MANUALS

OF

HEALTH

WATER AIR AND DISINFECTANTS

W. NOEL HARTLEY, F.R.S.E. F.C.S.

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MANUALS OF HEALTH.

WATER, AIR, AND DISINFECTANTS.

BY

W. NOEL HARTLEY, F.R.S.E., F.C.S.,

DEMONSTRATOR OF CHEMISTRY, AND LECTURER ON CHEMISTRY IN THE EVENING CLASS DEPARTMENT, KING'S COLLEGE, LONDON.

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WATER.

WATER, AIR, AND DISINFECTANTS.

CHAPTER I.

WATER, ITS PROPERTIES AND COMPOSITION.

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THE Patriarchs of old dug wells for the use of themselves and their herds and flocks. Those they guarded jealously, and their servants sometimes fought for the possession of the waters, and disputed the right of others to make use of them. Thus did the servants of Abraham and Abimelech fight for the well which Abraham had dug, until an agreement made between them at Beersheba set the matter at rest.

The traveller, weary with toil through the day, lights his camp fire in the evening by some running stream or spring. The Arab in his desert wanderings seeks a resting-place beside one of those fountains so rare in sandy plains. Most ancient towns are situated on a river or lake, or near to where a river formerly ran. Where such natural provision is lacking, the want is supplied by the knowledge and skill of man. The ruins of ancient Roman cities contribute to the neighbouring valleys as a prominent feature in the landscape, a pile of massive masonry which served in former times to convey water to the citizens from districts many miles distant. Some of these aqueducts were magnificent structures, carried across valleys on arches more than 100 feet high, hewn through rocks, and tunnelled through mountains. The water thus brought from afar was received and stored in large reservoirs, some for supplying private houses, others for public use. While every care was taken that the water should not be wasted or stolen, the Government most wisely distributed large quantities for the public good, to the baths, the fountains, ponds, the circus, and the amphitheatres. The water-works were placed under the care of a *præfectus aquarum* or *curator*, under whom was employed a body of four or five hundred slaves. Their occupation was to take care of the reservoirs, and attend to the pipes and masonry; whilst some of them acted as water-carriers. The whole formed a complete and very efficient system of water-supply, for the common good of the people and the healthy condition of the city. There was a provision of pure water for drinking and washing, for bathing, for beautifying the public places with fountains, for the amusements and recreations of the people, for the use of various trades, and for flushing the sewers and watering the streets. The quantity supplied amounted to about 300 gallons per day for each head of the population. Though the luxury of modern Britain is supposed at the present time to be approaching that of ancient Rome, we cannot charge the municipal authorities of our cities with extravagance in matters relating to the public health, the beautifying of public places, or the recreations for the populace. Water-works nowadays are like other works of the nineteenth century, things made to pay; they are, with few exceptions, establishments built by private speculators. One of our chief necessities in life has, by the influence of civilization, become an article of sale, subject to commercial influences, deterioration in value, and even adulteration and unwholesomeness. What was, in the simple days of old, every man's property for the trouble of fetching, is now an article of trade. Men are induced or obliged by the struggle for existence, to place their dwellings in such localities, and to live so closely packed together, that there is a permanent deficiency in the natural supply of wholesome water. Communities grow careless, and trusting to commercial enterprise for an artificial supply, place themselves in the unsatisfactory position of being obliged to take whatever in quantity and quality is supplied to them. A certain supply of pure water is absolutely necessary for the healthy life of each individual—without it, each person is liable to be a source of danger to all his neighbours, hence it becomes the duty of the community to take charge of its own water-works. Certain town corporations do this; for instance, that of Manchester.

The philosophy of the Ancients classed water as one of the elementary constituents of nature. The laborious investigations of chemists, pursued in various directions, have yielded an immense number of facts, and these show that all natural and artificial substances whatever consist of three kinds, viz:—elementary or simple bodies, compounds or combinations of two or more elementary or simple substances, and mixtures. Simple bodies are such as cannot be analyzed or pulled to pieces chemically; examples of such are metallic iron, copper, charcoal, sulphur, gold, silver, quicksilver or phosphorus. By no means can we split up any of these things into two or more substances; if we could they would be either compounds or mixtures. Simple substances have the power of combining together in such a way that they lose their identity or individuality, some, if not all, of their individual properties becoming thus entirely altered, and new properties being developed. The different proportions in which the simplest forms of matter are capable of combining are fixed and definite; thus, each substance has appropriated to itself a certain proportionate weight or value, and these values are of mathematical exactitude, more certain and unchangeable than the fact that twelve pence make a shilling, or twenty shillings a pound. Thus, two parts by weight of hydrogen gas and sixteen parts by weight of oxygen gas combine and form the liquid compound water. If we take measures of the gases instead of weights, we find that two measures of hydrogen unite with one measure of oxygen to form water. Hence the proportional numbers which regulate the combination of hydrogen and oxygen may be called 2 and 16, or 1 and 8, parts by weight, or 2 and 1 parts by measure. The study of other kinds of combinations, however, leads chemists to fix the combining proportion of hydrogen to be 1, and that of oxygen 16, so that we say that water consists of two combining weights of hydrogen $=2$, united to one combining weight of oxygen $=16$. Again, 12 parts by weight of carbon, or charcoal, can combine with 32 parts by weight of oxygen, and as other considerations lead one to fix the combining proportional weight of carbon at 12, and that of oxygen at 16, therefore we say that one proportional combining weight of carbon $=12$, can be united to two proportional weights of oxygen = twice 16. This latter combination is carbonic acid, commonly so-called, the gas which forms the gas-bubbles or froth on beer, ginger-beer, and champagne, and the gas which escapes from soda-water. From no other proportion of their constituents can these substances be formed, and no matter in which of the many ways they can be produced, the proportions of their constituents are never varied, consequently their properties are always the same, never differing in any respect if the compounds are pure, that is to say, unmixed with other substances. Pure water, therefore, is always precisely of the same composition, absolutely and exactly of the same properties, and, consequently, its effect on the animal organism when in a healthy state will always be the same. It is evident, then, that a vast distinction exists between mixed and combined substances, because a mixture can be made in any proportions at will, like a bottle of medicine, or a bottle of sauce, and the mixture varies in properties precisely in accordance with predominance of certain constituents. Such water, however, as we are in the habit of using is sometimes possessed of poisonous properties, as will be seen hereafter, because the presence of hurtful matters is not always self-evident. Furthermore, it is a remarkable fact that scarcely any one has seen perfectly pure water. Now although this is strictly true, there are impurities and impurities; there are those which are harmless and which render water palatable, and there are those which are noxious and which may yet go undetected by colour, taste, smell, or even by all but the most delicate chemical tests. The germs of disease may elude even the most searching powers of the microscope, and yet be imbibed in a glass of water. Fortunately there are always found to occur collateral impurities, and the aid of the chemist can certainly help to form an opinion as to when a water is safe for domestic use. By analysis or the separation from the water and splitting up of the impurities into their constituent substances, likewise by ascertaining the amounts of them present, knowledge is obtained which enables us to discriminate between noxious and wholesome waters.

On the surface and in the crust of the earth are found mixtures of elementary and of compound substances. Compounds may be divided broadly into organic and mineral matters. Organic matter consists for the most part of substances which constitute the organism and tissues of living things, such as starch, sugar, gum, and woody fibre in plants, and albumen—a substance resembling white of egg—or gelatine and fat in animals. These are invariably compounds of which carbon forms an essential constituent, and they possess the property of being combustible.

By mineral matter is meant such substances as are not organic or carbonaceous, that is, capable of being carbonized or charred. All kinds of matter, and especially mineral matters, may be classed, generally speaking, into acids, bases, and salts. Many kinds of earth are salts, as, for example, common salt, gypsum, and Epsom salts. These are neutral substances, or bodies exhibiting no very decided chemically active properties. Some earths are the bases of salts, as, for instance, lime and magnesia ; others partake of acid properties, as, for instance, silica, known in an insoluble form as sand.

The union of a base with an acid results mainly in the formation of a salt. Two of the acid substances found most abundantly in nature are carbonic acid and silica or silicic acid ; the former is a gas, the latter a solid substance, capable under certain circumstances of dissolving in water.

When carbonic or silicic, as examples of acids, act on bases, as, for instance, lime or magnesia, respectively, the salts which may result are called carbonate of lime or silicate of magnesia. The properties of carbonate of lime are not those either of lime or of carbonic acid, they are new properties. In the same way, those of silicate of magnesia do not belong to silicic acid or to magnesia. Hence, a variety of combinations results in an increase of different substances, each with an invariable nature.

Water is absolutely necessary for the performance of the functions of nutrition, of growth, and reproduction in plants and animals. It is quite impossible to imagine a creature, whether animal or vegetable, with an active existence constructed in such a way and of such materials that no water need enter into its composition, keep moist its living tissues, and endow them with pliancy so characteristic of life. Life in a dormant condition only can apparently exist without moisture, such as, for instance, has lain within grains of wheat for long periods of something like a hundred years.

Except in a very few and rare cases, air is as necessary to the continuance of active vitality as water. Just as we cannot live without what we commonly call food, so is it impossible to live without a continued supply of water and air; and, therefore, these substances may be regarded as peculiar forms of food. They are odourless and tasteless, within the reach of all persons, and they require no special preparation for use. The fact that we seldom suffer long for the want of one or the other, has blunted our sense as to their really inestimable value. As already mentioned, water is a combination of hydrogen with oxygen. The largest proportion of water on the earth's surface was doubtless there when our existence first began; but besides this quantity, a constant succession of chemical changes has been and is continually going on, which takes the hydrogen from portions of water for the formation of vegetable tissues and sets oxygen free in the air; during the combustion and decay of these tissues the hydrogen and oxygen re-combine again, and water is re-formed. The burning of all ordinary combustibles and the respiratory process of animals throw water into the air in a vaporous condition. In each and every case the water is of the same composition and properties. The rays of the sun pouring down on the ocean warms the surface water, the winds sweeping across lick up the vapour and carry it high above to the colder regions of the atmosphere, there the chilling it undergoes in its expansion during ascent causes it to assume the form of mists and clouds. Ever changing in shape as they are swept about by the air-currents, apparently ever changing in colour as they reflect the beams of coloured sunlight, these vapourous masses descend, when the accumulations of moisture are great, and the condensation considerable, as dense and frowning clouds, so near the earth as to cap the mountain tops, their density increasing till they discharge themselves in showers of liquid rain. If a mist when descending is chilled below the freezing-point of water, feathery flakes of snow are the result; if, in the same manner, the rain-drops already formed are chilled, they fall as hail.

In all of these cases the water, whether as hail, snow, or rain, is the substance in a very nearly pure condition,—in such a state of purity as it can never preserve after having once touched the earth. Its contamination depends principally upon its power of dissolving almost all kinds of substances with which it comes in contact. It dissolves a considerable portion of the air as it descends; it likewise dissolves substances existing in the smoke of towns; it dissolves the hardest and most refractory rocks to some extent, and it supports in a floating or suspended condition various insoluble matters of very minute size. These latter are most frequently fragments of organic or carbonaceous matter, sometimes lifeless and harmless, at other times some of it is in the form of living and deadly organisms. The reason why the suspended matter in water is organic arises from the fact that such substances being, as a rule, lighter than mineral matters, do not subside so soon.

When water is cooled down to 32° Fahr. it has the property of changing its condition,—it assumes the solid state of ice. Under particular circumstances this change is accompanied by the formation of exquisitely-grouped crystals. If a good magnifying glass be used for the examination of single snow-flakes, which have fallen in very cold weather, they are frequently seen to be built up of regular cubical crystals, arranged as very beautiful geometrical patterns, taking the most fanciful and delicate forms. Ice, the solid condition of water, is specifically lighter than water in the liquid state, so that it always forms at the surface. This is a very remarkable fact, because if water, like most other substances, were to contract continually by cooling until it attained the solid condition, it would of necessity become heavier. Something unusual must occur to account for this. If water be placed in a tall cylinder at the ordinary temperature of 60° Fahr., and if the upper part be cooled, we find that the coldest portion always descends to the bottom of the vessel, but this descent ceases when the cooling has gone below 39° Fahr., and then the temperature above and below is uniform. Let the cooling be still continued, and a reversion of the conditions takes place,

—the colder water is found always at the top and the warmer at the bottom; finally, the upper portion freezes. The obvious conclusion is that at 39° Fahr. the liquid is denser, that is, it occupies less space, and is specifically heavier than at any other temperature. Above or below 39° Fahr. water expands; no matter whether it be heated or cooled, when at this point, it therefore becomes lighter. Hence, ice is always formed and floats on the surface of water. This peculiarity, which is shared by very few other substances, prevents lakes and rivers from being cooled to their freezing-point throughout their depth, and thus becoming solid masses of ice. They are protected by the coldest temperature being only at the surface.

Every one knows that water may be converted into vapour by boiling, but it is a less familiar fact that vapour arises from water at even very low temperatures. Circumstantial evidence that a large body of air moving over water can evaporate a considerable quantity is afforded by the rapid drying of a turnpike road by a brisk wind following rain.

