is *the* instrument for the scientific man. A long strip of white porcelain, fixed to the board at the back of the scale, facilitates accuracy of reading. There are three points to be remembered in making an observation with one of these instruments, and they should be attended to in the order in which they are mentioned— Barometers.

*Firstly.* The temperature of the attached thermometer should be noted and recorded.

*Secondly.* The screw at the base of the cistern should be adjusted until the point of the ivory cone visible within it meets the reflection of the same that is seen on the surface of the mercury. A piece of looking-glass placed at the back of the cistern is a great aid to the observer in dull weather.

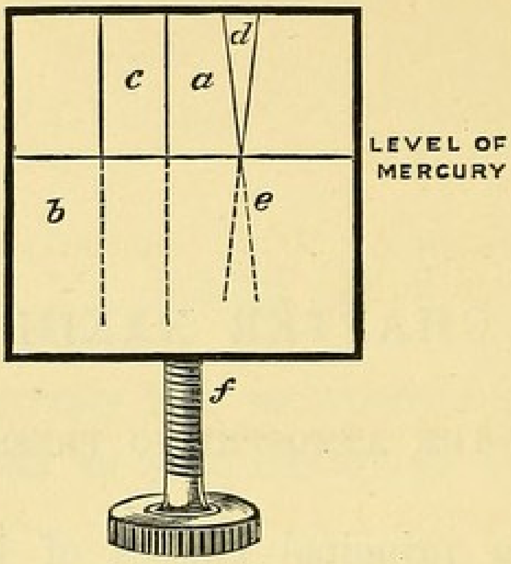



FIG. 60.

*a.* Interior of cistern.
*b.* Mercury.
*c.* Tube containing mercury.
*d.* Ivory point fixed to top of cistern.
*e.* Reflection of same, seen on surface of mercury.
*f.* Screw for elevating or lowering the level of the mercury in the cistern.

*Thirdly.* The vernier should be adjusted so that its lower horizontal edge forms a tangent to the convex curve of the mercurial column, and not an arc to that curve.

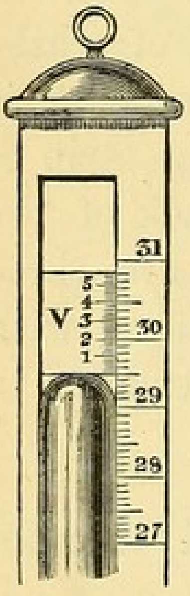



FIG. 61.

There are corrections to be considered in making barometrical observations, namely, those for index error, capacity, and capillarity, furnished by the certificate of verification from the Kew Observatory, which should accompany every good instrument; the correction for height above mean sea level; and the correction for temperature.

Three simple arithmetical calculations have then to be applied to every reading—

(*a*) Correction of Kew certificate.
(*b*) Reduction to mean sea-level.
(*c*) Reduction to 32° F.

Tables are published by the help of which both of these reductions are accomplished easily and rapidly.[1] For example:— Application of corrections to readings.

| | |
|---|---|
| Observed reading . . . . . | 28·900 |
| Kew correction . . . . . | − ·015 |
| | 28·885 |
| Deduct temp. correction for 50° F. (attached therm.) at 28·9 or about 29 inches . . . . | − ·056 |
| Reading at 32° F. . . . . . | 28·829 |
| Correction for height (350 ft.), the air being 50° F. . | + ·380 |
| Observed reading corrected and reduced to 32° F. at mean sea-level . . . . . | 29·209 |

Adie's barometers are useful instruments, in which allowances are made for the capillarity and capacity errors in their construction. There are two kinds—one adapted for a house or observatory, and the other the marine variety, which will work efficiently when exposed to the motion of the ship.

In making an observation with an Adie's barometer, it is simply necessary to read the height by the help of the vernier, and apply to the observed reading the necessary corrections for height and temperature.

The exact height of the column of mercury is read thus:— Mode of reading.

In Fig. 61 the zero of the vernier is on a level with the line indicating $29\frac{1}{2}$, so we record the reading as 29·50.

If the zero of the vernier and the scale occupy such relative positions as are sketched in Fig. 62, we read the barometer to 1000th of an inch in this way:

[1] Mr. Glaisher's and Mr. Lowe's tables are employed and may be found at the end of either of Mr. Buchan's elementary books on meteorology, or may be obtained from Messrs. Negretti and Zambra, or Messrs. Casella and Co., the meteorological instrument makers.

1. We see that the reading is somewhere between 29 and 30, so we write down 29.

2. We perceive that the zero of the vernier is on a level with a part of the scale somewhere between 1 and 2 tenths, counting upwards, and that it is more than $1\frac{1}{2}$ or ·15, so we write down 29·15.

3. We then glance down at the subdivisions of tenths on the scale and on the vernier, in order to discover which subdivision of the scale lies in one and the same straight line with a subdivision on the vernier. In the accompanying example we perceive that this takes place at the line on the vernier just above figure 3, namely, at ·034, which, when added to the scale reading 29·15, equals 29·184, which we call the observed reading.

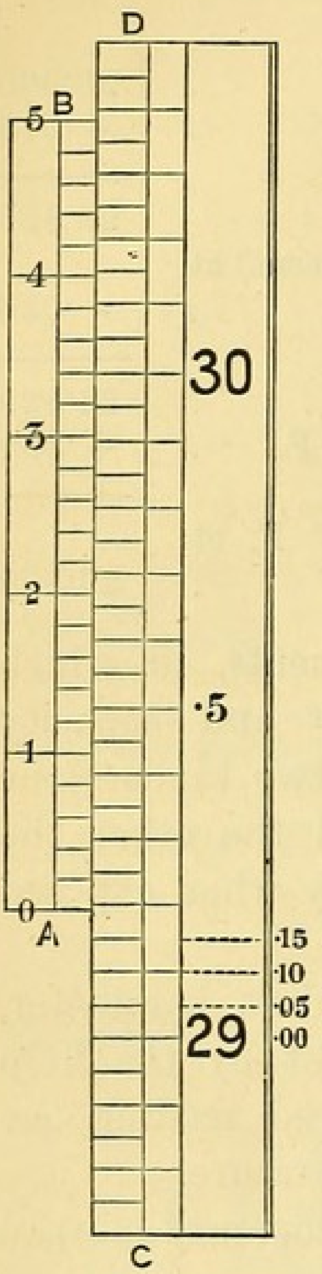



Fig. 62.

C D is part of the fixed scale of the barometer, and A B is the sliding scale or vernier.

With a little practice barometer readings to the 1000th of an inch can be taken with the greatest ease and rapidity.

It is occasionally desirable to ascertain whether the space above the mercurial column is devoid of air. By gently inclining a barometer, so as to allow the column of mercury to strike against the top of the tube, a sharp metallic click should be heard. If such a sound is not audible, air is present where a vacuum should exist. If the air cannot be expelled by inverting the barometer, it should be taken to an instrument maker.

## CHAPTER XXXIV

### 2.—THE TEMPERATURE OF THE AIR

THE thermometers required are the following :— Thermometers.

1. The dry bulb thermometer of Mason's hygrometer, described on page 424, furnishes the temperature of the air in the shade.
2. A mercurial maximum self-registering thermometer, for indicating the highest temperature reached by the air in the shade. I prefer the pattern made by Negretti and Zambra, but those of other makers are very good. The maximum temperature of the twenty-four hours generally occurs about 3 P.M.
3. A self-registering minimum thermometer for recording the lowest temperature of the air in the shade. Many laborious attempts have been made to manufacture if possible *mercurial minimum* thermometers because :—(*a*) in spirit minimum thermometers there is a tendency to the evaporation of the spirit, and a condensation of it at a distance from the column, and to the breaking up of the column into distinct portions ; (*b*) it is desirable to employ the same fluid mercury for registering minimum temperatures as that for recording maximum and other temperatures.

Casella's mercurial self-registering minimum thermometers are most beautiful instruments, but cannot be recommended for general use, as they require the most delicate manipulation, and they cannot, it appears, be made so as to stand wear and tear. I have had one in use for many years, and it has never once been deranged in its action, but it was selected from amongst many. Negretti and Zambra have sold for years a mercurial minimum thermometer with a bulb of very large dimensions. This firm has, I believe, improved upon it, and patented another provided with a needle. The extra-sensitive self-registering spirit minimum thermometer of Casella, with a forked bulb, is an excellent instrument. If the column of spirit should happen to separate, it can be reunited by taking the thermometer in the hand farthest from the bulb, and giving it one or two sharp swings. The thermometer should then be hung in a slanting position, so as to allow the rest of the spirit still adhering to the sides of the tube to drain down to the column. If this method of restoring union is unsuccessful, gentle heat should be applied very carefully to the end of the tube where the detached portion of the spirit is lodged, so as to drive it towards the column.

The minimum temperature of the twenty-four hours generally occurs some time before the sun rises. The *mean temperature* is calculated by taking the average of the maximum and minimum readings, which is so near the true mean as to be practically correct. It is almost as important, from a public health point of view, to note *the daily range of temperature* as to observe the extremes to which the temperature occasionally reaches. The mean daily range of temperature is obtained by deducting the average daily minimum from the average daily maximum temperatures.

The mean temperature.

Its daily range.

Thermometer stands.

The thermometers which have been adverted to being employed to indicate the temperature of the air in the shade, it is necessary, if we would obtain correct information, to protect them from the sunlight, wet, etc., whilst at the same time permitting the freest access of air. Accordingly, cases, called thermometer stands, of which there is a great variety, are employed, in which the instruments are suspended. There are Lawson's,[1] Glaisher's,[2] Martin's,[3] James',[4] Morris',[5] Stevenson's,[6] Griffith's,[6] Stow's,[6] Welsh's Kew standard,[7] and Pastorelli's[7] stands.

The stand below depicted resembles Stow's more than the other thermometer stands, but is superior.

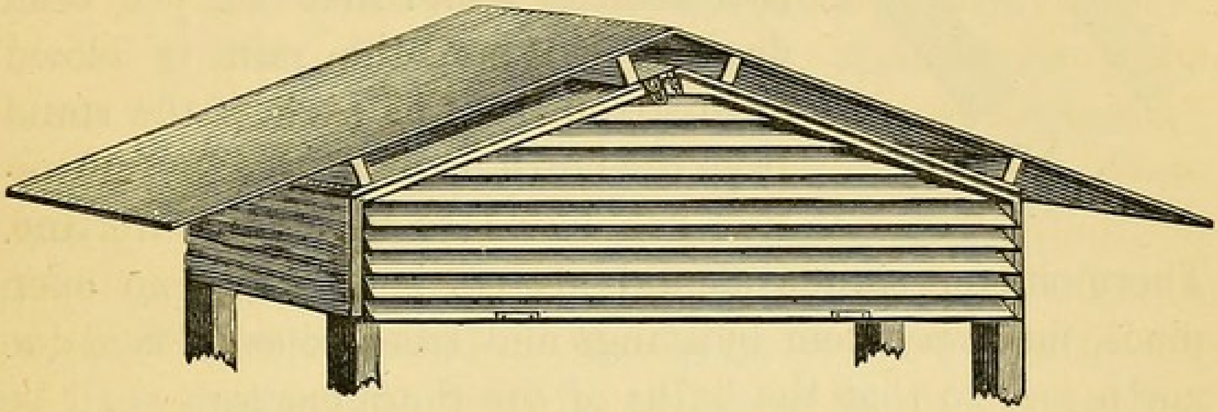


FIG. 63.

(*a a a a*) The uprights, $1\frac{1}{2}$ by $\frac{3}{4}$ inch, serve for the suspension of the maximum and minimum thermometers.

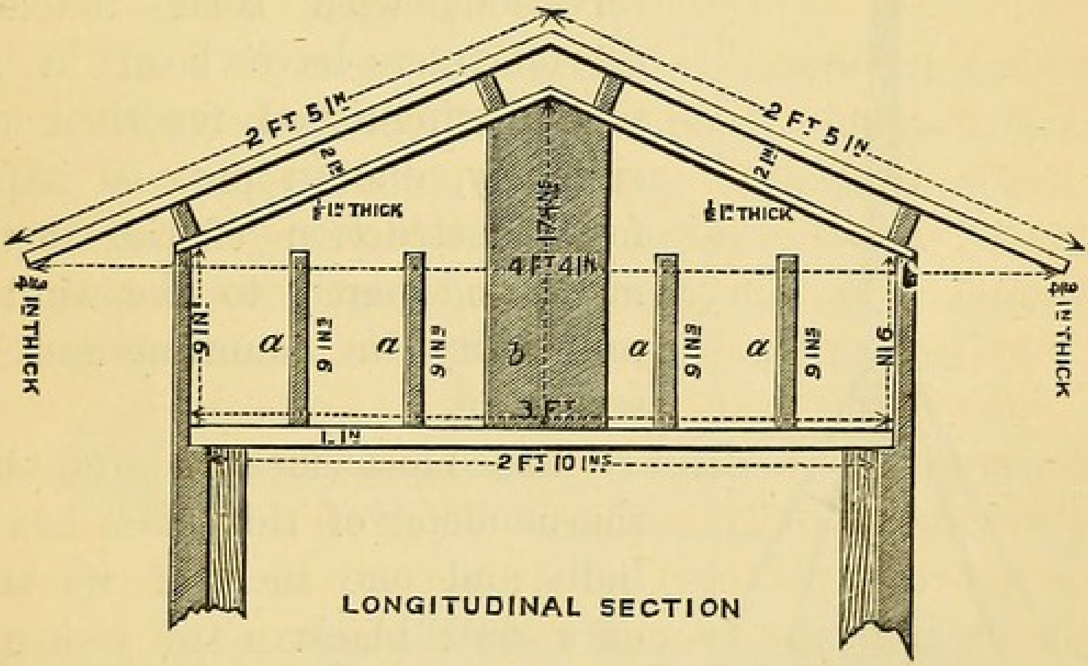
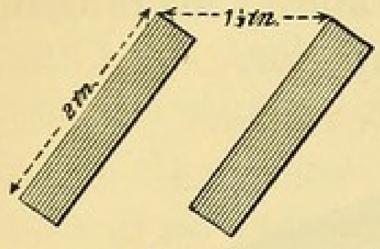



FIG. 64.

[1] Described in *Met. Mag.*, October 1868, p. 127.
[2] Described in *Met. Mag.*, November 1868, p. 155.
[3] Described in *Met. Mag.*, December 1868, p. 169.
[4] Described in *Met. Mag.*, December 1868, p. 170.
[5] Described in *Met. Mag.*, January 1869, p. 187.
[6] Described in *Met. Mag.*, February 1869, pp. 1, 2, 3, and 4.
[7] Described in *Met. Mag.*, March 1869, pp. 17, 18, and 19.

(*b*) Piece of thin board ¼ inch thick, against which Mason's hygrometer is fixed. It stands in the centre of the interior at an equal distance from the front and back of the stand.

I have three of these stands, and have but one fault to find with this form, which is apparently inseparable from every thermometer stand that has yet been devised. When the rain is blown against the front or back of the stand from the north or south, the thermometers are liable to receive a wetting. Thermometer stands should always be fixed in an open place, far away from buildings and trees, so as to face due north, and so that the bulbs of the thermometers shall be at a distance of exactly 4 feet above the ground.



Louvre.

Fig. 65.

Solar Maximum.

4. *Solar Maximum Radiation Thermometer.* — Comparative observations with solar radiation thermometers have been in the past distinguished for their discrepancy, due in part to imperfect construction of the instrument, and partly to the want of uniformity in mounting and observing it.

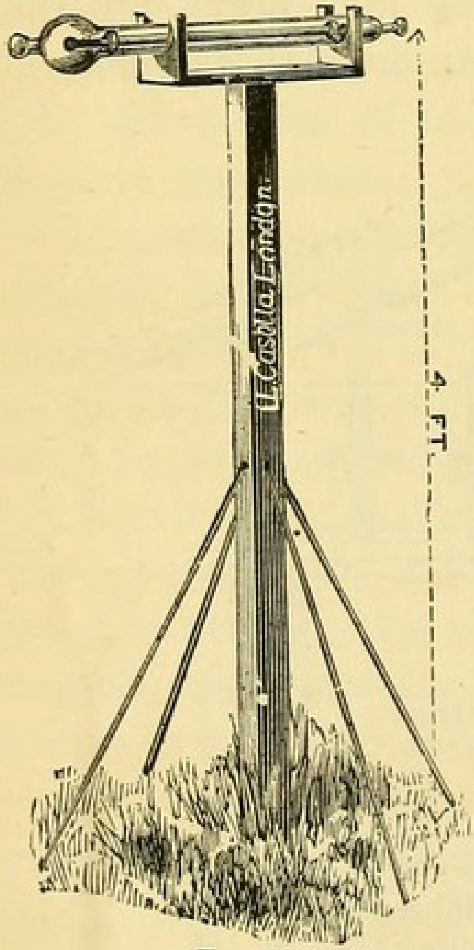


Fig. 66.

The most modern and best thermometer of this class has its bulb and one inch of its stem of a dull black. Its jacket is provided at each extremity with a platinum wire to test by the aid of a Ruhmkorff's coil the degree of rarefaction of the air. If the interior of the jacket be perfectly clean, free from moisture, and sufficiently exhausted, a pale white phosphorescent light, with faint stratifications and an appearance of transverse bands, will be visible. Mr. Stow has drawn up the following suggestions for observers, which have been almost universally adopted :—

1. Adjust the instrument 4 feet above the ground in an open space, with its bulb directed towards the S.E. It is necessary that the globular part of the external glass should not be in contact with, or very near to any substance, but that the air should circulate round it freely. Thus placed, its readings will be affected only by direct sunshine, and by the temperature of the air.
2. One of the most convenient ways of fixing the instrument will be to allow its stem to fit into and rest upon two little wooden collars fastened across the ends of a narrow slip of board, which is nailed in its centre upon a post, steadied by lateral supports.
3. The difference between the maxima in sun and shade is a measure of the amount of solar radiation.

It has been found that solar radiation attains its maximum in most parts of the country during May, and its minimum during December, and that it is greater on the western than on the eastern side of England.[1]

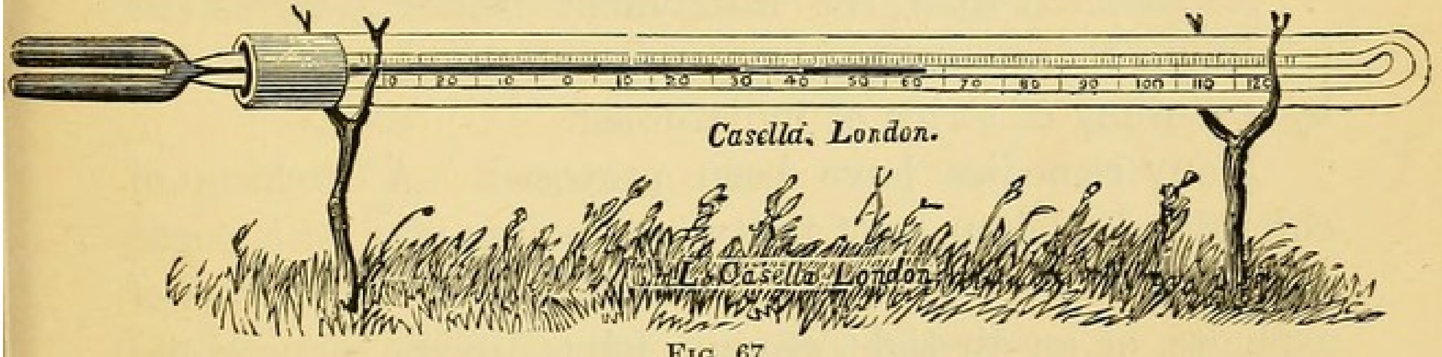



Fig. 67.

5. *Terrestrial Minimum Thermometer.*—The spirit self-registering minimum with a bifurcated bulb, exactly Terrestrial Minimum.

[1] *Vide* "Solar Radiation, 1869-74," by Rev. F. W. Stow, in *Quarterly Journal of Meteorological Society*, October 1874.

similar to the minimum thermometer for shade temperatures, with a substitution of a jacket for protection in place of a porcelain scale and hard wood back, is an excellent instrument.

This thermometer is exposed on grass which is kept closely cut, and should be surrounded by some arrangement for protecting it from dogs and other animals. A circular wire-fence, similar to that depicted in Fig. 68, is the best with which I am acquainted.

The obscurity produced by a condensation of moisture within the jacket, and the destruction of the material em-

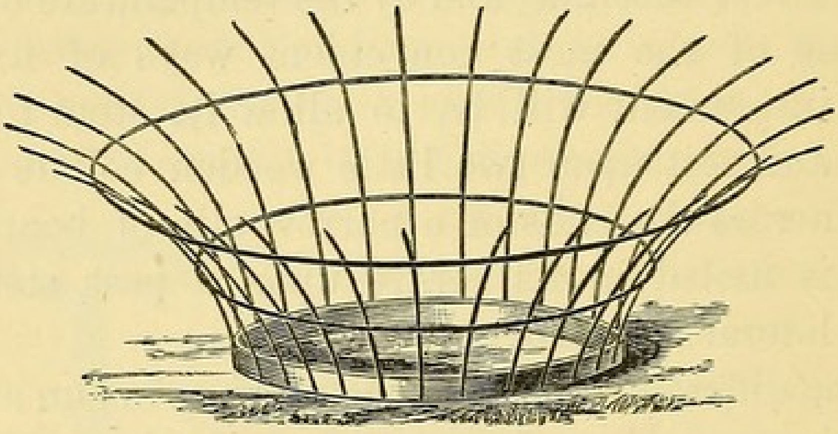


Fig. 68.

ployed for rendering apparent the divisions on the stem from the same cause, have sorely troubled observers in the past.

As received from the instrument maker a terrestrial minimum thermometer is generally attached to its jacket by a stuffing of strips of indiarubber.

Many remedies have been proposed. A packing of chloride of calcium, or of putty and sealing-wax, or a bored cork painted over on its exterior with two or three layers of asphalte, or an air-tight ground joint. Some have bored a hole at the closed end of the jacket, and others have discarded the jacket altogether.

I would recommend that this last-named plan be adopted, or that a bored indiarubber cork be employed, painted externally with several coats of asphalte, or that the thermometer be fitted to the jacket like a stopper to a bottle. In either case the markings on the stem should be rendered indelible, in the manner described on page 420.

Every thermometer should be numbered and graduated on the stem, and should be verified by comparison with standard instruments.

A special department at the Kew Observatory occupies itself with the verification of meteorological instruments, charging a small fee for the labour. No one should buy a thermometer or barometer unless it is provided with a recent certificate of the verification of the same.

*Proof of the Necessity for the Verification of Thermometers.*—The inaccuracies in the readings of thermometers, which render a verification of all a necessity, are due partly to the difference in the diameter of the bore throughout their entire length, which defect appears to be inseparable from their manufacture, and partly to the tendency which thermometers have to read higher from age. Verification of Thermometers.

It is sometimes difficult indeed to find two thermometers, out of a large number, that read exactly alike. Here is a certificate of verification from the Kew Observatory, which belongs to a thermometer in my possession:—

| | |
|---|---|
| At 32° . . . . . . | 0·0 |
| „ 42° . . . . . . | 0·0 |
| „ 52° . . . . . . | +0·1 |
| „ 62° . . . . . . | −0·1 |
| „ 72° . . . . . . | +0·1 |

*N.B.*—When the sign of the correction is + the quantity is to be added to the observed scale reading, and when — to be subtracted from it.

They may in truth be likened to human faces, for scarcely two are to be found very closely resembling one another. A mercurial maximum thermometer was some time ago purchased by one of my friends of each of the most eminent meteorological instrument makers. They were compared together, and all found to differ from each other in their readings.

Mr. Alexander Buchan states[1] that he once compared a number of first-class high-priced thermometers, every one of which was from 1·2° to 1·7° too high.

Some thermometers have been offered to the public with the assurance that "every instrument is carefully verified by a Kew standard thermometer"; which simply means a well-made thermometer that has been verified at the Kew Observatory—one, in fact, whose errors are known. A thermometer which had been thus verified and declared free from error was sent by me to this observatory. The certificate returned with it contained the following corrections:—

| | |
|---|---|
| At 90° . . . . . . . | – 0·2 |
| „ 95° . . . . . . . | – 0·2 |
| „ 100° . . . . . . . | – 0·1 |
| „ 105° . . . . . . . | – 0·0 |

Another thermometer sent out by a different maker is in my possession which was "guaranteed accurate in its indications, having been compared, degree by degree, with a standard thermometer verified at Kew." It is about ·4 of a degree in one part of the scale, and ·5 in another part, higher than is correct.

Here is the certificate of a third thermometer, which was supposed to be perfectly accurate before returned from the Kew Observatory:—

| | |
|---|---|
| At 85° . . . . . . . | – 0·3 |
| „ 90° . . . . . . . | – 0·4 |
| „ 95° . . . . . . . | – 0·5 |
| „ 100° . . . . . . . | – 0·4 |
| „ 105° . . . . . . . | – 0·4 |

[1] *Handy Book of Meteorology.* Blackwood. 1867.

It is not by any means an easy matter to verify thermometers with precision. The verification can only be satisfactorily conducted by means of instruments specially adapted for the purpose, such as are to be found in the great observatories.

It should be done, moreover, with the greatest care, by men who are accustomed to the work.

The following memoranda for purchasers, which were published in a paper[1] read before the British Medical Association in 1869, may be advantageously repeated:—

(*a*) Mercurial thermometers which are two or three years old are always to be preferred.

(*b*) No instrument should be bought without a certificate from an observatory of its *recent* verification.

Mercurial thermometers are liable to read higher than is correct through age; and this change especially occurs during the year or two immediately succeeding their period of construction. The bulb, having been formed by the action of heat, undergoes contraction after its manufacture, the fibres of the glass taking some little time to assume their permanent position. Hence it has been usual amongst some makers of meteorological instruments to lay down their thermometers, like their port, for improvement with age, before engraving the scale on their stems. "By quite a recent discovery in the manufacture of these instruments," writes one who sells thermometers, "the glass bulb of the thermometer is reduced to its ultimate degree of contraction before the stem is divided, thus obviating the necessity of keeping the tubes filled for the space of one or two years before dividing them, and rendering it possible to make an absolutely accurate instrument in a week." With the object of ascertaining the truth of this statement, I made a careful examination

[1] "Remarks on Clinical Thermometers."—*Medical Times and Gazette*, October 16, 1869.

of one of these thermometers, and discovered that it was incorrect. Its readings were about two-fifths of a degree too high.

The verification of a two or three-year old mercurial thermometer at an observatory should not be relied on as a guarantee of its perpetual accuracy. The authorities of the Kew Observatory consequently append to their certificates the following, amidst other notes:—"This instrument ought, at some future date, to be again tested at the melting-point of ice, and if its reading at that point be found different from that now given, an appropriate correction ought to be applied to all the above points."

Markings of degrees of thermometers.

The markings on the stem of thermometers, which indicate the degrees and parts of degrees, are exceedingly apt to crumble away and disappear after but a short exposure to the air, for the reason that instrument makers do not know of a durable composition with which to form them. The markings of the divisions may be replaced by the observer in either of the following modes:—

The stem of the thermometer, having been thoroughly cleansed by scrubbing it with an old tooth-brush dipped in a mixture of strong aqueous caustic soda and methylated spirit in equal proportions, is washed with water and dried. Silicate of soda is mixed with water sufficient to produce a syrupy solution. A little of this fluid is mingled with some lampblack, so as to form a paste, which is brushed over the divisions as a coating. The thermometer is rolled between a flat piece of wood and a strip of cardboard, so as to remove all of the black coating from the stem except that which fills the grooved lines of the divisions. By means of another brush dipped in the clean syrupy solution of silicate of soda, a coating of this artificial glass is rapidly spread over the whole of the stem of the thermometer, which is then allowed to dry.

Some mix with the syrupy solution of sodic silicate some common precipitated manganic dioxide, to which a little lampblack has been added.

Others smear over the scale of divisions on the stem some compound of lead, converted into a paste with a solution of silicate of soda. The paste which does not fill the lines is rapidly removed by rubbing the stem of the instrument between two smooth surfaces. The divisions containing the paste are then brushed over with a little ammonium sulphide, which forms with the lead the black sulphide of lead.

# CHAPTER XXXV

## 3.—THE HYGROMETRIC CONDITION OF THE AIR

Moisture of air as shown by rain-gauge, hygrometer, and spectroscope.

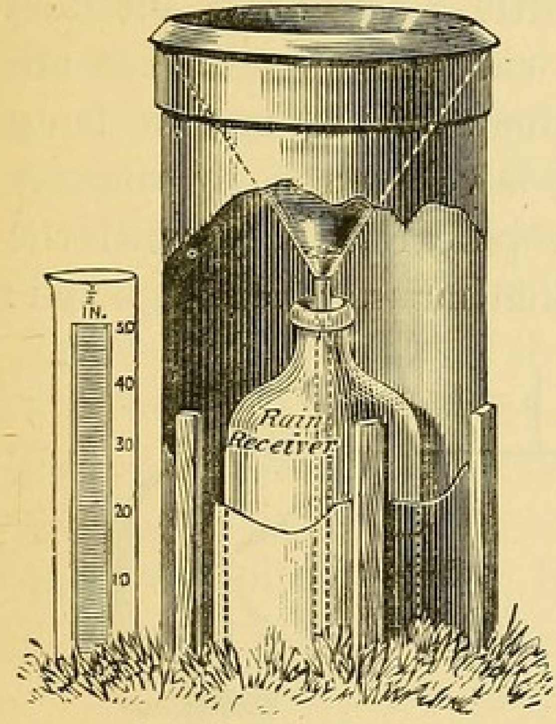
THE hygrometric state of the air is determined by —1*st*, an estimation, by the help of the rain-gauge, of the amount of water which reaches the earth in the form of rain, hail, snow, and fog; 2*d*, a consideration of the indications of the hygrometer, an instrument for determining the amount of aqueous vapour present in the air, near the surface of the earth; and 3*d*, a rough estimate of the degree of development of the atmospheric lines of the solar spectrum as shown by a spectroscope.

The amount of moisture in the air cannot be determined by either of these instruments separately, but is exhibited by the combined information afforded by them. A month's rainfall may simply imply the amount of rain which fell on one excessively wet day, the remaining days of the month being dry and fine. The air is frequently very moist, even when no rain falls. The rainfall of New York is nearly double that of London, yet the relative humidity of the air of New York is much less than that of London. Whilst the number of aqueous lines in the solar spectrum between $D^1$ and $D^2$ at New York, corresponding with the weight in grains of aqueous vapour in each cubic foot of air, is at its minimum in January, and at its maximum in August or September, Dr. D. Draper shows that the relative humidity of New York reaches its maximum of 96 in January, instead of in August or September.

The degree of humidity of the air is affected by many circumstances—such as direction of the wind, temperature, season of the year, distance from masses of water, and configuration of the land over which it lies.

*A Rain Gauge*, quite good enough for all practical purposes, can be purchased for about half a guinea, the glass measure, which is divided into $\frac{1}{100}$ths of an inch, being included. Rain Gauge.

It should be fixed, by means of four or more wooden stakes, firmly into the ground, so that its summit is 12 inches above the surface. The farther removed the site is from buildings and trees the better. It should always be as far from a neighbouring object as that object is high. Snow should be melted before it is measured.



Rain Gauge. Fig. 69.

Printed directions for making observations generally accompany these instruments. Any information as to the estimation of the rain is freely given by Mr. Symons, of Camden Square, London, who is at the head of all rainfall registration in this country. Forms for its registration may be obtained from Mr. Stanford, Charing Cross, London.

Dr. Trench, the late Medical Officer of Health for Liverpool, was strongly impressed with the belief that there is an inverse ratio between the rainfall and the amount of mortality from infantile summer diarrhœa. If this disease is dispersed, or rendered less virulent by an excessive rainfall, it is often superseded by catarrhal and rheumatic affections, which, although less mortal, are often exceedingly intractable, and sometimes lead to serious results.

Hygrometers.

*The Hygrometer.*—The amount of aqueous vapour present in the air is determined by instruments called hygrometers, of which there is a great variety. Reynault's and Mason's hygrometers are generally preferred; but, as the working of the former instrument with ether and an aspirator is troublesome, the latter has almost entirely supplanted it in everyday practice. It consists of two verified thermometers, fixed side by side; the bulb of one being kept always damp by a covering of muslin connected with a little reservoir of distilled water by means of a lamp wick. Great mistakes are commonly made in the adjustment of the muslin, lamp wick, and water reservoir. I have seen a hygrometer in the observatory of a Philosophical Society with the wet bulb arranged in the mistaken manner here depicted:

Mason's hygrometer.

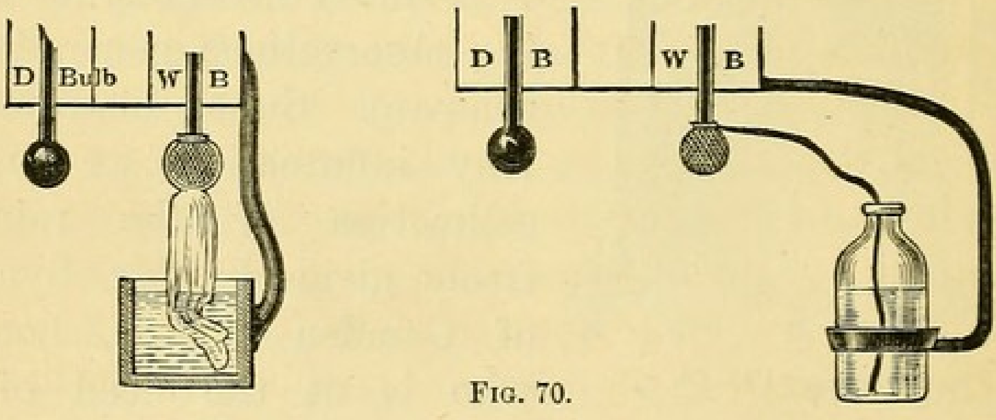



Fig. 70.

The Improper Mode. The Proper Mode.

Bulbs of Mason's Hygrometers.

In the first sketch the wet bulb is smothered in wet muslin, to which is attached a piece of lamp wick as large as one's little finger, whilst close below the bulb is an open vessel full of water. Every provision would seem to be made here for producing an artificial local dampness of air around the bulb, and for rendering it simply impossible that the thermometer should really furnish us, by indicating the temperature of an evaporating surface, with the true hygrometric state of the air in the neighbourhood.

The finest muslin, which generally contains starch, should be boiled in distilled water to extract it. Lamp wick should be boiled in distilled water and a little carbonate of soda to remove all grease. The smallest thread of lamp wick that will keep the muslin permanently damp should be employed, and the little reservoir of water should be fixed away from the bulb, so as not to create a local artificial climate.

The first drawing represents the ignorant and careless use, and the second drawing the intelligent employment, of the hygrometer.

The hygrometer is fixed against a thin board that occupies the centre of the thermometer stand. Like the other shade thermometers it should face the north. If the air is saturated with moisture there is little, if any, difference between the readings of the dry and wet bulb thermometers. The readings of the wet bulb are, as a rule, lower than those of the dry bulb thermometer. The generally accepted statement that the greater the difference between the dry and wet bulbs the less is the amount of watery vapour present in the air, requires some qualification.

An increase of temperature, by expanding the air, and thus separating the particles farther from each other, increases, whilst a fall of temperature, by drawing them closer together, diminishes the capacity of the air for moisture. Air of a temperature of 57·2 dry bulb, and 51 wet bulb, with a relative humidity of 64, may contain exactly the same amount of vapour in grains per cubic foot (3·4) as air of a temperature of 70·5 dry bulb, and 56·8 wet bulb, with a relative humidity of 42. The semi-diurnal rise of temperature is more frequently accompanied by an increased capacity of the air to absorb moisture than an actual increase in its amount.

The relative humidity of, or percentage of, moisture in the air is afforded by reference to a table to facilitate calculation.[1]

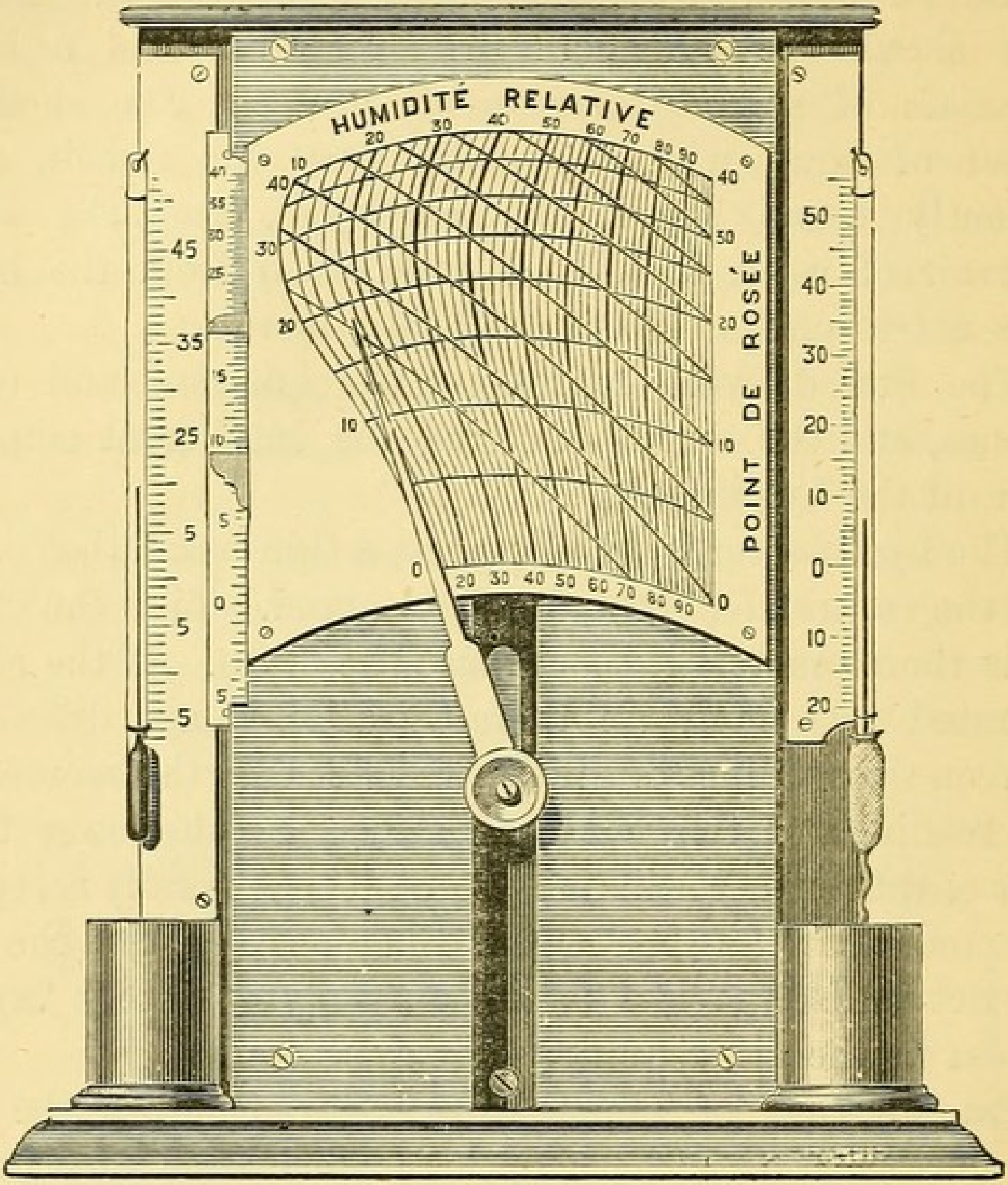



FIG. 71.

One of the best, if not the best, hygrometer for popular use, as it requires no tables and calculations, is one that was designed by Mr. Lowe of Boston, U.S., and is employed in France. It is especially adapted

[1] The fullest information as to the use of Mason's hygrometer, and the calculation of the dew point, etc., is to be found in James Glaisher's *Hygrometric Tables*, adapted to the dry and wet bulb thermometers. Third edition. Taylor and Francis, Fleet Street, London.

The tables prepared by William Bone, which are obtainable from Negretti and Zambra, are also useful.

for the sick room, as it can be easily managed by an intelligent nurse in accordance with the instructions of the physician (fig. 71).

It consists of two thermometers precisely alike, the bulb of one being dry and the other kept always moist. On the inner side of the dry bulb scale is a third scale, on which two indices move up and down. In the central portion of the lower part of the hygrometer is a screw head with a pointer attached to it. By the help of the vertical, oblique, and horizontal lines the relative humidity, dew point, and elastic force of vapour of the air may be seen at any moment at a glance. The instructions as to the mode of working the instrument are thus given in the *Meteorological Magazine* of December 1877:—

"(1) Read the dry bulb thermometer, and raise the screw head in order to set the upper index on the extra scale at the dry bulb temperature; (2) read the wet bulb, and turn the screw head until the lower index is at the wet bulb temperature. The extremity of the long hand will then point to (*a*) the relative humidity; (*b*) the dew point; and (*c*) the elastic force of vapour, according as one reads the vertical, oblique, or horizontal lines." The only objection to this instrument is that very common one which has already been adverted to in referring to Mason's hygrometer, as to the position of the reservoir of water, etc. This defect can, of course, be easily removed.

Lowe's hygrometer.

*The Spectroscope.*—Whilst hygrometers indicate the degree of moisture of the air around them, the spectroscope furnishes us with a means of roughly estimating that contained in the higher regions of the atmosphere. The water lines in the solar spectrum are very numerous, especially in the red portion. The principal aggregation of them forms what is known as the atmospheric zone or "rain-band," on the red side of D. In Ångström's atlas more than 50 lines may be easily counted in this zone.

The Spectroscope.

There is a minor rain-band between *b* and F, which he describes as "très forte pendant les mois d'été," and which has been named the "Maxwell Hall's Jamaica Rain-Band." Prof. J. P. Cooke of Cambridge, Massachusetts, U.S., confining his attention[1] to the study, by means of a powerful spectroscope, respecting the relation between the number of interstitial lines in the otherwise empty space bisected by the solar Nickel line between $D^1$ and $D^2$ (for D discloses itself as a double line under a high power), and the weight of aqueous vapour per cubic foot of air, found an augmentation of their number as the weight of water gas increased from ·81 to 6·57 grs. per cubic foot. Prof. Piazzi Smyth has often counted 11 or more of these water lines in this space.[2] Without diving deeply into this subject by the help of powerful instruments, we shall find that much information is afforded by a practical acquaintance with a small waistcoat-pocket spectroscope, which enables the observer to study the changes in the apparent thickness of the Fraunhöfer line D in the solar spectrum, and compare its size and distinctness with the unchangeable lines E, *b*, and F, on the less refrangible, or green and violet side of the spectrum. What has been described by Prof. Piazzi Smyth as "the rain-band" is the blurred appearance on the red side of D, which becomes more or less distinct in proportion to the amount of moisture in the air and to the probability of rain falling.

The line D is seen by a small spectroscope to separate the red from the yellow, and F appears to be in a position where the green merges into the violet parts of the spectrum. The degree of visibility of the fine lines in the green part of the spectrum between D and E is also worth noting, as when rain is imminent they become less distinct. On the yellow side of D are often to be seen, especially when the sun is on the horizon, "low sun-bands" which should be dis-

[1] *American Journal of Science*, November 1865.
[2] *The Visual Solar Spectrum.*

regarded in rain prediction. The line D, with the attached "rain-band," may be compared as to its thickness and distinctness with the Fraunhöfer lines E, *b*,[1] and F, forming as

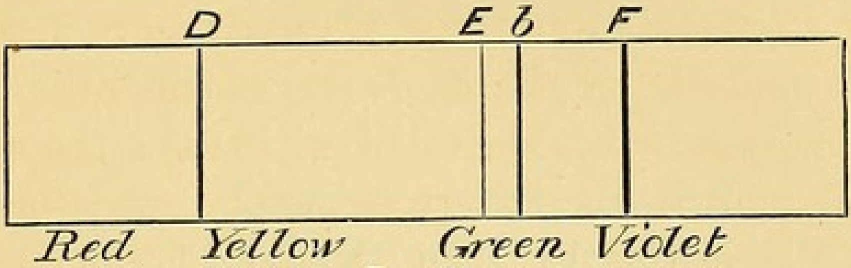


FIG. 72.

they do three grades, or standards of comparison, a thickness equal to F showing a large excess of moisture in the air.[2]

[1] *b* is in reality a double line, but is seen with difficulty as such if a spectroscope of very moderate dispersion, like that recommended, be employed.

[2] When the information afforded by the spectroscope is supplemented by that given by the thermometer, the probability or otherwise of the condensation of the moisture, in the form of rain, hail, or snow, at or around the place of observation may be estimated with some approach to precision. Dr. H. R. Mill has offered to the public the following guide, which may be useful to weather prophets. It refers to appearances presented by a small Hilger's spectroscope, and the rules for prediction are based on observations made at Edinburgh.

| Thickness and distinctness of line D. | Temperature. | Prediction. |
|---|---|---|
| le. *b* . . . . . . | —— | No rain. |
| ,, . . . . . . | Below 40° F. | Possibly rain. |
| =*b* . . . . . . | ,, 40° F. | Rain. |
| *b* . . . . . . | Between 40° & 45° | Probably rain. |
| *b* . . . . . . | ,, 45° & 50° | Probably no rain. |
| *b* . . . . . . | Above 50° | No rain. |
| gr. *b*, le. F. (thin lines distinct) | Below 45° | Probably no rain. |
| ,, ,, ,, ,, | Above 45° | No rain. |
| ,, ,, (thin lines indistinct) | Below 60° | Probably rain. |
| ,, ,, ,, ,, | Above 60° | Probably no rain. |
| =F. . . . . . . | —— | Rain. |
| gr. F. . . . . . . | —— | Much rain. |

le. signifies less than. gr. signifies greater than.

Those who have not worked at the spectroscope in connection with meteorology will find information on this subject in an article entitled "Rain-band Spectroscopy," by Professor P. Smyth, in the *Transactions Scottish Meteor. Socy.*, Nos. 51-54, and in *The Rain-band* (Hilger, 1883), by H. R. Mill, and also in *A Plea for the Rain-band, and the Rain-band Vindicated*, by J. R. Capron, published by Stanford of Charing-Cross, 1886.

## CHAPTER XXXVI

### 4.—THE DIRECTION AND STRENGTH OF THE WIND

THE *direction* of the wind is easily ascertained by noting the movements of the lowest stratum of clouds. The upper strata of clouds are sometimes to be seen travelling in an opposite direction to that in which the lower are moving.

Anemometers and pressure plates.

The strength of the wind is estimated by its velocity or pressure. Instruments named anemometers are employed to register its velocity, and pressure plates its force.

The belief of meteorologists in anemometers has suffered a rude shock by the investigation made by the Rev. Fenwick Stow, on a simultaneous comparison of the behaviour of different anemometers.[1] He discovered that the results were discordant, and that the indications of the only instrument which comes within the reach of the purses of most of us, namely, Robinson's cup anemometer, are very fallacious.

Pressure plates are open to several objections, and are generally costly contrivances, arranged with vanes, so as to keep the surface of the plate always at right angles to the flow of the wind.

The cheapest and simplest which I have seen is one

[1] "On Large and Small Anemometers."—*Quarterly Journal of the Meteorological Society*, April 1872.

that has recently been introduced by Mr. Thomas Stevenson, which can be obtained for 24s.[1]

A is a wood box, $\frac{3}{8}$ inch thick, attached to the top of a stake fixed in the ground, which turns with the wind on a vertical axis.

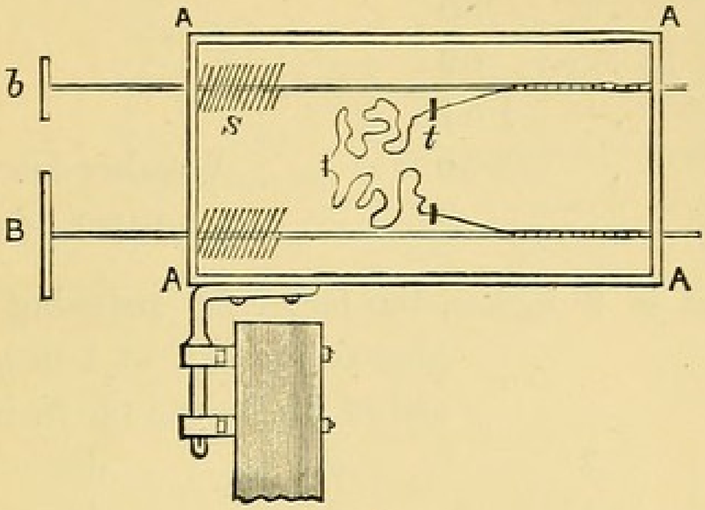



FIG. 73.

*b* is a small disc, fixed on a light brass tube, $\frac{1}{4}$ inch in diameter, which rests on two brass rollers.

B is a larger disc, fixed on a light brass tube, $\frac{1}{4}$ inch in diameter, which rests on two brass rollers.

When acted on by the wind the brass spring *S* is *lengthened*, the maximum elongation being recorded by a fine thread attached to the rod, which is pulled through a small hole in a brass plate (*t*) fixed to the side of the box. The rods are graduated by weights, each division corresponding to the elongation of the spring, due to a weight of 1 ounce.

"To ascertain the maximum elongation that has taken place in the observer's absence, press the thread against *t*, then push in the disc until the part of the thread which had been drawn through the hole in *t* is again drawn 'taut,' and read off the result from the graduated tube."

[1] *Scottish Meteorological Journal*, July 1874–July 1875, p. 266.

| | Pressure in lbs. per sq. ft. | Remarks. |
|---|---|---|
| July 3 | 2·54 | |
| 4 | 7·50 | Stormy winds with sudden gusts. |
| 5 | 3·44 | |
| 7 | 1·05 | |
| 8 | ·80 | |
| 31 | ·62 | |
| Aug. 1 | 1·54 | |
| 2 | 12·00 | Weather described in newspaper as a heavy gale. |

| | | | | |
|---|---|---|---|---|
| When the disc is | 6 | inches, the factor for reducing the divisions (due to pressure of 1 oz.), to the standard of lbs. to the sq. ft. is | | ·318 |
| Do. | 3 | do. | do. | 1·273 |
| Do. | $1\frac{1}{2}$ | do. | do. | 5·09 |

This variety of pressure gauge has been constructed for storm stations with one disc of 3 inches diameter, and the other $1\frac{1}{2}$ inch, but admitting of a 6-inch one being put on at any time when the winds are light.

One great objection to these, as to almost all other wind-pressure plates, is, that they only move in a horizontal line. Supposing the wind to descend upon them, or ascend towards them, in sudden gusts, they do not feel and therefore cannot register its force.

Table for rough estimate of force of wind.

I have been in the habit of employing the accompanying table (extracted from Buchan's *Meteorology*) for many years, and think it can hardly be improved upon as a guide to the formation of a rough estimate. The scale is 0 to 6, 0 representing a calm, and 6 a hurricane,—a violence of wind which is unknown in this country.

| Estimated Force. | Pressure in lbs. per sq. ft. | Velocity in miles per hour. | Popular Designation. | Estimated Force. | Pressure in lbs. per sq. ft. | Velocity in miles per hour. | Popular Designation. |
|---|---|---|---|---|---|---|---|
| 0·0 | 0·00 | 0·0 | Calm. | 3·0 | 9·00 | 42·4 | Very fresh. |
| 0·1 | 0·01 | 1·4 | Lightest breath of air. | 3·5 | 12·25 | 49·5 | Very fresh. |
| 0·5 | 0·25 | 7·1 | Very light air. | 4·0 | 16·00 | 56·6 | Blowing hard. |
| 1·0 | 1·00 | 14·1 | Light air. | 4·5 | 20·25 | 63·6 | Blowing hard. |
| 1·5 | 2·25 | 21·2 | Light breeze. | 5·0 | 25·00 | 70·7 | Blowing a gale. |
| 2·0 | 4·00 | 28·3 | Fresh ,, | 5·5 | 30·25 | 77·8 | Violent gale. |
| 2·5 | 6·25 | 35·4 | Fresh ,, | 6·0 | 36·00 | 84·8 | Hurricane. |

# CHAPTER XXXVII

## 5.—THE ELECTRICAL STATE OF THE AIR

THIS subject may be discussed under two heads:—(1) As to the mode of collecting atmospheric electricity; (2) As to the mode of determining its kind, whether positive or negative, and its tension.

Mode of collection.

(1) Mode of collecting atmospheric electricity. Various contrivances have been employed—such as an insulated metal point; a kite; a pole, with an insulated pointed wire, or bundle of copper wires, or conducting ball on its summit, connected by an insulated wire with an electrometer; a rod with a burning fuse or match; a copper tube, with an oil lamp always burning attached to its extremity; an insulated can of water, with a fine discharging tube, dropping minute quantities of water through the air;[1] balloons with wire coverings;[2] a spirit lamp on an insulated stand; a gas jet, so constructed that it cannot be extinguished by the wind; etc. etc.

The insulated can of water is, of course, useless in frosty weather, and troublesome when it is desired to make observations at different places; otherwise the water dropper is a most convenient apparatus.

[1] A description of this may be found in *Deschanel's Natural Philosophy*, by Professor Everett, part iii. p. 604.

[2] *Nouveau Procédé pour Étudier L'Électricité Atmosphèrique*, by M. Monnet. Published by the Société des Sciences Industrielles de Lyon.

Sir Wm. Thompson employs for travelling, in connection with his portable electrometer, blotting paper steeped in a solution of nitrate of lead, dried, and rolled into matches, which are attached to a brass rod projecting from the instrument.

Determination of its kind and tension.

(2) Mode of determining its kind, whether positive or negative, and its tension.

The electrical condition of the air has been most frequently determined in the past by the employment of an electrometer, which is figured in almost every meteorological work and catalogue of instruments. It therefore needs no description, beyond stating that its essential parts are gold leaves and a brass rod 2 feet long, with a lighted fusee composed of nitrate of lead to collect the electricity. As a glass rod, when rubbed, produces *positive*, and a stick of sealing-wax, when thus treated, *negative* electricity, and as all bodies similarly electrified repel each other, whilst those oppositely electrified attract one another, the custom has been in employing this instrument to apply the excited sticks in turn, in order to ascertain the kind of electricity with which the gold leaves diverge. It will indicate the presence of the electric fluid on almost any fine night, and will show by the aid of the rod of glass or wax the positive or negative character of it, but the intensity of the same is not referable to any accurate scale.

It is now almost abandoned for investigations as to the electrical condition of the atmosphere. The only instruments with which I am acquainted that are of any service in these delicate investigations as to the nature and tension of atmospheric electricity are Sir William Thompson's portable electrometer,[1] Messrs. Elliott and Co.'s modification of Thompson's quadrant electrometer,

[1] Obtainable in this country from James White of Glasgow.

Peltier's electrometer,[1] Lamont's electrometer, and Palmieri's electrometer. Thompson's portable electrometer is easily managed, but if it is once out of order, or has been neglected, is almost hopelessly ruined. Its price is £10 : 10s. Elliott and Co.'s modification of Thompson's

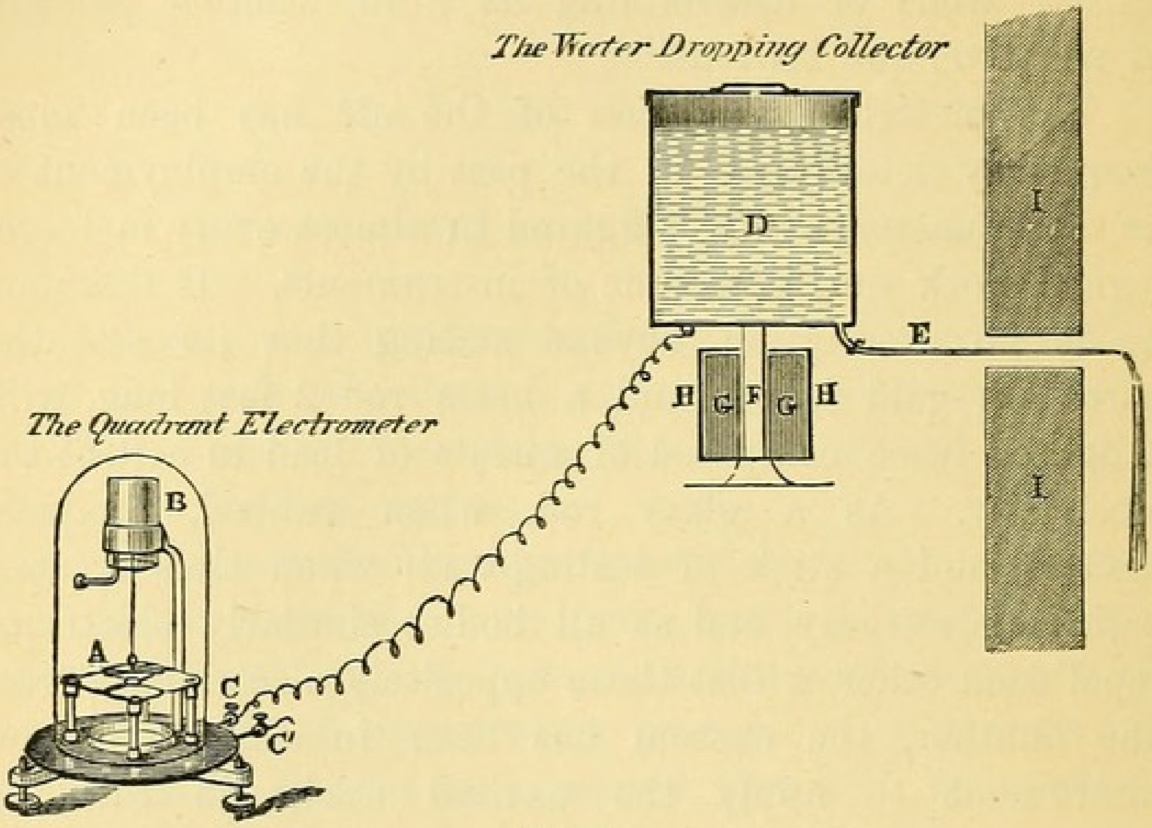



FIG. 74.

A. The needle with mirror. B. The Leyden jar. C. Electrode in communication with body to be tested. C′. Electrode in connection with the earth. D. Copper vessel containing water. E. Brass pipe, with tap, tapered to discharging orifice. F. Glass stem. G G. Pumice moistened with sulphuric acid. H H. Brass case lined with gutta-percha. I I. Section of wall.

quadrant electrometer is not at all portable, but is cheaper, being £5 : 5s. It requires a collector which, if an insulated can of water, costs an extra three guineas. Some excellent drawings of the former or the portable instrument are to be found in *Noad's Students' Text-Book of Electricity*, pages 466 and 467, and in *Deschanel's Natural Philosophy*, by Professor Everett, part iii. page 593. The latter has nowhere, to my knowledge, in conjunction with the in-

[1] Both obtainable from Messrs. Elliott and Co., 112 St. Martin's Lane London.

sulated can of water collector, been delineated. Peltier's electrometer has been employed for more than thirty years at Brussels by M. Quetelet, and is described in the *Annuaire Météorologique de France,* 1850, page 181. Palmieri's electrometer is hardly known in this country, but is valued in Italy, Austria, and France. M. Branly's modification of Thompson's electrometer is also employed by the French.

The Medical Officer of Health who contemplates making a special study of this subject—and it affords in relation to health and disease a boundless field for research, which has up to the present time been scarcely cultivated—would do well to acquire a practical familiarity with the principal electroscopes, electrometers, and distinguishers that have been at various times in use. He will find the works of Saussure and Schübler, of Quetelet,[1] Lamont,[2] Duprez, Thompson's reprint of papers on electrostatics and magnetism, and the bulletins of the Observatories of Kew and Greenwich, of service. They contain records of the annual, seasonal, monthly, and diurnal changes in the electrical condition of the atmosphere of great value. A comparison between the monthly electrical observations at different observatories in relation to the development of atmospheric ozone is to be found in *Ozone and Antozone,* page 67, etc. M. Mascart's *Traité de l'Électricité* is a book which will be also found useful by the student.

The quality of the electricity present in the air is ascertained by observing the attraction or repulsion of the needle. If the jar is charged positively, the needle will be repelled when a positive charge is in the air, and

[1] "Observations des Phénomènes Périodiques," extracted from *Mémoires de l'Académie Royal de Belgique*, vol. xxix.

[2] "Entnommen aus dem Jahresberichte der Münchner Sternwarte, p. 72, und aus dem vii. Bande der Annalen der K. Sternwarte zu Bogenhausen bei München."

attracted by a negative charge. It is not easy to charge the jar exactly to the same potential.

To obtain accurate quantitative results from examinations of the electrical condition of the air requires some practice and skill.

The insulated cans are constructed so as to run for twenty-four hours. It should be remembered that the proximity of houses, trees, etc., will influence the readings of the electrometer very much indeed.

Medical officers of health might very fairly be excused from attempting to deal with a subject which is confessedly a very difficult one, seeing that the officials at the Kew Observatory are continually in trouble with their atmospheric electrical apparatus, were it not that health officers are morally, if not legally, bound to neglect the study of no influence which is likely to affect the public health.

Some one has said very truly that a man must be a brave one indeed who ventured in the present day to attribute any morbid or incomprehensible action to electrical influence, as the whole subject of electricity has suffered so much from the hands of the teachers of popular science. Just as the old-fashioned medical man ascribes all obscure affections to that much-abused viscus, the liver, so every phenomenon which could not be readily explained has in the past been attributed to electricity, and its first cousin, magnetism. The observations made at the Kew Observatory tend to show that the atmosphere always contains free electricity, which is positive in far the great majority of cases at a certain height above the ground (at 5 feet on flat ground). Out of 10,500 observations made during the years 1845-1847, only 364 showed the presence of negative electricity. In damp or rainy weather it is occasionally negative. The lowest stratum of air close to the earth's surface generally furnishes negative electricity. Quetelet, who carried out a series of observations at the Observatory of Brussels from 1844 to 1848, only observed the electricity to be negative twenty-three times, and these exceptional indications either preceded or followed rain and storms. Beccaria recorded a negative state of the atmosphere only six times during a period of fifteen years. It has always been accepted as an article of belief that positive electricity, like ozone, is never to be found in a dwelling-house. We now know that both can be detected in rooms, although the latter is soon used up, unless the windows are open, or some efficient system of ventilation exists. Sir William Thompson, by means of his delicate instruments, has shown that either positive or negative electricity may be carried even through narrow passages from one room to another by air.

M. Palmieri, of the Vesuvian Observatory, has recently made some interesting experiments showing that when steam is condensed by cold, negative electricity is developed; but that positive electricity is manifested when evaporation takes place.

### *Registration of Meteorological Observations.*

Registration of observations.

There is a great variety of registers for recording meteorological phenomena, but they do not teach the eye much, unless arranged in the form of curves. Perhaps the most useful is that represented at the end of *Ozone and Antozone,* or the meteorological diagram of observations made at the Kew Observatory, which appears in the *Times* once a week.

# SECTION III

# SANITARY EXAMINATION

OF

# FOOD

## CHAPTER XXXVIII

### THE PURITY OF FOOD

It will be observed that the 8th Duty (*vide* page 4) which especially relates to the examination of food, simply imposes on the Medical Officer of Health the obligation, when required, of delivering an opinion as to whether any given sample of either of the three great solid necessaries of life, namely, flour, meat, and vegetables, is or is not injurious to health. On the wholesomeness of these substances the health of the great mass of the public to a large extent depends.

That teas are faced, to give them a bloom, with ferrocyanide of iron, considered by the majority of physicians to be deleterious to health; that ales are salted to make customers more thirsty; that nearly every sherry is plastered; that fusel oil is a frequent accompaniment of raw spirits; that sugar often contains iron and sand; that preserved vegetables are frequently coloured with copper; that lemonades, beer, and porter not uncommonly contain lead; that tea is weighted with iron, and weakened with leaves of the thorn and other plants; that butter is sometimes made without cream; that coffee is adulterated with rotten figs, which have been roasted and ground to powder;[1] that ports are

[1] One sample of coffee recently examined in the Paris Municipal Laboratory was reported to contain red earth, flour, coffee grounds,

manufactured at chemical works:—are all facts which are now pretty well known to the public, who have the remedy in their own hands, in the shape of "The Sale of Food and Drugs Act" of 1875, and as amended in 1879.

As none of these articles are necessaries of life, the detection of their fraudulent manipulation does not fall within the scope of the duties of the Medical Officer of Health as laid down by law, and will not therefore be dealt with in this work.

It is as difficult to propound any exact definitions of wholesome and unwholesome food, as to draw a boundary line between the animal and vegetable kingdoms, for there is an almost insensible gradation of one into the other. Game, venison, and mutton which have been hung for a short time are more digestible than if eaten fresh. Cheese which is of a certain age is more palatable than when it is very new. Chinamen are said to swallow stale in preference to fresh eggs. The Esquimaux eat putrid blubber. Oysters acquire a flavour when stale, which renders them more appetizing to the gourmand than when fresh. But as a general rule, to which there are some few exceptions, it may be said that freshness is allied to wholesomeness, and staleness to unwholesomeness in the matter of food.

Allied to the great question as to the purity of food lies the extensive one:—(1) as to the proportion which the amount of flesh-forming, heat-giving, and saline ingredients bear to the health of individuals of different ages and circumstances of life; (2) as to the amount necessary to maintain healthy life in our prisons, lunatic asylums, pauper schools, workhouses, and reformatories.

caramel, talc, plumbago, vermicelli, semolina powder, bean dust, carrots, bread crusts, acorns, sawdust, red ochre, brick dust, ashes, mahogany shavings, vegetable earth, and sand.

It appears that in some of the Cambridge Sanitary Science Examinations questions on these subjects have been introduced. As the Medical Officer of Health is inconsistently (*vide* 1st Duty, page 4) excluded from the medical supervision of Public Institutions, even from the Hospital for Infectious Diseases, this branch of the food question must be omitted from this handbook.