When water in its return from the clouds as rain falls upon the earth a portion is absorbed at once by the soil, while another portion runs down the hill-sides and sloping lands in order to attain the lowest possible level or position of rest; it thus at first forms two or more mountain rills, which coalesce and form a stream or burn; the stream pursues its onward course, augmenting as its journey proceeds farther and farther from its source by the addition of a thousand little rills. It then, perchance, meets another stream, the two unite and form a river, the river in its turn traverses a country of a more even nature; its size is swollen by streams, the velocity of its progress diminishes, and it in its turn enters into union with waters comparable with itself in size and importance; it broadens out into a tidal stream, and finally loses its identity in a vast ocean. Occasionally its course is apparently interrupted for a time by the formation of a lake, but onward, through the lake, like the river Rhone through the lake of Geneva, its progress is traceable. The isolated mills and houses on the banks of streams are succeeded, as the waters grow, by hamlets and villages, and villages by towns of increasing size and importance, terminating in seaports. What alterations succeed each other in the contents of the water! First, the rainfall is charged with gases, then with the solid soluble portions of the soil; next with vegetable and the small amount of animal matters in surface drainage; houses and mills then partially pollute the waters; then towns pour their refuse into the rivers, until, finally, what with factories of various kinds, paper mills, bleach works, distilleries, mines, chemical works, and the sewage of vast populations, a foul and stinking ditch of vast dimensions, like the Clyde at Glasgow, pollutes the air above it.

What becomes of the water absorbed by the soil? It is first charged with carbonic acid, which endows it with increased solvent powers; carbonate of lime or chalk is dissolved, sulphate of lime or gypsum, sulphate of magnesia or Epsom salts, minute quantities of oxide of iron of alumina, and of silica are added to these impurities. It percolates the porous earth until it arrives at less porous strata, these, as they dip in certain directions, cause the water to accumulate at the lowest levels, and there it sometimes forms underground reservoirs, sometimes it is retained by porous materials, as chalk, greensand, or even red sandstone, and may be released by boring into such strata. Again, its accumulation beneath makes it force its way upwards, to pour itself, as a bright and sparkling spring, down a mountain's side, and thus to constitute the first-born condition of a mighty river.

CHAPTER II.

HARD AND SOFT WATERS.

Variation in the Character of Water according to the Rocks it springs from—Hard or Lime-containing Waters—Their Power of destroying Soap—Temporary and permanent Hardness—Method of estimating Soap-destroying Power—Tables illustrating the Hardness of various Waters—The Superiority of Soft Water for Cooking and Washing—Means of Softening Water.

When rain which has once fallen upon the earth has been collected again, it is found to have varied its nature according to the composition of the rocks with which it has come in contact. Water from the chalk and mountain limestone, or from the new red sandstone strata, has a harsh feeling when used for washing the hands; it throws the soap into a curd upon its surface. The soap rubbed on one's hands feels as if it were rendered useless, while, if we perform the operation with rain-water or distilled water, or even with the original water after it has been well boiled, a distinctly different effect is produced, and a very little soap seems to have a much greater cleansing power. Such harsh-feeling waters are called hard. It is observable that people who habitually have to make use of hard water take a very little in their hands, remove them from the basin, and rub them over and over with soap until a lather covers them; the hands are then rinsed in the water to get rid of the soap. The operation is differently performed by those who are accustomed to soft water; they are less particular about removing their hands from the basin when soaping them. The soap with soft water forms a mass of bubbles, a lather, in fact, on its surface in the basin, instead of a disconnected curd. What is the meaning of this? The soap is a combination of certain acids which, with glycerine, are the constituents of fat: these acids in hard soap are combined with soda. It is a common property of these combinations of fatty acids with soda to produce a lather with pure water. If, however, the water is not pure, but contains earthy ingredients, the soda is displaced by the earth, and the compounds resulting are not capable of lathering, but resolve themselves into a curd, which is destitute of detergent properties. In other words, those properties belonging to the soap which make it of use are destroyed. Hence, the hardness of water is truly a soap-destroying power. By means of boiling, and by the addition of soda, the earthy matters can be removed, and the water is softened, hence, the use of soda in washing. It follows, therefore, that the softer a water is the less soap and soda is used for washing purposes, and the more agreeable it is to the touch. Hardness of water is of two kinds, due respectively to different circumstances. For instance, that hardness which is remedied by boiling the water, is due to the presence in it of carbonic acid gas; this retains in solution a considerable amount of the carbonates of lime and magnesia, and boiling simply expels the gas, and separates the earths in an insoluble form. When the insoluble earths are separated they are apt to cake on kettles and boilers; in domestic utensils this is called *fur;* in steam boilers it forms a dense rock-like incrustation, which prevents much of the heat of the furnace-fire from reaching the water. Such a condition of hardness in water is called temporary. Permanent hardness, in contradistinction to this, is such as cannot be remedied by boiling; it is caused by such salts of magnesia and lime as cannot be removed by simply boiling the water. The hardness of water is comparatively estimated by finding the amount of soap which it can destroy. Thus, when such a proportion as 12 pounds of best hard soap must be added to 10,000 gallons or 100,000 pounds weight of water before a permanent lather can be produced by shaking, the water is said to have one degree (1°) of hardness; and it has been found that 1 pound of carbonate of lime in 10,000 gallons of water will produce the same effect, and that 2 pounds of carbonate of lime in the same quantity of water will produce an effect which is twice as great, or which requires twice as much soap to make a permanent lather, and hence, such a water is said to have two degrees (2°) of hardness, and so on.

To give an idea of the hardness of waters generally used for domestic purposes, a table is here appended, showing the hardness of water from different sources:—

FROM NON-CALCAREOUS ROCKS.

Lakes.	Temporary hardness.	Permanent hardness.	Total.
Bala Lake, Wales	0°·1	0°·3	0°·4
Grasmere	—	2°·7	2°·7
Rydal Lake	0°·7	2°·4	3°·1
Windermere	1°·6	2°·4	4°·0
Loch Katrine	—	0°·9	0°·9
Buttermere	—	1°·0	1°·0

WATER FROM CALCAREOUS DISTRICTS.

Rivers.			
The Frome, Gloucestershire	19°·6	4°·0	23°·6
The Thames, above Reading	12°·8	8°·2	21°·0
The Thames, above Hampton	17°·9	6°·6	24°·5
The Ouse, above Bedford	13°·5	15°·1	28°·6
The Wharfe, at the Strid, Bolton Abbey	6°·9	7°·0	13°·9

In shallow wells the water from the new red sandstone rocks has a hardness sometimes as high as 90°;

in wells sunk in the gravel, the hardness may reach as high a figure as 152°; while with deep wells in magnesian limestone it may vary between 14° and 57°, and from deep wells from the chalk beds, the average hardness is 27°. It has never been conclusively shown that hard waters are prejudicial to health, though many medical men are of opinion that excessively hard waters are likely to produce stone in kidneys and bladder. As a matter of fact, some people prefer to drink hard waters, and consider soft water as flat and tasteless, and there are others with an exactly opposite liking for soft water. In the laundry and in the kitchen the immense superiority of soft water cannot be doubted for a moment. It has a much greater power of dissolving sticky and greasy substances; it requires less soap, and effects a great saving in time and fuel in consequence. In the brewing of tea, in the making of soup, the boiling of meat, and the cooking of vegetables, the great advantages of soft water are chiefly experienced,—thus, for instance, 10 ounces of tea made with soft water will be as strong as 18 ounces of tea brewed with hard water. M. Soyer, the renowned *chef de cuisine* of the Reform Club, states that in the making of soup more meat is required, and the operation takes a longer time when hard water is used; this is particularly noticeable in making beef tea. The boiling of peas, beans, and cabbage must be continued longer; they acquire a yellow colour, and are somewhat hardened. Beef is hardened and requires a longer cooking, the pores of the flesh not opening so freely as in soft water. Bakers who come from Glasgow to London cannot understand why the bread does not rise so well here, although they use the same yeast and flour, the fact being most probably due to the town of Glasgow being supplied with water, from Loch Katrine, having a hardness of no more than 0°·9, while in London they are obliged to use water taken from the Thames above Hampton, which has 20° to 24° of hardness.

Nearly one-third of the tea used in the metropolis is wasted by reason of the hardness of the water supplied to our houses.

Dr. Clark, of Aberdeen, has shown how, by adding one ounce of quicklime to 1,000 gallons of water for each degree of hardness, the water will be rendered clear, soft, and quite fit for drinking in twelve hours' time. One hundredweight of quicklime, costing eightpence, would soften water as effectually as $4\frac{3}{4}$ cwt. of carbonate of soda, and would prevent the destruction of $20\frac{1}{4}$ cwt. of soap.

The relative cost of these substances would be as follows :—

	£.	*s.*	*d.*
1 cwt. of quicklime, say....................	0	1	0
Labour	0	2	0
	0	3	0

	£.	s.	d.
$4\frac{3}{4}$ cwt. of carbonate of soda	2	17	9

	£.	s.	d.
$20\frac{1}{4}$ cwt. of soap	47	1	8

hence the saving effected by the use of softened water would be enormous.

CHAPTER III.

OF ORGANIC IMPURITIES IN WATER.

Their serious Nature—The forms in which Nitrogen derived from Organic Matter exists in Water—Unwholesome Nature of even minute Quantities of Organic Matter—Various Means of measuring the Unwholesomeness of Water—Examples of good and bad Water—The Significance of Chlorine in Water—The injurious Qualities of Water due to minute Solid Particles—The Propagation of Typhoid Fever and Cholera by impure Water—The Mortality in this Country from such Causes.

The inconveniences and the waste incurred by the use of hard waters have been sufficiently shown, but great as the importance is of having a supply of soft water, this is as nothing compared with having the use of water free from organic impurities; for while it has never been shown beyond doubt that hard water is unwholesome, it is a fact universally allowed by scientific authorities, that any organic contamination is liable to be particularly injurious to health. If this organic matter in water is of animal origin, the risk incurred by taking it into the system is one of the greatest which man can be subjected. Organic matter under the influence of warmth constantly undergoes putrefaction or fermentation. Putrefactive and fermentative changes are caused by minute, excessively minute organisms, and these changes spread to wholesome and sound organic substances by mere contact,—the reproduction of the minute forms of life being so rapid as to pass beyond all conception. Organic matter of animal origin is generally nitrogenous, that is to say, one of its constituents is nitrogen. The four forms in which nitrogen is found in water are the following:—

1. As free gas, that is to say, derived from atmospheric air by simple solution. In this condition it is harmless.

2. In combination with oxygen, as nitrates and nitrites of earthy matters. These nitrates and nitrites are the ultimately oxidized forms of organic matter, and not in themselves so injurious, but they indicate that some source of contamination does exist or has existed.

3. In combination with hydrogen, as ammonia. In this condition a certain amount of animal contamination is indicated.

4. In combination with carbon, oxygen, and hydrogen. In fact as organic matter, of which albumen, commonly exemplified as white of egg, may serve as the type.

The solution of air in water renders it brisk and pleasant to drink, free from what one calls flatness. Nitrates and nitrites give a peculiarly pleasant freshness to water. So much is this the case that people have been frequently known to drink this water from preference to any other, although it has on analysis been found to have been polluted to an alarming extent by other substances more deleterious from which the nitrates and nitrites have been derived. Ammonia, derived as it is from decomposed animal and vegetable matter, which has not been rendered harmless by a slow chemical process of burning, denoted by the term oxidation, is indicative of a dangerous condition of any water in which it may be found.

Even in very unwholesome waters the amounts of organic matter are exceedingly small. The chemist can tell how much carbon and how much nitrogen this organic matter consists of, but he is powerless to say, by applying any distinctive test, that he is acquainted with the nature of the organic matter, and that it is such as will act as fever-poison or as cholera-poison ; but we know positively by observation, that the outbreaks of the most violent attacks of typhoid fever and cholera have been the result of drinking water containing organic matter.

Chemists have a method of estimating the quantity of dangerous nitrogenous substances in water, by finding out with great accuracy the amount of ammonia they will yield when submitted to a particular treatment. As substances of the same class as albumen, or white of egg, and gelatine, are productive of ammonia by the same treatment, any ammonia so produced is called for convenience *albumenoid* ammonia, that is to say, ammonia derived from substances resembling albumen, or what is equivalent to ammonia resulting from the destruction of the animal contamination.

Practical experience has shown that a good potable water contains but very little free ammonia, and when chemically treated, so that the nitrogen of the organic matter is separated as ammonia, this does not amount in the best kinds of drinking water to more than 8 parts in 100 million parts of the water, and it should not amount to more than 1 part in 10 million parts of water.

The following list contains examples of good and bad waters, showing the free ammonia and the organic ammonia in each case :—

IN 100 MILLION PARTS OF WATER.

London Water Supply, 1872.	Free Ammonia.	Ammonia from Organic Matter.
New River Company, Oct. 2	2	8
" " Nov. 21	1	6
East London Company, Oct. 10	1	4
" " Dec. 4	1	18
Kent Company, Feb. 7	1	2
" " Nov. 20	1	2
Manchester Town Water	1	6
" "	1	7
Edinburgh	0	7
Glasgow	0	8
Chester	0	7
Scarborough	1	6
Birkenhead	0	2
Chelmsford	8	2
Leek	0	2
Lytham	0	1
Guildford New Supply	0	1

The following are examples of deep well waters analyzed by the same method :—

IN 100 MILLION PARTS OF WATER.

	Free Ammonia.	Ammonia from Organic Matter.
Caterham	4	0
Cold Harbour, Dorking	1	0
Frome, Somersetshire	0	2
Kirby Lonsdale	1	3
Chatham	3	3
Henley-on-Thames	2	2

These next examples show water in various degrees of impurity, beginning with the imperfectly-filtered Thames water occasionally supplied to London by the water companies ;—

IN 100 MILLION PARTS OF THE WATER.

	Free Ammonia.	Ammonia from Organic Matter.
Dec. 1872. Southwark and Vauxhall Company	0	18
Dec. 1872. Lambeth	1	16
Nov. 1873. Great Yarmouth	0	18
UNFILTERED THAMES WATER.		
Thames, a little above Hampton Court, unfiltered	4	28
Thames, at London Bridge:—		
Two hours' flood	176	35
High tide	102	59
,,	102	50
LONDON PUMP WATERS.		
June, 1867. Great St. Helen's pump, London	375	18
,, Bishopsgate Street pump	750	25
,, Drapers' Hall	600	31
VARIOUS POLLUTED WELL WATERS.		
Well at Leek Workhouse	2	34
Well at Windsor	120	8
Well at Eton	0	84
Effluent from Sewage	1620	90

It is easily seen from the examples that *albumenoid* ammonia, or ammonia derived from the destruction of organic matters, rises above the proportion of 1 part in 10 million parts of the above waters, and frequently it is greatly in excess of this amount. The presence of free ammonia in considerable quantities in some of these waters, is evidence of their pollution by urine. Urea, one of the chief constituents of urine, undergoes an easy process of fermentation, which converts it into carbonate of ammonia. When urine is an extensive source of pollution in a water, we always find chloride of sodium, common salt, present in considerable quantities. It is important, therefore, for the chlorine in water to be estimated, for if chlorine be present in only very minute quantities, we can assert the absence of animal contamination with tolerable certainty. When an analysis indicates the presence of much organic ammonia, little free ammonia, and an absence of chlorides in a specimen of water, we draw the conclusion that it is contaminated with vegetable matter. Such water, exemplified by that of the Leek workhouse, is very injurious to health, those who drink it being prone to attacks of diarrhœa.

The following table expresses in grains per gallon the proportion of chlorine in various kinds of water. Of course, now and again, the purest kinds of water are found to have more chlorine than the proportion found even in sewage, especially does this happen in the neighbourhood of brine springs.

	Grains of Chlorine per Gallon of Water.
Bala Lake, Wales	0·7
Ullswater, Cumberland	0·7
Thames, at Kew	0·8
New River Water Company	1·1
Guildford New Supply	0·9
Leek Town Water	0·7
,, Workhouse Well	0·5
London Pumps: Portland Place	2·2
,, ,, Goodge Street	12·4
,, ,, Oxford Market	33·2
Well in Windsor	6·9
A Sample of Sewage	9·9

The following table gives the quantity in pounds and decimal fractions of a pound of organic carbon and organic nitrogen found to have been present in one million pounds weight of water. Minute as these quantities are in proportion to the amount of water through which they are diffused, or in which they are dissolved, they are nevertheless in some of the instances sufficient in quantity to render positively poisonous what would in their absence be wholesome and fit for the use of man.

Source of the Water.	In One Million Pounds of the Water.	
Lakes.	Organic Carbon. lb.	Organic Nitrogen. lb.
Buttermere Lake	1·27	0·4
Colinton Water	2·03	0·42
Coniston Water	0·85	0·17
Crummock Water	1·83	5·5
Derwentwater	2·18	0·43
Windermere	2·99	0·76
Grasmere	2·35	0·50
Loch Katrine	2·56	0·08
Lake of Zurich	9·20	0·09
Water supplied to Towns.		
Caterham	0·20	0·06
Manchester	1·83	0·09
Northampton	1·68	0·24
Thames, at Hampton	2·6	0·24
Shallow Well Waters.		
Aldgate Pump, London	1·44	1·41
A Well at Hampstead	10·06	1·37
Certain Private Wells	13·86	3·26
" "	26·62	5·31
A Town Pump	7·59	2·83

The people of Glasgow are blessed with an ample and constant supply of the very pure water of Loch Katrine, which is brought to their city, a distance of thirty miles, through underground tunnels and pipes. The Caterham and the Manchester supplies are samples of most excellent potable waters, serving as standards of what is good and wholesome. The water from the Thames at Hampton is not considered wholesome until it has received sufficient filtration, and the filtering process even is not always capable of reducing it to that state of purity which is necessary. Each of the well and pump waters is an example of what is foul in a drinkable form, and of a deadly nature, though it may be in daily use.

In villages and isolated country houses, more frequently than in towns, the use of wells as sources of water for domestic purposes is very common. In making a well, a hole is dug in the ground of such a depth that a sufficient quantity of water can be drawn from it, from time to time, as may be required. When the weather is very dry, the water-supply becomes scanty, and sometimes altogether ceases. This is a proof that the water is derived from surface-drainage soaking through a few feet of soil and so collecting in the hollow made for it. It is well known that if the water which at first may be impure manages to percolate a great thickness of porous earth it will be purified. Commonly, however, no care is exerted to make it do this, chiefly through ignorance, and partly on account of expense. In fact, in the majority of cases, people in the country make two holes in their gardens; in one all the excreta, solid and liquid, are deposited, and from the other the supply of water for domestic purposes is taken. This latter source derives much from the liquid deposited in the first hole before it has gone sufficiently through the slow purification by filtration, when, in fact, little more than the lumps of solid matter have been drained away. This is a widely-spread custom of a most shockingly disgusting nature. Abundant evidence exists, derived from the researches of chemists and physiologists, to show that many diseases known as a class by the term zymotic diseases (from the Greek word *ζυμοω*, I ferment) are spread by drinking foul water.

Scarlatina, diphtheria, measles, and typhus fever can be transmitted from diseased to healthy persons, not only without contact, but also without any apparent communication : it is presumable that under these latter conditions the poison is conveyed through the air from one person to another.

Cholera and typhoid fever can undoubtedly be transmitted from one person to a whole community. The discharges from the stomach and bowels of patients are charged with highly infectious matter; if these happen to gain access to water, such as that of a stream, river, or well, which is used for drinking purposes, communication of the disease very frequently follows. The result of the inquiries of the Commissioners appointed to inquire into the best means of preventing the pollution of rivers, state that it is a widely-spread custom, both in towns and villages, to drink either the water of rivers into which the excrements of man are discharged, or the water from shallow wells which are largely fed by soakage from middens, sewers, or cesspools. "Thus vast multitudes of the population are daily exposed to the risk of infection from typhoidal discharges, and periodically to that from cholera dejections." Out of a population of 22,712,000 dwelling in England and Wales alone, about 15,000 persons annually meet with death by the agency of typhoid fever. The amount of suffering, corresponding to this shocking mortality, which must be endured by those who recover from attacks, by those families who are bereft of the breadwinner, by those who are impoverished through long-continued and serious sickness, and the anguish endured by survivors who have lost their nearest and dearest relatives, must be deplorably great.

When we think of the fact that man has it in his power to destroy this disease, to shut it out of the country, it will be readily conceded that no better

Christian work can be done than the propagation of such knowledge as will carry a firm conviction to the minds of the people at large, and give them such warnings and instructions as may secure the mitigation, if not the extinction, of the disease.

CHAPTER IV.

WATER AND EPIDEMICS.

History of various Outbreaks of Typhoid Fever and Cholera, showing their Connection with Impure Water—The Case at Millbank Prison cured by a Pure Water-supply—The Outbreak at Terling—The bad Condition of Health in Chichester due to Impure Water—Advantages of boiling doubtful Water shown by the Case at Tottenham in 1862—Remarkable Outbreak at Guildford in 1861—Dr. Budd's Narrative of Cases at Clifton and at Cowbridge in Wales—Epidemics of Cholera in London in the years 1832, 1849, 1854, and 1866—The Causes of these Epidemics traced—Passage of Cholera Poison through untrapped Drains—The Broad Street Pump Case.

The repeated outbreaks of typhoid fever in various localities in England have been the subject of the most searching inquiries, prosecuted when the disease was raging. In the great majority of cases these inquiries have established the fact that water polluted by sewage, if not by actual typhoid discharges, had been consumed by the people attacked. As the instances are very striking in many cases, and as they tell their own story when simply narrated, it will be well to give them in outline.

The convict prison of Millbank is situated about two hundred yards from the river Thames, just between the districts of Westminster and Pimlico. It was built in 1816, and for very many years the greatest alarm existed on account of the apparent unhealthiness of the building. Epidemics of typhoid fever, diarrhœa, and dysentery, were of very frequent occurrence, and prior to the year 1854, during three outbreaks of cholera which occurred in the Metropolis, and which raged in the prison, the mortality was very great. In the month of August, 1854, the health of the convicts began to improve in a remarkable manner; this improved condition has continued up to the present, and now typhoid fever has become extinct, and dysentery and diarrhœa have long ceased to be causes of death. In 1823 a select committee was appointed to inquire into the cause of the frequent sickness, which the medical officer of the prison attributed to a diet too generous for the necessarily small amount of exercise compatible with confinement. Having consulted Sir James McGrigor, the chief of the Army Medical Staff, a reduced dietary was adopted by the medical authorities. There then followed an alarming epidemic of diarrhœa, dysentery, and fever. Out of 880 convicts there were at one time nearly 500 laid up. Want of sufficient nutriment in the diet, the depression caused by solitary confinement, cold, defective ventilation, and some peculiarity in the locality, were suggested as causes of the disease. Sir Humphry Davy reported on the ventilation, the building was disinfected by Faraday, and all that man could do at that time was done to stay the evil, but the unhealthiness of the place still continued. In the year 1849 the death-rate reached the great number of 82 persons per 1,000; in 1852 it was 30 per 1,000, in 1853, 28 per 1,000, and the number increased in 1854 to 69 per 1,000, but in 1855 there was a sudden fall to 11 per 1,000. In the twelve years, from 1843 to 1854, inclusive, the death-rate was 33 per 1,000 persons; in the sixteen years, from 1855 to 1870, it was only 12 per thousand. It is thus evident that a real and permanent beneficial change in the sanitary state of the prison was very suddenly effected.

Taking into account all the causes of alteration in health, the following will be a sufficient enumeration of those likely to affect a number of convicts all placed under the same conditions:—1. Drainage; 2. Ventilation; 3. Diet; 4. Clothing; 5. Discipline; 6. Water-supply. An examination of all the circumstances of the case show that in no degree whatever was the cessation of typhoid fever caused by any alteration in drainage, ventilation, diet, clothing, or discipline. It was owing simply and solely to a change in the water-supply. Water pumped up from the Thames as it flowed past the building was filtered and used in the prison. It was derived from the same source, and not far from the same spot, where the sewage of the building was emptied out. In the year 1854 a very severe cholera epidemic was rife in London and within the prison. On the 10th of August water from the Thames ceased to be used, for a new supply from the artesian well in Trafalgar Square had been laid on. *Six days afterwards the disease suddenly ceased, and a marked improvement took place in the health of the prison.* In the nineteen years immediately subsequent to the change in the water-supply, the total number of deaths from typhoid fever, dysentery, and diarrhœa, amounted to only four.

Were this an isolated case, it would be curious, but not conclusive, evidence that the water alone was in fault.

In the autumn of 1867 a severe outbreak of typhoid fever occurred at the village of Terling, in Essex. Out of its 900 inhabitants, fully 300 were attacked, chiefly within a period of two months, and 41 cases were fatal. The village, consisting chiefly of labourers' cottages, is built on gently-sloping banks of gravel, which descend to a stream called the Ter. The most favourable conditions for breeding sickness were in great and unusual abundance. Unpaved yards and gardens, manure heaps, cesspools, decaying vegetable matter, and filth of every description surrounded the cottages, trickled down the sloping fields at the back, oozed into the porous earth, converted the lowlying ground near the stream into a foul and stinking swamp, and, finally, soaked into the wells, or ran into the stream from which the inhabitants drew their water-supply. The disease broke out with terrific violence; the villagers were panic-stricken; weeping women called from their cottage doors for help; rich and poor were alike attacked, and every one felt his life in the greatest peril. The epidemic had been preceded by a drought, and was coincident with a rise of water in the wells consequent on a heavy rainfall. In the central part of Terling each group of two or three cottages, and sometimes each cottage, had its own well, and some of these wells were only five feet deep. Where the ground was undulating the well was always placed at the lowest level. These wells were nothing more than uncovered holes dug on a lower level and in the same porous soil on to and into which the excreta of the inhabitants and all the filth of the place were emptied. The connection between the outbreak of fever and the heavy fall of rain was evident: the wells were filled with surface-drainage and soakage from this foul spot. Only two wells were so exceptionally placed that they could not easily be contaminated, and those supplied the only two large groups of cottages in which none of the inmates suffered from the disease.