# CHAPTER XXXIX

## INSPECTION AND EXAMINATION OF ANY ANIMAL INTENDED FOR THE FOOD OF MAN

Study of the diseases of animals.

THE possession by the Medical Officer of Health of some knowledge of the diseases of animals is of great value to him, not only in guiding him in the formation of an opinion which may be required of him as to the wholesomeness of their flesh for food, but as opening out to him a field which has hitherto been barely worked, as to the relation between certain diseases of man and those of his humble associates. The writings of Gamgee, Fleming, and Williams will be found to be of great service to those who are engaged in the study of veterinary medicine. It is wise to take every opportunity that offers of making oneself conversant with the diseases of animals, and of encouraging the performance of post-mortems in all doubtful cases. During my studies, cases of cattle plague, pleuro-pneumonia, typhoid fever in pigs, foot-and-mouth disease, splenic apoplexy and other forms of anthrax, glanders, fever of a puerperal description following parturition, ringworm, hydrophobia, distemper, etc. etc., have come under my notice. It is only for the Medical Officer of Health to look out for samples of these maladies, and many chances will present themselves in rural districts of making a practical acquaintance with them.

The diseases of live stock in their relation to public supplies of meat may be summarized in the following manner:[1]—

1. *Contagious Fevers.*
2. *Anthracic and Anthracoid Diseases.*
3. *Parasitic Diseases.*

1. Contagious Fevers.

(*a*) Epidemic pleuro-pneumonia, or lung fever, principally found in horned cattle.
(*b*) Aphthous fever, or foot-and-mouth disease (murrain), which affects horned cattle, sheep, and swine.
(*c*) Smallpox of sheep (Variola ovina).
(*d*) Cattle plague (Rinderpest, Typhus Con tagiosus).

2. Anthracic and Anthracoid Diseases = milz brand of German pathologists.

They prevail as epidemic diseases localized in particular sections of the country, and are known as—

(*a*) Splenic fever, or apoplexy of horned cattle and sheep.
(*b*) The braxy of sheep = splenic apoplexy.
(*c*) The black quarter, or black leg, of horned cattle and sheep.
(*d*) The gloss anthrax, or tongue carbuncle, of almost exclusively horned cattle.
(*e*) The forms of anthrax which affect the mouth, pharynx, and neck in swine.
(*f*) The apoplexy of swine and their so-called blue-sickness, or hog-cholera.
(*g*) The parturition fever of cows, etc.

[1] *Vide* Public Health Report of Medical Officer of Privy Council. No. 5. 1862.

3. THE PARASITIC DISEASES, such as—

"Measles" of the pig; the various, chiefly visceral, diseases of stock which depend on larvæ of the tænia marginata and tænia echinococcus; the "rot" of sheep; the lung disease in calves and lambs; and the easily overlooked, but highly important, disease of swine, which consists of an infestation of their muscular system by the minute immature forms of the "trichina."

# CHAPTER XL

## INSPECTION AND EXAMINATION OF CARCASES OF ANIMALS, MEAT AND FLESH EXPOSED FOR SALE, OR DEPOSITED FOR THE PURPOSE OF SALE, OR OF PREPARATION FOR SALE, AND INTENDED FOR THE FOOD OF MAN

THIS section of the duties of the Medical Officer of Health as to food would seem to rank first in importance, and to comprehend a consideration of the suitability not only of the beef, mutton, lamb, veal, and pork that may be prepared for the food of the whole community, but the wholesomeness of those kinds of animal food which are employed by certain special classes of the people, such as game, poultry, and fish.

Mr. John Gamgee expresses his belief that as much as one-fifth part of the common meat of the country—beef, veal, mutton, lamb, and pork—comes from animals which are considerably diseased.

Mr. Simon, in the report already alluded to, gives the following digest of Mr. J. Gamgee's investigations, made at the request of the Government:—

"Horned cattle affected with pleuro-pneumonia are much oftener than not slaughtered on account of the disease, and when slaughtered are commonly (except their lungs) eaten, and this even though the lung disease has made such progress as notably to taint the carcase; that animals affected with foot-and-mouth disease are not often slaughtered on account of it, but, if slaughtered, are uniformly eaten; that animals affected with anthracic and anthracoid diseases, especially swine and horned cattle, are (except their gangrenous parts) very extensively eaten; that the presence of parasites in the flesh of an animal never influences the owner against selling it for food; that carcases too obviously ill-conditioned for exposure in the butcher's shop are abundantly sent to the sausage-makers, or sometimes pickled and dried; that specially diseased organs will often, perhaps commonly, be thrown aside, but that some sausage-makers will utilize even the most diseased organs which can be furnished them; that the principal alternative, on a large scale, to the above-described human consumption of diseased carcases is that, in connection with some slaughtering establishments, swine (destined themselves presently to become human food) are habitually fed on the offal and scavenage of the shambles, and devour, often raw and with other abominable filth, such diseased organs as are below the sausage-maker's standard of usefulness."

### *Characters of Good and Bad Meat.*

The appearance and odour of good fresh meat is known to most people. The Medical Officer of Health, however, should possess a critical knowledge which may enable him to guide a sanitary authority in cases of doubt, where, from disease or otherwise, the ordinary characters of good meat are partially absent, or attended by some irregularity. The muscle of young animals is pale and moist, and that of old ones is dark-coloured. A deep purple tint is suggestive that the animal has not been slaughtered, or has been slaughtered in a dying state, or has suffered from some fever.

The characters of good and bad meat are generally thus laid down.

*Good*—Firm and elastic to touch; marbled appearance; should scarcely moisten the finger; no odour, beyond that peculiar to fresh meat, which every one knows; upon standing, a small quantity of a reddish juice oozes from it, and it becomes dry upon the surface; marrow of bones is of a light red colour. Good.

*Bad.*—Wet; sodden; flabby; purulent fluid in intermuscular cellular tissue; fat resembling jelly, or wet parchment, or exhibiting hæmorrhagic spots; sickly or putrefactive odour; on standing it becomes wet; marrow of bones of a brownish colour, sometimes with black spots. Bad.

It should be remembered that meat may not reach the standard of good meat and yet be perfectly wholesome, so difficult is it to lay down rules to which there shall be no exceptions; for example, a perfectly fresh leg of mutton is tough and by no means pleasant eating. If kept until it begins to lose some of the characters above enumerated as indicating good meat, which may be a long time if the weather be cold, and especially if the air be dry, it is tender and digestible. If an opinion cannot readily be formed, the lungs and their coverings, the liver, brain, and other viscera of the suspected animal should be carefully examined. Signs of inflammation are to be found in the lungs and pleura; hydatids may be present in the brain and liver. The condition of the mouth, stomach, and intestines should be examined, if there is a probability of rinderpest, and that of the feet, teats, and mouth when there is a suspicion of aphthous fever.

There never can be any doubt as to the propriety of condemning meat that has become putrid, for it produces violent gastro-intestinal disturbance, until the offending matter has been removed either by vomiting or purging. Numerous cases are to be found in medical records of fatal results following the ingestion of animal substances in a state of advanced putrefaction. Certain kinds of meat which will not "keep" well readily undergo some change which results in the formation of a poison that will produce violent gastro-intestinal disturbance. Veal in the form of a pie, if placed aside in a warm cupboard, will often when consumed produce such unpleasant effects. If, on cutting a cold veal pie, the jelly is found to be in a fluid state it is wise to avoid it.

Certain damaged meat, such as mouldy veal, musty bacon, decaying mutton, sausages, bacon,[1] pork pies, brawn,[2] potted meats[3] in a state of incipient putrefaction, cheese, etc., have acted like irritant poisons, producing great nervous depression and collapse. It has been supposed that these defects are owing to the formation of a rancid fatty acid, or a poisonous organic alkaloid, or to the development of a fungus, termed *Sarcina botulina.*

The smell, appearance to the naked eye and under the microscope, will readily reveal the condition of meat in this state.

The detection of decomposition in sausages is found to be more difficult. It has been recommended to mix the sausage with water, to boil and add freshly-prepared lime-water, when an offensive odour will be evolved if the sausages are unwholesome. The existence of an acid reaction to litmus paper, an unpleasant odour and a nauseous taste, are signs of their unfitness for human food.

Acid, alkaline or neutral?

*Reaction with Litmus Paper.*—Good meat is acid, and therefore turns blue litmus paper to a red colour. Bad meat is alkaline or neutral, and accordingly changes red litmus paper to a blue colour, or neither the blue nor red litmus paper are altered by it.

Degree of Resistance.

*Degree of Resistance of various parts when pressed.*—

[1] *Medical Times*, March 7, 1845.

[2] *British Medical Journal*, May 10 and 17, 1873.

[3] *Medical Times and Gazette*, August 5, 1854.

Plunge a long clean knife into the flesh. In good meat the resistance is uniform; in bad meat some parts are softer than others.

Smell.

*Smell of Meat.*—The knife after removal should be smelt. If the meat is chopped up into small portions and some hot water thrown on it, its odour can be readily determined. An unpleasant odour indicates disease, or incipient putrefactive changes. Meat which has a smell of physic is generally condemned.

Amount of moisture.

*Loss of Weight in drying at 212° F.*—Good meat, if dried for some hours on a water bath, will not lose more than 70 to 74 per cent of its weight.

Bad meat will often lose 80 per cent. (*Vide* Precautions to be adopted in estimating loss of moisture, on page 496).

If there is any reason to think that an animal, the meat of which is *sub judice*, has been drugged, although the appearance and smell of the meat are unobjectionable, it is sometimes necessary to cook and taste it, for the fat of a drugged animal, after cooking, has often a peculiar bitter taste. Such drugged meat sometimes creates illness. As to the meat of an animal respecting which there is any suspicion of poisoning by arsenic, antimony, or strychnine, a rough and ready test is the physiological one of giving a portion of the meat to a cat or dog, or to the butcher who is selling it, and to note if symptoms of poisoning are produced, and if so, the exact nature of the symptoms, for each of those poisons produces characteristic effects, which are fully laid down in all books on toxicology. Such cases of poisoning of meat are rare. Mr. Gamgee reports one[1] in which an animal had been excessively drugged with tartar emetic (about ℥ij.) Of 321 persons who ate of the flesh, 107 suffered from violent

[1] Fifth Report of Medical Officer of Privy Council, 1862.

gastro-intestinal disturbance, one case proving fatal. Antimony was chemically found, both in the flesh of the ox and in the interior of the individual who died. Doses of the flesh, which were given experimentally to animals, produced signs of poisoning.

The following analyses of Letheby and Ranke may prove interesting :—

| | Beef. | | Veal. | Mutton. | | Fat Pork. | Roast Meat. No dripping lost. |
|---|---|---|---|---|---|---|---|
| | Lean. | Fat. | | Lean. | Fat. | | |
| Nitrogenous matter . | 19·3 | 14·8 | 16·3 | 18·3 | 12·4 | 9·8 | 27·6 |
| Fat . . | 3·6 | 29·8 | 15·8 | 4·9 | 31·1 | 48·9 | 15·45 |
| Saline matter | 5·1 | 4·4 | 4·7 | 4·8 | 3·5 | 2·3 | 2·95 |
| Water . | 72·0 | 51·0 | 63·0 | 72·0 | 53·0 | 39·0 | 54·00 |

*The Prevalent Diseases of Stock in relation to the supply of Meat for Human Food.*

Theoretically, the meat of the healthiest animals that have been slaughtered is alone fit for the food of man.

Practically, meat that has been obtained from sickly and even diseased animals has been eaten with impunity, and no proof has been afforded that such meat has always been injurious to health, although abundant evidence is on record which shows the occasional evil results of its consumption.

To understand this fact, which has been deemed incomprehensible, it is necessary to make a distinction between the diseases from which our stock suffers, and between the meat furnished by animals at different stages of these diseases.

1. *Contagious Fevers.*

Pleuro-Pneumonia. *The Epidemic Pleuro-Pneumonia of Cattle* is an infectious disease, the poison of which is eliminated through the lungs. The appearance of the lungs and pleura is similar to that presented in a post-mortem of pleuro-pneumonia in the human subject, with which every medical man is acquainted. The divergence of opinion that has prevailed in the medical profession as to what is and what is not wholesome meat, has expressed itself chiefly in connection with the flesh of pleuro-pneumonic cattle. Some would condemn meat that exhibited evidence of perverted nutrition far short indeed of actual disease, whilst others would allow unsound meat to be eaten unless it exhibited such signs of disease as to excite disgust in the consumer. These are the two extremes of opinion, and both parties have much to urge in support of their opposite views. These unfortunate differences have led to great variations in practice, meat in precisely the same condition being confiscated in one part of London, for example, which is permitted to be eaten in another part. They have led also cattle-dealers, farriers, and other interested individuals, to rebel against the opinion of scientific medical officers of health, of which we had an instance some years ago in Dublin.

In September 1877 the Public Health Committee of the Corporation of this city addressed a circular letter, at the suggestion of the Medical Officer of Health, Dr. Cameron, to a great number of medical men in the United Kingdom, including medical officers of health, and to veterinarians, containing the following queries :—

1. Do you consider the flesh of oxen killed whilst suffering from contagious pleuro-pneumonia fit for food for man?
2. If you consider that such flesh may be used under certain circumstances, please state whether or not it is fit for food in the second stage of the disease, in which the lungs are usually much increased in

size, partially hepatized, and sometimes more or less infiltrated with pus ?

290 replied that under no circumstances should pleuro-pneumonic beef be used as food by man; 45 stated that it might be used in the early stage, but, with two exceptions, they believed it to be unwholesome in the advanced stages of the disease.[1]

It should be recorded that Loiset affirms[2] that during nineteen years 18,000 oxen affected with pleuro-pneumonia were killed and used as food by the 150,000 inhabitants of Lille, or nearly 1000 carcases every year, without any apparent injury to them.

Other authorities have made similar observations as to its innocuous character.[3]

My own opinion is that, until it can be shown that the meat of animals in the congestive and inflammatory stages of the disease is deleterious to health, a Medical Officer of Health has no right to have it destroyed. I could not, however, sanction the employment of the meat of an animal that had reached the suppurative and advanced stages of the disease.

Foot-and-Mouth Disease.

*Foot-and-Mouth Disease.*—Although this specific eruptive fever, which runs a definite course and is accompanied by eruptions in the mouth, on the teats, and on the feet, is rarely fatal, it has created greater ravages, and has caused a more heavy loss than cattle plague. Mr. Vacher, who has made a special study of the diseases of animals, says of it:[4] "The eruption consists of blisters which leave, if they break, bare red spots like small ulcers. After they dry up, crusts form. Round the feet the contents of the blisters burrow between the soft

[1] "Report on the Use of Flesh of Animals affected with Contagious Pleuro-Pneumonia as Food for Man," by Dr. C. A. Cameron.

[2] Reynal's *Traité de la Police Sanitaire.*

[3] "Report to Board of Trade," by Dr. Greenhow, 1857.

[4] *Sanitary Record*, October 15, 1885.

parts and hoof which is sometimes shed. Occasionally (especially in sheep) no regular blisters occur on the feet, but the skin becomes red and swollen, and exudes a thick, gummy fluid. The head, feet and udder should be seized. When the eruption has extended into the intestines, as is not infrequent with calves suckled from a diseased udder, or when there is much inflammation and abscesses, the carcase should be condemned." The loss of milk, the abortion of cows in calf, the loss of time and produce, interferes greatly with the meat-producing powers of the country.

One of the witnesses before the Select Committee of the House of Commons in 1873 stated that in 1872 the country lost £12,000,000 from foot-and-mouth disease alone.

There is no evidence on record to show that the flesh of cattle and sheep affected with this disease has injured health, although it is generally pale, flabby, and unduly moist. It is an undoubted fact, however, that the milk of these animals has produced "sore" or "festered" mouths, especially amongst children (*vide* page 539).

Smallpox of Sheep.

*Smallpox of Sheep.*—Mr. Vacher states that the eruption at first resembles flea-bites which become solid pimples, containing a clear fluid which changes into pus, and that the wool comes off readily. The flesh of animals thus affected has an unpleasant smell, and does not possess some other of the characters of good meat, being soft, pale, and dropsical. It produces, if eaten, sickness, diarrhœa, and febrile symptoms.

Cattle Plague or Rinderpest.

*Cattle Plague* (*Rinderpest*).—The flesh does not exhibit any unhealthy appearances in this disease, unless it is in an advanced stage, when it is dark and crackles from the presence of air. In addition to indications of catarrh in the air passages, there are signs of inflammation and ulceration in the intestinal canal. The patches of ulceration reminded me, in some post-mortems made under my superintendence, of the ulcers in enteric fever. Mr. Vacher refers to the existence of an eruption on the back, loins, and inside of the thighs, and in the cow on the udder. When this disease ravaged Italy in 1711 the Government of Venice consulted the Faculty of Padua as to whether such flesh was unwholesome. The decision arrived at was that it was unattended with danger. In 1714, when the disease prevailed, no evil consequences were observed. In 1775, when the plague raged in the southern provinces of France, the flesh of diseased animals was consumed by three-fourths of the inhabitants, and no instance of inconvenience was recorded (Fleming). This author also informs us that the same freedom from any injurious effects was noticed at Hong-Kong, in China, in 1860. During the invasion by rinderpest of this country, in 1865-67, there can be no question but that a vast quantity of animals suffering from this disease were consumed as food, and *we*, as medical men, are unable to prove that any great injury resulted to the public. The meat thus employed was doubtless that of animals in the early stage of the disease. If such meat is consumed the greatest precautions should be taken as to thorough cooking. It is a matter of doubt whether the flesh of an animal in the advanced stages can be eaten with safety.

### 2. *Anthracic and Anthracoid Diseases, etc.*

Splenic Fever or Apoplexy.

*Splenic Fever or Apoplexy.*—The memoranda of Mr. Vacher respecting this disease, which sometimes assumes the form of apoplexy, are:—" Meat dark, often dropsical; whole carcase is bile stained; liver generally enlarged and softened; lungs generally inflamed; increase of weight of spleen, with *rounded* edges, in an ox from 3 lbs. to 7 lbs. or 10 lbs., and in sheep from 2 or 3 oz. to 5 or 6 oz." Great differences of opinion have prevailed as to whether animals thus diseased should be used as human food.

Large quantities of this meat have been eaten, and with apparently no injurious effects; but so many disastrous occurrences have followed its employment as to warrant the Medical Officer of Health in condemning such meat. The poison of this diseased meat resembles some others in acting with greater virulency when inserted subcutaneously than when taken into the stomach. A butcher cuts his hand in dressing an animal that has suffered from this disease, and rapidly dies of septicæmia. A carrier was packing some of this diseased meat for the London market, and a splinter of bone entered his hand. Phlegmonous erysipelas, which ended speedily in blood-poisoning, terminated his life in a few hours. A man was engaged during a dark night in resurrectionizing a diseased animal that had been buried. He hoisted some of the meat in a sack over his back, which was covered by his shirt alone. In some way or other the juices of the meat passed through the sack and shirt, and came into contact with the skin of the back, on which there was probably some abrasion. Erysipelatous inflammation of the skin, attended with intense depression of the vital powers, rapidly set in, and the man expired.

The dust from the wool and hair of animals that have died of this disease is often inhaled by the sorters, packers, and cleaners of the same, and becomes the medium for the conveyance of the poison. "Woolsorters' disease" has been proved to be due to a specific organism, named the bacillus anthracis, which is abundant in the blood and tissues of the diseased.

M. Pasteur has so attenuated by cultivation the virus of splenic fever as to have been able to produce a benign and mitigated kind, protective against the deadly form. He believes that these bacilli are conveyed by earthworms from a buried carcase to the surface, thus propagating it to animals who are grazing above.

I cannot think that meat containing such a deadly poison should ever be sold to the public.

Anthrax, Black Quarter, and Gloss Anthrax.

*Anthrax, Black Quarter, Gloss Anthrax.*—The literature of the past teems with examples of the poisonous nature of the flesh of animals that have suffered from anthracic diseases, although many instances can be adduced, showing the escape of people who have been imprudent enough to risk their health and lives in consuming it.[1] The malignant pustule of the human subject is produced by these anthracic diseases of stock, which are included by the French under the head of "Charbon," thus named because the regions of the body where the disease is localized are coloured black. In this country the development of carbuncles, boils, and other forms of blood-poisoning has been attributed to the use of meat from animals affected with anthracic diseases. All such meat should be condemned. The use of the milk of animals suffering from anthracic diseases should be interdicted.

The Braxy of Sheep.

*The Braxy of Sheep*, which kills 50 per cent of the young sheep of Scotland,[2] is readily recognized by the shepherds by a short staggering gait, bloodshot eyes, rapid breathing, fever, scanty secretions. The braxy mutton is preferred to salt mutton by the hardy Highland shepherds, but it is not, as a rule, cooked and eaten until it has been steeped in brine for two months, and has been suspended for some time from the kitchen roof. Dr. Letheby writes:[3] "Every now and then, however, when perhaps the diseased parts have not been entirely removed, or when the salting has not been sufficiently prolonged, or the cooking has not been thoroughly effected, the most serious consequences result from it, insomuch that many

[1] *Vide* Fleming's *Manual of Veterinary Sanitary Science*, vol. ii. p. 195.

[2] *Vide* the Prize Essay on Braxy, by Mr. Cowan of Glasgow, in *Transactions of the Highland and Agricultural Society*, 1863.

[3] *Vide* Dr. Letheby's *Lectures on Food.*

medical practitioners, who are acquainted with the habits of the Scotch shepherds in this respect, and have seen the mischief occasioned by the meat, declare that braxy mutton is a highly dangerous food for man."

Parturient Apoplexy or Milk Fever.

*Parturient Apoplexy* (*Milk Fever, Dropping after Calving or Lambing*).—The condition of the meat should govern the Medical Officer of Health in the formation of an opinion as to whether the flesh of such animals is or is not fit for human food. Mr. Gamgee writes:[1] "Notwithstanding the sporadic nature of parturient apoplexy in cattle, it is marked by the development of a poison capable of inducing a similar disease in other animals, of affecting the human frame, and hence of rendering the flesh of animals affected by it unfit for human food." Professor Williams writes:[2] "If this assertion were correct the number of the human race would, ere this, have been much reduced, for it is a well-known fact that the flesh of cows, slaughtered whilst suffering from parturient apoplexy, is a common article of diet, and that no bad consequences result from it, provided the animal has been slaughtered early, before the system has been empoisoned by the excessive doses of medicines which are so generally prescribed in this malady, and antecedent to a general vitiation of the animal solids and fluids by the accumulation of effete materials." Convictions in such cases have been obtained. (*Vide*, for example, one reported in *Sanitary Record*, March 2, 1877, page 144.) In cases of accidents during parturition, there can be no valid reason for objecting to a carcase which presents the characters of good meat.

Tubercula Diseases.

*Tubercular Diseases.*—Large quantities of meat that finds its way into our markets has come from animals more or less affected with pulmonary or mesenteric phthisis. This consumptive disease is named "pearl disease," and

[1] *Our Domestic Animals in Health and Disease.*

[2] *The Principles and Practice of Veterinary Medicine.*

by cattle-dealers "grapes." The pearls are either tubercular caseous deposits or enlarged glands, sometimes containing pus or cheesy and at other times gritty matters. In the early stages of the disease the meat does not present any of the characteristics of bad meat, and cannot be rejected, for no proof exists that such food has injured health. If it is eaten, care should be taken that it is well cooked. In the advanced stages, when the lungs are riddled with cavities and the glands are in a purulent state, it should be destroyed.

Hog Cholera, Scarlet, Typhus, and Typhoid Fevers.

*Typhoid Fever, Hog Cholera, Scarlet Fever, Pig Typhus, Spotted Fever, Swine Plague.*—Diarrhœa and dyspnæa, with coughing, are the symptoms of an extremely infectious disease in the pig, which may or may not be accompanied by a patchy or general redness of the skin ("red soldier"), by livid blotches ("blue disease"), or an eruption like variola ("smallpox"). I had an opportunity of studying this disease in a part of Yorkshire some years ago when there was a great mortality from it.

The Privy Council of December 17, 1878 provides that "the Typhoid Fever of swine (otherwise called Soldier Disease or Red Disease) shall be deemed to be a disease under the Contagious Diseases Animals Act of 1878 for the purposes of slaughter and compensation, and also under the Animals Order of 1878, for the purposes of movement, destruction of carcases, disinfection, etc." Mr. Klein, F.R.S., has shown[1] that this disease is not of the nature of typhoid fever, and may more correctly be named infectious pneumo-enteritis. Mr. Vacher has pointed out that "soldier disease" and "red disease" are not synonyms for the so-called typhoid, but are merely popular names given to any affection of swine accompanied by general or patchy redness of the skin, such as is seen in anthrax

[1] *Vide* Seventh Annual Report of Local Government Board, 1877-78, containing Supplement of Medical Officer for 1877.

fever, rubeola (*rougeole* of the French), erysipelas, erythema, and other skin affections, as well as asphyxia, heat apoplexy, and scalding from salt water in sea voyages.

Mr. Vacher's memoranda respecting swine plague are: "The redness of the skin extends through the fat, sometimes the patches are blue, or there is an eruption like smallpox; red spots and ulcers in intestines. There may be intestinal ulcers, and no lung or skin affection, or *vice versâ;* butchers sometimes rub salt along edges of reddened fat. Edge so treated can readily be removed with a knife. Sucking pigs die in great numbers when sows are affected with 'hog cholera.'" Convictions are obtained for the destruction of animals that have suffered from these blood diseases.[1] The carcases exhibit appearances so different from those of good meat as readily to fall under condemnation. It is stated that whole families have been made seriously ill by eating the flesh of "soldier pigs."

*Accidents, Fractures, Wounds.*—The flesh in these cases may generally be utilized as inferior meat, except in the neighbourhood of the injury. If gangrene has set in, its use should be prohibited. Accidents.

The flesh of overdriven animals has been stated by Gamgee to have produced eczema of the skin, and other unpleasant effects.

## *Arguments against the Employment of Diseased Meat.*

The arguments that are employed by those who would perpetrate such raids on our meat markets as to condemn not only all diseased meat, but even that of animals whose nutrition is temporarily perverted, are:— Arguments *against* employment of Diseased Meat.

[1] *Sanitary Record*, February 5, 1876, p. 96 (typhoid fever).
,, ,, January 6, 1877, p. 12 (scarlatina).
,, ,, August 31, 1877, p. 145 (scarlatina).
,, ,, October 26, 1877, p. 270 (spotted fever).

1. That cases of apparent poisoning sometimes arise in a quite indefinable manner ; and that, if such cases prove fatal, no known poison can be detected by the toxicologist.

   It is true that cases of blood poisoning occasionally occur, which have equally been ascribed to the air from drains and cesspools, or to filthy water.

2. That there has been a great increase of carbuncular diseases ever since 1842, the year in which the infectious blood disease of cattle, known as pleuro-pneumonia, was first recognized in this country.

   An increase in this class of disease occurred during the years from 1842 to 1854 ; but since this latter year there has been a decline.

3. That Dr. Livingstone had remarked that those African tribes that fed on cattle which died of pleuro-pneumonia were often affected with malignant carbuncles.

   If Dr. Livingstone was correct as to the nature of the disease from which the cattle suffered, which appears very doubtful, it would seem that the meat was eaten in the most advanced stages of the disease. If, as is highly probable, the cattle died of some form of anthracic disease, the result that followed is only that which would be expected.

4. That the Registrar-General of Scotland had noticed that, since lung disease in animals was introduced into Scotland, there had been a gradual increase in the proportion of deaths from carbuncles.

5. That cooking does not necessarily destroy the poisonous properties of diseased meat is rendered probable by the experiment of Dr. Davies, who successfully vaccinated with lymph which had been buried in the middle of a leg of mutton whilst roasting.

## *Arguments in favour of the Employment of Diseased Meat.*

Arguments *for* employment of Diseased Meat.

The arguments used by the opposite section in the profession, who would not confiscate meat unless it was almost repulsive, are :—

1. That our animal food is exposed to so high a temperature as to kill animal poisons, and coagulate and render inert any albuminous morbid contagium.

2. As the venom of the cobra and the rattlesnake is rendered innocuous after exposure to the disinfectant chemistry of

digestion, so the poisons of such diseases as smallpox, etc., probably undergo similar destruction.

"These two protective influences do not," as Mr. Simon has pointed out,[1] "cover the whole field of danger:—

"(*a*) Meat is often only half cooked; and,

"(*b*) Complete coagulation of albumen may leave some morbid poisons in operation."

3. That the diseased flesh of glandered horses, of animals that have died of contagious disease, rinderpest, anthracoid diseases, and even rabies, have been eaten, *after being well cooked*, with impunity.

We are, one and all, aware that terrible outbreaks of disease have occurred from the use of meat other than that which we are unanimous in condemning. Here are two out of many instances:—

Severe and extensive outbreaks of disease.

Prof. Gamgee has given evidence with reference to a convict establishment, containing 1500 inmates, in which diseased meat was permitted to be used, out of which number 40 or 50 cases of boils and carbuncles occurred per month.

The late Dr. Letheby's sausage case, of November 1860, was remarkable. "A fore quarter of cow beef was purchased in Newgate market by a sausage manufacturer who lived at Kingsland, and who immediately converted it into sausage meat. Sixty-six persons were known to have eaten that meat, of which sixty-four were attacked with sickness, diarrhœa, and great prostration of the vital powers, and one of them died. Dr. Letheby found that the meat was diseased, and that it, and it alone, had been the cause of the mischief."

It is extremely difficult to trace cases of illness to the use of diseased meat, for such does not generally produce such striking and alarming effects as have been referred to in the foregoing examples, but is slow and insidious in its action, unless in a state of putrefaction,

[1] Fifth Annual Report, 1862.

when it often induces symptoms of gastro-intestinal disturbance.

The Medical Officer of Health of Dublin, where diseased meat has, until recently, been disposed of to the public in an unblushing manner, states that he has received complaints from at least 100 persons with respect to the quality of the meat—nearly always beef—which they alleged had created nausea and severe diarrhœa.[1]

He most thoroughly endorses my own views when he writes, "As a rule, bad water and vitiated air do not kill like arsenic or strychnine, neither does the flesh of diseased animals." People are often to be found who habitually drink water which is highly contaminated with sewage; whilst others are almost always immersed in a vitiated atmosphere, and exhibit no sudden and easily perceived injury thereby. The deterioration of health is gradual and often subtle. Now, although this is undeniably true, yet the views of the public on this question should have their weight; for, without a consideration of the subject in its breadth, it is possible to be led into unpractical conclusions.

Pecuniary losses.

The loss to this country from the contagious diseases of animals is over one million a year, which is felt by all classes of the community in the increased prices of meat, milk, butter, etc. Whilst every effort is being made by the Legislature, with a due regard to the injury inflicted on trade by too many or by too severe restrictions, to prevent the spread of these diseases, the confiscation of animal food should not be attempted, unless we possess evidence that such meat is likely to be in any way prejudicial to health, for meat is already so expensive as to be almost beyond the reach of the agricultural labourer. Then, on the other hand, it cannot be right, as Dr. Cameron says, for the flesh of diseased animals to be

[1] *Vide* Report on Pleuro-pneumonic Flesh as Food, and *Dublin Journal of Medical Science*, 1871.

palmed off on the public as that of healthy animals, even if such meat is not considered injurious to health, for the flesh exposed for sale in the shops is presumably derived from healthy animals.

The practice in the city of London is to condemn the flesh of animals that have been suffering from all febrile and wasting diseases; and of any animal that has been killed immediately before, during, or after parturition, for the reason that an animal would not be slaughtered at that time unless death appeared to be imminent.

Much meat finds its way into the market which is simply inferior meat, or that of ill-fed, half-nourished animals; or of cattle that have died as the result of accident, such as rupture of the stomach from eating too much clover, etc.

Sheep often die of exhaustion or mechanical impediments in parturition. These animals are much disposed to over-eat themselves. They distend themselves to such an extent that they at length fall down in a stupefied condition or in a fit—they "drop," as the agricultural people express it. The farmer generally cuts the animal's throat in haste, before it dies, and rapidly sends it to the butcher. The meat, in such cases, must be judged of by its characters when dressed by the butcher for food. The flesh of animals that have died, and of those that have been over-driven or fatigued, will not keep long, and their flesh is very prone to rapidly present an unwholesome appearance. All such inferior meat is sold at a low price, without apparent injury to health, if it does not exhibit the characters of bad meat.

It is a matter open to great doubt, as to whether it is justifiable for a Medical Officer of Health to attempt to interdict the use of any meat of inferior quality that does not exhibit the characters of bad meat, respecting which there exists on record no evidence showing that the flesh of animals similarly affected has proved unwholesome to man.

### 3. *Parasitic Diseases.*

*"Measles" of the Pig, Ox, and Sheep.*—Prof. Gamgee states that 3 per cent, and probably 5 per cent, of the pigs of Ireland are affected with this disease. The flesh of these animals is infested with a parasite named *Cysticercus cellulosus*, which is generally visible to

"Measles."