Chichester, a town most favourably situated as regards most of its sanitary conditions, but, like the village of Terling, wanting in the matter of a water-supply unconnected with refuse, has been subject to outbursts of typhoid fever and continued low fevers.

The water frequently became offensive to the sense of smell, and the conditions under which this was noticed were: (1) When the wells were low, the solution of sewage being then most concentrated; and, (2) When heavy rain, by overflowing or by soakage sent a lot of cesspool stuff direct into the wells. So foul was the water, that it frequently had an offensive smell, and the flavour of it was generally slightly salt and sweetish.

At Tottenham, in 1862, occurred a large number of cases of typhoid fever, and the history of some of the cases is interesting, because it shows, firstly, the immediate connection between a drain and a pump well; and, secondly, that the effect of boiling poisoned water is to some extent beneficial as a preventive of illness. Many houses in the village were supplied with water provided by the Local Board of Health. Some of the inhabitants, however, either from a dislike to this water, or from the want of regularity in the supply, borrowed water from their neighbours' wells. These wells, which had a depth of seven or eight feet, were sunk in porous gravel; the water was said to be bright, clear, and pleasant to drink. The people never suspected that anything was the matter with it, were surprised at the notion, and amused at its being sent away for analysis. The report of the late Dr. Miller, of King's College, who made the analysis, stated it to be quite unfit for use as a beverage. It contained a very unusual proportion of ammonia, and a notable amount of organic matter, from which he concluded that some sewer drainage had gained access to the well. This proved to be the fact, for after some carbolic acid had been poured down the sink in the yard where one of the wells was situated, the water drawn from the pump smelt distinctly of that substance. One house alone of those using such water escaped the fever, and on inquiry, it was found that the family had always boiled the water first before using it for drinking purposes.

Typhoid fever at one time not unfrequently pre vailed in Guildford and the neighbouring villages, and in the month of August, 1861, those dwelling in the high-lying and usually healthy parts of the town were attacked. The better class of people were affected equally with the poor, the cleanest and best kept houses as much as the squalid and dirty. Inasmuch as there is no system of sewers in the town, it is evident that drainage could not directly have been the cause of the outbreak, because the highest parts would be those with the best natural drainage and with freest supply of air. After much investigation the following facts were established, that on August 1st, water from a new well had been stored in a high pressure reservoir for the use of the upper part of the town; that on the 17th of the month this water was distributed to 330 houses. The water was submitted to Dr. Miller for analysis, and the results showed that it had been polluted with animal matter. Dr. Buchanan, who reported on the case to the Medical Department of the Privy Council, entertained suspicions that some sewage contamination was the agent of the disease. Mr. Taylor, one of the Poor Law medical officers of the town, thus wrote to him in 1867 :—" I take upon myself to inform you that your suspicions as to the percolation of sewage matters into the new well have been now rendered almost certain. The engineers employed in the repairs of the steam-engine noticed some exudation in the wall of the engine-house next the alley where the sewer runs, and the pit of the fly-wheel contained a notable quantity of the same. As the exudation had the smell of sewage, the ground was opened in the alley at a point adjacent to the engine-house. The sewer was found leaking in various places, and the soil between it and the wall of the engine-house was saturated with sewage, of which as much appeared to run outside as inside the sewer. This was found to be an old-fashioned 12-inch drain, constructed with red unglazed tiles, with butt joints and common mortar. The tiles forming the lower half of the cylinder were in places completely worn away, and at one point several feet of them were missing, and the upper tiles had fallen in upon the soil below. All the joints gave exit to water, and the ground was a quagmire of filth beneath and on each side. Dark-coloured slush had to be dug out and removed in baskets, making the men vomit who were employed in the work." To give force to the significance of these facts, it is necessary simply to state that the well was situated directly beneath the floor of the engine-house, and that 177 cases of fever occurred in the 330 houses drawing water from this well. The 598 houses supplied by the low-level service escaped with only 30 cases.

To Dr. William Budd, of Bristol, we are greatly indebted for our knowledge of the propagation of typhoid fever. Some of the most accurately and carefully observed cases, showing the part that water takes in the communication of the disease, he has described in his work on the subject. The following may be related :—Richmond Terrace, Clifton, in the year 1847 consisted of thirty-four houses of a good class. Thirteen of these houses drew water from a pump at the end of the terrace, which water at the latter part of September began to show unmistakable signs, by taste and smell, of sewage taint. An actual leakage into the well was subsequently discovered. Early in the following month typhoid fever broke out nearly simultaneously in each of the thirteen houses in which the tainted water had been drunk. In one house, a school for young ladies, there were laid up before the end of a week, the mistress, six of the pupils, and two maidservants. The other families in the terrace, living side by side with those afflicted, continued all the time to be perfectly free from fever. It was remarkable that only a few doors from the school just referred to, there was another girls' school, with a like number of pupils, which with all the internal arrangements made it the counterpart of the former. In the one, however, eleven persons out of seventeen were stricken with fever, in the other there was not a single case. The former drank water from the well, the latter took it from elsewhere. Had strychnine been put into the well in large quantities, no clearer case could have been made out that the water was poisoned.

When fever breaks out in a house, a suspicion may be entertained that it is passed on from one person to another by the air they breathe, or by personal contact; this is, however, less likely to take place in a prison, and cannot be the case when the sick persons dwell in different houses, and have no intercourse with each other; when these houses are not in the same street, not even in the same town, and when persons have even been so far removed from each other after assembling at one spot and partaking of the same beverages, as to be spread through distant counties, then no doubt can exist, and no other conclusion can be drawn, but that these people had absorbed typhoid fever poison in their drink. Such a case is the following, related by Dr. William Budd, F.R.S., of Bristol: —In November, 1853, two public balls were held in the chief inn of a small town, Cowbridge, in Wales. About 140 persons from different parts of that principality, likewise from the counties of Gloucestershire, Somersetshire, and other parts, attended these balls. After these people had returned to their homes numbers were attacked with typhoid fever in a most virulent form, and as many as eight died from it. Except in the Cowbridge ball-room, many of these had never been in each other's company. It is not recorded that the fever was especially prevalent in the place at the time, and with the exception of one or two who lived in the house, only those who attended the balls appear to have been attacked. It afterwards transpired, that there had been an outbreak of fever in the hotel immediately before the balls were held. The disease occurred in the person of a gentleman staying in the place, who was laid up with it, but being in a state of convalescence, had left previous to the commencement of the festivities. As no one at the balls had been in his presence, the possibility of direct personal infection was out of the question. There was likewise no likelihood of the air of the place being concerned in the communication of the disease, since no smell was apparent, either in the ball-room, or in any other part of the house. From several considerations, however, it appeared probable that the drinking water was the vehicle in which the disease was transmitted. An examination of the courtyard of the hotel made it evident that such was the case. The cesspool and drain which had received the bulk of the discharges from the patient were in such close contiguity to the well, that under any but extraordinary circumstances the percolation of deleterious matter was almost certain. The drinks supplied, lemonade amongst others, were in abundance, and freely partaken of. It is, therefore, tolerably certain that many persons must have drunk of water drawn from a well situated near to a receptacle which had for a considerable period received the discharges from the diseased intestines of a fever patient. A very large proportion, between forty and fifty, of the guests were infected. In many cases it was ascertained that the persons sickened with such amazing rapidity, that the cause of illness resembled a case of chemical poisoning, rather than one of fever. Of the inmates of the hotel, the landlady suffered severely, while others of the household had slighter attacks of fever. It is right to say that the defects of the building were remedied, and the place is now in good order as regards its sanitary arrangements.

An outbreak of fever in the small town of Winterton, in Lincolnshire, which place is endowed with a healthy situation and an excellent system of drainage flushed by a running brook, illustrates the fact that a good natural position and well-constructed drains may have their beneficial effects destroyed by a contaminated water supply. Without entering into particulars, it will suffice to say that cesspools, ash-pits, and pig-sties so surrounded the wells of certain houses that, as the substratum consisted of porous oolitic limestone, there can be no wonder that the water in use for drinking was described as having a disagreeable taste, and a light brown colour ; while under the microscope it showed large quantities of organic matter, and many of the low forms of animal and vegetable life. Out of four houses standing together, No. 1 had three inmates, two of whom had had fever. No. 2, where four persons had lived, the inmates were always ill, and one had died of fever. No. 3 contained seven persons, all of whom had had fever; but in No. 4 four persons were found free from disease, and they had never been ill.

In houses Nos. 1, 2, and 3, water such as that described above was in use, but the people in No. 4, not liking the taste of it, drew their supply from a neighbour's well, and were always in good health.

After such evidence as this, no person, even the most sceptical, can doubt the justice of concluding, firstly, that typhoid is chiefly communicable by water; secondly, that the fouling of water by excrementitious matters is a by no means uncommon occurrence, especially in the case of villages and small towns; thirdly, that typhoid fever is a decidedly preventable disease if people are careful what water they drink.

With cholera, a most deadly epidemic, the evidence is even more conclusive, or, at least, is sharper than in the case of typhoid fever. It is a disease which, on its approach, raises the whole country in alarm; and terror takes hold of a town or district where it makes its appearance. Yet the hand of Death, when aided by such an agent, may be arrested. It is a preventable disease. It is a very remarkable fact that the cholera never visited this country before the year 1831; it then died out, and has re-appeared at intervals since that time. It generally first shows its appearance in Eastern countries, and travels westward until it arrives at our shores; it then spreads inland from the seaports, but its most serious outbreaks have always been in London. The periods of the most serious epidemics occurred in the years 1832, 1849, 1854, and 1866. During the first and last of these periods the condition in the water supply of the Metropolis underwent important changes. Thus, formerly, a considerable portion of London was supplied with water from the rivers Thames and Lee, and from shallow wells. Partly owing to the smaller population, and partly to the absence of that system of sewerage which subsequently discharged the whole of the outflowings from dwellings into the Thames, the Lee, and the Ravensbourne, the river waters were not so polluted as they subsequently became. Just prior to the year 1854 a small portion of the water taken from the

Thames within the Metropolitan district was replaced by a corresponding quantity conveyed from the river above Teddington Lock, and out of the reach of London sewage. Subsequently, the whole of the foul supply from the tidal Thames was abandoned for water taken from above Teddington; the filthy Ravensbourne water was rejected by the Kent Company, and an ample amount was pumped up from deep wells in the chalk. Now the East London Water Company, although it had improved its arrangement by taking in the better water of the Lee, at Lee Bridge, instead of that at Old Ford, where it had become much fouled by sewage, nevertheless reserved to itself the power, although without legal right, of distributing unfiltered water from the reservoirs at Old Ford. This power was exercised after the outbreak in 1866, with what effect will presently be seen.

Putting facts succinctly together, we get a table of the following kind :—

	Character of Water Supply.	Total Mortality from Cholera.	Deaths from Cholera per 10,000 of Population.
Epidemic of 1832	Polluted	5,275	...... 31·4
,, 1849	Very much polluted...	14,137	...... 61·8
,, 1854	Less polluted	10,738	...... 42·9
,, 1866	Much less polluted ...	5,596	...... 18·4

The cholera epidemic which spread over Europe in 1872–3 was introduced into England on three or four occasions, but it failed to spread, doubtless from precautions which were taken, and on account of the improved sanitary arrangements. Thus, in a glance, we see a collection of facts of the broadest kind, showing that death and water-pollution went hand in hand in these four periods. In 1854 the mortality from cholera was very great on the south side of the river, where more than half a million of people were being submitted to a gigantic physiological experiment, if we choose so to look at it. In 26,000 houses supplied by the Lambeth Company with water from Thames Ditton, the deaths amounted to 294; whilst in 40,000 houses furnished with Thames water of a foul nature from Battersea, the deaths were 2,284. The houses lay in the same district, side by side, the water pipes often interlacing, the drainage, the position, the air, and the surroundings being the same, but the inmates supplied with comparatively pure water died from cholera in the proportion of 40 to every 10,000 persons, while those drinking foul water were killed at the rate of 130 in 10,000 human beings.

In 1866 the investigation of the cause of the dreadful suffering from cholera in the district supplied by the East London Water Company proved beyond all doubt that the illegal power of supplying foul and unfiltered water from the reservoirs at Old Ford was exercised three times in the course of six months,—once in March, once in June, and again in July.* General orders were given to the man at the pumping station to turn on the unfiltered water whenever the better supply was deficient, and no doubt, though he could not remember the precise occasions, he had recourse to this expedient more frequently than he had admitted. This man was warned on or shortly after the 1st of August of the danger of this proceeding, for on that date the Registrar directed the attention of the Water Company to a remarkable connection between the district suffering from cholera and the East London water supply. To quote from the report of Mr. Simon, the medical officer at that time of the Privy Council, "the area of intense cholera

* It will be seen that this case resembles the outbreak of typhoid fever at Guildford.

in 1866 was almost exactly the area of this particular water supply, nearly, if not absolutely filling it, and scarcely, if at all, reaching beyond it." From the very date of warning the fury of the disease abated.