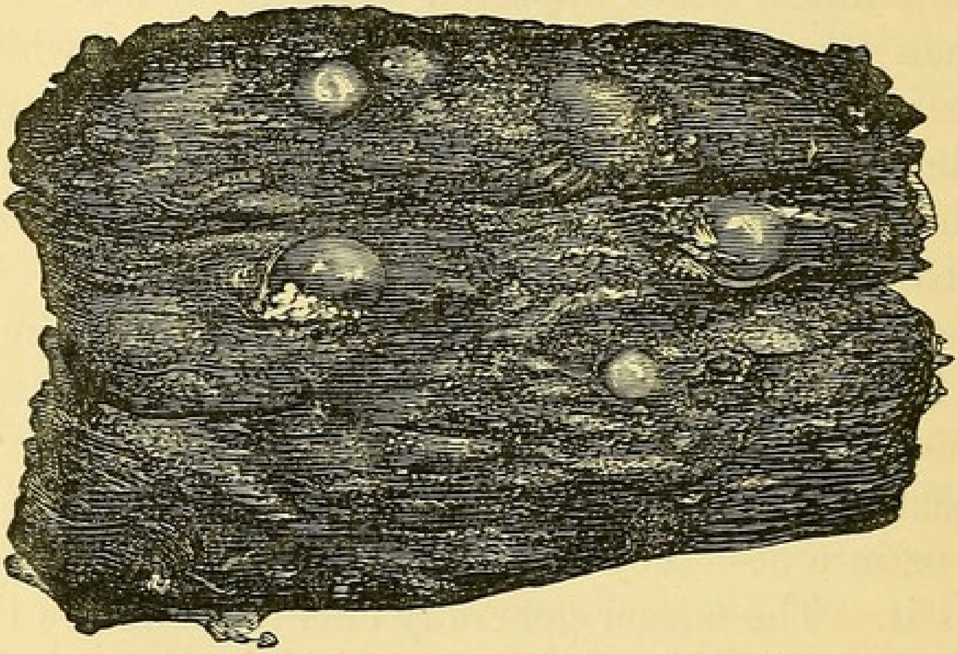


FIG. 75.—Measly Pork, by Dr. Lewis. (After Parkes.)

the naked eye. They are sometimes so numerous that when such flesh is cut a crackling sound is emitted. If one of these semi-transparent little bladders is pricked, and the contents are squeezed out on to the slide of a microscope, the head or sucker and ring of hooklets are readily seen with a low power.

The measles of cattle is produced by the *Cysticercus bovis*, which becomes the *Tænia medio-canellata* of man.

Mutton is liable to the presence of the *Cysticercus ovis*, of which, in its mature form as a tapeworm, we have but little knowledge.

When meat thus infested is swallowed, the outer coat of the vesicle is dissolved by the digestive juices, liberating an animal which is seen to possess a bladder-like tail and a crown of hooklets, with which it attaches itself to the coats of the intestines. Here it develops into the *Tænia solium* or common tapeworm, each joint of which contains large numbers of ova which are often eaten by animals.

The origin of the echinococcus or hydatid disease is thus described by Drs. Woodman and Tidy (*Forensic Medicine*):—"A piece of diseased offal is eaten by a dog which passes by the bowels, either in the field or in the stream, segments of the developed worm (*Tænia echinococcus*). Cattle and sheep swallow these segments. At last the animal that has swallowed them becomes the food of man, and then the larval tapeworm becomes a bladder-like hydatid. In the ox it goes to the peritoneal cavity; in the sheep to the brain, producing 'staggers'; and in the man to the liver."

The "sturdy," "turnsick," or "gid" of sheep is induced by the presence of a hydatid in the brain, named *Cœnurus cerebralis*, the mature form of which is named *Tænia cœnuris.* The *Strongylus filaria* is a parasite that is found in the lungs of the calf and lamb, where it produces what has been termed phthisis pulmonalis, verminalis, or parasitic bronchitis.

In diagnosing the presence of cysticerci in meat, it is necessary to recognize the hooklets.

The treatises of Cobbold, Leuckart, and Küchenmeister, may be advantageously consulted by those interested in the study of the transformations of these parasites.

*The trichina spiralis* (θριξ, a hair) is observed most frequently in the flesh of the pig. It has been declared[1] to have been found in mutton and frequently in beef, and that the reason that this parasite has always been associated with pork is, that in the flesh of the pig its cysts

Trichina spiralis.

[1] *Public Health*, February 23, 1877, p. 131.

are most easily seen. It has been noticed in rabbits, horses, and many other animals. Whereas hogs have been supposed to get their trichinæ from eating rats which have been found largely infested with them, it has been conjectured by some that rats and mice derive them from trichinosed pork. They are so numerous that a piece of muscle the size of a pin's head has been estimated by Vogel to contain 12,000 trichinæ. They are most abundant at the extremities of muscles at their insertion into bones and tendons.

The symptoms of trichinosis, being enumerated in many books which are easily accessible to medical men, require no description. The best accounts of it are from the pens of German physicians. A good summary of their views is to be found in the Report on Trichinæ and Trichinosis, by Dr. W. C. W. Glazier (U.S. Marine Hospital Service). The symptoms may be arranged during the progress of the disease in three stages, as has been pointed out by Dr. Richardson :—(1) A stage of intestinal irritation, corresponding with the full development of the trichinæ, which has sometimes been mistaken for cholera; (2) a stage of moderate fever attended with pains in the muscles, like those of rheumatism, corresponding with the time when the embryos find their entrance into the muscles and are becoming encysted; (3) a prolonged and chronic stage of impaired muscular movement with emaciation, corresponding with the period when the larvæ are entirely encysted in the muscle and are fixed in position. If the case proceeds to a fatal termination, death either results from coma or from severe pneumonia. It is often very difficult to diagnose the second stage from that which presents itself to the medical man when summoned to a case of enteric fever.[1] The indications of the thermometer

[1] If the outbreak on board the Reformatory School ship *Cornwall* in 1879 was in truth trichinosis, it would seem that the existence of rose-coloured spots and hæmorrhage from the bowels are symptoms not diagnostic of enteric fever.

may render some help when coupled with the œdema, especially of the face, and profuse perspirations usually characteristic of trichinosis. Trichinæ have been found in all countries, if search has been made for them. American

Trichinosis and Enteric Fever.

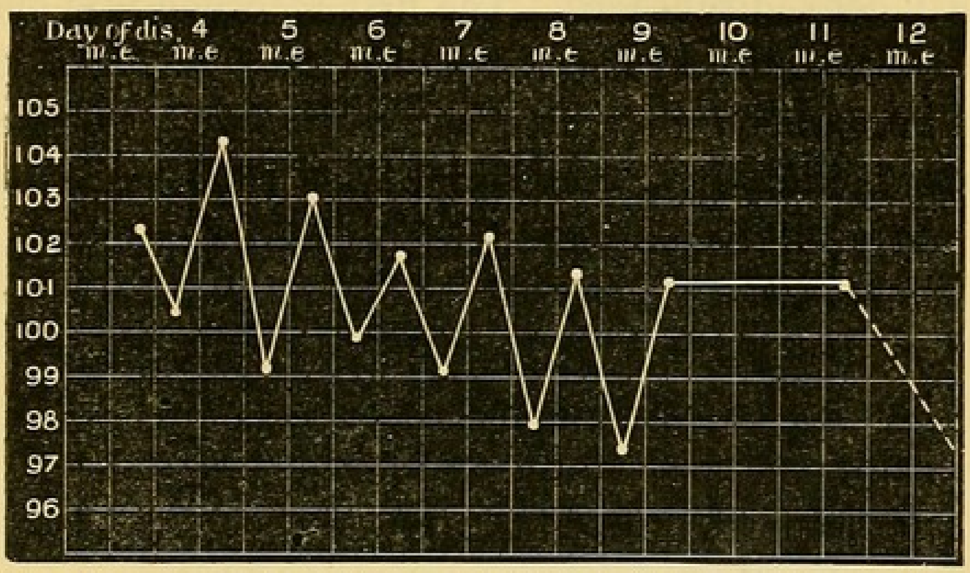



Fig. 76.—Fever curve of a mild case of trichinosis (Maurer, Ziemssen, iii., 632).

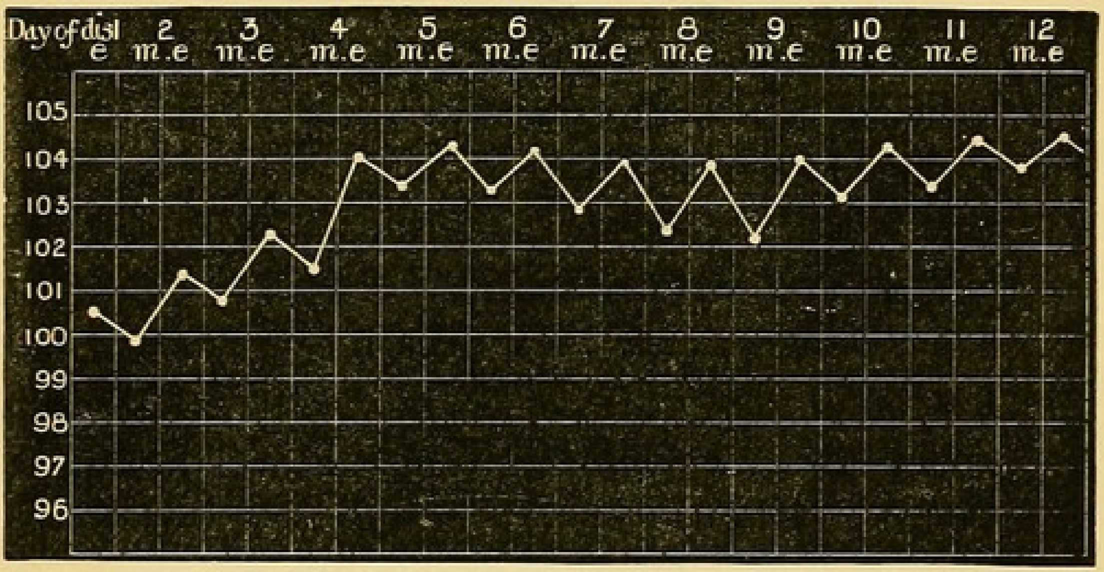



Fig. 77.—Range of Temperature during the first 12 days in a case of Enteric Fever. *m. e.* morning and evening (Wünderlich).

pork has earned a suspicious character by reason of the occurrence of outbreaks of trichinosis in the United States, and the discovery of trichinæ in imported hams. This disease is rarely seen in this country.[1] Epidemics have

[1] Two or three outbreaks have been reported:—one at Thaxted, in which more than forty persons suffered from the consumption of sausages made from salt pork, probably foreign, which contained specimens of the trichinæ spiralis; and another in a family in Cumberland, from eating trichinæ infected pork.—*Brit. Med. Journal*, April 29, 1871.

Outbreaks. been reported from Russia, Sweden, Denmark, Switzerland, and even India, but the headquarters of the disease is situated amongst our neighbours, the Germans, who have such an unconquerable predilection for uncooked or imperfectly cooked sausages. The first recorded was observed in Dresden and in Plauen[1] in 1860. Soon afterwards outbreaks occurred at Stolberg, Rügen, Hettstädt,[2] Custen and Wurmsdorf, Hedersleben, Calbe, Burg near Madgeburg, in

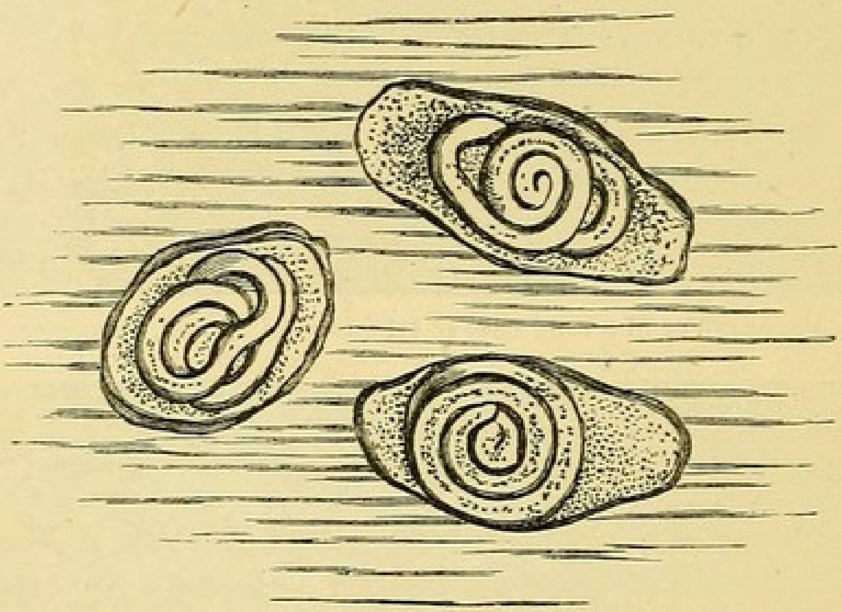


FIG. 78.—Encapsulated Trichina Spiralis × 250.

Anhalt, Leipsic, Jena, Eisleben, Quedlinburg, Dessau, Stassfurt, and Weimar. At Hettstädt 103 persons were affected, and 83 died.[3] The chief trichinæ district has been in the past in the vicinity of Madgeburg. In Dr. Glazier's report references are made to no less than 150 epidemics of trichinosis (from 1860 to 1877 inclusive), 3800 cases with 281 deaths being arranged in a list, and 700 cases with 50 deaths not being therein included. There is a great difference in the susceptibility of individuals to

[1] *Annales d'Hygiène*, October 1863.

[2] *Brit. Med. Journal*, January 16, 1864.

[3] *Vide* Report by Dr. Thudichum on the "Parasitic Diseases of Quadrupeds used for Food," in Seventh Report of Medical Officer of Privy Council, 1864.

trichinosis infection, some being quite unaffected by the consumption of trichinosed flesh.

*Modes of Detection.*—Sausage manufacturers in Germany are said to have the eyes of all pigs after slaughter examined microscopically by a medical man, as the Modes of detection.

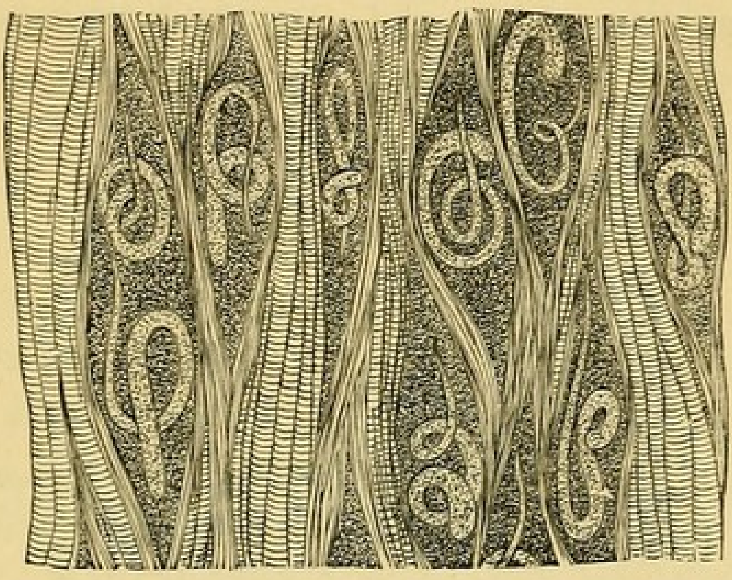


FIG. 79.—From human body dying during the Hedersleben epidemic. Trichinæ about 7 weeks old, completely developed, but without a trace of capsule. (Leuckart.)

muscles of the eye are the first affected. A portion of the flesh removed from underneath the tongue is often examined; but the diaphragm, psoas, biceps, and masseter muscles have been found to contain trichinæ in greater abundance than the other muscles of the body. Meat suspected to contain trichinæ may be examined thus:—A thin section having been made with a Valentine's knife, or by the aid of one of the several microtomes now obtainable, is immersed for a few minutes in a mixture of liq. potassæ 1 part and water 8 parts, until the muscle becomes clear. If they are present white specks appear, in which the worm is seen, by the aid of the microscope, coiled up. A drop or two of weak hydrochloric acid will often render the parasite more visible. A little ether may be added with the same object in fat meat. When the capsules are calcified, they can be plainly seen with the naked eye.

A ready way of detecting these animals in flesh, is that of soaking it in a strong solution of logwood, which dyes the meat but does not colour the trichinæ.

Care must be taken to avoid confounding these parasites with Rainey's corpuscles or capsules (Psorospermia) which have on their surface minute hair-like markings.[1] These bodies were observed in the flesh of cattle that died

Rainey's corpuscles (Psorospermia).

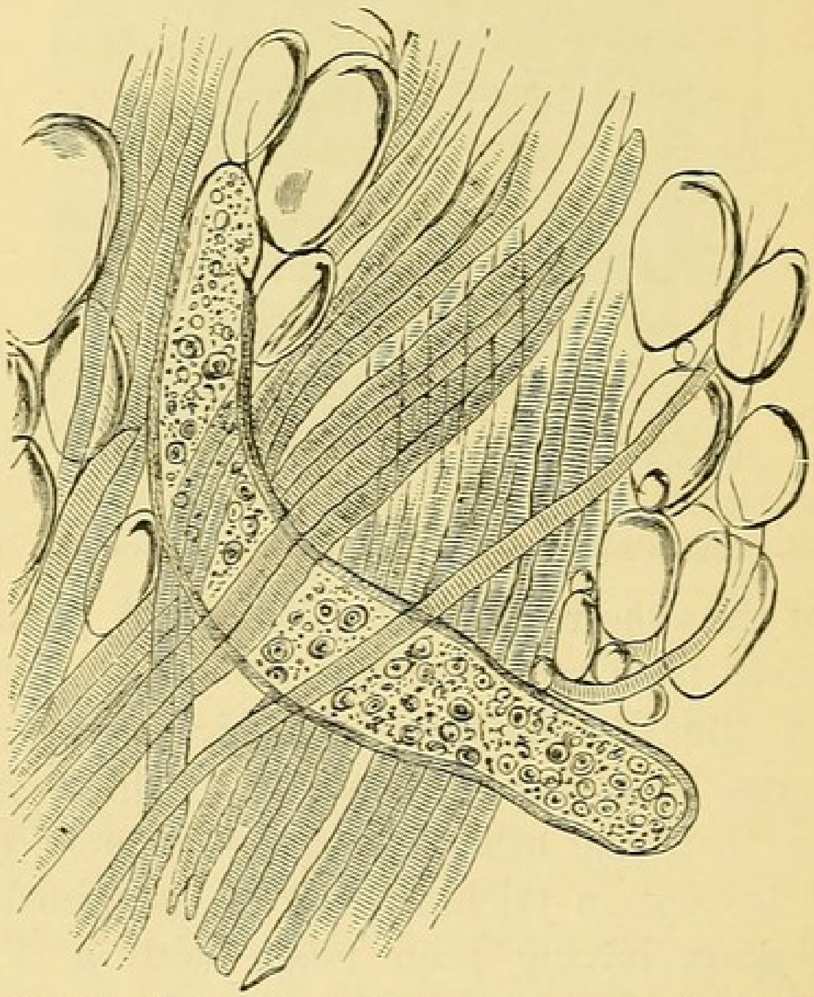


FIG. 80.—A Psorosperm lying loose among muscular fibres.

of rinderpest, when the disease entered the country and destroyed our herds in 1865, by some who were not accustomed to examine meat microscopically, and who discovered in their presence, so they thought, the cause of the disease. The muscle trichina spiralis is easily distinguished from the *Filaria sanguinis hominis* (found in the blood and urine of cases of chyluria) and from

[1] *Phil. Transactions*, 1857.

the embryo of the *Dracunculus* (Guinea-worm), by having a sharp head and a blunt tail, whereas the heads of the latter are round and the tails are sharp.

An instrument, termed a harpoon, was devised and employed some years ago in Germany, when such large numbers of people suffered from the disease, for diagnosing the presence of the parasites in the human muscles, and for noting their increase or diminution. It resembled a trocar with a minute forceps at the pointed extremity, which was plunged into the living muscle. The small pincers having been opened by the aid of some mechanism in the handle, a bit of the muscular tissue was seized and withdrawn. This minute portion of muscle was examined microscopically, and, if present, the number of trichinæ in the quantity were counted.

*The Fluke* (Distoma hepaticum = *the rot*) is a parasite[1] that is found in the livers of men and animals, especially the sheep. The carcase has a flabby, emaciated appearance, and the meat is of a greenish-yellow colour from bile staining. Mr. Vacher's memoranda respecting this disease are as follows:—"Due to presence in bile ducts of little animals provided with suckers, in shape like soles, and measuring from 1 to $1\frac{1}{2}$ inch long, and about $\frac{3}{8}$ inch wide. Sometimes so numerous as to block up bile ducts. Symptoms, jaundice and dropsy." Many regard sheep's liver, thus infested, as a dainty dish. The eating of garden snails, whelks, mussels, shell fish, etc., is considered as another mode by which men become affected with this disease, which occasions hæmaturia and dysentery. The rot is the name given to this disease as it occurs amongst sheep, thousands of which it kills annually. The Fluke.

Old farmers consider that the parasite flourishes on unsound marshy land especially in autumn, and that

[1] A good description of the transformations undergone by this parasite is to be found in Aitken's *Practice of Medicine*.

they are able to indicate the parts of large fields which give "liver rot" to their sheep.

Conclusions. *Conclusions.*—Salting does not kill cysticerci, although a high temperature and smoking are said to do so. In India such meat is allowed to be eaten if well cooked. Cooking, salting, and smoking simply lessen the danger, even if efficiently performed, and do not remove it.

Much meat that is eaten is very unwisely consumed in a raw state, and more frequently in a half-cooked condition.

Salting, like cooking, is generally performed in an irregular ever-changing manner, the brine sometimes being used so many times as to have become actively poisonous.

All meat which contains cysticerci, trichinæ, flukes, and all other animal parasites which are apt to infest man, should be condemned as unfit for human food.

In the reign of Henry III. butchers who sold measly pork were placed in the pillory.

## *Immature Veal and Lamb.*

Immature Veal and Lamb. In some places there is a chronic state of irritability maintained between the Health Authority and the butchers, as to whether "slink" meat is fit for food, and my opinion has been sought to settle the vexed question. In Halifax a bye-law has been passed condemning calves under 21 days old, or under 48 lbs. in weight. In dairy counties, where farmers are desirous of getting rid of calves as quickly as possible, they are killed when only 14 days old. Cows very readily slip their calves, and the flesh of such animals is always inferior, being innutritious and indigestible. These immature calves and lambs are sometimes healthy, and at others weakly and even unhealthy. The last-named furnish meat which is pale and soft.

The flesh of these prematurely-cast calves and lambs cannot be deemed unwholesome unless diseased or born of diseased cows or ewes, but constitutes meat of inferior quality, and as such should be sold. The Germans consider that healthy calves less than 8 to 10 days old furnish meat of diminished value.

### *Poisonous Pork, Ham, Sausages, etc.*

Frequently cases occur in which pork, in some form or other, has acted on those who have eaten it as an irritant poison. The remarkable outbreaks of choleraic diarrhœa at Welbeck in 1880, and at Nottingham in 1881, must be fresh in the recollection of medical officers of health. In the former more than 72 persons, and in the latter 15 persons suffered. There was an incubation period varying from 12 to 48 hours. The symptoms were the same in all—shivering, headache, thirst, giddiness, faintness, vomiting, cold sweats, diarrhœa, great prostration, etc. Violent enteritis and pneumonia were produced in both outbreaks. The same kind of bacillus was found in the blood of the fatal cases in each outbreak. They are rounded at their extremities, some containing spores.

Poisonous Pork, Ham, and Sausages.

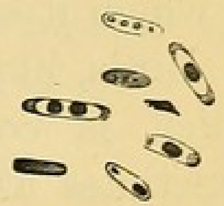


Fig. 81.
Isolated bacilli from artery of kidney, some of which contain spores × 700 diam. (Klein.)

Experiments by feeding and inoculating animals with the pork and with the cultivated bacilli produced fatal results by pneumonia and peritonitis.

The conclusion arrived at was, that either the bacillus itself, or some virus or ptomaine essentially associated with it, was the active agent in the production of these alarming epidemics.

# CHAPTER XLI

## INSPECTION AND EXAMINATION OF POULTRY, GAME, ETC.

As violent gastro-intestinal disturbances are often excited by the consumption of game in a very "high" condition, a Medical Officer of Health would be warranted in pronouncing any birds or hares exhibiting a state of putridity as injurious to health. Pheasants fed on the laurel have created illness when eaten. Poultry is not improved by "hanging," like game, and when it begins to emit a disagreeable odour is so stale, as to be approaching a state in which it should be condemned.

Birds, like mammals, are subject to a sort of variola which is contagious. Fowls, turkeys, and geese are sometimes affected by it. The presence of pustules on the body of the bird renders it for the time unsaleable.

Cholera and anthrax in poultry are diseases that are not known to render it injurious to the health of man when eaten, although there is a strong suspicion that obscure forms of illness may have been induced by the consumption of poultry thus affected. Turkeys, geese, ducks, and pigeons are all subject to cholera. Mr. Vacher writes respecting it: "Flesh redder than natural. Heart speckled with red or dark spots, often inside and out. Intestine inflamed, with red spots or livid patches."

Pheasants, pigeons, turkeys, and fowls are known to be attacked with so-called diphtheria. The Wiener

*Allgemeine Medicinische Zeitung* informs us that Prof. Gerhart of Würzburg has carried out a number of experiments which have led him to the conclusion that this disease may be communicated to man by these birds. An outbreak of diphtheria occurred in 1882-83 amongst the poultry at Nesselhausen, in Baden. Two-thirds of all the labouring persons employed about the fowl-raising establishment there became ill with ordinary diphtheria, and one man conveyed the infection to his three children. No other cases of diphtheria occurred during all this time in the town itself or in its neighbourhood. A similar outbreak has been observed amongst the inhabitants and poultry of Marseilles, which has been described by Dr. Nicati in the *Revue d'Hygiène et de Police Sanitaire,* No. 3, March 1879. MM. Delthill and Bouchard at the recent Nancy Congress expressed their belief from observation in the existence of a connection between diphtheria in children and a disease amongst fowls and pigeons known as the "pip" or "croup."

It is often necessary to have rabbits confiscated, as they are frequently offered for sale in a putrid state.

# CHAPTER XLII

## INSPECTION AND EXAMINATION OF FISH

ALTHOUGH the quantity that is annually condemned throughout this country is very great, an immense amount of unwholesome fish is consumed by the poor, and creates diarrhœa, nettle rash, and other affections. Mackerel cannot be eaten in too fresh a state; whilst whiting is improved by hanging for a short time, when the weather is not hot, if dusted with salt.

When fish has changed colour, and has an offensive or ammoniacal odour, it should be seized as unfit for human food.

A bright red colour of the gills cannot be relied on as a sign of freshness, for they are often tinted by the salesman. The diminution in the brilliancy of the colours of a fish, and the extent of drooping of its tail when it is held in the hand, are the best signs of staleness.

Some fish in the tropics are always poisonous, whilst others are poisonous to some, but not to all persons, and others are at times only injurious. Pilchards, mussels,[1] eels,[2] crabs,[3] lobsters, oysters, mackerel,[4] turtle, and sardines,[5] have at times produced very unpleasant, or dan-

[1] *Medical Times and Gazette*, November 1, 1862, April 30, 1864, and Guy's Hospital Reports, October 1850, and *Lancet*, March 7, 1846, and May 5, 1866.

[2] *Lancet*, June 21, 1873. [3] *Lancet*, October 27, 1866.

[4] *Lancet*, July 30, 1864. [5] *Medical Times and Gazette*, December 13, 1862.

gerous, and even fatal results. Most commonly dyspepsia, swelling of the tongue and fauces, itching of the eyes and eyelids, an eruption resembling nettle rash, with great irritation, are the symptoms complained of. Less frequently numbness of limbs, feeble action of heart and coma, and, in rare cases, death has resulted. The nature of the animal poison contained in these fish is unknown. It is, in some cases, thought to be due to some particular food in which the fish has indulged, and in others to be developed only during the breeding time. There is some suspicion that shrimps, cockles, and oysters, when affected with some parasitic fungus, may acquire properties poisonous to man, and create choleraic symptoms amongst those who eat them.[1] Stale, decomposing fish are often plunged into brine, which is supposed to stop the putrefactive process. Such salted fish has often produced illness. An outbreak occurred in 1878 in St. Petersburg, attacking more than 100 persons, which resulted from the consumption of salt codfish. This fish was found, on subsequent examination, to present a yellow hue, the flesh being friable and a little mouldy. The muscular fibres were shown by the microscope to be in a state of decay. The poisonous symptoms produced by some salted and smoked fish have been ascribed to a ptomaine secreted by a microbe.

Symptoms when poisonous.

Mr. Vacher considers that salmon affected severely with the fungus disease known as "the salmon disease" should be seized if exposed for sale.

[1] Report on East Kent for 1884, by Dr. Robinson.

# CHAPTER XLIII

## MEAT OF POISONED ANIMALS

Intentional or accidental poisoning.

ANIMALS are often injured or destroyed by animal or vegetable poisons. The meat of animals may be rendered unwholesome or poisonous by the food eaten, or by poisons administered intentionally or taken accidentally. Cattle and horses, poultry and game are sometimes destroyed by arsenic. Dr. Ashby records the case of the poisoning of beasts by water accidentally impregnated by arsenious acid, which had entered the earth at a spot fifty yards away from the well.

Cattle and horses are injured or destroyed by eating yew leaves, bryony, meadow saffron, etc. The stomachs and alimentary canals of animals thus destroyed will be found the seat of more or less inflammation. Fragments of the vegetable substance may also be discovered. Farmers often seek the advice of the health officer on these cases, according to my experience.

The flesh of game is apt to be rendered unwholesome by the food eaten. The flesh of hares fed on the rhododendron, chrysanthemum, and after coursing[1] (when they have a resinous taste and odour, and have been considered to be in a state of uræmia), has been found to exert poisonous effects.

[1] *Lancet*, September 27, 1862, and *British Medical Journal*, November 30, 1878, p. 817.

Pheasants fed on the laurel have created illness when eaten. A case is recorded where the flesh of a turkey proved poisonous,[1] and no poison could be found on analysis.

Fish are sometimes destroyed by cocculus indicus, but more frequently by lime, both being thrown into ponds and streams where they abound.

[1] *Medical Times and Gazette*, March 18, 1871.

## CHAPTER XLIV

### DESTRUCTION OF CONDEMNED FLESH

THE question often arises as to how flesh, which is considered to be unfit for human food, should be disposed of.

If it is handed over to the knacker to be sold as food for cats, there is a risk lest the meat should ultimately find its way to the butchers' stalls of the low parts of our cities and towns, and be sold to the poor. If the meat is not unsuitable for dogs, it may, with greater safety, although with some risk in the case of some diseases, be sold as food for packs of hounds.

If meat is buried, there is a danger lest it may partly be brought to light by dogs.

If it is buried too deep to allow of such interference, the meat is still liable to get into the market by the aid of a resurrectionist.

Resurrection of diseased meat.

Cases of the resurrection of diseased pigs are recorded in the *Sanitary Record* of February 16, 1877, page 105, and February 5, 1876, page 96. Remembering that every part of an animal, even to its bones and hoofs, whether diseased or not, possesses a distinct money value, the disinterment during dark nights of such bodies is not to be wondered at.

Perhaps the best mode of preventing the sale of condemned meat as human food is to impregnate it with some substance that will render it unsaleable.

In the city of London, where vast quantities, as much sometimes as 35 tons (=100 oxen), of putrid and diseased meat, dressed for sale, are seized in one day, the meat is plunged into a bath of the following composition, preparatory to its conveyance in carts to Deptford, where, by the help of machinery, it is separated into meat, fibre, fat, and bone, and subsequently utilized in trade:—

*Dr. Sedgwick Saunders' Chemical Bath.*

| | |
|---|---|
| Chloride of calcium . . . . | 2 cwts. |
| Chloride of sodium . . . . | ½ cwt. |
| Sulphate of iron (green copperas) . . | 1 cwt. |
| Carbazotic or picric acid . . . | 2 lbs. |
| Water . . . . . . . | 300 gals. |

The chlorides deodorize putrid and stinking meat, whilst the picric acid and sulphate of iron discolour it, and render it so disgusting to the taste, as to remove all fear of its appropriation for human food.[1] If the meat is covered with the fluid, it can thus be kept free from smell for several weeks.

In country districts, where seizures of meat are few and far between, condemned meat may be most conveniently rendered unsaleable by making deep incisions into the flesh, and pouring therein *impure* carbolic acid, which possesses a disgusting odour. Creosote and oil of turpentine have also been used.

Instruments have been invented for introducing such fluids readily into various parts of a carcase. Defays made a tube with a lancet point, provided with a flask containing the fluid; and Köpp recommended a spatula with sharp edges, grooved on the surface, which is dipped into the fluid each time that it is plunged into the flesh.

[1] Report upon various Methods of dealing with Meat seized as unfit for human food in the City of London," by Dr. Sedgwick Saunders.

# CHAPTER XLV

## INSPECTION AND EXAMINATION OF FRUIT AND VEGETABLES

VEGETABLES, like animals, seem to possess wonderful powers of discrimination between the poisonous and non-poisonous in their food. It is wise to avoid water-cress which has been grown in effluent water below the standard of purity, and also strawberries, early cauliflowers, etc., which have been recently "top-dressed" with manure, if we have an opportunity of choice. Asparagus—a vegetable that rapidly confers when eaten a characteristic odour on the urine—has been found, when raised in certain localities, to produce colic and diarrhœa-symptoms which have been attributed to the presence of minute amounts of sulphide of carbon in the soil.

Half-decomposed fruit and vegetables are deleterious to health, exciting diarrhœa. Unripe fruit, especially plums, are exceedingly hurtful to young children. In times of cholera or epidemic diarrhœa, the exposure of such for sale would justify seizure.

Every now and then the opinion of the Medical Officer of Health is sought by the Nuisance Inspectors, as to whether quantities of fruit and vegetables are or are not injurious to health. Simply damaged and stale fruit and vegetables cannot, of course, be so regarded; but all decomposing and offensive vegetable matter should be condemned.

The poor are the chief consumers of this unwholesome food. With vast numbers fresh fruit and vegetables are impossible luxuries. I cannot but think that an immense profit is to be made by any enterprising company that would undertake to supply the wants of the poor of a great city with fresh vegetables, at prices within their reach; for the present arrangement, whereby the poor are supplied with stale vegetables, is attended with such an enormous waste of these important necessaries of healthy human life.

# CHAPTER XLVI

## TINNED PROVISIONS

Preserved Australian meats, and American tinned fish, fruits, and vegetables, etc., are apt to become impregnated with small quantities of lead from the solder and tin which frequently contains as impurities arsenic and antimony. The vegetable and other acids associated with these provisions have a corrosive effect, which is increased by the galvanic action set up between the metals. Copper, which is used to impart a brilliant green colour to peas and French beans, is often to be detected. It is reported that the importation of these foods from abroad has led to the production of inferior imitations manufactured out of damaged food in the East End of London. A great deal of imperfectly-preserved food of this kind has been employed in the neighbourhood of the metropolis for the feeding of pigs, where collections of this decomposing material have proved a nuisance.

# CHAPTER XLVII

## INSPECTION AND EXAMINATION OF CORN

CORN is generally understood to comprehend the grains of wheat, barley, and oats, to the exclusion of those of rye, maize, etc.

The differences between the appearance of different kinds and samples of wheat and barley, as indications of varying degrees of quality, can be better learnt from any farmer than from a description; whilst almost every medical man necessarily acquires practical experience in diagnosing good oats.

Grains of corn are sometimes damaged and rendered of little value by a "growing out." When such corn is ground the flour is known in trade as "weak." Such flour cannot strictly be said to be injurious to health, except as taking the place of an equal quantity of more nutritious material.

Grains of corn should be free from smell, sprouting, discoloration, and any evidence of insects or fungi.

The insects sometimes found in corn, and in meal of different kinds, are the weevil and the *Acarus farinæ*, the former visible to the naked eye, and the latter by the aid of a pocket lens or microscope. If grains are seen to be pierced with minute holes, and are found to have been deprived of their contents, the weevil is the culprit.

The weevil.

FIG. 82.
Calandra granaria or Weevil.

"Ear-cockle."

"Earcockle," "Purples," or "Peppercorn," are names applied to a blighted condition of ears of corn, in which the grains become green and afterwards black. The grains are filled with a cotton-like substance in place of flour, which, when moistened, is seen to be composed of animalcules in a state of great activity (*Vibrio tritici*).

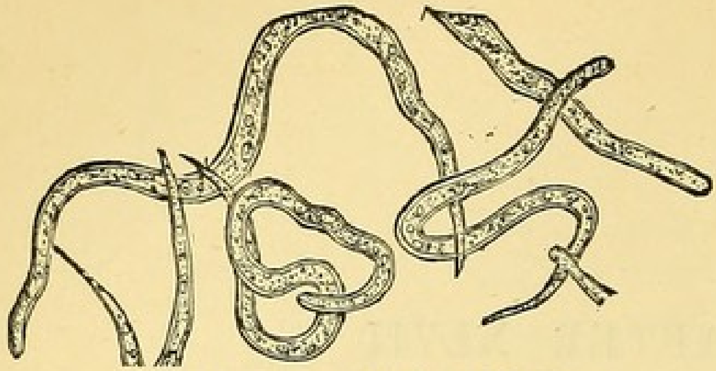


Fig. 83.—Vibrio tritici, × 100 diam.

The wheat midge.

The wheat midge (*Cecidomyia tritici*) is a great enemy of the farmer, who sometimes sees, early in June, myriads of these little flies hovering about the wheat for the purpose of depositing its eggs within the blossoms. The caterpillars that are produced from these eggs interfere with the development of the ovary, so that abortive grains are alone found. Small birds happily prey on the midge, and thus lessen the mischief.

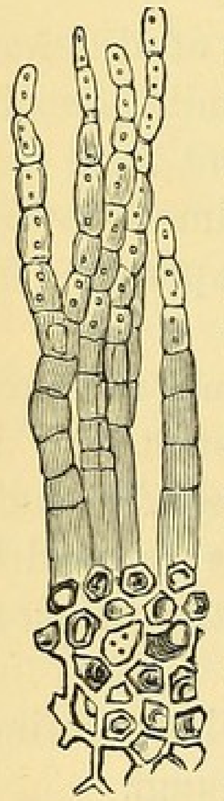


Fig. 84. Oidium abortifaciens or Ergot. (After Hassall.)

Certain vegetable parasites also deteriorate corn in value, and sometimes render it poisonous.

Ergot.

*Ergot* (*Oidium abortifaciens*) is a fungus which shows a decided preference for rye, but also attacks the ears of wheat.

In countries where rye bread is eaten to a large extent, a peculiar disease, named ergotism, has prevailed epidemically. This disorder has been noticed in two distinct forms—the one a nervous disease, characterized by spasmodic convulsions; and the other, which is known in France as gangrenous ergotism, and in Germany as the creeping sickness. The symptoms of each form are well described in Christison's work on *Poisons*.

There are two chemical tests for ergot—the first by Laneau, and the second by Wittstein.

Make a paste of the flour with a weak alkali; add dilute nitric acid to slight excess, and then neutralize with an alkali, when a violet red colour is produced if ergot be present, which becomes rosy red when more nitric acid is added, and violet when an alkali is introduced.

The second test for ergot is to add liquor potassæ to the flour, which develops a herring-like smell if it contains ergot.

*Smut* or *Dust Brand* (*Ustilago segetum*) is a fungus that exhibits a partiality for barley and oats. "Smut."

Fig. 85.—Ustilago segetum, × 420 diam.

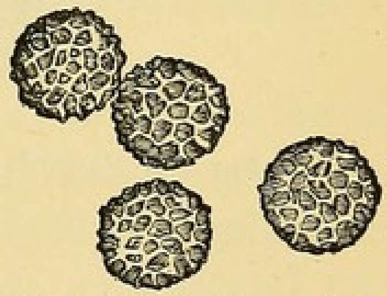


Fig. 86.—Tilletia caries, × 420 diam.

*Bunt* or *Pepper Brand* (*Tilletia caries*) is a fungus only met with in wheat grains. It is developed at the expense of the seeds in the form of spores resembling a fine dust. The spores are about ·0007 of an inch in diameter. As its name indicates, it possesses a disgusting smell, whilst the powder of "Smut" is inodorous. It is questionable whether or not the consumption of flour containing this fungus is deleterious to health. It is chiefly employed in the manufacture of gingerbread. Bunt or Brand.

Rust. *Rust* (*Puccinia graminis*).—This fungus infests the chaff, stem, and leaf. In its young state it was formerly know under the name of *Uredo rubigo* and *linearis*.

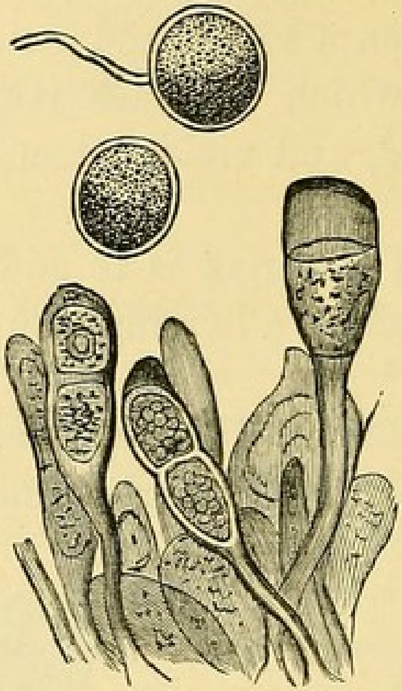


FIG. 87.—Puccinia graminis, × 500. (After Hassall.)

## CHAPTER XLVIII

### INSPECTION AND EXAMINATION OF FLOUR

In the inspection of flour we should note the colour, smell, taste, and feel, for we may then receive a valuable hint as to its wholesomeness or quality. Weevils (*Calandra granaria*, vide fig. 82) are often found by this rough scrutiny. Physical characters.

The examination of flour that devolves on the Medical Officer of Health is of two kinds: chemical, to determine its quality and the presence of injurious admixtures; and microscopic, to discover adulterants and animal parasites, which are often found in damaged flour. Chemical and microscopic.

The adulteration of wheaten flour with that of cereals of less nutritive value, or with vegetables that are deficient in nitrogenous principles, may be considered by some as one of fraud, which does not concern a guardian of the public health.

The weakening of the strength of the "staff of life," on which the poor man has principally to lean for the support of himself and family, is an undoubted injury of very serious import. The substitution of fat-forming for flesh-producing principles into the staple article of diet cannot but be regarded as a wrong that is calculated to diminish the working powers of labourers of all classes.

The regulations for the government of King Henry VIII.'s household ordain that "his highness' baker shall not put alum in the bread, or mix rye, oaten, or bean flour with the same, and, if detected, he shall be put in the stocks." The use of alum in bread-making was punishable in the reign of George IV. by a fine of £20 or twelve months imprisonment.

The nutritive value of the different farinaceous articles of food, especially of those with which flour is apt to be adulterated, is well seen in Dr. Letheby's Table of Analyses, an abridgment of which may be usefully inserted for reference.

Nutritive Values of the principal Farinaceous Foods.

NUTRITIVE VALUES IN ONE HUNDRED PARTS.

| | Water. | Albumin, etc. | Starch, etc. | Sugar. | Fat. | Salts. | Total per cent. Nitrogenous. | Total per cent. Carbonaceous as Starch. |
|---|---|---|---|---|---|---|---|---|
| Bread . . . . . | 37 | 8·1 | 47·4 | 3·6 | 1·6 | 2·3 | 8·1 | 55·00 |
| Wheat flour . . . | 15 | 10·8 | 66·3 | 4·2 | 2·0 | 1·7 | 10·8 | 75·50 |
| Barley meal . . . | 1 | 6·3 | 69·4 | 4·9 | 2·4 | 2·0 | 6·3 | 80·30 |
| Oatmeal . . . . | 15 | 12·6 | 58·4 | 5·4 | 5·6 | 3·0 | 12·6 | 77·80 |
| Rye meal . . . . | 15 | 8·0 | 69·5 | 3·7 | 2·0 | 1·8 | 8·0 | 78·20 |
| Indian meal . . . | 14 | 11·1 | 64·7 | 0·4 | 8·1 | 1·7 | 11·1 | 85·35 |
| Rice . . . . . . | 13 | 6·3 | 79·1 | 0·4 | 0·7 | 0·5 | 6·3 | 81·25 |
| Peas . . . . . . | 15 | 23·0 | 55·4 | 2·0 | 2·1 | 2·5 | 23·0 | 62·65 |
| Arrowroot . . . | 18 | ... | 82·0 | ... | ... | ... | ... | 82·00 |
| Potatoes . . . . | 75 | 2·1 | 18·8 | 3·2 | 0·2 | 0·7 | 2·1 | 22·50 |
| Carrots . . . . | 83 | 1·3 | 8·4 | 6·1 | 0·2 | 1·0 | 1·3 | 15·00 |
| Parsnips . . . . | 82 | 1·1 | 9·6 | 5·8 | 0·5 | 1·0 | 1·1 | 16·65 |
| Turnips . . . . | 91 | 1·2 | 5·1 | 2·1 | ... | 0·6 | 1·2 | 7·20 |

If wheaten flour is made by grinding together the whole of the grain, it contains more flesh-forming material than any other of the cereals, sometimes reaching to 22 per cent. The finer the flour the less of nitrogenous matters, of fat and of mineral matters, and the more of starch. The most nutritious portions of the grain are the outer or coarser which, containing a larger proportion of cellular fibre and woody matter, are less easily digested by persons of weakly constitution. Bread and puddings made of whole meal flour are highly nourishing, if they can be easily digested, and do not exert a too great laxative influence on the intestines through the mechanical irritation of the small portions of husk or bran.

The most distinguished dentists of the day tell us that one great cause of the caries of teeth is the substitution of the fine and delicately prepared for the coarser and rougher foods that belonged to a former and less civilized state of society. Whole meal bread, potatoes undeprived of their skins, etc., etc., are suggested as preferable. Whether or not such coarse foods act beneficially on the teeth in a mechanical manner by scouring them, and so preventing accumulations of food and tartar, does not transpire. Caries of teeth.

### *Chemical Examination.*

The unsoundness of flour is shown by the amount of water, ash, sugar, dextrine, gum, and gluten, etc.

Wanklyn's analysis of fine wheaten flour is as follows:—

| | |
|---|---|
| Water | 16·5 |
| Ash | 0·74 |
| Fat | 1·2 |
| Sugar, Gum, and Dextrine | 3·3 |
| Albuminous matters (Gluten, etc.) | 12·0 |
| Starch | 66·3 |
| | 100·0 |

*Water.*—Place a little flour in a small platinum dish (such as is employed for obtaining milk residues) of known weight, and weigh it. Place the dish thus charged over a hot water bath for one hour and a half to drive off moisture. Weigh and then replace the dish on the bath, and after the interval of half an hour Amount of moisture.

again weigh. The object of weighing twice is to be sure that all water is expelled. For example :—

| | |
|---|---|
| Sample of flour and dish . . . | 9·959 |
| Platinum dish . . . . | 7·978 |
| Weight of flour . . . . | 1·981 |

*After Exposure on Hot Water Bath.*

| | 1st Weighing. | | 2d Weighing. |
|---|---|---|---|
| Flour and dish . . | 9·680 | . | 9·650 |
| Dish . . . | 7·978 | . | 7·978 |
| | 1·702 | . | 1·672 |

To obtain percentage—

| Weight of flour taken. | | Weight of flour after expulsion of moisture. | | |
|---|---|---|---|---|
| 1·981 | : | 1·672 | : : | 100 |

$$\begin{array}{r} 100 \\ \hline 1·981)167·200(84·4 \end{array}$$

$$100 - 84·4 = 15·6 \text{ per cent.}$$

Good flour contains on an average from about 10 to 16 per cent of moisture. The more water that is present the greater the liability to change, and the less nutriment in a given weight. Prof. Parkes counselled that flour containing over 18 per cent of water should be rejected.

Weight of ash.

*Ash.*—Burn the dried contents of the dish by applying the flame of a Bunsen's burner. The coke formed requires to be stirred with a piece of thick platinum wire. It is at length reduced to an ash, which should be weighed. For example :—

| | |
|---|---|
| Weight of ash and dish . | 8·035 |
| ,, dish . . | 7·978 |
| Weight of ash . | ·057 |

| Weight of flour taken. | | Weight of ash. | | |
|---|---|---|---|---|
| 1·981 | : | ·057 | : : | 100 |
| | | 100 | | |

$$1{\cdot}981)5{\cdot}700(2{\cdot}87$$

Ash 2·87 per cent.

The average weight of ash is ·7 to ·8 per cent. Dr. James Bell asserts that it varies from ·35 to ·86 per cent. If a sample of wheaten flour yields more than 1 per cent there is something wrong about it, and the presence of a mineral is suspected. The inorganic substances with which flour is most commonly adulterated are carbonate of lime or magnesia, sulphate of lime, silicate of magnesia, bone dust, etc. If the ash exceeds 2 per cent, add hydrochloric acid. If distinct effervescence is produced, chalk has been probably added.

To detect mineral substances shake a known quantity of flour with chloroform in a burette. The flour floats and inorganic bodies subside, which may be drawn off by the tap, dried by a gentle heat, and weighed. The ash of flour consisting of ground leguminous seeds is heavier than that of wheat-flour, and is strongly alkaline.

The ash of flour is composed mainly of the three phosphates of potash, magnesia, and lime.

The ash of pure oatmeal does not exceed 2·36 per cent.

Alum is sometimes purposely mixed with flour before Alum. it is made into bread. It may be detected by the logwood test (*vide* page 517), but if the characteristic colour reaction is not obtained with this test, Mr. W. C. Young advises[1] that the flour should be made into a paste with boiling water before applying the ammoniacal logwood tincture, when, if alum is present, a bluish-gray colour is developed permanent for a week. An approximative

[1] *Analyst*, January 1879.

estimate of the quantity of alum may be determined, by making comparative experiments as to the depth of the bluish colour with pure flour, made into an emulsion, to which different known quantities of a standard solution of alum in water (1 gramme to the litre) have been added.

Sugar, Dextrine, and Gum.

*Sugar, Dextrine, and Gum.*—Weigh out 100 grammes of flour, and, having placed it in a large porcelain evaporating dish, introduce some water, and mix the water and flour thoroughly together with the fingers, so as to ensure the complete admixture of every particle of the flour with the water. This semifluid mixture is poured into a half-litre flask, and water is added until the mark is reached denoting that quantity. The contents of the flask are filtered. After rejecting the first portions of the filtrate, 50 c. c. of the filtrate are collected and evaporated to dryness in a platinum dish of known weight on a water bath.

| | |
|---|---|
| Weight of dish and substance after evaporation | 26·875 |
| ,, dish . . . . | 26·210 |
| | ·665 |

As a tenth (50 c. c.) of the 500 c. c. (half-litre) which contained the 100 grammes of flour was taken, it is necessary to multiply by 10 to obtain the percentage: $\cdot 665 \times 10 = 6 \cdot 65$ per cent.

A cold aqueous extract should not exceed 4·7 per cent.

*The Albuminous principles* are divided into those which are soluble and those which are insoluble in cold water. The former, which include vegetable albumen, are calculated in the last-described estimate of the cold water extract. The latter are known under the name

Gluten.

of gluten, a mixture, according to Ritthausen, of gliadin, gluten-casein, gluten-fibrin, and mucedin.

Place 100 grammes or 100 grains in a Berlin evaporating dish, and mix it thoroughly with a little water, so as to make a dough. Add water to it, meantime kneading it well with the fingers. Pour off the water and add fresh. This addition and removal of water is carried on until the water ceases to be milky in appearance, when, all starch having been thus removed, only a tenacious mass of gluten remains, which is to be dried on the water bath and weighed.

Good flour contains from 8 to 12 per cent of gluten. Prof. Parkes says that flour should be rejected in which it falls below 8 per cent.

Metallic poisons.

Accidental and intentional admixtures of arsenic with flour sometimes, but rarely, occur. I have only encountered one case although I have been in the profession nearly thirty years.

A remarkable case of an outbreak of lead poisoning, in which between fifteen and twenty persons were simultaneously affected, has recently been published by Dr. Alford.[1] It was traced to the admixture of lead with the flour in the process of grinding the corn. The millstone being of a very loose nature, large spaces existed in it, which had been filled up by pouring into them quantities of molten lead. There were ten pounds of lead upon the surface of the millstone, and the cavities were all filled with the same metal. The tests described in the foregoing pages are sufficient to identify either of these poisons as they occur in flour.

### *Microscopic Examination.*

The flour of diseased corn is often seen to contain the spores of fungi (*vide* page 490).

The most common animal found in flour that has been

[1] *Sanitary Record*, May 25, 1877, p. 321.

kept in a damp place, or been otherwise damaged, is the *Acarus farinæ* which multiplies with great rapidity.

The Acarus Farinæ.

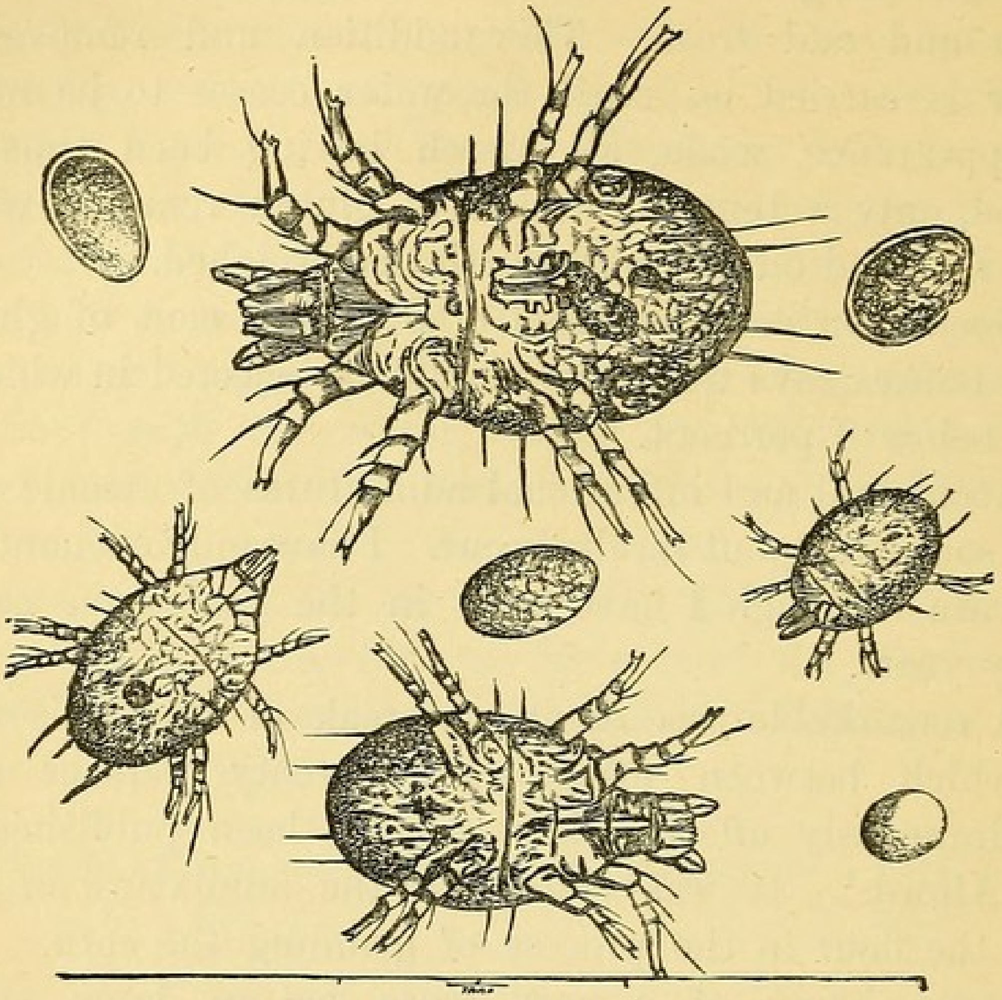


FIG 88.—Acarus Farinæ, × 85 diam. (After Parkes.)

Wheat Starch

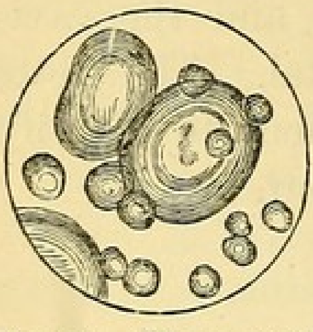


FIG. 89. Wheat starch × 420 diam. (After Cameron.)

Barley-meal, beans, potato, maize, oat, rye, and rice are the most common adulterants of wheat flour, which may all be detected by the microscope.

Barley Starch.

1. *Barley.*—The starch granules of barley so closely resemble those of wheat that they cannot readily be distinguished from one another. Barley starch consists rather of small and large grains, with very few of an intermediate size; whereas this peculiarity does not exist in the case of wheat starch.

When mingled together, as in the adulteration of wheat with barley, it is thus almost impossible to distinguish the two starches. As the finest flour con-

Testa of Wheat.

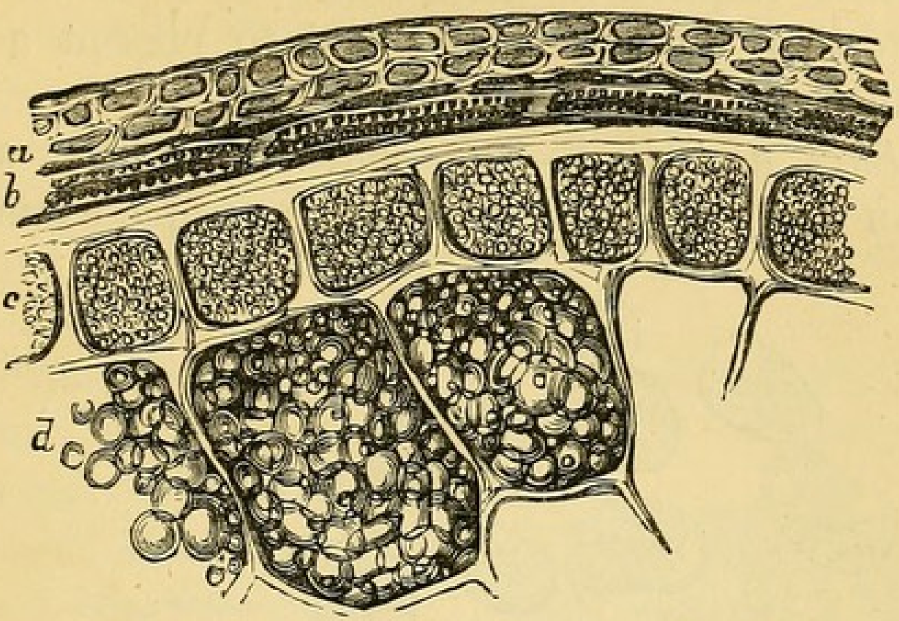



FIG. 90.—Testa of Wheat, × 200. (After Hassall.)

*Transverse Section of Testa of Wheat Grain.—d.* Cells of substance of grain containing starch granules. The testa consists of 3 coats, 2 longitudinal and 1 transverse.

*Longitudinal Coat—Outer Layer.*—Margins of cells, distinctly beaded.

*Transverse Coat.*—Margins of cells, beaded, but to a less extent.

*Longitudinal Cells of Surface of Grain*=*c.* consists of only 1 layer.

tains portions of the investing membranes of the grain, the presence of barley meal is diagnosed by an examina-

Testa of Barley.

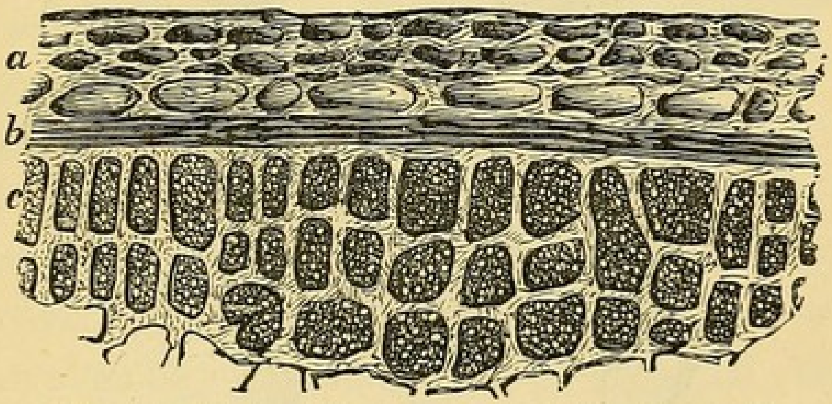



FIG. 91.—Testa of Barley, × 200. (After Hassall.)

*Transverse Section of Testa of Barley Grain.*—The cells of substance of grain containing starch granules are not here depicted. The testa consists of 4 coats, 3 longitudinal and 1 transverse.

*Longitudinal Coat—Outer Layer.*—Margins of cells not beaded, but slightly waved.

*Transverse Coat.*—Margins of cells not beaded or waved.

*Longitudinal Cells of Surface of Grain*=*c.* consists of 3 layers.

tion of portions of the testa, which should be sought for.

The cells of the substance of the grain of barley are seen when emptied of starch to be of more delicate structure than those of wheat, and to present a fibrous appearance.

Bean Starch. 2. *Bean and Pea.*—The addition of bean and pea meal can easily be detected by a microscopic examination.

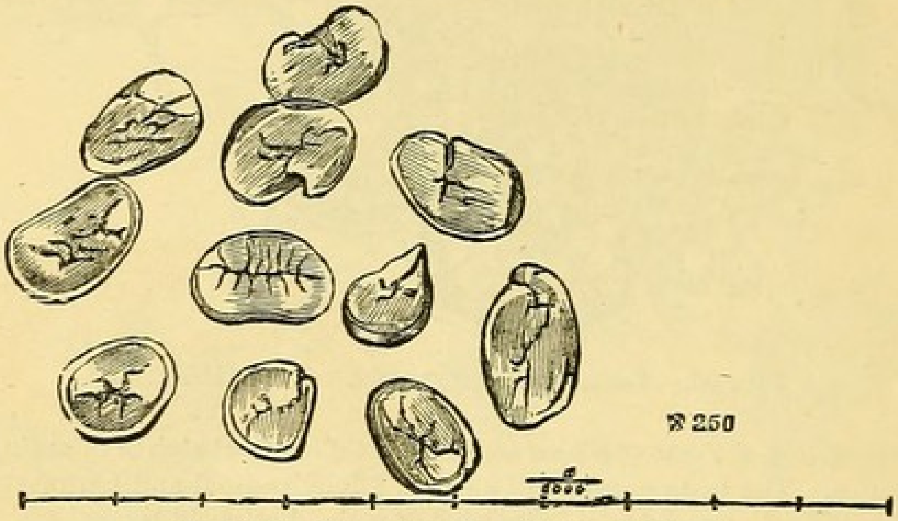


FIG. 92.—Bean Starch. (After Parkes.)

If a little boiling water be thrown on flour thus

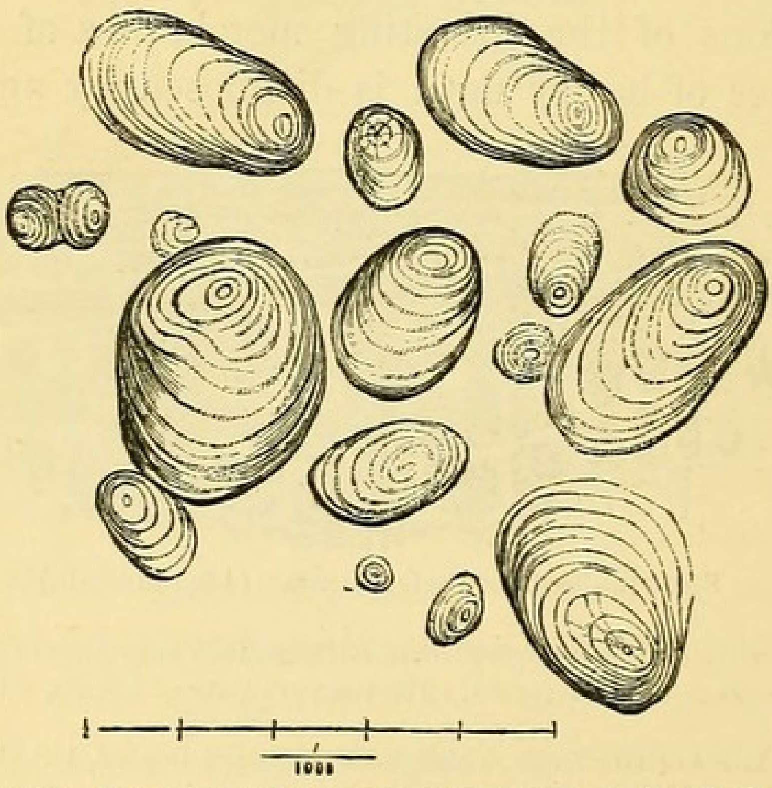


FIG. 93.—Potato Starch not polarized, × 285. (After Parkes.)

adulterated, the characteristic smell of beans and peas is evolved.

Donne's test consists in pouring successively a little nitric acid and ammonia on the flour. If it is not adulterated with beans, no marked reaction is apparent; but if bean meal is present a deep red colour is observed. Lassaigne suggests the addition of a solution of an iron salt, which gives to pure flour a pale straw colour, but to a mixture of beans and flour shades ranging from orange to dark green.