The following figures show the close relation between the first distribution of foul water in the early part of July, and the appearance of disease; and again between the warning given by the Registrar-General to the water company on the 1st of August, and the subsidence of the epidemic.

Deaths from Cholera in the East-end and in the Rest of the Metropolis on certain Dates in the Year 1866.

Date.		East End.	Rest of London.
July	8	0	1
	9	0	3
	10	0	0
	11	3	3
,,	31	171	29
August	1	170	34
,,	30	10	12
,,	31	7	16
Sept.	1	8	15

Now, the question arises, was the sewage which gained access to and polluted the water at Old Ford especially infected by the poisonous matter from cholera patients? It was conclusively proved that the discharges from the first two persons who died from epidemic cholera in the eastern districts were poured into the river Lee and into the Canal on the 26th and 27th of June, at a point about 600 yards from the uncovered reservoir. The temperature at this season was excessively high, the canal was in a foul state, and organic matter therein was undergoing rapid putrefaction. Here it must be mentioned that, although water is a most deadly propagator of cholera, offensive matters, when they become dried, may be carried about by currents of air, may adhere to the clothes, and becoming detached therefrom be inhaled. Infection, when so spread, is not confined within so small an area; the distribution of the disease is apparently fickle, and thus rapid and extraordinary strides are made through whole districts. Disease has been distinctly traced to such causes, the circumstances being such as to render absolute proof that such has been the case.

The late Dr. Parkes, F.R.S., when reporting on an outbreak of cholera in Southampton, gave an instance which came under his observation, convincingly proving that sewage in passing through untrapped drains may froth, and that the bursting of bubbles may throw spray into the air, rendering it infectious. Only quite recently Professor Frankland has made certain experiments which tend to show that decomposing sewage, which slowly effervesces, actually does throw minute particles of liquid into the air, which are capable of being transmitted considerable distances by gentle currents.

Cholera may spread to a small extent in districts with a pure water supply, but to show how comparatively small infection is under such circumstances the following table is supplied:—

DEATHS FROM CHOLERA IN MANCHESTER AND SALFORD.

	Polluted Water Supply.			Pure Water Supply.	
Year of epidemic ...	1832	1849	......	1854	1866
Number of deaths ...	890	1115	......	50	88

GLASGOW.

	Polluted Water			Pure Water.
Number of deaths ...	2,842	3,772	3,886...	68

Here, if the cholera had never visited these places after the substitution of pure for foul water, no conclusions could have been drawn, but observing such small numbers of victims to the attack, we see that the spread of the disease when not distributed in water is comparatively trifling. We see that large communities may take poison into their mouths as food without suspicion. It may be argued that they do not like it, that the water is unpalatable, but that they can get no other, and could they obtain a supply elsewhere, their senses would direct them to it. This is, however, contrary to fact. The celebrated case which has oftentimes been quoted, and has become known as the Broad Street Pump Outbreak, shows that persons drank and preferred to drink water in a highly concentrated state of pollution because it was cool, colourless, bright, sparkling, and refreshing. The carbonic acid which it derived from its organic impurities no doubt contributed to its pleasant taste, and the saline matter contained in it possibly prevented its decomposition until after its exposure to the air. In the course of five or six days, from the 30th of August, 1854, not fewer than 500 persons died of cholera in a district round Golden Square, London, which numbered 5,000 inhabitants. The pump well was found to be connected with a cesspool in an adjoining house, while nearly all those who died had drunk of this water; but 70 men employed at a brewery in Broad Street never partook of it, and escaped the cholera. At any point decidedly nearer to another pump the mortality as a rule ceased, and many apparent exceptions were found to be cases of death in persons who really had a preference for the more distant Broad Street water. One extremely marked case was that of a lady living so far away as Hampstead, about three miles from the spot. Having a particular fancy for the water, she sent a bottle to be filled with it,—she died after partaking of it, and her niece died under the same circumstances, though no one else in the neighbourhood was affected.

CHAPTER V.

ZYMOTIC DISEASES.

Zymotic Organisms or Living Ferments—The Supposed Cause of Zymotic Diseases—M. Chauveau's Experiments with Small-pox Virus and Vaccine Lymph—The Active Virus due to Solid Particles—Each Particle capable of communicating the Disease with undiminished virulence—Rapid Reproduction and Minute Size of Zymotic Organisms—The Case of Typhoid Fever at Lausen, near Basle—Conclusions.

Let us see if any facts can account for the singular propagation of disease by water, such as appears indisputable from the foregoing facts. Physiologists and chemists have for the last fourteen years been collecting facts of an abstrusely scientific character, which carry conviction into the minds of those who correctly study them, that many diseases spreading themselves in the manner of epidemics, do this by detached living particles of an excessively minute size, which find suitable breeding places in the internal organs of animals. These living particles multiply, and with such rapidity, and exert such an action upon the ordinary vital functions, as to disarrange and disturb them in a specific manner. The action of these living germs has a great similarity to the change which takes place in the brewing of beer, and the curdling of milk in warm weather, and the putrefaction of flesh. The diseases caused by them are on this account called zymotic diseases Though this view has not been so firmly established as scientific men always desire that their theories shall be, nevertheless it is supported by such distinct evidence, as to be worthy of greater reliance than many convictions upon which men base their actions in ordinary life. Be the theory true or false, its sanitary teachings cannot be disregarded. The single link wanting is the actual recognition, or a real knowledge of the appearance of the spores, germs, or seeds of disease. As yet the microscope has failed to give us this information. Take a familiar case somewhat parallel to this. If dogs, poisoned by means of strychnine, are found lying about the streets in various parts of the town, sometimes in one quarter, and sometimes in another, we are certain that a man or a number of men are conveying poison to the dogs, although we may never have seen them, and cannot speak as to their personal appearance. The most important facts we know regarding disease germs are somewhat of the following character. M. Chauveau in the year 1868 experimented with the virus of small-pox, sheep-pox, glanders, and the lymph used in vaccination. As is well known, the smallest quantities of these matters if introduced into the blood by a scratch or other slight abrasion, set up the disease within the body. The question arises, does the infectious matter consist of minute solid particles, which we may call germs, or is the serous liquid of which these poisons chiefly consist, the cause of the change in the vital functions? If the serous-liquid be the active principle, then dilution with water, and separation of the solid particles, will yield a clear fluid with the active properties retained in it. It was found, however, that such a liquid has no action whatever when used for the inoculation of rabbits, horses, and infants. This question is therefore answered in the negative. The means, however, of getting the fluid free from solid particles was extremely difficult, they were so minute in size as to pass through all kinds of filters, and they were separated only imperfectly by subsidence. When vaccine matter was diluted with ten times its bulk of water the coarser particles were allowed to settle, but a very fine granular material remained diffused through the liquid which retained the properties of the virus unimpaired. Thus it was proved that the power of infection resides in the suspended granules which are organized, and not in the unorganized fluid or soluble material of the virus. Going a step farther than this, we may argue that if the organised granules are the poisonous agent, and if the effect of inoculation depends upon the reproduction and multiplication of these in the bodies of the animals operated upon, the mixture of vaccine matter with water should obviously produce but little effect upon the virulence of the disease produced. If only one single granule gain admission to the wound, its infinite multiplication should in time have the same effect as concentrated lymph. If again, on the other hand, the infection resides in the liquid soluble matter, its dilution should produce a larger number of cases with a less virulent form of disease. Experiments made in great number, showed that though the number of attacks by diluted virus was diminished, the virulence of the disease was unaffected. In other words it has been proved that solid living particles, each particle being a distinct organism of an exceedingly minute size, are alone the effective matters in such virus, and that the disease is caused by their reproduction and multiplication within the body. To give some idea of the minute size of certain zymotic organisms, and their development with rapidity in countless numbers, it is only necessary to mention the fact, that a solution of sugar, containing a little tartaric acid and ammonia, and an addition of wood-ashes will, if filtered and boiled keep perfectly clear in a stoppered vessel. Now let one drop of ordinary water which has not been boiled, but in which no impurity can be detected by the microscope or by chemical tests, be allowed to fall into the sugar solution, keeping the clear liquid in a warm place, and in twelve hours it will be so full of organisms as to be thick and cloudy in appearance. The microscope will show these to be excessively minute little bodies in the most rapid and lively motion.

The spreading and multiplying of minute forms of life is exemplified by ordinary mould. If the most minute dusty speck from a growth of mouldiness be allowed to fall on a suitable field for its growth, such as for instance, some damp bread in a warm cupboard, damp paper or meat, the consequence is, that in a few hours there will be a fine crop of light and feathery microscopic vegetation. Many instances could be brought forward one after another of such almost miraculous and rapid fertilizations of suitable materials as would be perfectly astounding. Take the case of the American water-weed (*Anacharis*), it was brought over to this country as a rarity, and was shortly afterwards, that is to say in a few years' time, found in almost every river, stream, and pond in England. This is a case of extraordinary rapidity of propagation of a large kind of vegetation.

The conclusions that have been drawn are warranted by a confirmation of the facts in this country. In like manner scarlatina, diphtheria, measles, and typhus fever are transmitted from one person to another, sometimes without any apparent communication, except the atmosphere, and it is presumable that this is the means or vehicle for conveying the infectious matter. In the case of scarlatina, a dry scaling of the skin has now been pretty well ascertained to convey the disease, and accordingly anointing the body with a disinfecting oil, has been found to act beneficially as a prevention of infection. Applying these facts to cases of typhoid fever and cholera, we know that specific discharges from the bowels of patients are instrumental in the propagation of these epidemics. Like vaccine virus diffused in water, and passing through a fine filter, these matters may easily penetrate a gravelly soil, and become dispersed through the contents of a well or stream. Each person absorbing only one single particle of such matter is liable to the disease, with all its virulence unabated. The notion that thousands are annually dying in this country from such causes is disgusting in the highest degree. It is nevertheless true.

It is now obvious that water is the medium through which certain zymotic diseases are propagated, and there is little room for doubt that they are spread by means of a specific poison, consisting of organized and living matter. There is reason to believe that exposure to such influences as resolve dead organic matters into harmless mineral compounds, are without action on organisms endowed with life. Instances may be cited which show the persistently active state of typhoid and other such poisons, even after diffusion through large quantities of water, and exposure to presumably destructive influences. One of the best illustrations of this occurred in the Swiss village of Lausen, near Basle. It was investigated in a truly philosophical spirit by Dr. A. Hägler, of Basle. In this healthy village, which had never within the memory of man been visited by epidemic typhoid, and in which not even a single case had occurred for many years, there broke out in August, 1872, an epidemic, which simultaneously attacked a large portion of the inhabitants. About a mile south of Lausen, and separated from it by the mountainous ridge of the Stockhalden, which was probably an old moraine, from the glacial epoch, lies a small parallel valley—the Fürlerthal. In an isolated farm-house situated in this valley, a farmer, who had just returned from a long journey, was attacked by typhoid fever on the 10th of June. During the next two months, three other cases occurred in the same house, viz., a girl who was attacked on the 10th of July, and the farmer's wife and their son, who sickened in August. The inhabitants at Lausen were entirely ignorant of what had occurred in this solitary mountain farm, which was cut off from all communication with the rest of the world; when, on the 7th of August, ten of the villagers were suddenly struck down by typhoid fever, whilst during the next nine days the number of cases had already increased to 57 out of a population of 780 persons living in ninety houses. In the first four weeks, the number of cases reached 100 (that is to say out of every 100 persons in the village, more than twelve were attacked); and altogether to the close of the epidemic at the end of October, 130 persons, or seventeen in every 100 of the population were attacked, besides fourteen children who were infected at Lausen during their summer holidays, and became ill after their return to schools in other localities.

The fever cases were pretty equally distributed throughout the entire village, but those houses, six in number, which were supplied with water from their own private wells, and not from the public fountains, were entirely exempt. This remarkable difference naturally led to a suspicion that the public water-supply was connected with the cause of the epidemic, although the apparently immaculate source of this supply seemed to negative any such suspicion. The water came from a spring situated at the foot of the adjacent Stockhalden ridge. It was there received in a tank lined with brickwork, and carefully protected from pollution; nevertheless, a careful investigation into the source of this spring placed beyond doubt the origin of the infection. Ten years previously, it had been proved that direct water communication through the intervening mountain existed between the spring and a brook in the Fürlerthal, flowing past the farm-house in which the typhoid fever cases occurred. At that time there was spontaneously formed, by the giving way of the soil for a short distance below the farm-house and close to the brook, a hole about eight feet deep and three feet in diameter, at the bottom of which a moderately clear stream of water was observed to be flowing. As an experiment, the whole of the brook water was now diverted into this hole, at the bottom of which it entirely disappeared, but in an hour or two the spring at Lausen, at that time nearly dry from a long drought, overflowed with an abundance of water, which was turbid at first, but afterwards clear, and continued until the Fürler brook was again confined to its bed. It was, however, afterwards noticed that whenever the meadows below this hole were irrigated with the water of the Fürler brook, the volume of the Lausen water-supply became greatly augmented a few hours afterwards. Now this irrigation, practised every year, was carried on in the summer of the epidemic from the middle to the end of July, the brook being polluted by the dejections of the typhoid patients,—for it was in direct communication with the closets and dung-heaps of the infected house, whilst all the chamber-slops were emptied directly into it, and the dirty linen of the patients washed in it. Soon after the irrigation had begun, the water supplied to Lausen was at first turbid, acquired an unpleasant taste, and increased in volume. About three weeks after the commencement of the irrigation the sudden outbreak of typhoid fever in Lausen occurred.