3. *Potatoes.*—If potato starch is found in flour, the admixture is as much a fraud as the dilution of milk with water. The pyriform appearance and eccentric hilum are characteristics of this starch. It is well to add a drop of weak liq. potassæ, when examining flour under the microscope, for this re-agent swells up potato starch granules enormously, and has very little effect on those of wheat starch. Chevallier's method is a good one, and is thus described by Mr. Wynter Blyth:[1] "Equal weights of flour and sand are to be triturated with water until a homogenous paste is formed, which is then diluted and filtered; to the filtrate is added a freshly-prepared solution of iodine, made by digesting for about 10 minutes 3 grammes of iodine in 60 c. c. of water, and then decanting. If the flour is pure, this addition will give a pink colour, gradually disappearing; whilst if potato starch should be present, the colour is of a dark purple, only disappearing gradually. By comparing the reaction with flour known to be pure, this difference of behaviour is readily appreciated."

Potato Starch.

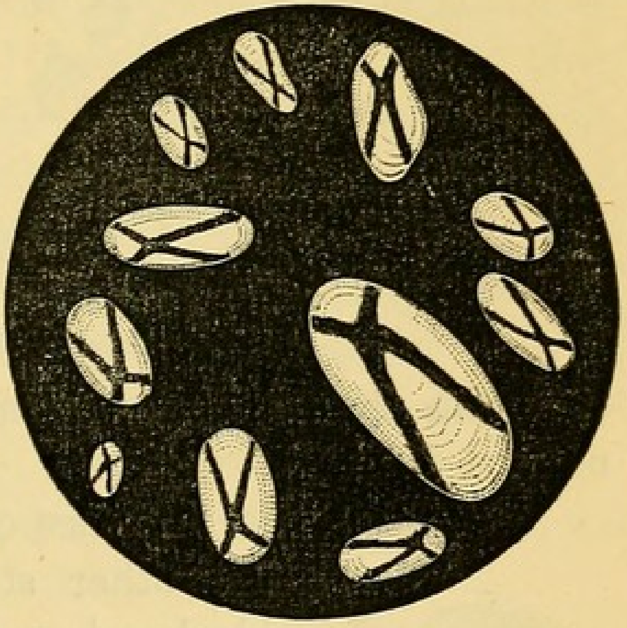


Fig. 94.—Potato Starch polarized, ×200.

[1] *Foods—Composition and Analysis.*

Maize Starch.

4. *Maize.*—The starch granules on the outer part of

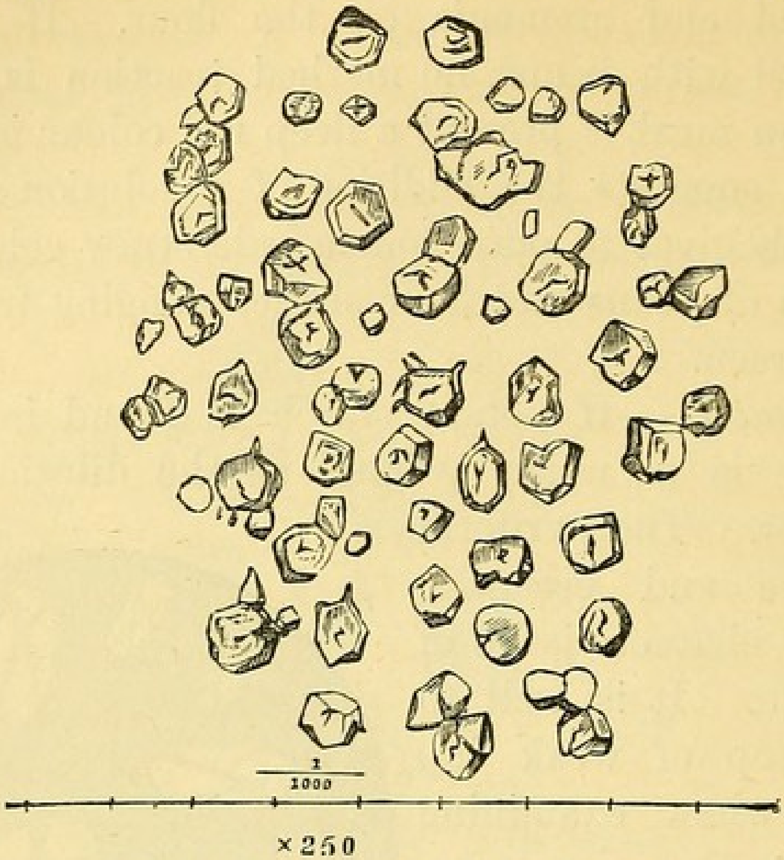



FIG. 95.—Maize Starch. (After Parkes.)

the grain are of hexagonal, and in the centre of a spherical or oval form.

Oat Starch.

5. *Oats.*—The granules of oat starch, unlike those of the other starches, do not exhibit the black characteristic crosses under the influence of polarized light. As oats is a very highly nitrogenous material, the admixture of a little oatmeal, with other farinaceous foods, cannot be objected to on sanitary grounds.

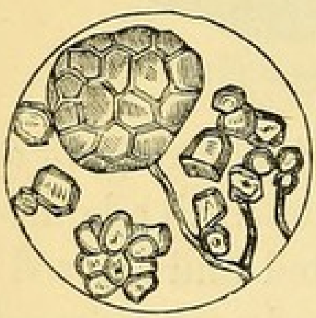


FIG. 96.—Oat Starch, × 420. (After Cameron.)

*Oatmeal* contains more fatty matters than wheaten flour. Where, as in Scotland, oatmeal, to a very large extent, takes the place of wheaten flour, the toning down or weakening of oatmeal with the less nutritive barley meal, is a practice which is much to be objected to.[1] The microscope shows the presence of

Adulteration of oatmeal.

[1] Conviction for adulterating oatmeal with from 25 per cent to 35 per cent of barley meal.—*Sanitary Record*, January 20, 1877, p. 42.

starch granules, which may be either wheat or barley. As wheat is not employed as an adulterant, the granules will almost certainly be those of barley.[1] It is asserted that retail dealers mix barley meal with the somewhat buff-coloured oatmeal, to impart a white and cleaner hue. The presence of about 1 per cent of barley in oatmeal may be charitably looked upon as accidental, but as much as 5 per cent must be regarded as a fraud.

As a mode of estimating the percentage of barley in oatmeal that is adulterated with it, Dr. Muter suggests the measurement of the starch granules by the aid of a $\frac{4}{10}$ inch objective, and a "B" micrometer eyepiece. Oat granules measure ·00037 inch. Barley granules measure ·00073 inch, and a few of them four times this size, namely ·00292 inch. He writes:[2] "The best criterion to go on for the estimation of the percentage is the number of granules measuring ·00292 inch, which are found in barley to bear a very constant relation to the ·00073 inch granules."

6. *Rye.*—The peculiar rayed hilum of rye starch serves to distinguish it from any other. Rye Starch.

FIG. 97.—Rye Starch, × 420. (After Cameron.)

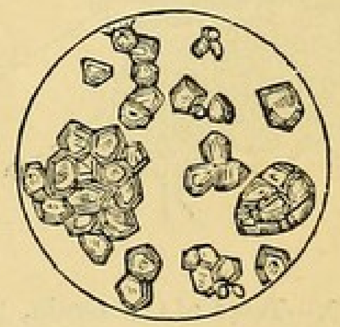


FIG. 98.—Rice Starch, × 420. (After Cameron.)

7. *Rice.*—Rice meal is sometimes adulterated with lime, which can easily be detected with hydrochloric acid. A large quantity was seized in Liverpool in 1879 which Rice Starch.

[1] English barley is of course dearer, but foreign barley is cheaper, than oats.

[2] *Analyst*, January 31, 1877, p. 190.

contained from 40 to 50 per cent of powdered marble. Inferior rice is sometimes fraudulently mixed with wheaten flour to render bread whiter and heavier, for rice retains much moisture.

Darnel Grass.

*Lolium temulentum*, or *Darnel Grass.*—The seeds of this grass are apt to become accidentally or fraudulently mixed and ground with the grains of wheat. As the seed contains a poison of the acro-narcotic class, it is necessary to be able to diagnose the dangerous admixture. Giddiness, tremor, convulsions, and vomiting are the symptoms commonly produced by eating bread containing the flour of darnel grass. Many accidents from consuming flour thus poisoned are recorded.[1] In the well-known case of poisoning at the Cologne prison, in which sixty persons were affected, one and a half drachms of darnel were found in every six ounces of the flour. The starch granules of the darnel closely resemble those of oats, but the difference in the appearance of the testa of the two grains is very striking.

Testa of Oat Grain.

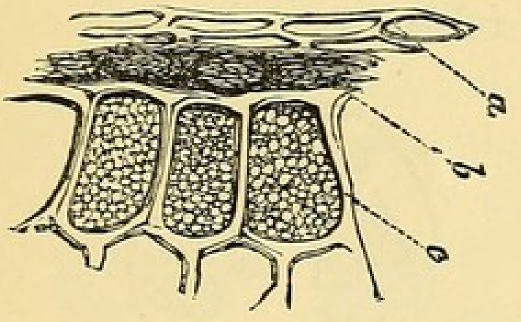



FIG. 99.—Testa of Oat Grain, × 200 diam. *a*, outer ; *b*, middle ; *c*, inner coats. (After Hassall.)

Testa of Darnel Grain.

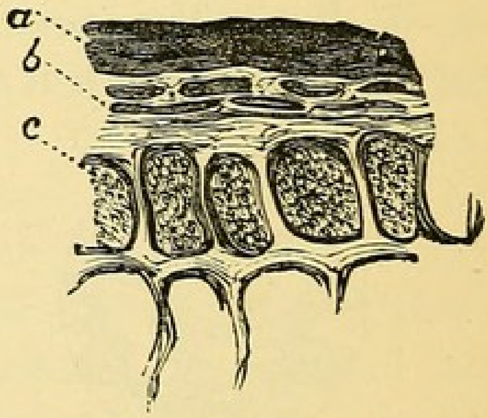



FIG. 100.—Testa of *Lolium temulentum* (Darnel) Grain, × 200. (After Hassall.)

Pure flour, when mixed with alcohol, forms a straw-coloured solution, which possesses an agreeable taste. Flour which contains darnel is said to give a greenish solution, with a disagreeable repulsive taste, and on

[1] *London Medical and Physiological Journal*, xxviii. 182 ; Buchner's *Toxikologie*, 174 ; *Annalen der Pharmacie*, xvi. 318.

evaporation a resinous yellow-green extract is left (Parkes).

If some difficulty is experienced in forming an opinion, the physiological test of administering a small quantity to a dog, and noticing the effect, is admissible. Some rare cases of poisoning have occurred from the mixture with flour of vetches named *Lathyrus sativus*, and *cicera*, and of the pollen of the male catkin of the hazel.

If, whilst inspecting a specimen of flour with the microscope, particles possessing a resemblance to fragments of bone are noticed, the appearance of which, when magnified, is well known to every medical man, a drop of a solution of nitrate of silver should be added, and the flour again examined by the microscope. If these minute objects really consist of bone dust, they will become yellow under the influence of this reagent.

# CHAPTER XLIX

## INSPECTION AND EXAMINATION OF BREAD

An inspection of bread will often afford many suggestive hints as to its condition. It is quite unnecessary to describe the appearance, taste, and smell of good bread, for every one is familiar with it. How few, however, have any notion as to the unwholesome manner in which the greater part of the bread that is eaten is manufactured. Pure bread is rarely procurable in our towns and cities, under the present system that prevails of "flesh dough-kneading." The cellars employed as bakehouses in London and other cities are generally filthy places, with drain smells, infested with beetles, mice, and rats, which make playful incursions into the kneading-trough and flour-sack. The work of kneading is so laborious as to excite profuse perspiration, which drops into the dough. The flour rises in clouds, and the workers begin to cough and sneeze. When the process is almost finished, the dough adhering to their arms is scraped off, and the flour that has settled on their hair is brushed off with a coarse brush into the kneading-trough. Thus cast-off epithelium from the skin, hairs, head scurf, nasal and pulmonary excretions of men, the majority of whom are dirty and unhealthy, are mingled with the dough that forms our daily bread. Fifteen years ago these revolting disclosures were made *àpropos* of the grievances of journeymen bakers,

Mode of manufacturing our daily bread.

and are to be found in Government Blue Books.[1] Notwithstanding the publicity given to these facts, the manufacture of nearly all bread is carried on at the present time in the same disgusting way.[2] Forgetfulness would appear to be bliss no less than ignorance. As guardians of the public health, it behoves medical officers, not only in the interest of the journeymen bakers themselves, whose lives are so terribly shortened by their unwholesome avocation, but in that of the public at large who are supplied with foul bread, to bring about the employment of machine-made bread. Bread can—now that many mechanical dough-kneading and mixing machines of different kinds exist, and the dough can be baked by gas, hot air, or steam, with a complete absence of smoke, dust, or sulphur fumes—be manufactured so that the human hand never touches it, and so that the bakers shall not receive any injury to their health.

### *Microscopic Examination.*

The presence of fungi in bread, such as the several varieties of *Penicillium* or common mildew, which gives a greenish or brownish or reddish hue in patches, or the *Oidium orantiacum* which is distinguished by yellow spots, shows that it is unfit for human food, for there is good reason to believe that illness has been produced by such bread.

As cooking so greatly alters the appearance of starch granules, the flour from which the bread is made should be examined.

### *Adulterations of Bread.*

The most common adulterants of Bread are—

Alum.

[1] *Vide* Report of H.M. Special Commissioner, H. S. Tremenheere, Esq., C.B., to the Secretary of State of the Home Department.

[2] Vide *Medical Examiner*, July 12, 1877 and July 19, 1877.

Terra alba (hydrated sulphate of lime) and whiting (fine carbonate of lime), carbonate and silicate of magnesia.
Sand.
Sulphate of copper.
Rice.
Potatoes.

Alum.

1. *Alum.*—If the grain of wheat is subjected to warmth and moisture—as, for example, from long exposure in the field, or from storage in warm, damp granaries—a certain degree of germination occurs, an action which is accompanied by the conversion of the albuminous matters into diastase (a substance that changes part of the starch into dextrine), and a saccharine body called glucose. In the manufacture of bread from this damaged or partially fermented flour, a larger quantity of sugar is formed from the starch under the influence on it of the diastase than is desirable, a sweetish, unpleasant, dark-coloured loaf being the result.

Alum, if added to damaged flour, checks the action of the diastase on the starch, and thus prevents its conversion into dextrine and sugar, at the same time improving the colour of the bread.

Damaged flour being apt to create dyspepsia and diarrhœa, this astringent salt is found to neutralize to some extent these ill effects. The scoundrels who thus swindle the public by passing off as a superior food of the first quality, at a high price, an unwholesome and inferior doctored article, are happily amenable to the law. One unfortunate stumbling-block in the way of preventing this extensive system of fraud, which is so injurious to that part of the community that depends so largely for its sustenance on bread—namely, the agricultural labourer—has been the difference of opinion amongst scientific men as to whether or not alum is injurious to health in the quantities in which it is generally detected in bread. The view that prevails amongst physicians is that a daily dose of alum, even if in minute quantities, is not by any means conducive but rather deleterious to health. Dr. Dauglish holds that the efficacy of alum in the prevention of the solution and decomposition of starch in the loaf is more or less continued in the stomach; for the alum, whilst neutralizing the action of the diastase, will further neutralize the influence of the gastric juices, the result being imperfect digestion, with the consequent elimination from the system of substances which should otherwise meet with ready assimilation as true food, including a large proportion of gluten and unaltered starch.[1] Many scientific chemists, who have but a smattering of medical knowledge, consider that alum in bread is harmless, except perhaps when present in large amount. In many districts, where the only water obtainable is muddy, it is the practice to place a pinch of alum in a large butt of water to clarify it by a precipitation of the suspended impurities. The men in such parts drink nothing but beer. I have never seen amongst the wives of these men who drink such water a perfectly healthy woman.

Sulphate and Carbonate of Lime, Carbonate and Silicate of Magnesia.

2. *Terra Alba* (*Hydrated Sulphate of Lime = Plaster of Paris*) *and Whiting* (*Carbonate of Lime*), *Carbonate and Silicate of Magnesia.*—The presence of these and other mineral substances in bread is suspected if the ash, which should not exceed 2 per cent, is excessive. They are added to increase the weight. The flour from which the bread has been made should, if possible, be procured, for flour can be reduced to ash far more rapidly than bread. Care should be taken not to mistake the coke for the ash. Re-ignition will diminish the weight of the coke, but not that of the ash. The Medical Officer of Health and

[1] "Bread and Bread Stuffs," by B. Dyer.—*Sanitary Record*, December 14, 1877.

Analyst of the City of London seized, in January 1879, a large quantity of flour which consisted of as much as 70 per cent of plaster of Paris. There are several mills in the United States that grind white stone into a powder, sold at $\frac{1}{2}$ cent per lb, of three different degrees of coarseness—"the soda grade, sugar grade, and flour grade"—for purposes of adulteration. The prompt action of the Russian Government during the Russo-Turkish campaign, on discovering that the flour furnished by the head of the Commissariat Department contained a large percentage of terra alba, is to be commended. The man who endangered the success of the enterprise was immediately shot for his dishonesty.

Sand.

3. *Sand.*—The admixture of sand with bread is easily shown by the silica determination. The average amount of silica in good bread is about ·025 per cent.

Sulphate of Copper.

4. *Sulphate of Copper* is used by bakers on the Continent in small quantities to give a white colour and otherwise improve the appearance of bread manufactured from damaged flour. The continual use of bread thus adulterated cannot fail to be injurious to health, whatever the quantity of the poison may be.

*Modes of Detection.*—1. Cut a smooth slice of bread and draw across its surface a glass rod dipped in a solution of ferrocyanide of potassium. If copper be present, the streak will be of a brownish-red colour.

2. Burn a quantity of bread (or flour, if it is desirable to test it) to an ash. Boil the ash in a platinum crucible with a few drops of strong sulphuric acid, which should afterwards be diluted with water. Place in the solution a piece of zinc. If copper be present, it will be deposited on the surface of the platinum.

Potatoes.

5. *Potatoes* are generally added when they are cheap, in a mashed form, to dilute the flour and render bread

heavier, for they contain between 70 and 80 per cent of water. Bread thus adulterated has a damp appearance and taste. Many housewives add a few boiled potatoes to the flour in making their bread, with a view to prevent the bread from soon becoming dry.

*Mode of Detection.*—Make a solution of bread. Test it with red litmus paper. If it is not alkaline, burn some of the bread, and test the ash with litmus paper. If the ash, instead of being neutral, is alkaline, potatoes are probably present. The percentage of water in the bread and its appearance must also be noted.

6. *Rice* is added to bread to whiten it and to render it heavier, as it contains a large quantity of water. Rice.

*Mode of Detection.*—The ash of rice is necessarily low, namely ·85 per cent. An excessive percentage of moisture, an unnatural whiteness of the bread, and a low ash, are suggestive of this adulteration. The flour with which the bread is made should be examined microscopically, for the granules of rice are different from those of any other starch.

## *Chemical Examination.*

*Water.*—The mean amount of moisture found by Dr. Odling in the crumb of good bread was 43·4 per cent, the maximum of all the 25 specimens examined yielding 46·7 per cent of water. Water should not exceed about 45 per cent.

Place a small portion of bread in a platinum dish of known weight. Weigh. Dry over water bath for some time. Weigh. Expose the dish on the water bath for another half-hour, and again weigh.

Calculate the percentage. For example :—

| | |
|---|---|
| Bread and dish . . | 28·910 |
| Dish . . . | 26·205 |
| Weight of bread . | 2·705 |

After drying at 212° F.

| | First weighing. | Second weighing. |
|---|---|---|
| Bread and dish | 27·810 | 27·665 |
| Dish . . | 26·205 | 26·205 |
| Weight of bread | 1·605 | 1·460 |

2·705 : 1·460 : : 100
100

2·705) 146·00000 (53·97

100·00
53·97 of solid.

46·03 of moisture.

Result 46·03 per cent of water.

The addition of mashed potatoes or boiled rice (starchy foods that are deficient in the nitrogenous elements) is to be suspected if the percentage of water is excessive. If bread possesses an unnatural whiteness, and no alum or terra alba can be detected, rice is the probable adulterant.

Ash should not exceed 2 per cent.

*Ash.*—Take 100 grammes of bread (crust and crumb in about equal proportions) and, having cut it up into fragments, burn it in a Berlin dish of about 5 inches in diameter. The coke that forms should be broken up by the help of a platinum rod. It is not advisable to employ a persistently intense heat, as there is a danger of volatilizing the alumina of the alum, and of cracking the dish. When the cinder and ash cease to glow, and when they exhibit a gray colour, the burning may be considered complete. The ash should not be thoroughly decarbonized for fear of volatilizing the alumina. The burning of 100 grammes of bread consumes four hours. This process can be accomplished in half the time by employing 50 grammes, but in that case greater care and accuracy are required in working. The ash is transferred to a platinum dish, for weighing, by the help of the feather end of a quill pen, with which the interior of the porcelain dish can be very thoroughly cleaned. Before the weight is taken, it is desirable to complete the incineration by heating the contents of the platinum dish to redness for a short time, to ensure a thorough burning. If the operator is possessed of a large £5 platinum dish, the employment of the Berlin dish is dispensed with. The ash should be weighed. It does not in pure bread exceed 2 grammes in 100 grammes of bread, or 2 per cent.

For example :—

| | |
|---|---|
| Ash and platinum dish . | 27·770 |
| Platinum dish . . | 26·205 |
| Ash . | 1·565 |

Result 1·5 per cent of ash.

*Silica.*—Add 5 c. c. to 10 c. c. of strong hydrochloric acid (pure) to the ash in the platinum dish. Add 20 c. c. to 30 c. c. of distilled water, and boil, taking care to avoid splashing. The hot liquid is passed through a small Swedish filter paper into a beaker. Place some distilled water in the platinum dish and heat to boiling point, using a feather or glass rod to detach any solid particles adhering to the sides of the dish. Pour these washings through the filter. Finally wash the precipitate on the filter with hot distilled water by the help of a wash bottle. The well-established rule of avoiding the addition of the wash water to the filter before the mother liquor has entirely passed through it should of course be remembered.

Silica varies in good bread from ·018 to ·032 per cent.

As the precipitate on the filter has, like many other precipitates, a tendency to clamber up the sides of the filter and pass down between the filter and the funnel, it is necessary to wash it down the sides of the filter by the help of a jet of water from the wash bottle.

A great bulk of liquid is to be avoided in making these washings. *Several* successive washings with small quantities of hot distilled water are preferable to the practice of using two or three large quantities. Let the filter drain and dry, by suspending the funnel containing it in a ring of a retort stand, at such a distance above a Bunsen's burner, or a spirit lamp, as to prevent the possibility of ignition or charring. The filter and the precipitate on it will soon dry. Fold the filter and carefully transfer it into a little platinum or porcelain crucible provided with a cover (or into a platinum milk dish), and burn the filter to an ash, and weigh.

It is advisable to employ round Swedish filter papers yielding definite and known quantities of ash, as, for example, one or two milligramme filter papers. If none are at hand, cut a filter of the requisite size out of a sheet of filter paper and weigh. The weight of the ash is always $\frac{1}{2}$ per cent the weight of the filter paper; therefore, a filter paper weighing 500 milligrammes has an ash of $2\frac{1}{2}$ milligrammes. We have now arrived at the weight of the silica in the total ash.

For example :—

| | |
|---|---|
| Platinum dish and ash . | 7·8200 |
| Dish . . . | 7·7700 |
| Weight of ash . . | ·0500 |
| „ of filter ash . . | ·0015 |
| | ·0485 |

Result ·0485 per cent of silica.

Alumina. *Alumina.*—Unadulterated flour, with which bread is made, contains such a variable amount of alumina, in part due to clay and other extraneous matter, that it seems impossible to draw a line between bread adulterated or not adulterated with alum. The differences between the amount of alumina in Calcutta, Russian, and English grown wheat is very striking. California sends us wheat which yields a remarkably small amount of alumina, whilst Egyptian wheat exhibits an enormous amount. At first it was stated that the average amount of alumina present in good unalumed bread should be considered as equivalent to 2 grs. in the 4 lb. loaf; then analysts decided that 10 grs. of alum in the 4 lb. loaf should be substituted as a minimum to be subtracted from the result of an analysis. The investigations of Dr. James Bell and others have since shown that this allowance is insufficient, as alumina in the form of silicate, equivalent to more than 40 grains of alum in the 4 lbs., has been found in good unadulterated flours. He states[1] that no rule can be laid down for the correction which should be made. It has now become the established rule amongst analysts, that a bread or flour should never be declared adulterated with alum, although it may yield a large amount of alumina, if the logwood and carbonate of ammonia test fail to give it a permanent blue or lavender colour.

So the whole question as to whether a bread is or is not alumed, resolves itself very much into a consideration of the behaviour of the bread when subjected to the logwood test. A Fellow of the Chemical Society writes thus:[2]—"Since it is impossible to fix upon a standard of natural alumina, and since it is erroneous to regard its amount, even in the presence of alum, as in any degree a measure of alum, it may be asked what is the use of estimating it at all? I venture to suggest that it might indicate whether the grain was or was not cleansed properly before grinding, but the estimation of silica would answer just as well."

The Hadow-Horsley's Test for alum.

The Hadow-Horsley reagent for the detection of alum

[1] *Analysis and Adulteration of Foods.*

[2] "Alum in Flour and Bread," by M. D. Penney, *Chemical News*, February 21, 1879.

in bread is employed as a qualitative auxiliary test by analysts. It is prepared thus:—

"1. Make a tincture of logwood by digesting for eight hours 5 grammes of freshly-cut logwood chips in 100 c. c. of strong alcohol, and filter;

"2. Make a 10 or 15 per cent solution of carbonate of ammonia in distilled water.

"A teaspoonful of each solution mixed with a wine-glassful of water in a white ware vessel forms a pink-coloured liquid. Bread containing alum, immersed in this liquid for five minutes or so, and then placed upon a plate to drain, will in an hour or two become blue or lavender *on drying;* but if no alum is present, the pink colour fades away and gives place to a dirty brown. Salts of magnesia yield with this test a somewhat bluish colour, which is not so permanent as that furnished by alum. Moreover, the increased weight of ash indicates mineral additions. If, on drying, a greenish tinge appears, an indication of copper is afforded, as carbonate of ammonia produces that colour, but never a blue."

Dr. James Bell, of Somerset House, writes[1] of this test, "It is one which we have never known to fail to indicate alum." Mr. Wynter Blyth has suggested[2] an improvement of it with gelatine in this wise: "From 300 to 400 grs. of bread are crumbled in distilled water and a slip of pure gelatine added, and the whole allowed to soak for 12 hours. On dissolving the gelatine in a little logwood, to which its own volume of a 10 per cent solution of ammonium carbonate has been added, if the bread is pure the solution will be reddish-pink, if the bread is alumed the solution will be blue."

An approximative estimate of the amount of alum present may be made by the help of a known quantity of a standard solution of alum (1 gramme to the litre),

[1] *Op. cit.*

[2] *Op. cit.*

which should be added to the same amount (300 to 400 grs.) of a sample of unalumed bread. The relation between the amount of silica and that of alum should be considered in the examination of a bread, for it may have been made of flour containing much clay and mud, such as is found in Egyptian wheats. A large amount of alum in conjunction with a small quantity of silica indicates that the excess is due to the *addition* of alum.

The amount of alum generally added to bread adulterated with this substance varies between 20 and 30 grains in a 4 lb. loaf, although more than 100 grains have in exceptional cases been discovered in the same quantity of bread.

It does not necessarily follow that, because bread on analysis proves to have been alumed, the baker has mingled it with his flour in the manufacture of his bread. Some millers alum the flour before they supply it to their customers.

Accordingly, when a loaf is purchased for analysis, a sample of flour from each sack found on the premises should also be taken for examination.

In rare cases, salt, which is, of course, freely used in bread making, has been found to contain alum.

# CHAPTER L

## INSPECTION AND EXAMINATION OF MILK

MILK contains the three classes of principles in association with water which are required for human food—namely, the Albuminous or Nitrogenous, the Oleaginous, and the Saccharine—and is the only article supplied by nature which combines all the elements requisite to secure healthy nutrition in a form suited to the young animal. It must not be omitted, therefore, from the category of the necessaries of life to which the attention of the Medical Officer of Health is restricted, although, if he does not hold the post of public analyst, he may not find it requisite to make an official examination of a milk, except as a guide for himself in his own investigations as to the origin and spread of diseases. On professional analysts rests the duty of ascertaining the amount of water added, or the amount of fat abstracted, in order to aid the law in the punishment of fraud. Enteric fever, scarlet fever, and diphtheria, are diseases which have been indubitably spread through the medium of milk. The exact manner in which the poisons of these diseases obtain entrance to this liquid food often taxes the skill of the Medical Officer of Health. In milk outbreaks of typhoid fever not a single link in the chain of evidence should be neglected. If the health officer finds on analysis that the water used in the dairy contains excremental filth, and traces the pollution to its source, which has been infected with the specific poison of the disease, it is still desirable to ascertain whether or not the milk has been diluted with water. Here is an example of the assistance that such an examination may afford a Medical Officer of Health :—Fever once appeared in a large public school, and as no mode of the entrance of the poison could be discovered, it was at first supposed to have arisen *suâ sponte.* The water supply on analysis proved to be pure. The milk was supplied from two or three sources, and was not complained of. On making an analysis of the milk it was found to have been manipulated with water. An analysis of the water from each of the three farms whence the milk was derived was made, and one of these waters was discovered to be polluted with animal excrement, whilst the other two waters were of undoubted purity. On visiting the dairy farm possessing the polluted water supply, it transpired that the closet and well were in affectionate proximity, and that the former had recently received the specific poison of the disease from one of the labourers. If milk under such circumstances should not evince by chemical examination any decided departure from the normal state of the secretion, due regard being paid to its variation in composition, by reason of the age and food of cow, time after calving, weather, etc., it must not be concluded that the poison of the disease has not been communicated to the milk through the medium of water, for there is every reason to believe that the smallest quantity of water containing the specific poison, such as may be introduced by merely rinsing the milk-cans, is sufficient to infect a large quantity of milk. An analysis of milk in suspected typhoid outbreaks often affords only negative evidence. The undoubted admixture of water with milk introduces us to a fresh scent in our endeavours to trace the introduction of the poison, although the absence of signs of any decided adulteration does not preclude the possibility that the milk may have been poisoned through the medium of water. As a rule, however, milks fraudulently watered are adulterated with at least 10 per cent of water. No ray of light, however feeble, should be neglected in tracking this prevalent and wholly preventable disease. The microscope affords also aid which is not to be despised. In milk outbreaks of scarlet fever a comparison should be made with this instrument between milk that has been exposed to infection—as, for example, from being stored within a few yards of persons suffering or recovering from this disease—and the milk of the same animals that has not been thus endangered, with the object of discovering epithelial scales, for its poison would seem to be mainly distributed through the air by the aid of the dust of the skin to which it attaches itself.

Good milk, the chemical composition of which is to be found in every physiological work, is slightly acid or neutral, or very feebly alkaline to litmus paper. Its specific gravity is about 1·030 or 1·034.

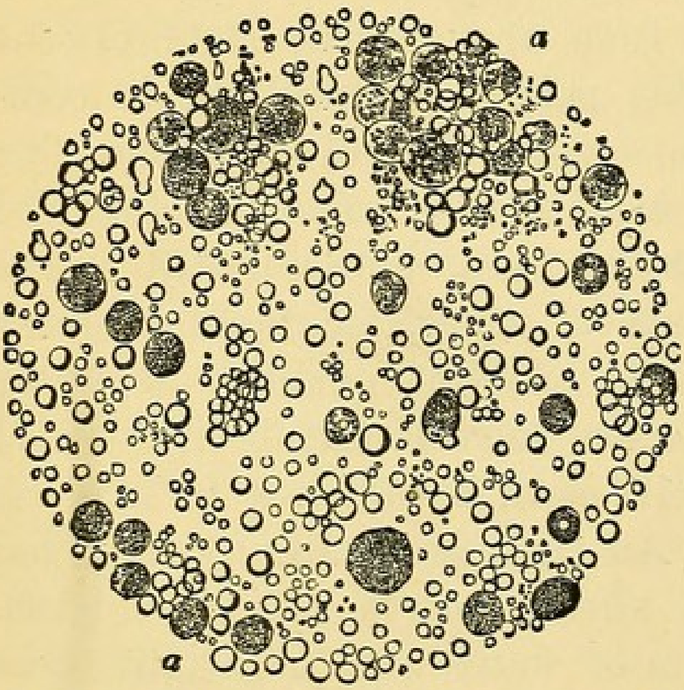



FIG. 101.—Milk containing colostrum corpuscles, at *a* and elsewhere. (After Carpenter.)

*Microscopic Appearance.* Milk is seen to consist of a number of oil globules of different sizes, called milk globules, and a little epithelium suspended in a somewhat turbid fluid. Immediately after calving are sometimes perceived large yellow compound bodies termed colostrum corpuscles. The secretion of the colostrum immediately after birth is, as every one knows, designed to purge the young animal.

In the milk of a woman suffering from an acute disease, colostrum corpuscles and large granular cells rich in fat are visible.[1]

Foreign bodies are sometimes noticed by the microscope in milk; for example, blood and pus corpuscles, epithelium, etc.; also mineral matters, such as chalk, starch, vegetable organisms.