In his search after the cause of this outbreak, Dr. Hägler did not rest satisfied with the evidence just recorded, but supplemented it by the following ingenious and conclusive experiments:—The hole in the Fürlerthal was re-opened and the brook again let into it; three hours later the fountains of Lausen delivered double the quantity of water: 18 cwt. of common salt previously dissolved in water were now poured into the hole, and soon the water at Lausen exhibited a great increase in the quantity of this substance contained in it, and the amount augmented until the solid matter in the water increased threefold. The passage of the Fürlerthal water to the fountains of the fever-stricken village was thus ascertained beyond doubt; but another interesting question here presented itself: did the water find its way through the Stockhalden by a natural open conduit, or was it filtered through the porous material of the old moraine? To decide this point, two and a half tons of flour were first carefully and uniformly diffused in water, and then thrown into the hole, but neither an increase in the solid constituents nor the slightest turbidity of the Lausen water was observed after this addition.

This investigation makes the following conclusions inevitable:—

1. That the epidemic followed immediately after the use, for dietetic purposes, of water which had received the dejections of persons suffering from typhoid fever, and that it was confined to persons who drank the infected water.

2. That the water still retains its infective properries after a filtration which is efficient enough to temove very minute starch granules, but not sufficient

at all times to prevent the passage of visible suspended matter in a still more minute state of division.

3. That spring water which has been polluted with human excrements before its descent into the earth, and which is subject to visible turbidity, is not always safe for domestic use.

4. That water which is polluted with *normal*, as distinguished from *infected*, excrementitious matters of human origin, may be used for dietetic purposes with impunity.

The misfortunes of the luckless inhabitants of Lausen show that typhoidal poison may be still retained in an active state in water which has filtered naturally through nearly a mile of porous earth.

CHAPTER VI.

UNSAFE WATER, AND ITS PURIFICATION.

The rapid Fouling of Spring Water in country places—Difficulty of supplying Pure Water to Villages—Special instances stated—The means of supplying fresh wholesome Water as carried out at Coaley—Typhoid Fever in the Milk-Can—Cottage Tanks for collecting Rain Water—Sanitary precautions connected with Wells and Cisterns—Indications of unsafe Water—Its Appearance, Flavour, and Odour—Water clear, bright, and agreeable to drink sometimes poisonous—How to Purify Water—Best form of Filter—How to make a Filter—How to test Water for impurities.

THE difficulties in supplying country places with water may be illustrated by the following facts. A spring which rises in the parish of Standish, Gloucester, is, in fact, the source of the Arlebrook, a stream flowing into the Severn at Epney, after a course of five miles through a clay district. The water of the spring is of most excellent quality, pure and wholesome, but by the time it has reached the first hamlet on its course it is hopelessly fouled, and quite unfit for drinking. It receives the drainage of a large mansion and several farm-yards within a mile from its source. The cottagers fill their buckets from the stream for domestic use at a place near where their own pollutions foul the water. At Epney, a village of ten or twelve cottages and two farm-houses, situated near to the Severn, the water is drawn for the daily supply of a considerable population. Though means have been taken to remedy these defects, it is doubtful whether they will be quite effectual.

RESULT OF THE ANALYSIS OF THE ARLEBROOK WATER EXPRESSED IN PARTS PER 100,000.

On the 31st of October, 1873.	Organic Carbon.	Organic Nitrogen.
Spring at the head of Arlebrook...	·040	·010
Arlebrook at the first hamlet ...	·213	·061
Arlebrook at Epney	·248	·060

The quantities of organic carbon and nitrogen originally present in the water are multiplied five and six times before the stream has passed the first hamlet. Another parish, Frocester, under like circumstances, possesses springs which give forth water of unimpeachable purity. After flowing for some distance, a sample of the water was taken at a spot where a cottager was about to fill her kettle. Here the waters had been fouled more or less directly by the drainage from the court-house, the mansion-house, and the village inn, all provided with water-closets, also from a butcher's shop and slaughter-house, from farm-yards, and the village generally. Below the village lies a thickly-populated district, which might easily derive a supply of wholesome water from these upland springs. Abundant in quantity and delightful in purity, it is hopelessly spoiled within a mile of the place where it rises, and long before it reaches the people in need of it. The cottagers, perfectly aware of the filth they are liable to drink, complain that they are obliged to take their day's supply of water early in the morning, before the more disgusting of the day's pollutions have taken place. It is sad to think of persons living under such conditions, and it is outrageous that they should have to do so.

In Coaley-parish, adjoining Frocester, there is a spring of pure water, copious in quantity, and rising out of the limestone. As regards freedom from organic matter, there is scarcely a sample of water in the kingdom which surpasses it. This spring feeds the brook, from which at short intervals all through the parish the inhabitants have until lately taken their water for daily use. The following table shows the character which this water has acquired at a distance of not much more than a mile from its source.

Analysis of the Coaley water, September 8th, 1873.

In 100,000 Parts of the Water were found

	Organic Carbon.	Organic Nitrogen
Coaley Spring Water	·024	·006
Coaley Brook Water	1·014	·259

Although turbid, the water was palatable, but utterly unfit for domestic purposes. It can, in fact, only be properly described as sewage, useful as manure for producing heavy crops of grass. Such formerly was the daily beverage of the people. In the years 1865–66, many cases of fever occurred which the medical officer of the district considered were clearly traceable to the impure state of the water. Meetings of the landowners were held to debate on the best remedy for the evil. It was at last decided that a good supply of pure water should be provided.

There being on the hills this never-failing spring of pure water, an application was made to Lord Fitzhardinge, the owner, for permission to utilize it, to which he kindly consented. It was decided to take advantage of the powers given by the Inclosure Acts, and to carry out the work under the inclosure of the waste and commonable lands in the parish, then about to be commenced. The works consist of a receiving tank or reservoir at the spring head ; from the tank the water is conveyed in cast-iron pipes in a nearly straight course through the parish, the line taken being in part the waste land by the side of the main road or street, which was part of the land to be enclosed. Stand-cocks or water-pillars are fixed in the most convenient situations, regard being had to the different centres of population. The works cost about £750, and were defrayed by a rate levied on the persons claiming under the inclosure. The annual cost of supervision and maintenance does not exceed £12.

This was a very proper action on the part of the landowners. As the proceedings were for the most part entirely voluntary, great commendation is due to them for such practical public spirit.

The head springs of the Thames tributaries are fouled by the hamlets and villages scattered around them. Here, in the chalk hills, are abundant springs of beautifully pure water being rapidly polluted by surface contributions of foul drainage, thus becoming a dangerous, and sometimes an injurious source of supply for the districts which they traverse. The remedy is similar to that which substituted delicious water from Coaley spring for the old supply from an open sewer.

The inhabitants of towns depend upon country farms for milk, and it is curious to trace how the sanitary failings of the country may contribute to those of the town.

At the head of one of the tributaries of the Thames, above Aylesbury, there flows a good spring water, which supplied the farm-house and hamlet of Adwell, from which spot it necessarily continues its course in a polluted condition. The following figures show the state of the water in its original and its contaminated states :—

In 100,000 Parts of the Water were found

Sept. 17th, 1873.	Organic Matter. Carbon.		Organic Matter. Nitrogen.
Adwell Spring	·135	...	·028
The same one mile below the Spring ...	·279	...	·042

The second sample of water was taken at a point where the farmers have been accustomed to send carts every day to fetch water for domestic use. These particular samples have an interest attached to them, inasmuch as they were examined at the time of an outbreak of typhoid fever in Marylebone (August and September, 1873), which it was believed originated from the use of milk supplied from farms in the neighbourhood. No typhoid fever existed in that immediate vicinity at the time, but the company which received the milk from two of these farms, which were supplied with water at this point, at once very properly insisted that the water-carts should for the future be sent a mile further on to be filled with the spring water.

Chilton Grove Farm was one from which it is believed that milk was supplied in Marylebone, and here alone of all the farms doing business with the dairy company whose customers had been attacked, had there been a case of typhoid fever. The farmer had succumbed to the disease shortly before the outbreak in the London parish. The homestead at Chilton Grove was supplied with water from a well twenty feet deep. This was sunk close to the kitchen door, and near to foul drainage from the scullery, the yard, and the pig-styes. Chamber-slops were thrown into a filthy ditch within a few yards of it, from which foul water necessarily drained into the well close by. There are accordingly grounds for belief that matter containing specific typhoid poison, during the time that the fever occupied the farm-house and was prevalent in the neighbourhood, had gained access to the well water which was used in washing out the milk cans, and that in this way the milk itself had become infected. This well water had long been known as unsatisfactory, and another well had been dug in the pasture field several hundred yards away, and the two had been connected by a drain, so that the pump had drawn from both alike.

As soon as inquiry had traced the Marylebone fever to this source, the pump handle was removed, and a fortnight afterwards the following analyses were made of water from the two wells.

Analyses of well waters from Chilton Grove:—

In 100,000 Parts of the Water were found

Sept. 17th, 1873.	Organic Matter. Carbon.	Organic Matter. Nitrogen.
Well Water by Farm-house	1·386	·326
Well Water in the Field	·494	·075

Although the better specimen of the two is far from pure water, yet it was found that the house well when no longer supplied from the field by the continual draught which brought the connecting pipe into use, contained a liquid so fouled as to be obviously dangerous and even offensive from the large proportion of actual excrementitious matters which it contained. Nevertheless, this in a diluted form was the daily supply of water for the use of the household and the scrubbing of the milk-pans.

In cases where pure water is only obtainable from very deep wells, it is lifted sometimes only by hand or by a donkey and wheel. Such a laborious and slow process causes the cottagers to prefer taking their drinking water from surface ponds, from which they can draw it by simply dipping in a bucket. Such waters are usually turbid, and are not desirable for dietetic purposes.

At Shurville Hill, near Goring, Oxfordshire, is a block of cottages, four in number, in which fever occurred a few years since, attributable it was thought by the doctor in attendance to the bad drinking-water in use, which was obtained from a wayside pond. The owner of these cottages afterwards provided a tank, 10 feet deep and 8 feet in diameter, which receives the rain water running off the roof, and this, after settling, is preferred by the people to the pond water which they used to drink. There are ten people living in these cottages, one of whom, a laundress, uses a large quantity of water, and another who feeds a large number of pigs, takes much more than an average quantity from the tank: it has never yet failed to maintain a sufficient supply for their wants. This water, though of inferior quality as regards organic impurity, is nevertheless the next best supply to that derived from springs or deep wells. The rain-fall in this district is between 25 and 30 inches in the year, an amount much less than the average for the whole island. There would in all probability be a quite sufficient supply of rain water collected from the tiled roofs of cottages and barns in any part of the country for use throughout the year. In some other cases most excellent, palatable and pure water has been collected from a clean house-roof, and stored in a covered tank.

The frequent occurrence of wells and cesspools together, and the use in villages of surface drainage water for drinking, even when the other evils are absent, make it absolutely necessary that great care should be exercised in the use of water. Wells should never be less than 50 feet deep, and the deeper they go the less likely is the water to be contaminated if the sides be properly bricked down for some distance. Landowners whose property contains whole villages, should take care to consult a geologist (see "Public Healths Act,") as to the best site for a well near the centre of the village. Borings should then be made until the supply of water obtained be ample and pure. A most excellent method of getting water in a gravelly soil, is to sink a Norton's Abyssinian tube well for 50 or 60 feet. A pump placed over the well would thus give the cottagers at least a wholesome water for drinking purposes; their own wells might be closed up or used only for cleaning purposes. In the unfortunate state of the law at present, no compulsion can be brought to bear upon the landlord to make wholesome the dwellings which he lets to others. In some cases no water is provided; in others it is foul. Persons enter into occupation of the house, and are soon under the influence of poisoned drink. In towns the water company supplies the water, and it is the duty of the sanitary authorities to procure information as to the purity of the supply; the company is responsible for this until the water is delivered on the premises. When the supply is continuous, that is to say, when there is no cistern, as is the case in many towns, there can be no fear under ordinary circumstances of the water being fouled within the dwelling. Occasionally it may be turbid, especially when new iron main pipes have been laid down, but this is of no consequence, because the turdidity is not due to injurious matter, but merely to a little oxide of iron or rust, which is washed along. In many places the water supply is intermittent, that is to say, the water is turned on for a few hours each day to keep a sufficiency in the cistern. When the cistern is made of lead, which is disadvantageous, it should not be disturbed, but if constructed of slate or brick, with cemented sides, it should be occasionally cleaned out, and the water run off. The danger arising from cleaning a lead cistern, is that which may arise from the displacement of a crust of carbonate of lead, which protects the metal from the action of the water. When pure water is left in contact with bright metallic lead, the air soon begins to oxidize or rust the lead; this rust of lead dissolves in the water, and persons drinking from it are subject to lead poisoning. When the water is hard, as most waters are, the dissolved mineral matter protects the metal.