### *Physical Peculiarities.*

Fresh Milk coagulated.

*Milk coagulating during or immediately after milking*, especially after it is warmed.—The secretion of this acid milk may be owing (1) to inflammation of udder, (2) to digestive disturbance or a febrile state.

Yellow Milk.

*Yellow Milk.*—This colour, when not due to the colostrum of newly-calved cows, is observed when there is irritation or congestion of the udder. Dairymen colour their milk with annato. When milk is boiled the colouring matter remains in the whey. An unnatural yellow colour of cream is sometimes produced by an organism called by Klein the *Bacterium xanthinum*, and by Verheyen the *Vibrio xanthogenus*. The eating of orchids and of *Rheum palmatum* by cows has been said to render the milk of a yellow colour.

Viscid Milk.

*Viscid Milk*, which is stringy and mucus-like when poured from one vessel to another, and has a stale unpleasant taste, has been found to contain a large proportion of albumen, as well as carbonate of ammonia. Microscopically it resembles colostrum, but it is distinguished from it by its power of producing the same alteration in a large quantity of healthy milk. The viscidity of milk has been ascribed to a half-starved condition of cows, and to damp unwholesome dairies

[1] Lehman's *Physiological Chemistry*.

The colours of *blue, red,* and *green* milk or cream are all probably due to the development of organisms, respecting the nature of which very little is at present known. The ferment produced will give rise to the same alteration when a small portion of either of these milks is added to a large quantity of good milk. Several micro-organisms are believed to possess the power of producing the lactic fermentation, whilst the *Clostridium butyricum,* called also the *Bacillus butyricus,* is alone capable of converting lactic acid into butyric acid.

Blue Milk.

*Blue Milk* has a disagreeable taste, and has been found to produce diarrhœa and severe febrile gastritis.[1]

Pigs, rabbits, and sucking calves suffer from diarrhœa after feeding on it.

A distinction has been drawn between milk which is blue when drawn, and that which is blue when coagulated or in the condition of cream, the former being supposed to be not injurious and the latter injurious to health. The probability is that the colour is due to one and the same organism, which becomes poisonous only at a certain stage of its development. It has been described under the name of the *Bacillus syncyanus.*

The blue colour has been attributed to the consumption by the cows of certain plants, as the *Myosotis palustris, Mercurialis perennis, Fagopyrum, Polygonum aviculare,* and *Anchusa tinctoria.*

Reddish Milk.

Cows fed on madder or galium (commonly called bed-straw) have been found to secrete a reddish milk.[2]

Milk is a fluid which is extremely liable to be affected, as to its odour and taste and quality, by the food of the cows that secrete it, and by chemical changes that are due to foul conditions of air to which it may be exposed,

[1] Virchow's *Archiv.*, Band xliii. p. 161 (1868).

[2] Reimann's *Färber Zeitung.*

and to the special ferments[1] which attach themselves to it.

We are all familiar with the taste of turnips in our milk and butter during the depth of winter. Vine and chestnut leaves will render milk bitter, and beech leaves will diminish the supply of milk. Milk is also bitter if bitter medicines have been administered to the cow, and in disease of the liver. Changes in taste and odour.

Milk has been found to possess a sweet or bitter unpleasant taste and a "rotten" disagreeable odour when supplied by cows badly kept on damaged forage and filthy water, and when kept in dirty, unwholesome, damp dairies.[2]

Mr. Smee exposed milk to sewer gas, but could find no change in composition on making a chemical analysis. On distilling the milk at a temperature not exceeding 120° F., a distillate was obtained which had an unpleasant taste and an offensive smell. "Tasting the distillate set up intense headache, vigorous rapid pulse, and was followed by severe diarrhœa.[3] Milk exposed to the vapour arising from animal matter undergoing putrid decomposition, similarly treated, was offensive and produced results dangerous to health.

## *Chemical Examination.*

Milk is adulterated with many substances, some (such as salt) to cover the addition of water, others to render its estimation difficult, and some (such as borax and salicylic acid in minute quantities) to increase its keeping properties. The chief adulteration of milk consists in the addition of

[1] *Vide* p. 392 as to the formation of a poisonous alkaloid or ptomaine named tyrotoxicon and its connection with infantile diarrhœa.

[2] I visited a dairyman's establishment once where the water in the cowshed, with which the milk was confessedly adulterated, was sewage water, and the cans of milk were stored in a bedroom redolent of organic matter.

[3] *Milk in Health and Disease.*

water, which has been carried on to such an extent in London, that it has been found, that the number of cows supplying the metropolis with milk would not yield more than sufficient to provide daily each inhabitant with about a tablespoonful of pure milk. The salt may be estimated by a standard solution of nitrate of silver (*vide* page 136) applied to a solution of the ash. The addition of carbonate of soda to neutralize sourness in stale milk is shown by the milk yielding a high ash which effervesces on the addition of an acid. Chalk, gypsum,[1] and other inorganic substances, are easily detected by an estimation of the weight of the ash. It is desirable that the Medical Officer of Health should be able not only to diagnose these milk sophistications, but be in a position to ascertain whether a milk contains the normal proportions of its principal ingredients, for the supply of a young child with an abnormally poor milk (*vide* page 533) signifies the deprivation at the most important age of a portion of what sometimes is, and always should be, its sole nourishment, which may lead to the development of strumous or some other disease of a mal-assimilative kind. A great change has been of late effected in the chemical analysis of milk, which has principally consisted in a more complete removal of the fat,[2] in the employment of the specific gravity test corrected for temperature, and in the lowering of the minimum limit of the amount of "solids not fat" below which milk is to be considered adulterated. A representa-

[1] The adulteration of milk with mineral matters appears to have been a very ancient custom, if the statement that St. Irenæus wrote, A.D. 140, "Lacte gypsum male miscetur," is to be credited.—*Notes and Queries*, 5th Series, xi. 216.

[2] It has been shown that at least ·3 per cent more fat is obtained by the plaster process than by the Wanklyn process, and another ·2 per cent more by Adam's coil process than by the plaster, so that at least ·5 to ·6 per cent more fat is procured by the Adam's coil than by the Wanklyn process.

tive committee of the analysts of the country have for the last two years been engaged in an endeavour to improve our methods of milk analysis, and in December 1885 forwarded their Report to the Council of the Society of Analysts, which report contained the following conclusions—

"1. *As to the Process of Analysis.*

"That in future the method to be recommended for adoption by the members of the Society of Public Analysts be as under :—

"(1) *Total Solids.*—These to be estimated by evaporating in a platinum dish about 5 grammes of milk. The residue to be dried to practical constancy, at the temperature of a water oven or water bath.

"(2) *The Process of Fat Extraction*, with Mr. Adam's paper coils (*vide* Estimation of Fat, page 528).

"(3) *The 'Solids not Fat'* in all cases to be determined by difference. We strongly recommend that in all cases the specific gravity be taken as a useful control.

"2. *As to Standards or Limits.*

"We further recommend that, concurrently with the method above laid down, the following be the limits below which milk should not be passed as genuine, viz.—Total solids, 11·5 per cent, consisting of not less than 3 per cent of fat, thus leaving not less than 8·5 per cent of *non-fatty solids.*"

Milk should always be analyzed in a fresh state, for when sour or otherwise decomposed, correct determinations are more difficult. To ascertain whether or not water has been added to cows' milk, the estimation of the amount of milk solids is necessary.

*Determination of the Total Solids.*—Procure (1) two or three little platinum dishes each of which is numbered; (2) a copper water bath resembling that depicted in Fig. 14, provided with holes corresponding to the number of little dishes, in place of the large holes there exhibited; and (3) a bulb pipette graduated to 5 c. c. Weigh the dish and place it on the water bath. Having shaken the sample of milk, place 5 c. c. of it, measured with the

Average of total milk solids 12·8 per cent.

pipette figured below, in the dish. Light the Bunsen's burner, and boil the water in the bath vigorously. Complete evaporation to dryness will consume three or

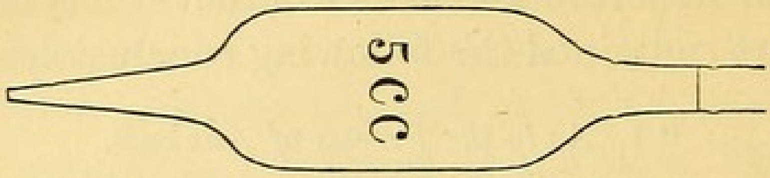



FIG. 102.—Milk Pipette.

four hours. At the end of this time remove the platinum dish, wipe it, cool it, and weigh it at intervals until a *constant* weight is obtained. Some place it in a hot air oven to render the drying complete. For example :—

| | |
|---|---|
| Milk solids and platinum dish . | 8·408 |
| Platinum dish (No. 2) . . | 7·768 |
| Milk Solids | ·640 |

Multiply by 20 to obtain the amount present in 100 c. c. of the milk—

$\cdot640 \times 20 = 12\cdot80$ grammes in 100 c. c. of milk.

As 100 c. c. of average milk weigh 102·9 grammes, it is necessary, if it is wished to obtain a percentage statement (which is more easily understood by the public), to divide by 1·029.

12·80 grammes in 100 c. c. of milk ÷ by 1·029 = 12·44 per cent of milk solids.

The milk solids of other animals are :—

| | Per cent. | Analyst. |
|---|---|---|
| Woman | 12·50 | Bell. |
| Mare | 11·60 | ,, |
| Ewe | 24·78[1] | ,, |
| Goat | 14·40 | Payen. |
| Ass | 9·50 | ,, |

Average of fat ranges from 3·5 to about 4 per cent.

*Determination of the Fat.*—If it is considered desirable to know the extent of watering to which a milk has been

[1] About 11 per cent of this large amount consists of fat.

subjected, it is necessary to estimate the amount of fat in the milk. "Pipette 5 c. c. of milk into a beaker 2 inches deep by $1\frac{1}{4}$ inch in diameter, weigh and place into it one of Mr. Adam's coils, viz. a rolled up strip of white demy blotting-paper (sharply cut to $2\frac{1}{2}$ inches wide, and 22 inches long), which must have been previously extracted with ether in a Soxhlet apparatus (to remove resinous soap employed in the manufacture of such paper) and the ether driven off. When as much as possible of the milk has been taken up by the paper the coil is removed and placed dry end downwards upon a slip of glass, and the beaker (which should be kept covered by a bell jar during the absorption of the milk) is at once re-weighed. Dry the coil in a water oven for a period of one to two hours, and extract the fat by ether in a "Soxhlet" apparatus, twelve syphonings at least being necessary; the flask in which the solution is collected being as small and light as possible. Boil off the ether and place the flask in a water oven, in a horizontal position, and dry to constancy, allow to cool for about 10 minutes and weigh." Two improvements have been suggested on the official method by Mr. Wm. Thompson.[1] He employs filter paper, in the place of blotting-paper, which does not need extraction with ether before use, because the amount of extract contained therein is so small (·0006 gramme) as to fall within the region of experimental error. Whilst fixing one end of the strip of filter paper ($21 \times 2\frac{1}{2}$ inches) between two glass rods, and holding the other extremity in the left hand, 5 c. c. of the milk are diffused over the paper thus horizontally held, by means of a pipette having a long stem under the bulb. The strip of paper thus moistened with 5 c. c. of milk is dried by moving it backwards and forwards over the flame of a Bunsen's burner or spirit lamp. The dried

[1] *Analyst*, April 1886.

strip is made into a scroll by coiling it around a glass rod, and is then introduced into a Soxhlet's fat extractor in which it requires half a dozen syphonings.

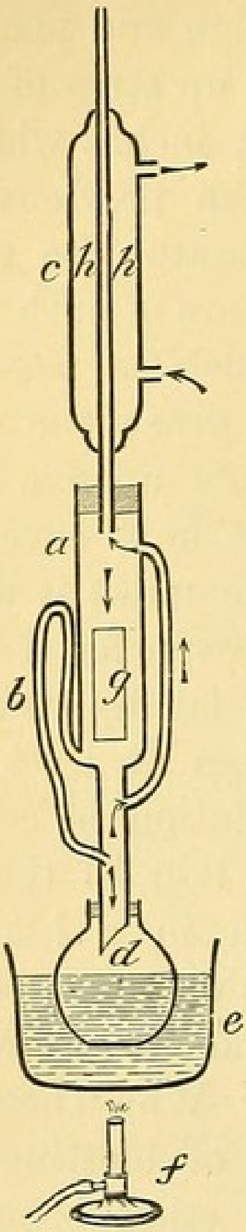



FIG. 103.

*a* Soxhlet Fat Extractor.
*b* Its syphon.
*c* Glass Liebig's condenser with openings for attachment of indiarubber tubes, through which water enters and flows away.
*d* Flask.
*e* Shallow beaker containing water.
*f* Bunsen's burner.
*g* Coil.
*h h* Water.

The small size Soxhlet's Fat Extractor will be found most convenient, and enough ether is poured into it to nearly reach the upper opening into it of the tube through which the ether vapour ascends. The ether boils at a very low temperature, so the gas jet or spirit lamp flame should be very small. As the ether in the flask boils, the vapour passes up through the tube into the extractor, *en route* to the condenser where, being condensed, it falls back into the extractor, until the latter is filled to the level of the top of the syphon which then runs the ether back into the flask, carrying with it in solution some of the fat. The extractor again and again fills and discharges itself so long as the heat is maintained. At the conclusion of the extraction, when the extractor is nearly full of ether, the flame and condenser should be removed, and the ether be allowed to syphon off into a bottle for future use. If all the ether in the flask has not been distilled over, the apparatus should be fitted together again and the remaining portion distilled and syphoned off into the bottle.

The weight of the fat derived from the known amount of milk operated on being obtained, the percentage can be easily calculated in the manner previously explained.

*Determination of the solids not fat.*—Deduct the quantity of fat from the total milk solids, and the important datum "solids not fat" is obtained. Dr. James Bell states that in the case of individual cows they vary from 8·00 to 11·27 and in the case of dairy samples from 8·50 to 9·91, but that the average ranges from 9·0 to 9·1 per cent.

Average of "solids not fat," 9 per cent.

*Determination of ash.*—The adulteration of milk with chalk or other inorganic substance is easily detected by an estimation of the ash. This determination also serves to confirm or otherwise the examination as to total solids, for a milk highly adulterated with water gives too low an ash.

Average of ash ·7 per cent.

Place the platinum dish containing the dried milk solids on a pipe triangle, and incinerate by means of an argand burner at as low a temperature as possible (so as to avoid the volatilization of the chlorides) until a *white* ash is obtained. Allow the dish to cool, and weigh. Subtract the weight of the dish from that of the dish and ash, and multiply the result by 20 to obtain the amount of ash in 100 c. c. of milk. For example:—

| | |
|---|---|
| Ash and platinum dish . . . | 7·807 |
| Platinum dish (No. 2) . . . | 7·768 |
| | ·039 |

$$·039 \times 20 = ·78 \text{ grammes of ash in 100 c. c. of milk.}$$

If a percentage statement is required divide by 1·029.

$$·78 \div 1·029 = ·75 \text{ per cent of ash.}$$

*Determination of specific gravity.*—Dr. Vieth states[1] that the specific gravity of milk varies from 1·030 to 1·034 with very few exceptions, or, using another ex-

The Lactometer.

[1] *Analyst*, April 1885.

pression, from 30 to 34 degrees, and that the specific gravity of a mixed milk, *i.e.* the product of a number of cows, should never fall below 1·029 unless an excess of cream be present, or water has been added. The more milk sugar, casein, and other mineral matter contained in milk, the greater the specific gravity. The effect of these solids is more or less counteracted by the fat globules, which tend to lower the gravity because fat is lighter than water. As the addition of fat tends to diminish, its abstraction (skimming) increases the specific gravity, bringing it up sometimes to 1·037. The practice in the milk trade is to rob the fresh milk of cream by pouring into it skimmed milk. The specific gravity having been thus raised abnormally high, is toned down to the specific gravity of good rich milk by dosing it with water. Subject to a correction for temperature, the Society of Analysts have, notwithstanding, decided that the readings of the lactometer may be usefully employed to check results. As lactometers are generally adjusted at 60° F., the corrected specific gravity is arrived at by the *subtraction* of about 1 degree from those furnished by the lactometer for each 10 degrees of temperature *below* 60° F. and by adding about 1 degree for each 10 degrees *above* 60° F. For intermediate temperatures the proportionate fraction of 1 degree would be either subtracted or added as the case may be, *e.g.* if the reading of the lactometer was 25 degrees at the temperature of 56° F. the corrected specific gravity would be about 24·6, and at 62° F. it would be about 25·2.

A great controversy has for some time been carried on, as to the extent to which the components of milk may be influenced by breed, feeding and keeping of cows, age, time of year, intervals between milking times, distance of time from calving, etc. Milk from cows of the Ayrshire breed resembles most closely human milk. Dr. Sharples points out,[1] that any admixture of sugar and water with the milk of a cow of this breed to make it resemble human milk will certainly do more harm than good. It is free also from the excess of fat which often renders the milk of an Alderney cow unfit for the food of delicate children. Certain cows produce what are termed abnormal milks; that is, milks that are exceptionally rich or exceptionally poor. Abnormal milks.

The following analyses of rich and poor milk were made by Dr. Shea and Dr. J. Bell respectively. The rich milk was obtained from an animal fed on a sewage farm, chiefly on rye grass:

| | Sp. Gr. | Total Solids. | Fat. | Solids not Fat. | Ash. |
|---|---|---|---|---|---|
| Rich milk | 1·035 | 14·8 | 5·6[2] | 9·20 | ·85 |
| Poor milks | 1·027 | 10·4 | 2·42[2] | 8·0 | ·69 |
| | 1·030 | 10·9 | 2·20[2] | 8·6 | ·62 |

Milk taken at the commencement of a milking, which is called "fore milk," is poorer than that drawn afterwards, and that which is obtained at the termination of a milking is generally rich with cream.

The law provides that milk shall be taken to mean whole milk, that is, the mixed milk of an entire milking of a number of cows.

Although the milk of individual cows may be found to vary, the milk of a dairy which consists of a mixture of the poor with the rich is pretty constant in composition. Its range in composition is thus given by Dr. James Bell.[3]

Percentage.

| Total Solids. | Fat. | Solids not Fat. | Ash. |
|---|---|---|---|
| 12·8 to 13·2 | 3·8 to 4·1 | 9·0 to 9·1 | ·71 to ·72 |

The average composition of 11,389 samples of milk analyzed in 1885 by Dr. Vieth was as follows:—

| Total Solids. | Fat. | Solids not Fat. | Sp. Gr. |
|---|---|---|---|
| 13·06 | 3·93 | 9·13 | 1·032 |

[1] *Proc. of American Academy of Arts and Sciences*, vol. xii. 1877.

[2] Too low in consequence of the imperfection of the method employed for its extraction.

[3] *Op. cit.*

It has recently been stated,[1] that the introduction of cream separators has been attended by the development of a new fraud, which consists in mixing the skim milk derived therefrom with ordinary milk. It would be doubtless difficult to distinguish this sophisticated milk from one of the poor abnormal milks from healthy cows.

The *Lancet* suggests that the limits of strength of milk like that of spirits should be defined by Act of Parliament, and that no milk should be allowed to be sold with less than 3 per cent of fat and 9 per cent of solids not fat. An Act of this kind would give milk dealers a legal right to water their rich milk down to this level. They would most certainly embrace this opportunity of making a profit, if they had no customers for their richer (higher priced) milk. In the interests of the public health, it should remain a punishable offence to mix any water, be it much or little, with milk, for the milk epidemics of enteric fever show, that the admixture of the smallest quantity of specifically contaminated water with milk is sufficient to infect large numbers of milk drinkers.

Standard of good milk.

Great differences of opinion have been expressed by analysts as to whether a milk is or is not watered, as to the quantity of water employed in its dilution, and as to the amount of cream abstracted, which have led magistrates to refuse to convict in cases where the adulteration is not greater than 10 per cent of water, so that milk sellers may cheat to at least this extent without fear of punishment. The want of agreement between analysts has arisen, partly, from the imperfection of the process employed, and, partly, to the abnormality in the composition of certain unadulterated milks. It is to be hoped that with improved methods of analysis and an adjustment of the minimum standard which have now been established,

[1] *Lancet*, March 6, 1886.

the milk trade may be carried on with more honesty to the consumer and more justice to the vendor.

*Milk supplied by, and tainted by, Diseased Animals.*

Happily this secretion diminishes or disappears in many of the diseases of animals, notably in anthrax.

Loiset states that at the public *abattoir* of Lille the employès of the cattle dealers and salesmen have consumed the milk of diseased cows for a great number of years without the slightest inconvenience.

Milk is not the diet of men and women, but of children, amongst whom the mortality under five years of age of affections resulting from improper food is frightful. The assertion of Loiset as to the harmlessness of the milk of diseased animals when taken by men seems in no way to determine whether or not such milk is wholesome as the food for the sucking animal, for which it was alone designed by nature.

The milk of diseased animals does not keep well. It is found, on microscopic examination, to contain pus, blood, and a larger quantity of epithelium than is present in good milk, casts of lacteal tubes, vibriones, cells, granules, etc. The milk of animals that have been driven fast, which is termed "heated milk," has been found to produce colic and diarrhœa amongst children.

*Cattle Plague.*—There is no evidence to prove that the milk of animals suffering from cattle plague is hurtful. The changes that occur in it are, according to Dr. A. Gamgee, as follows:— **Cattle Plague or Rinderpest.**

1. Remarkable diminution of sugar of milk.
2. Enormous increase (except, perhaps, at the commencement) of butter.
3. Slight increase of salts.
4. The casein is generally increased.

The milk of animals in a state of disease which exhibits such a derangement in the normal proportion of its ingredients cannot be wholesome as the food for infants and children.

Pleuro-pneumonia.

*Contagious Pleuro-pneumonia.*—There is no evidence to prove that the milk of animals affected with this disease is hurtful to adults or middle-aged persons.

Foot-and-Mouth Disease.

*Foot-and-mouth Disease.*—Much discussion has taken place as to whether the milk of cows suffering from this disease is injurious or not to man.

Pigs fed with the milk of animals thus affected are invariably seized with the disease in a few hours. It generally destroys sucking pigs and calves.

Aphthous and herpetic patches, followed by sores, and sometimes diarrhœa, have been attributed to the use of such milk.

These symptoms have naturally been observed most amongst children, because they are our great milk-consumers. The condition of the milk differs much, according as the udders are more or less affected. The milk is sometimes unaltered to the unaided eye; at others it is red, or brown, or yellow, from the presence of blood and pus, or ropy, or resembling whey and curds, or fœtid. Microscopically it is found to resemble the milk of cattle affected with rinderpest. In the first stage an aggregation of the milk corpuscles takes place. Subsequently pale, fine granules, spherical granular cells a little larger than pus corpuscles, bacteria, vibriones, epithelial cells, yellow granular masses not unlike colostrum globules seen in the milk of cows newly calved, may be discerned.

Milk in Foot-and-Mouth Disease. Early Stage.

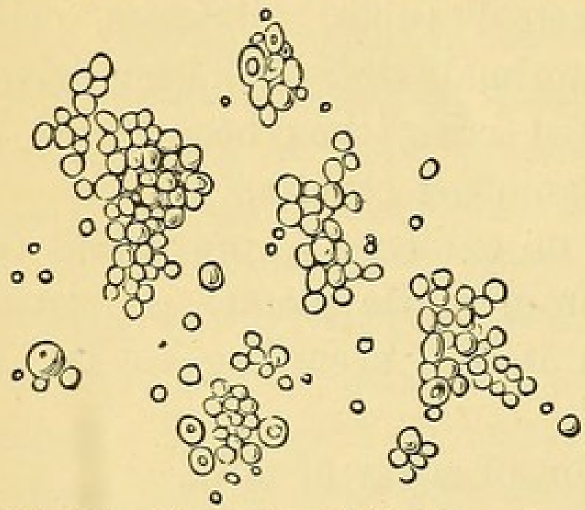


Fig. 104.—Clustering of Milk Corpuscles, × 200 diam.

The milk from which the drawing, Fig. 105, was made, was taken from a cow which had been suffering from the disease for ten days. The fluid, after standing for some time, separated into two parts—a curdy deposit and an amber-coloured whey. The same elements were found in both constituents, viz. large granular masses of a brownish-yellow colour, numerous pus-like bodies, bacteria, vibriones, moving spherical bodies, and a few milk globules. These morbid elements were found in specimens of milk which, in their physical characters, presented no appreciable peculiarity to the unaided eye.[1]

Foot-and-mouth Disease. Later Stage.

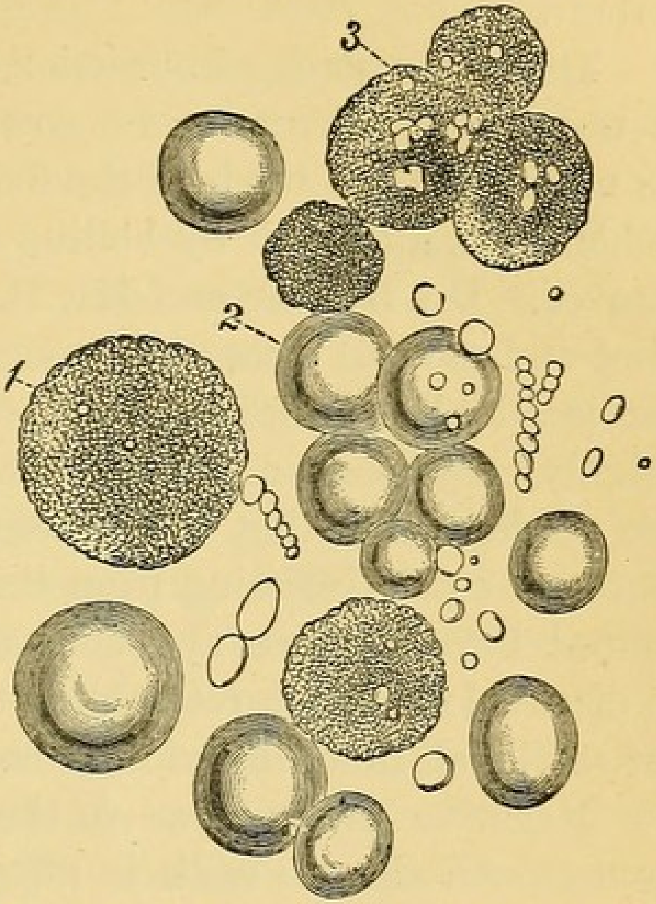



Fig. 105.—1. Large granular bodies; 2. Milk corpuscles; 3. Pus-like bodies. × 1300 diam.

As to the chemical composition of the milk, he has found that its constituents vary much in amount during the progress of the disease. During these fluctuations there is a deficiency of fat, of salts, and of milk solids not fat, the last named falling below nine per cent on one or two occasions.[2]

Dr. Klein considers[3] that the virus of foot-and-mouth disease is a particular kind of micrococcus, and he has found that by feeding sheep with it—with a twentieth generation—the typical disease is reproduced.

[1] *Lancet*, October 23, 1869.
[2] *Proc. of the Society of Public Analysts*, 1876, vol. i. p. 238.
[3] *Lancet*, January 2, 1886.

Continental veterinarians recognize foot-and-mouth disease milk by its easy coagulability on the application of the least heat, with a separation into numerous little curds floating on the whey, the latter being of a pale-bluish colour.

There is a strong impression afloat that milk drunk in a warm state, direct from a cow affected with the disease, is more likely to produce the foot-and-mouth disease than when cold, and that by boiling the milk all danger is removed. Dr. Balfour and Mr. H. Watson have shown that foot-and-mouth disease is communicable to the human subject by the milk obtained from cows infected with this highly contagious acute specific fever. There appears to be no doubt but that the discharges from the vesicles and sores of cattle suffering from this exanthem will, if introduced into chaps or abrasions of the skin in man, create a diseased condition resembling the foot-and-mouth disease of cattle, attended by violent constitutional disturbance.

Negative evidence as to the injurious nature of foot-and-mouth disease milk is afforded by the investigations of the French Commune in 1839, by the epidemics of 1810, 1811, 1834, and 1835, in Paris by Lawson Tait,[1] and Dr. Thorne Thorne.

Positive evidence is given by Röll, M'Bride,[2] Gooding,[3] Hislop,[4] Latham,[5] Briscoe,[6] Nauheimer and the Author. Cases where the foot was also involved have been recorded by Spinola[7] and Amyot.[8]

There are grounds for thinking that aphthous fever

[1] *Medical Times and Gazette*, October 1869.
[2] *British Medical Journal*, November 13, 1869.
[3] *Medical Times and Gazette*, January 1872.
[4] *Edinburgh Medical Journal*, November 1869.
[5] *British Medical Journal*, May 1872.
[6] *British Medical Journal*, October 1872.
[7] *Recueil de Méd. Vétér.*, 1873, p. 577.
[8] *Medical Times and Gazette*, November 4, 1871.

assumes, like certain eruptive fevers in the human subject, variations in type, sometimes being very mild in form and at others of a malignant kind. It is very certain that the milk of cows suffering from this disease is often consumed without ill effects. At times some startling epidemic occurs in connection with the milk supply of cows suffering from foot-and-mouth disease, as for example at Dover in February 1884, when 188 individuals were affected with inflammatory sore throat, enlargement of the lymphatic glands and vesicular eruptions in the mouth, with fatal results in several cases.[1]

Stomatitis, with aphthous ulcerations in the mouth of children, is known to be produced by milk which contains pus from an abscess in the udder. "Sore mouths" were exceedingly prevalent amongst the children throughout the country during the extensive outbreak of foot-and-mouth disease in 1869. The conclusions arrived at by Dr. Thorne from an investigation made by him on the "Effects produced on the human subject by consumption of milk from cows having foot-and-mouth disease" are as follows:[2]— (1) That a disease appears sometimes to have been produced in the human subject, when the milk of cows suffering from foot-and-mouth disease has been freely used without being boiled. There is no evidence to show whether this affection is of a specific nature or not; but it seems to consist in a derangement of the alimentary canal, accompanied by febrile disturbance, the presence of vesicles on the mucous membrane of the mouth and tongue, which, having ruptured, leave superficial ulcerations, and at times a herpetic eruption about the exterior of the lips. (2) That in a very large number of cases the milk of cows undoubtedly affected has been

[1] "Outbreak of Epidemic Sore Throat following use of milk from cows suffering from Aphthous Fever," by Dr. M. K. Robinson.

[2] Twelfth Report of Medical Officer of Privy Council, 1869.

used without producing any noticeable morbid effects. This absence of result may, though only to an inconsiderable extent, have been due to the smallness of the consumption and the boiling of the milk.

Outbreaks of illness from the employment of milk from foot-and-mouth disease cattle are recorded in *British Medical Journal*, November 30 and December 25, 1875, and in other periodicals.

The knowledge that we at present possess as to the milk in this disease warrants us in prohibiting the employment of it in any shape for children, and in dissuading adults from using it even when boiled, for it lacks the physical and chemical characters of good milk.

Anthracic Diseases.

*Anthracic Diseases.*—The milk of animals affected with these diseases is seldom consumed, partly because the secretion is very soon suspended, and partly because the physical appearance of the little milk that is supplied prevents its employment. It is, so Fleming says,[1] of a dirty bluish colour, streaked with blood, and soon becomes putrid.

Cases are recorded of diarrhœa and anthracic affections having been produced in man by drinking the milk of diseased animals.

Tuberculosis.

*Tuberculosis amongst Dairy Cattle.*—The most recent investigations show that the disease known as tuberculosis in man, or an infective[2] variety of it, consisting as it does of the deposition of tubercles in various parts of the body, especially in the lungs and mesenteric glands, is a communicable disease. That the same disease, as it exists in cattle, can be conveyed to calves, rabbits, guinea pigs, etc., by the milk of an animal suffering from the disease, has been proved over and over again by Chauveau, Klebs, Gerlach, Leisering, Zürn, Böllinger, and others.

[1] *A Manual of Veterinary Sanitary Science and Police*, vol. ii. p. 200.

[2] *Vide* paper "On an infective variety of Tuberculosis in Man, identical with Bovine Tuberculosis" by Dr. Creighton in *Lancet*, June 19, 1880.

Klebs asserts that, when milk has been deprived of its solid particles, the tuberculous virus is found in the fluid portion, that it is not destroyed by cooking, and that it is all the more active as the disease has reached to an advanced stage. He is of opinion that the disease may be developed in children through the medium of the milk. Such milk is liable to excite diarrhœa and debility in children.

Tuberculosis is a disease which is somewhat common amongst dairy cows that are shut up in towns in close, ill-ventilated, and foul cowhouses.. The milk of such diseased animals is deficient in fat, sugar, and nitrogenous elements, whilst it possesses an increased proportion of earthy matters. In these days when the filthy feeding bottle, containing its imitation of mother's milk, in the shape of cow's milk, sugar, and water and a pinch of salt, is almost universally substituted for the supply afforded by nature, can it be wondered at that there should be such an annual Herodian slaughter of innocents from diarrhœa, debility, atrophy, etc., when it is remembered that an immense quantity of the milk that supplies the bottle is derived from animals thus diseased?

The milk of milch cows suffering from tuberculosis should not be employed by children. The milk of all institutions occupied by the young, which are situated in his district, should be analyzed by the Medical Officer of Health, for he should be acquainted with the condition of this "all in one" sort of nutriment, as supplied in large quantity for the food of children.

If such milk should contain a deficiency of nitrogenous, fatty, and saccharine matters, as exhibited by very low milk solids, and if it is at the same time *rich* in mineral constituents, there is a suspicion, if unadulterated, that the milk is derived from animals suffering from tuberculosis.

The examination of sputa for the bacillus of tubercle (*vide* fig. 23) is now so constantly practised by the medical man as to render its recognition in other secretions an easy matter. It is reported that the cows of Paris have been recently found producing milk which contains this bacillus, and that the Council of Health have advised the closure of all the cowsheds of the city. Drs. Bang and V. Storch have found[1] that the cream prepared from such milk by a centrifugal cream-producing apparatus contains tubercle bacilli, and that both it and the butter made from it produce tuberculosis by inoculation.

Parturition or Milk Fever.

*Parturition or Milk Fever.*—A sample of the milk of a cow thus affected was found by Mr. Smee[2] to contain an abnormally large proportion of phosphates. He states that during the progress of this disease the earthy phosphates leave the animal's bones, producing a species of mollities ossium, which renders them exceedingly liable to fracture after recovery.

In this disease there is happily, as a rule, a suppression of the lacteal secretion, otherwise we should have frequent instances of the injurious effects of milk of such altered composition on children.

Changes take place in the proportion of the constituents of good milk in other diseases of cattle. The complaint known as the "grease" in cows is attended by a decrease of the alkaline salts, of the casein and the fat (Herheyer). In the vaccinia of cows the milk is strongly alkaline, and sugar is almost absent (Brewer).

Garget.

*Garget* is a name under which is included more than one affection of the udder of milch cows, which is attended by the secretion of milk having a viscid, ropy or stringy appearance containing pus and blood.

The outbreak of diphtheria in North London in 1878 was supposed by Mr. W. H. Power, one of the Medical Inspectors of the Local Government Board, to be connected with the employment of milk contaminated with the secre-

[1] *Lancet*, July 24, 1886. [2] *Op. cit.*

tions of animals thus affected, but the chain of evidence was incomplete. Such milk is, of course, quite unfit for use, although it is probable that the milk of cows affected with the milder forms of the complaint is consumed without ill effects. Dr. Thursfield, in a case of garget where a large quantity of milk was confiscated, in consequence of the presence of pus and blood in it, employed the Guiacum test of the late Dr. Day of Geelong, as confirmatory of the existence of blood in the milk. The addition of a few drops of the tinct. guaiaci, followed by a little of the solution of peroxide of hydrogen, form, when used in conjunction, but not apart, a persistent blue tint, diagnostic of the presence of blood.

A complaint amongst children, known as milk-sickness, has prevailed in America, caused by the unboiled milk of cows that have fed on the *Rhus toxicodendron,* which produces in these animals a complaint termed "the trembles." The milk of goats that have fed on the *Œthusa cynapium,*[1] and on euphorbiaceous[2] plants, has been found to be poisonous.

Milk tainted by diseased animals.

Milk is apt to be tainted with the excretions and secretions of man and other animals in a state of disease. The excretions from the intestinal canal in enteric fever, the dispersed dust of the skin after scarlet fever,[3] the secretions of the throat in diphtheria, the discharges from cattle suffering from foot-and-mouth disease or garget and from the nasal cavities of horses affected with glanders, are one and all liable to obtain access to milk.

[1] *British Medical Journal*, September 6, 1873.

[2] *Medical Times and Gazette*, June 31, 1863.

[3] Mr. W. H. Power has recently produced a report ("Milk Scarlatina—Reports to the Local Government Board") in which he attempts to establish a causative relation between an outbreak of Scarlatina in West and North London, and the consumption of milk of cows infected by a disease characterized by vesicles and sores on the udder and a shedding in patches of the hair.

### *Milk contaminated by water polluted with Organic Impurities.*

Apart altogether from the great subject of the poisoning of milk by water contaminated with specifically infected excremental matter, and the still larger one as to whether enteric fever ever arises without such specific infection, the question often obtrudes itself, as to whether any disease ever arises from the admixture with milk of water containing an excess of organic matter.

Early in 1881 I had under my care two or three children and a servant in one family suffering from aphthous spots in the mouth, which after a time disappeared, but were followed in the children by a swollen and painful condition of the lips. The lips resembled raw beef, and yet presented at the same time a blistered appearance. The children seemed weak and poorly but not ill. Everything was tried that could be thought of to cure their lips, but nothing improved them. At length the attention of the household was attracted to the milk, from the fact that dirt was noticed floating in it visible to the naked eye. The milk, which was poor in quality, was manipulated by the help of the contents of a shallow well surrounded by a collection of farmyard filth. The water was not considered sufficiently good to drink, but was used in the dairy business. There was no foot-and-mouth disease amongst the cattle which furnished the milk. The milk supply from this dairy was stopped, and the milk from a dairy, adjoining which ran spring water out of a rock, was substituted. The change in the milk supply was attended by an immediate recovery—a result which no remedial measures were able to accomplish. Another family attended by a medical friend was similarly affected at the same time, who were supplied from the same dairy. A change of dairies was in this case attended by an immediate recovery. Unfortunately a microscopic examination of the milk, which presented no abnormal appearances, was alone made. Soon after the occurrence of these cases, viz. in April 1881, the remarkable epidemic at Aberdeen was announced of milk contamination, producing a peculiar form of disease in 89 out of 112 families, comprising 322 individuals, of which three died, supplied with milk from the dairy at Old Mill Reformatory School, near the city. The symptoms of the complaint, as described by Dr. Beveridge,[1] were, briefly, a period of incubation of 2 to 8 days, followed by a sharp attack of pyrexia (the temperature rising to a considerable height), and by a dangerous prostration; a succession of one or more attacks at intervals; swellings of the throat involving the glands in succession, and in some cases the deep lymphatics of the neck. It differed from local inflammation in the extreme severity of the constitutional symptoms, in its periodical recurrence at pretty regular intervals, and in the extreme prostration; whilst it was diagnosed from diphtheria by the absence of any diphtheritic or false membrance, and in its not being contagious. The water supply of the byre was contaminated with organic matter mainly of vegetable origin.

| Analysis by Mr Jamieson. | | | | |
|---|---|---|---|---|
| GRAINS PER GALLON. | | | PARTS PER MILLION. | |
| Total Solids. | Chlorine. | Nitrogen as Nitrates. | Free Ammonia. | Alb. Ammonia. |
| 4·7 | ·7 | ·5 | ·03 | ·21 |

Prof. Y. Cossar Ewart found in the milk during its period of infective activity organisms "morphologically not unlike bacillus anthracis, having the same life-history." Rats inoculated with this milk and a cultivation

[1] "On a peculiar form of Disease arising from Milk Contamination."

of it containing these bacilli, died in from 15 to 20 hours. Pus obtained from an induration in the neck of one of the patients, which ended in suppuration, was found to contain these bacilli, and a rat inoculated with this pus died, and these bacilli were discovered in its tissues. These observations were safe-guarded with control experiments.[1]

The milk when chemically examined by Prof. Brazier yielded no abnormal results, but possessed a somewhat rank odour. The amount of milk consumed by the customers and inmates of the Reformatory was daily in excess of the actual yield of the cows by 12 imperial gallons, but this fact was partly explained by the purchase of small quantities from the neighbouring farmers.

The conclusions of the Commissioners, medical and legal, were :—

1. That the epidemic was caused by poisonous organic matter contained in the milk;

2. That the milk when taken from the cows was innocuous;

3. That poisonous organisms were contained in the cistern[2] in the byre, and in the water passing through the cistern, and were thence communicated to the milk.

This epidemic of Aberdeen bears a striking similarity to the epidemics of "false diphtheria" which the author has seen in Essex, a disease which was described by him in 1878, and which appeared to spread through the medium of water polluted with organic matter.[3]

[1] "On a new form of Febrile Disease associated with the presence of an organism distributed with milk," in *Proc. Royal Socy.*, No. 215, 1881.

[2] The detailed Reports of Profs. Ewart and Brazier do not prove that the poisonous bacillus or its spores were discovered in the water. It is no doubt a matter of regret that the water with which the milk cans were rinsed was not submitted to cultivation experiments similar to those to which the milk was subjected.

[3] *A Dozen Papers on Disease Prevention*, published by J. and A. Churchill.

# APPENDIX

## DISTILLED WATER AND CHEMICALS.

It is very important to be well supplied with an ample quantity of recently distilled water, free from ammonia, and to be enabled to prepare it oneself expeditiously and cheaply. The distilled water sold in chemists' shops is perfectly worthless for analytical purposes when it is necessary to estimate quantities of ammonia, for commercial distilled water is simply water freed from the greater part of its saline matters. It generally contains more or less ammonia. The analyst simply requires a large glass retort and a zinc vessel containing a worm to act as a condenser when full of water. The best water to use for distillation is the purest spring water. If such water is not conveniently obtainable in abundance, the purest water which contains the least amount of saline matter should be selected. Some analysts add a little carbonate of soda to the water which they distil. It is better to boil the water in a glass than in a metallic vessel, for the saline residue which lines its sides can be more readily removed by an acid from glass. The first[1] and last portions of the retort of water which we distil should be rejected. We should not begin to collect the distilled water until it passes over quite free from ammonia, which can easily be ascertained by treating (say 50 c. c.) with 2 c. c. of Nessler test. Distilled water will generally give off some little ammonia if re-distilled, so difficult is it to get rid of all traces of this body. If it is requisite to procure water of the greatest purity, it is necessary to distil twice-distilled water with alkaline permanganate of potash, taking care that this salt when dissolved is perfectly free from ammonia. If this solution cannot be guaranteed to be thus exempt, it should be boiled for a short time previous to employment.

Distilled Water.

[1] This impure distilled water will be found to be very useful for water baths.

Purity of chemicals.

All solutions and chemicals should be of the greatest purity. Chemicals adapted for analytical purposes are sold by Messrs. Hopkins and Williams of Cross Street, Hatton Garden, London. The chemicals of Kahlbaum of Berlin are obtainable through Messrs. Burgoyne, Burbidges and Co. of Coleman Street, London. The Medical Officer of Health should prepare his distilled water, and all his standard solutions, except the Nessler reagent, for the reason specified on page 216. If he wishes to avoid the labour of making the standard solutions, he can procure them from Sutton of Norwich. The apparatus may be procured from Messrs. Townson and Mercer, Bishopsgate Street; Messrs. Cetti and Co., Brooke Street, Holborn; F. W. Hart of Kingsland Green; Messrs. Burgoyne, Burbidges, and Co. of Coleman Street; Messrs. J. Allen and Co. of Marylebone Street, London; and from Dr. H. Rohrbeck, 100 Friedrich Strasse, Berlin.

## LIST OF APPARATUS REQUISITE.

Apparatus.

*Retorts* (2).—Capacity rather more than $1\frac{1}{2}$ litre (about 48 ounces), one being for distilling sample, and the other for making distilled water.

*Liebig's Condensers* (3).—A large-sized one for ammonia process, a medium-sized one for Thorp's process for nitrates, and a small glass condenser for air analysis.

*Nessler Glasses* (10).—Marked to measure 50 c. c.

*Bell Metal Clamps* (3).—Expensive but indispensable.

*Burette.*—Capacity 50 c. c., graduated to $\frac{1}{10}$ths, with an accurately ground tap at one end and a glass stopper at the other.

*Burette.*—Capacity 5 c. c., the $\frac{1}{10}$th divisions being widely apart.

*Burette graduated in Grains.*

*Burette.*—100 septems, graduated in 100 parts.

*Galvanized Iron Retort Stands* (3).

*Gmelin's Wash Bottle.*—Medium size.

*Measuring Flasks.*—1 litre, 500 c. c. = $\frac{1}{2}$ litre, 250 c. c., 100 c. c., 70 c. c., 50 c. c., 25 c. c., and $\frac{1}{2}$ deci-gallon flask.

*Bunsen's Burners* (3).—One large, one small, one small with chimney.

*Analytical Balance*, in a glass case, with weights. The balances of Becker of New York are good and cheap. The weights made by Oertling are unsurpassed.

*Flasks* with welted mouths for corks.

*Indiarubber Corks.*—Various sizes.

*Filter Papers*, cut, German, which will not permit the precipitate of sulphate of baryta to pass through them.

*Soxhlet's Fat Extractor.*

*Platinum Dish*, of a capacity of about 100 c. c.

" *Crucible.*

" *Dishes* (3) small, for milk.

*Berlin Evaporating Dishes* (6), about 4 inches in diameter. A nest of dishes of a smaller size.

*White Porcelain Tiles* (2), about 5 inches square.

*Pipette*, with bulb in centre, and marked with file to indicate 2 c. c. for Nessler test.

" with bulb of capacity of 5 c. c. for milk.

*Pipettes* (3), of the capacity of 5 c. c., and graduated to $\frac{1}{10}$ths; one for nitrate of silver sol., another for preparing ammonia standard, and the third necessary in the quantitative determination of nitrates and nitrites.

*Pipette* (1) of the capacity of 10 c. c., and graduated to $\frac{1}{10}$ths for the standard soap solution.

*Pipettes* (2 or 3).—Graduated in septems and grains.

*Steam Condenser* for preparing distilled water, made of zinc, containing worm. It is filled with cold water. A retort, in which the water is boiled, should be connected with it.

*Beakers.*—A nest of different sizes.

*Adapters* (2).

*Funnels.*—One large and several small.

*Sample Bottles* (36).—Stoppered. Made of stout glass.

*Tripods* (2).

*Wire Gauze* (2).—Pieces of coarse and fine, each about 4 inches square.

*Pipe Triangles* (6).

*Copper Water Baths* (2).

*Receiver* for estimation of nitrates, which resembles a very large Nessler glass. Marks with file should indicate 50 c. c. and 100 c. c.

*Glass Rods* of different sizes.

*Tongs* for laboratory.

*Watch Glasses.*

## RULES FOR INTERCHANGE OF DIFFERENT EXPRESSIONS OF RESULTS OF ANALYSIS.

To convert parts, per 100,000, into grains per gallon (=parts per 70,000), multiply by ·7.

To convert grains per gallon (=parts per 70,000) into parts per 100,000, divide by ·7.

To convert parts per million, or milligrammes per litre, into grains per gallon, multiply by ·07.

To convert grains per gallon into parts per million, or milligrammes per litre, divide by ·07.

To convert parts per 100,000 into parts per million, or milligrammes per litre, multiply by 10.

To convert parts of nitric acid into parts of ammonia, multiply by 17 and divide by 63.

To convert parts of ammonia into parts of nitric acid, multiply by 63 and divide by 17.

To convert parts of nitric anhydride into parts of ammonia, multiply by 17 and divide by 108.

To convert grammes per litre into grains per gallon, multiply by 70.

To convert parts of free ammonia, or ammonia from alb. ammonia, into parts of nitrogen, multiply by 14 and divide by 17.

To convert "nitrogen as ammonia" into free ammonia, multiply by 17 and divide by 14.

To convert "nitrogen as alb. ammonia" into alb. ammonia, multiply by 17 and divide by 14.

To bring cubic inches into gallons, multiply by 40 and divide by 11,091, or multiply at once by ·003607.

## RULES FOR CONVERSION OF DEGREES OF ONE THERMOMETER SCALE INTO THOSE OF ANOTHER.

Fahr. into Cent.—Divide by 9, multiply by 5 and deduct 32.
Cent. into Fahr.—Multiply by 9, divide by 5 and add 32.
Fahr. into Réaumur.—Divide by 9, multiply by 4 and deduct 32.
Réaumur into Fahr.—Divide by 4, multiply by 9 and add 32.

---

## METRICAL WEIGHTS AND MEASURES.

### *Weight.*

1 *milligramme* = ·015432 grain.

1 *centigramme* = ·15432 grain.

1 *decigramme* = 1·5432 grains.

1 *gramme* = 15·432 grains = weight of a cubic centimetre of water at 39·2° Fahr.

1 *kilogramme* = 15432·348 grains = 1000 grammes = 2·2 lbs. (Av.)

### *Capacity.*

1 *cubic centimetre* = 15·432 grains = 16·9 minims = ·06103 cubic inch.

1 *litre* = 15432·348 grains = 1 pint 15 ozs. 2 drs. and 11 minims = 61·027 cubic inches = 1000 cubic centimetres = 35·3 ounces = ·22 gallon = ·035316 cubic foot = 1000 grammes = 1,000,000 milligrammes.

1 *ounce* = 28·35 cubic centimetres = 1·733 cubic inch.

1 *cubic inch* = 16·4 cubic centimetres.

1 *cubic foot* = 28·31 litres = 1728 cubic inches.

1 *cubic metre* = 1,000,000 cubic centimetres = 1,000,000 grammes = 1,000,000,000 milligrammes = 1000 litres = 35·3 cubic feet.

1 *pint* = 34·59 cubic inches.

### *Length.*

English Inches.

1 *millimetre* = ·039.

1 *centimetre* = ·39.

1 *decimetre* = 3·94.

1 *metre* = 39·37 = 3·28 feet.

1 *kilometre* = 1000 metres = 1094 yards = ·62 mile = 3280 feet and 10 inches.

*Area.*

1 *square millimetre* = ·0015 square inch.

1 *square centimetre* = ·154 square inch.

1 *square metre* = 1542 square inches = 10·76 square feet.

*N.B.*—The Latin prefix indicates division, and the Greek prefix indicates multiplication.

| | |
|---|---|
| 1 *Septem* | = 7 grains = " decimillen." |
| 1 *Pound* (Av.) | = 7000 grains. |
| 1 *Gallon* (Imp.) | = 70,000 grains. |
| 1 *Decem* | = 10 grains. |
| ½ *Deci-gallon* | = 3500 grains. |

1 *minim* weighs ·91 grain.

1 *fluid drachm* weighs 54·68 grains.

1 *fluid ounce* weighs 437·5 grains.

# INDEX

## A


ABERDEEN, outbreak at, and milk, 545.
"Absorbers," or "barboteurs," 319.
Aeroscope, Pouchet's, 297.
    pump, 298.
Ages, mortality at different, 402, 403.
Ague and seasonal meteorology, 391.
Air analysis, 219.
    ,, pulverization of water, method of, 322
  atmospheric pressure of, 407.
  biological examination of, 340.
  carbonic acid in, 227.
  carbonic oxide in, 247.
  chemical examination of, 310.
  churchyard, 268.
  composition of, 224.
  compressed, therapeutic employment of, 377.
  continual pollution of, 246.
  copper in the, 343.
  dust in atmospheric, 294.
    ,, collector of Dr. Cunningham, 298.
  electrical state of the, 434.
  hygrometric state of the, 422.
    ,, ,, and health, 369.
  impure and respiratory diseases, 283.
  impurities suspended in, 258.
  lead in the, 343.
  marsh, 268.
  microscopic examination of, 301.
  nitrous acid in, 357.
  observations in Glasgow, 318.

Air of our houses, 270.
,, ,, its deterioration, 273.
,, rooms, 372.
,, streets, 277.
organic matter in, 232, 312.
oxygen in, 225.
peroxide of hydrogen in, 357.
pressure of the, 374.
purity of, 221.
solid bodies in, 292.
standard of pure, 285.
subsoil, 267.
temperature of the, 411.
,, ,, and health, 362.
washings, 236, 314.
Ammonia, 91.
albuminoid, estimation of, 44.
excess of in pure waters, 92.
free or saline, estimation of, 40.
standard solution of, 217.
Animal impurities in air, 258.
Animals, diseases of, 447.
Anthracic diseases and meat, 458.
,, ,, and milk, 540.
Anti-cyclones, 360.
Aphthous fever, 536.
Apparatus, chemical, requisite, 548.
steaming, 78.
Arsenic in the air, 343.
in the articles of the household, 261.
in wall papers, 260, 344.
,, Davy's sodium amalgam test for, 347.
,, Marsh's test for, 346.
Asparagus, poisonous, 486.
Aspirators, 317, 319, 320.
Asthma and seasonal meteorology, 396.

## B

Bacillus Anthracis, 306.
Comma-shaped, 306
Tuberculosis, 306.
Bacteria in air, 307.
in water, 161.
of a hospital, 308

Barley, testa of grain of, 501.
Barometric pressure, its determination, 407.
Baryta water, store bottle for, 338.
Bath chemical for condemned flesh, 485.
Bench marks, 406.
Biological method, Air, 340.
,, ,, Water—Frankland's, 76.
,, ,, ,, Koch's, 74.
,, ,, ,, Smith's, 75.
Braxy meat, 460.
Bread, adulterations of, 509.
alum in, 510, 516.
examination of, 508.
,, chemical, 513.
,, microscopic, 509.
foul and machine-made, 509.
lime and magnesia compounds in, 511.
sulphate of copper in, 512.
Bronchitis and seasonal meteorology, 396.
Brucine test for nitric acid, 109.
"Bunt," in corn, 491.

C

Carbonic acid in air, 240.
,, estimation of, 328.
,, ,, Abney's method, 332.
,, ,, Household ,, 333.
,, ,, Minimetric ,, 335.
,, ,, Montsouris ,, 329.
,, ,, Pettenkofer's ,, 328.
,, ,, Wanklyn's ,, 331.
oxide in air, 247.
test for, 252.
Cattle plague and meat, 457.
,, ,, and milk, 535.
Certificate of W. A. used by analysts, 214.
,, ,, ,, health officer, 213.
Cesspool filth, diagnosis of, in water, 210.
Chemicals requisite, 548.
Chlorine, determination of the, 135.
Cholera and seasonal meteorology, 395.
Codfish, poisonous, 481.
Coke as a fuel, 249.
"Cold spells," 365.
Colonies, enumeration of, 84.

Colour test for water, 20.
Copper in water, 159.
Corn, examination of, 489.
Cover glass preparations of water, 161.
Cyclones, 359.

## D

Damp Chamber, 83.
Darnel grass, testa of grain of, 506.
Data on which to form an opinion respecting a water, 195.
Density of population and mortality, 223.
Diarrhœa and dysentery, and seasonal meteorology, 391.
    autumnal, 392.
Diphtheria and poultry, 479.
    and seasonal meteorology, 398.
Distilled water, preparation of, 547.
District standards, 196.
"Drop cultures," 162.
Dublin, temperature of, 362.
Dust of the air, 301.
Duties of medical officer of health, 4.
Dysentery and seasonal meteorology, 395.

## E

"Ear Cockle" in corn, 490.
Edinburgh, temperature of, 362.
Electricity, atmospheric, 434.
    ,, ,, positive and negative, 439.
    ,, ,, water-dropping collector of, 436.
Electrometer quadrant, 436.
Enteric fever and milk, 520.
    ,, ,, and seasonal meteorology, 390.
Ergot of rye, 490.
Erysipelas and seasonal meteorology, 399.
Excremental filth in air, 255.

## F

Farinaceous foods, nutritive values of, 494.
Fat of milk, estimation of, with Soxhlet's extractor, 530.
Fever and seasonal meteorology, 389.
    surgical, 381.
Fish, inspection of, 480.
Fish-like odour of waters, 17.

Flesh, condemned, destruction of, 484.
Flour, acarus farinæ in, 500.
  alum in, 497.
  examination of, 493.
    ,, chemical, 495.
    ,, microscopic, 499.
  metallic poisons in, 499.
Fluke in meat, 475.
Food, the purity of, 443.
Foot-and-mouth disease, and meat, 456.
  ,, ,, ,, and milk, 536.
Forchammer process, an improved quantitative, 38.
Frankland and Armstrong process, 53.
  ,, ,, and Wanklyn processes compared, 63.
Fruit and vegetables, inspection of, 486.
Funnel, hot water for filtration, 77.
Furnishing materials, poisonous, 261.

## G

GAME, inspection of, 478.
Garget, 542.
Gases, poisonous, defiling air, 257.
Glasgow, observations on air in, 318.
Grandval and Lajoux's process for nitric acid, 120.

## H

HADOW-HORSLEY'S test for alum in bread, 517.
Ham, poisonous, 477.
Hardness, determination of the, 139.
Hard waters, influence on health, 142.
Health and extremes of temperature, 364.
  and low temperatures, 364.
Height, corrections for, to barometric readings, 409.
Heisch's test, 24.
Horsley's test for nitrates and nitrites, 106.
Hospitals, modern pattern, 374.
Hydrophobia, and seasonal meteorology, 399.
Hygrometer, Lowe's, 426.
  Mason's, 424.
Hygrometry, 422.

## I

INCUBATOR, 82.
Indigo process for estimating nitrates, 112.

Insanity and seasonal meteorology, 400.
Intermittent fever and seasonal meteorology, 391
Iron in water, 157.

K

"Keeping Powers" of a water, 19.
Knife-grinders of Sheffield, 262.
Koch's biological method for the examination of water 74.
Kubel's permanganate of potash process, 27

L

Lamb, immature, 476.
Lead in articles of the household, 262.
Lead in water, 156.
London, mortality of, 402.
    temperature of, 362.

M

Magnesia, determination of the, 145.
Measles and seasonal meteorology, 384.
"Measly" meat, 468.
Meat and accidents, 463.
    characters of good and bad, 450.
    diseased, arguments for and against its employment, 463, 464.
    ,, resurrection of, 484.
Memoranda for water analysts, 185.
Metallic impurities in air, 258, 343.
Metals, poisonous, determination of, 154.
Meteorological observations, registration of, 439.
Meteorology and health, 358.
    seasonal and disease, 380.
Metrical weights and measures, 551.
Micro-organisms, 305.
    in London waters, 85.
Microscopic examination of air, 301.
    ,, ,, water, 161.
Microzyme test, 25.
Milk, abnormal, 533.
    and affections of mouth and throat, 544.
    and typhoid fever, 520.
    blue, 524.
    changes in taste and odour of, 525.
    containing tubercle bacilli, 542.

Milk, examination of, 520.
,, chemical, 525.
,, ,, estimation of fat, 528.
,, microscopic, 522.
excretions and secretions of diseased animals, tainted with, 543.
fever, 461.
"fore," 533.
of diseased animals, 535.
organic impurities, contaminated with, 544.
physical peculiarities of, 523.
reddish, 524.
scarlatina, 543.
Society of Analysts, processes and standards, 527.
"whole," 533.
yellow, 523.
Mineral impurities in air, 258.
Miners, Cornish, mortality of, 258.
Mistakes of water analysts, 177.
Montsouris Observatory, apparatus employed at, 317, 341.
,, ,, observations on air at, 228, 304, 307.
Mortality and density of population, 222.
Mortality at different ages and seasonal meteorology, 402, 403.
of the sexes, ,, ,, 404.

## N

Nessler reagent, 216.
Neuralgia and meteorology, 360.
New York, mortality of, 403.
Nitrates and Nitrites, qualitative examination for, 106.
,, ,, quantitative ,, ,, 111.
,, ,, utility of the estimation of the, 100.
Nitric acid, the Brucine test for, 109.
,, ,, the sulphophenic acid process for the estimation of, 120.
Nitrogen, as nitrates and nitrites, 95.
,, ,, ,, in different strata, 98.
,, ,, ,, objections to estimation of, 99.
,, ,, ,, rules for guidance in the estimation of, 122.
Nitrous acid, the metaphenylene diamine test for, 110.
,, ,, the napthylamine hydrochloride test for, 357.
,, ,, the potassium iodide and starch test for, 110.

## O

Oat, testa of grain of, 506.
Odour, cucumber, of water, 18.
fish-like, of water, 17.

Odour of different diseases, 303.
Old age and seasonal meteorology, 405.
Operations, time favourable and unfavourable for, 382.
Opinion, formation of, as to a water, 188.
Ordnance bench marks, 406.
Organic nitrogen and carbon, 56.
matter in air, 232.
,, Remsen's collector of, 321.
,, Smee's ,, 322.
matter in water, 13.
,, recent or decomposing, 205.
Overcrowding and disease, 282.
Oxygen dissolved, estimation of, 86.
process, 26.
Ozone, estimation of, 349.
test papers, fallacies of, 352.
Ozonometry, errors of old method, 355.

## P

PARAFFIN in drinking water, 17.
Parturient apoplexy and meat, 461.
Parturition or milk fever, and milk, 542.
Peaty water, diagnosis of a, 205.
,, ,, objections to, 190.
Pericarditis and seasonal meteorology, 401.
Permanganate and caustic potash solution, 218.
of potash process, *qualitative*, 26.
,, *quantitative*, 26.
,, ,, an improved, 38.
,, ,, Drs. Letheby's and Tidy's, 28.
,, ,, Drs. Woods' and F. de Chaumont's, 33.
Phosphates, determination of the, 150.
Phthisis pulmonalis, 279.
,, ,, and seasonal meteorology, 398.
Plate cultivations, 81.
Pleuro-pneumonia and meat, 454.
Pneumonia and seasonal meteorology, 396.
Poisoned animals, meat of, 482.
Poisonous gases, 257.
Pond water, 190.
Pork, poisonous, 477.
Poultry, game, etc., inspection of, 478.
Previous sewage contamination of water, 57.

Processes of water analysis compared, 63.
,, ,, ,, value of, 71.
Provisions, tinned, 488.
Puerperal fever and seasonal meteorology, 400.
Putrefactive processes, defiling air, 254.

## R

Radiation, Solar, 367.
Rain, albuminoid ammonia in, 239.
-band, 428.
guage, 423.
water, 11, 207.
Rainey's bodies in meat, 474.
Record of analyses, 175.
Report, preparation of, 212.
Rheumatism and seasonal meteorology, 401.
Rinderpest and meat, 457.
and milk, 535.
Rust in corn, 492.

## S

Samples of water, collection of, 170.
Sarcinæ, 306.
Sausages, poisonous, 477.
Scarlatina and seasonal meteorology, 387.
Scarlet fever and meat, 462.
Sewage emanations, defiling air, 255.
in water, 210.
Sewer gas, pollution of water with, 137.
Sexes, mortality of the, and seasonal meteorology, 404.
Silver, nitrate of, standard solution of, 218.
Smallpox and seasonal meteorology, 383.
of sheep and meat, 457.
Smell of a water, 14.
"Smut" in corn, 491.
Soap, standard solution of, 216.
Soil, porosity of, 264.
Solar radiation, 367.
Solid bodies in air, 292.
Solid residue, determination of, 124.
,, ,, ignition of, 128.
Solutions, standard for water analysis, 216.
Spectroscope in hygrometry, 427.

Splenic apoplexy and meat, 458.
Standard of pure air, 224.
,, ,, water, 10.
"Standards, district," 196.
Starches, various kinds of, 500-505.
Starch tests for nitrous acid, 110.
Sterilizer, hot air, 79.
steam, 78.
Stoves, cast and wrought iron, 250.
Sulphates, determination of the, 147.
,, ,, ,, Houzeau's process for the, 148.
Surgical fever and meteorology, 381.
Swine plague and meat, 462.

## T

Teeth, caries of the, 495.
Temperature, corrections for, to barometric readings, 409.
extremes of, 364, 379.
its determination, 411.
management of children and, 367.
Thermometer scales, conversion of, 551.
solar max., 414.
stands, 412.
terrestrial min., 415.
Thermometers, markings of degrees of, 420.
verification of, 417.
Thorp's process for estimation of nitrates, 114.
,, ,, expeditious modification of, 119.
Time occupied in performing an analysis, 172.
Tinned provisions, 488.
Trichina spiralis and meat, 469.
,, ,, modes of detection of, 473.
Trichinosis and enteric fever, 471.
Tubercular diseases and meat, 461.
,, ,, and milk, 540.
Typhoid fever and meat, 462.
,, ,, and milk, 520.
,, ,, and seasonal meteorology, 390.
Typhus fever and ,, ,, 389.

## U

Urine in water, 209.

## V

VALUATION tables, 196.
Vapours, injurious, 257.
Veal, immature, 476.
Vegetable impurities in air, 258.
Ventilation, 284, 288.
absence of, 278.
through walls, 287.
Vibrio tritici in corn, 490.
Volatile matters, amount of, in a water residue, 132.

## W

WALL Papers, 260, 344.
Wanklyn, Chapman, and Smith process, 39.
Water analysis, 7.
,, comparison between processes of, 63.
,, value of processes of, 71.
animal organic matter in, 203.
colour of a, 20.
good artesian well, 11.
,, rain, 11.
,, shallow well, 11.
,, spring, 10, 201.
microscopic examination of a, 161.
polluted by sewage, 210.
,, by sewer gas, 137, 206.
,, by urine, 209.
suspicious, 201.
vegetable organic matter in, 204.
wholesomeness of a, 9.
Waters, different classes of, 11, 58.
Weevil in corn, 489.
Wheat midge, 490.
testa of grain of, 501.
Whooping-cough and seasonal meteorology, 386.
Wigner's, Mr., valuation table, 196.
Wind, direction of the, and health, 378.
,, ,, and strength of the, 430.
Woolsorters' disease, 309, 459.

## Z

ZINC in water, 159.
Zymotic test, 25.

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