In all cases where cisterns are in use they should be covered over, and so arranged with regard to closets that no gases can escape up into the water. Then the overflow or waste pipe should not go down directly in the sewer, but should lead into a trapped-drain outside the house, and this drain should communicate by a grating with the open air.

As to the water itself, every one would be prejudiced against that which was not clear. Now, though this is not *always* a serious matter, yet in the majority of cases a turbid water is certainly not good. It is the solid particles which are of an injurious nature; these may be so small as to be floating or suspended. When the solid particles are excessively small, and in very great number, they take away the bright and clear appearance, sometimes to so small an extent as to give a sort of delicate cloudiness, opalescence, or haziness, such an appearance as would be produced by the addition of a very small quantity of boiled starch to clear water, and subsequent shaking so as to mix it thoroughly. Water with this hazy appearance is most dangerous, as it always proceeds from hurtful organic matter.

When water is coloured, the natural inclination is not to drink it, yet this may proceed from circumstances which may not alter its healthfulness. Brown water will often run off a moor or common, a little colouring matter is dissolved away from the moss and peaty matters, but if such circumstances are known to account for the colour, there is no great cause for alarm. Taking these things into consideration the general rule may be adhered to, that water should be clear, bright, transparent, and free from suspended matter.

Potable water should be perfectly palatable, and to be so should possess not the faintest smell of any kind. It should be without any flatness, and be absolutely tasteless. Exceptions to this order of things may be named. In a mineral district a slight, very slight trace of iron will give an inky or chalybeate flavour, that which Sam Weller in "Pickwick," described as "the taste of warm flat-irons." There is certainly nothing to be feared from this, but one or two circumstances may occur through the use of such water which may as well be explained. It is apt to get brown, and leaves a slight deposit of iron rust at the bottom of a glass or bottle. When tea is made of such water, it is generally very dark, and may, indeed, be inky black. Inky black is the most correct expression that can be used, the colour being due actually to the colouring matter of ink, which is produced by the mutual action of tannin, which is the astringent principle of the tea and the iron in the water. In the same manner ink owes its colour to the action of tannin obtained from oak-bark, or nut-galls, on green vitriol, which is the sulphate of iron. Then the water may under other circumstances have a disagreeable flavour, and odour recalling that of a rotten egg. Here the smell of the water and of rotten eggs is caused by the presence of the same substance, sulphuretted hydrogen gas, or it may be to certain other compounds of sulphur existing in the water. Such a liquid should never be habitually used as a beverage. If there be no alternative, boil the water rapidly for some time, and let it cool before drinking. Water should be free from bitterness. A bitter taste may indicate the presence of a larger proportion of Epsom salts, or sulphate of magnesia, than it is desirable to be in the habit of taking. Water should never under usual conditions have the faintest suspicion of saltness or sweetness. In districts, of course, near the seaside, or in the neighbourhood of salt mines or brine springs, a brackishness is of little importance, but otherwise a sweet or salt flavour is an indication of danger by some filthy contamination. Water, as a rule, should be entirely without taste or smell. The account of the Broad Street Pump-water, and the outbreak of cholera it caused, affords an instance of a filthy water being not only clear, colourless, and palatable, but so agreeable to drink, as to be sent for from a distance of about three miles. One may venture to say that every favourite pump or well in or adjoining a churchyard, or other burial-ground, is of a similar nature. It is charged to a high excess with saline matter, organic matter, and carbonic acid.* The carbonic acid and saline matter give a refreshing flavour, which is increased by the presence of nitrate of lime. Water from a surface well, near a house and its adjuncts, is liable to this dangerous kind of pollution. If such water be kept for some days in a bottle of good size in a warm place, putrefactive changes occur, which make it turbid, stinking, and nauseous.

If those who dwell in isolated farm-houses or cottages, country places or villages, are unable to get water, except from doubtful sources, they should bear in mind that a deep well is to be preferred to a shallow one. That wells, if removed from all likely sources of pollution, are better than surface streams. Rain-

* The pleasant effect which carbonic acid has upon the palate is well instanced by the fact that bitter beer is sharp and agreeable when brisk, but is most nauseously bitter when flat.

water collected from the roofs of houses, and stored in underground tanks, frequently acquires a polluted condition, and therefore should not be used for drinking. If no other water than that from a suspected source is available, it should be efficiently filtered. If filtration for some reason cannot be carried out, the water should be boiled for some time, and placed in a covered stoneware jug or jar to cool. Water which has to be fetched from a distance should be kept in a cool place in a covered earthenware jar, so that impurities from the air or dust may be prevented from getting into it. It should never be allowed to stand in buckets, whether of metal or wood, or in a warm place, opened and exposed to impurity.

HOW TO PURIFY WATER. When water is coloured brown with peaty matter or mossy vegetation, the organic matter may be removed to a great extent, and the liquid made colourless and clear by the addition to it of a solution of alum. Dissolve a pinch of alum in a glass of water, and pour this into a ten-gallon jar of water, in about twenty-four hours the brown matter will have subsided and collected at the bottom of the vessel, and the upper portion is fit for use. It has no taste communicated to it, and is quite as wholesome as if no addition had been made to it.

If water can be procured only from a suspected source, it should be filtered. The best kind of filter is one containing animal charcoal, or one in which iron, in a peculiar, spongy form, acts as the purifying agent. No form of filter should be purchased the charcoal in which is not easily accessible and removable, otherwise it will have to be sent to the maker when cleansing is necessary. Animal charcoal should be renewed every three months, but spongy iron will remain good for more than a year at least. Purchasers must not be misled by statements to the effect that lime can be removed from water by filtration through any particular apparatus. No filter will remove lime. "The filtration of water is not difficult, even if you cannot afford to buy a regular filter. The compressed charcoal blocks are cheap and good; if they clog, rub them gently with a towel, or, if that does not clear them, with a hard brush; if they are still clogged, they must be gently scraped with a knife. But if the charcoal block is too expensive, a simple filter can be made as follows:—" Get a common earthenware garden flower-pot; cover the hole with a bit of zinc gauze, or a bit of clean-washed flannel, which should be changed from time to time; then get some rather small gravel, wash it very well, and put into the pot to the height of three inches; then get some white sand and wash it very clean, and put that on the gravel to the height of three inches; then buy two pounds of animal charcoal, (in coarse grains), wash that also by putting it into a jug and pouring boiling water on it, then when the charcoal has subsided, pour off the water, and put some more on for three or four times. When the charcoal has been well-washed, put it on the sand, and press it well down. Have four inches of charcoal if possible. The filter is now ready, pour water into the pot, and let it run through the hole into a large glass bottle.

"After a time the charcoal will get clogged, take off a little from the top, and boil it two or three times, and then spread it out and let it dry before the fire. It will then be as good as ever. From time to time all the charcoal, and sand also, may want washing. The sand may be put over the charcoal, and not between it and the gravel; but this sometimes leads to the charcoal being carried with the water through the gravel and out of the hole. The sand stops it.

"By filtering in this way, and boiling the water, many dangers are done away with."*

If you have a rain-water tank this should not be placed underground, as pollution has occurred in such places to a dangerous extent.

Rain-water should be filtered before use for drinking or cooking purposes. Wooden water-butts should not be used to collect it in.

Those who live in the country, either on a chalky or a gravelly soil, can never be safe from possible contamination in the water if the well and the cess-pit are near together. The landlord should be persuaded to remove the cess-pit, or, better still, put up a dry-ash or earth-closet instead.

How to test water for impurities :—

Colour, and Floating Impurities.—Take between half a pint and a quart of the water for the purpose of examination. Rinse out a clear white glass bottle two or three times with the water, and then fill it up. A glass water-bottle, such as is used for the table will do, or one of those stoppered white glass bottles used by druggists in their shops; if nothing of the kind is at hand, a good glass tumbler will answer the purpose.

Stand before a window in the full light of day, raise the glass of water at about 2 feet from you up to a level with the eye, and then gently lower it for 6 or 12 inches and note its appearance. If it be cloudy or hazy, or if it be seen to have little particles of stringy matter floating in it, though of exceedingly small size, almost invisible, it is a very bad sign. A reddish-brown tint may be due to peaty matter, and the source of the water must be taken into consideration. If the colour cannot be so accounted for it is a bad sign. If the water be clear, so far so good.

* Appendix to Dr. Parkes's "Personal Care of Health," p. 118. London: S. P. C. K.

Taste and Odour.—Any water with a decidedly nasty taste, or with a saltish or sweet taste, is unfit to drink.

Rinse a wine-bottle out with the water, put in a clean cork, and shake it up. If any smell is perceived on applying the nose to the uncorked bottle, the water is bad. If such be not the case place the bottle aside for a few days, a week or fortnight, corked and in a warm situation. In summer, out in the sunshine will be warm enough. Then shake and smell as before, any disagreeable smell is a bad sign. By this means water perfectly bright and clear has had its source of pollution detected. Surface-water from cultivated land, for instance, sometimes acquires the smell of a pond or ditch, or running brook choked with weeds,—what may be described as a "weedy" smell. It is faint, but quite perceptible. Water from a stable, and in other instances water from sewers and from gas-works, have revealed their presence in clear and tasteless well waters, when tested in this manner.

CHAPTER VII.

CLEANLINESS AS DEPENDENT ON AN ABUNDANT SUPPLY OF WATER.

Preventable Nature of Infectious and Contagious Diseases—The Duty of Cleanliness—Lord Palmerston's Letter to the Presbytery of Edinburgh—An Abundant Supply of Water the First Condition of Cleanliness—Professor Hull's Suggestions for the Water Supply of Villages—Provisions for this purpose in the Sanitary Laws Amendment Act.

INFECTIOUS and contagious diseases are for the most part practically suppressible. Medical authorities tell us this again and again. Practical experience has proved it; remove dirt, and disease takes itself off. The sweating sickness, which spread all over the country in the fifteenth century causing the most frightful mortality; the plague, which emptied the City of London in the seventeenth century, and the last traces of which were seen in this country 176 years ago; the jail fever or spotted typhus, which prevailed at a later date, all these diseases were spread by the filth in air or water. The ague which has greatly lessened, and small-pox which has been all but destroyed in this country, have been checked, the one by vaccination, the other by drainage.

The most prevalent and fatal disease remaining with us is the enteric fever, commonly called typhoid. To quote the words of Dr. Parkes ("Personal Care of Health," p. 101): "This disease is spread by persons swallowing in water or milk, or taking into their lungs very small portions of animal substance which have come from the bowels of other men, perhaps of men ill with this fever. Stated in this bare way it seems frightful; but I have purposely thus stated it, that the hideous nature of the mode of spreading may be seen, and because until it is known by every one this fever will prevail. When once it is seen by all that the disease is really one of want of cleanliness, and of defective attention to the disposal of excreta, typhoid fever will die out. Let it once be clearly proved that it is entirely preventable, and that certain measures can prevent it, and then an educated people will insist on these measures, and will aid in their execution."

It is indeed the duty of the enlightened man to instruct the ignorant, and compel him when possible to conform to such usages as will increase his value to his family, and prevent himself and them being a source of danger, a means of spreading sickness to the neighbours.

The following letter contains a lesson which should be preached alike to rich and poor. When in the year 1853 the cholera appeared in the United Kingdom, and in the autumn the Presbytery of Edinburgh questioned Lord Palmerston, through their Moderator, whether, under the circumstances, a national fast would be appointed on Royal Authority, being a humane man, with a vast amount of sound common sense, and having a due appreciation of sanitary precautions, he sent the following reply :—

"WHITEHALL, *Oct.* 19*th*, 1853.

"SIR,—I am directed by Viscount Palmerston to acknowledge the receipt of your letter of the 15th inst., requesting, on behalf of the Presbytery of

Edinburgh, to be informed whether it is proposed to appoint a day of national fast, on account of the visitation of the cholera, and to state that there can be no doubt that manifestations of humble resignation to the Divine Will, and sincere acknowledgments of human unworthiness, are never more appropriate than when it has pleased Providence to afflict mankind with some severe visitation; but it does not appear to Lord Palmerston that a national fast would be suitable to the circumstances of the present moment.

"The Maker of the Universe has established certain laws of nature for the planet in which we live, and the weal or woe of mankind depends upon the observance or neglect of those laws. One of those laws connects health with the absence of those gaseous exhalations which proceed from overcrowded human beings, or from decomposing substances, whether animal or vegetable; and those same laws render sickness the almost inevitable consequence of exposure to those noxious influences. But it has at the same time pleased Providence to place it within the power of man to make such arrangements as will prevent or disperse such exhalations as to render them harmless, and it is the duty of man to attend to those laws of nature, and to exert the faculties which Providence has thus given to man for his own welfare.

"The recent visitation of cholera, which has for the moment been mercifully checked, is an awful warning given to the people of this realm that they have too much neglected their duty in this respect, and that those persons with whom it rested to purify towns and cities, and to prevent or remove the causes of disease, have not been sufficiently active in regard to such matters. Lord Palmerston would, therefore, suggest that the best course which the people of this country can pursue to deserve that the further progress of the cholera should be stayed, will be to employ the interval that will elapse between the present time and the beginning of next spring in planning and executing measures by which those portions of their towns and cities which are inhabited by the poorest classes, and which, from the nature of things, must most need purification and improvement, may be freed from those causes and sources of contagion which, if allowed to remain, will infallibly breed pestilence, and be fruitful in death, in spite of all the prayers and fastings of a united but inactive nation. When man has done his utmost for his own safety, then is the time to invoke the blessing of Heaven to give effect to his exertions.

"I am, sir, your obedient servant,
"HENRY FITZROY."

"This letter created a great stir, and some indignation among certain sections of the community; but it was after all the embodiment of common sense. It reminded those in authority that it was their bounden duty not to neglect the teachings of science, or the spirit of practical Christianity. It suggested that until they had fulfilled their duty to their neighbour, they could not lift up clean hands in prayer and fasting. The lesson which it thus sought to inculcate on the municipal authorities of Scotland was greatly needed. Sanitary laws were at that time even less known and less cared for than now; and in the terror excited by the mysterious appearance of this terrible disease the fact was overlooked, that the conditions under which it was developed and diffused were under human control, and grew out of the negligence and folly of individuals and local authorities. To substitute a national fast for the paramount duty of cleansing the drains and purifying the streets, would have been a strange misunderstanding of the Divine Will, as revealed in the operations of natural causes."*

It was at this time that committees of the most influential inhabitants in the county of Moray were formed to enforce a more satisfactory condition of cleanliness of the towns and villages. They encountered great opposition from the inhabitants when endeavouring to induce them to remove the dunghills and dung-pits from near their doors and windows, such property being regarded with pride and satisfaction. One determined woman, on the outskirts of the town of Forres, no doubt with her future potato crop in view, met the M.P., who headed one of the committees, thus, "Noo, Major, you may tak our lives, but ye'll no tak our middens."†

It will be many a day before every cottager has an ample supply of wholesome water, it will be long ere the house of every artisan in populous districts will, in addition to a constant water-supply, have a large bath on his premises. I am told that in many parts of America the bath, large enough to drown a person, is a fixture in every little house. Such arrangements are of immense value, so conducive are they to household and personal cleanliness. When persons are inclined to be careless in such matters, anything which will tend to give as little trouble as possible will tend to destroy such carelessness. If, for instance, it be a much pleasanter sensation, and a more effectual operation, entailing less trouble, to wash with soft water instead of hard, the number of persons who will take to washing themselves more frequently will be very greatly increased: the old proverb, "Cleanliness is

* Extract from "The Life of Lord Palmerston," vol. II. p. 13. By the Hon. Evelyn Ashley, M.P.

† "Reminiscences of Scottish Life and Character." By Dean Ramsay.

next to Godliness," is quite as true as other proverbs, the reason being that cleanliness is conducive to health and morality.

In the "Quarterly Journal of Science" for July, 1876, Professor Hull proposes that, in villages standing on the Oxford Clay, the Lias, or the Keuper Marls, or such impermeable strata, or at such a distance from the subjacent water-bearing strata, that the depth of a well would be great, and the expense too costly, the supply might be drawn from the surface-drainage of pasture and meadow lands, and powers should be given to the local sanitary authorities to impound such streams as flow off those lands in small reservoirs under such regulations as to prevent pollution of stream or reservoir. In sinking a well, the surface-water should be excluded by 10 or 12 feet of substantial brick or stone work. Heavy penalties and strict regulations should be enforced in order to guard it against pollution, when the well is for public use in a village. He states on geological grounds that probably all the villages and hamlets in the Midland and Eastern counties could be supplied by wells.

Provision is made in the Sanitary Laws Amendment Act of 1874 empowering the Rural Sanitary Authority (which is therein declared to be the same body as the Board of Guardians), to purchase water-mills, dams or weirs, for the purpose of supplying its district with water for domestic use. These bodies have further authority to close such wells and pumps as yield water so polluted as to be injurious to health. Hence, there should now be no cause for the wholesale slaughter of human beings by the consumption of filth in their daily food. It has been shown that three sources of water-supply exist in out-of-the-way places :—1st, Deep wells or springs; 2nd, Streams from meadow and pasture land preserved from pollution; 3rd, Rain-water tanks, covered over, but placed above the ground. If total abstainers from intoxicating liquors would only agitate for supplies of pure water they would do infinitely more good than they are ever likely to do by their usual proceedings.

APPENDIX.

SUBJOINED are the sections referring to water-supply in the Sanitary Laws Amendment Act of 1874 :—

"50. If it shall be represented to any nuisance authority in the metropolis or to any sanitary authority that within their district the water in any well, tank, or cistern, public or private, or supplied from any public pump, and used or likely to be used for domestic purposes, is so polluted as to be injurious to health, such authority may apply to any justices having jurisdiction within their district, in petty sessions assembled, for an order to remedy the same, and thereupon such justices shall summon the person occupying the premises to which the well, tank, or cistern belongs, if it be private, and as regards any public well, tank, or cistern, or pump, such other person as shall be alleged in the application to be interested in the same, and shall either dismiss the application or make such an order in the case, by directing the well, tank, or cistern, or pump to be permanently or temporarily closed, or the water to be used for certain purposes only, or providing otherwise, as shall appear to them to be requisite to prevent injury to the health of persons drinking the water.

"For the purposes of such inquiry, the said justices may cause the water to be analysed at the cost of the sanitary authority applying.

"And all the expenses incurred by such authority in and about the procuring of this order, and in carrying it into execution, shall be charged upon the funds applicable to their general expenditure, but in the case of a rural sanitary authority, shall be deemed to be special expenses within the meaning of the Sanitary Acts.

"33. Any sanitary authority may, subject to the provisions of this Act and of the Sanitary Acts, buy up any water-mill, dam, or weir which interferes with the proper drainage of or the supply of water to its district, and may, for the purpose of supplying its district with water for drinking and domestic purposes, purchase, either within or without its district, any land covered with water, or any water or right to take or convey water; and for the purpose of buying up any of the properties aforesaid, the Lands Clauses Consolidation Act, 1845, and any Act amending the same, shall be incorporated with this section, but the compulsory powers of purchase contained in the said Lands Clauses Act shall not be exercised except in pursuance of a provisional order of the Local Government Board."

AIR.

CHAPTER I.

PROPERTIES AND COMPOSITION OF AIR.

Air a Gaseous Food—Its frequent Contamination and Unwholesomeness—The Nature of Air a Mixture of Gases—Variations in the Air of Towns—Solid Particles of Minute Size float in the Air—Presence of Water-vapour, Carbonic Acid, Ammonia, and Ozone in Air—Properties of Ozone—Physiological Action of Air—Carbonic Acid an index of the Vitiation of Air—How Constancy of Composition is maintained in the Air—Carbonic Acid in the Air of Towns—The Organic Matter in Town Air—These Substances are Effete Matters cast off by the Inhabitants.

THAT food for which we have the most immediate necessity is in a gaseous form, and is called air. Starvation is a matter of days with solids, hours with liquids, but of minutes with air. So much attention has been drawn to the importance of drinking pure water that at times when epidemics are rife much alarm is felt, and few persons would care to drink of a well contaminated with sewage to an extent so small that only the most delicate chemical analysis can detect its presence. Yet it is so strangely different with air, that an average body of men feel no repugnance to breathing impurities in such quantities that the amount of impurities may be instantly detected by the nose. The quantity of water which even a teetotaller would drink daily may certainly be stated on an average to be limited to three pints; the amount of air necessary, on a moderate computation, is 1,500 gallons. If water contained only one part of organic nitrogen in 1,000,000 parts, that is to say, 1 pound in 100,000 gallons of water, this would be a startling quantity from a sanitary point of view. The unwholesomeness of this, however, might be quite unperceived in drinking, but most persons in a healthy condition can detect the unwholesome state of an atmosphere without the aid of chemistry, simply by the sense of smell.

Air differs in character from water by being gaseous instead of liquid, by being mainly a *mixture* of two elements, oxygen and nitrogen, instead of a *compound.* In the year 1774 the active constituent of air, the oxygen, was discovered by Priestley; and in the same memorable year Lavoisier, a French chemist, discovered the nature of air, and the necessity of the oxygen of air for the respiration of animals and for combustion. A burning paper, a piece of charcoal, or a steel watchspring, if heated and plunged into this gas burns with intensely vivid light. The remaining gas, nitrogen, is a kind of choke-damp or irrespirable air incapable of supporting combustion or respiration. The proportion of oxygen to nitrogen gas in the atmosphere is one measure of the former to four of the latter. If a pint bottle full of oxygen be passed up through water into a jar full of water, and then four pints of nitrogen be added, the resulting mixture has all the properties of, and in fact is, purified air. The nitrogen is quite inactive, its only use appears to be the dilution of the oxygen and consequent moderation of its chemical activity. The properties of oxygen are the properties of air greatly intensified, or conversely, the properties of air are those of oxygen much enfeebled. Besides these principal constituents others are present in minute quantities, which may be thus enumerated :—

Oxygen and Nitrogen	Chief Constituents.
Water	Constituents present in Minute Quantity.
Ammonia	
Carbonic Acid	
Ozone	
Nitrous and Nitric Acids	

There are in addition, more especially in the air of towns, gases which may be regarded as impurities of artificial origin ; such as, for instance, hydrochloric and sulphurous acids, occasionally sulphuretted hydrogen from decaying organic matter, and marsh gas from the same source. Sulphurous acid results from burning coal containing sulphur, while hydrochloric acid escapes from chemical works, but is sometimes discharged during volcanic eruptions.

The ray of sunlight playing through a chink in a window-shutter, and crossing a darkened room, reveals an infinite number of motes in constant agitation. They are so small in size, so large in number, and so impalpable, that one can well believe that they have no real existence, that it is some optical illusion, depending on some unexplained property of gases which gives a sunbeam the appearance of being crowded with floating particles. Experiment, however, and microscopic investigation have shown them to consist of minute fragments of such kinds of matter as constantly surround us. Fragments of vegetation resembling hay, straw, and hay seeds,—particles of vegetable tissue partially burnt, hairs of plants and fibres resembling flax, cotton fibres, both white and coloured, starch granules, wool, white and coloured ; but in addition to these, and present in greatest abundance, fungoid matter, the germs of those minute fungi commonly called mould and mildew. These are the agents which cause mouldiness and decay. The presence of water vapour in the air is sufficiently evident if we look at the windows of a small warm room in winter; the glass is streaming with moisture on the inside. The cold air without condenses it to the liquid state upon the cold glass. When the temperature is very low the vapour is at once frozen, and then becomes hoar-frost. In the middle of summer a glass or bottle of ice-cold water becomes bedewed upon its outer surface by the condensation of aqueous vapour. A closed carriage in cold weather has streams of condensed moisture on its inner surface, and the greater the number of persons in the carriage the larger the amount of vapour condensed, showing that water vapour continually passes away from the body. Sometimes a sudden chilling of the atmosphere precipitates moisture from the air in various forms, such as meadow dew, mountain mist, or town fog. A town fog carries down with it a certain amount of soot and smoke, and the latter gives the yellow look which is characteristic of a foggy atmosphere where coal is burnt. The ammonia is present in country air in a very minute proportion, which does not amount to more than three volumes of the gas in ten million volumes of air. Ozone, which is a peculiarly condensed form of oxygen with greatly exalted chemical activity, is present in only minute proportions; thus, in country air it does not amount to more than one volume in 700,000 volumes of air. Its production probably arises from a continuous silent discharge of electricity between the clouds and the earth, acting upon the oxygen of the air in the same way that artificial electric discharges are found to do. Ozone has a very peculiar smell, and it is doubtless this which is perceptible near a place which has just been struck by lightning, and which is ignorantly described sometimes as a smell of sulphur. Ozone differs in its chemical activity from oxygen as much as oxygen differs from common air. It is capable of burning or oxidising substances without the application of heat; for instance, it eats through india-rubber tubing, and it burns or oxidises silver and mercury at ordinary temperatures. It is an energetic bleaching agent, and it owes this property to its power of destroying organic substances; sugar, for instance, is in a manner burnt up by it, and linen and cotton fabrics destroyed for all useful purposes by exposure to it when but in a very diluted condition. Its power, therefore, of disposing of noxious matter in the air renders its use in the atmosphere sufficiently obvious. Nitric and nitrous acids are doubtless formed by electric discharges causing oxygen and nitrogen in moist air to combine, the water vapour subsequently acting on the compound, and producing the two substances. When air is taken into the lungs it comes in contact with the venous blood, which, having passed through the body, is fouled to some extent. The venous blood is of a dull purple tint, and from it carbonic acid is disengaged in the lungs, the oxygen of the inspired air is to some extent absorbed by this blood, and a distinct change in colour depends on this absorption. From the dull purple of its depreciated state, it turns to a bright red tint when it is revived by oxygen.

It has been pointed out that the combined nitrogen in water is the index of a certain inexactly determined amount of organic matter. In dealing with the atmosphere, we have in the proportion of carbonic acid in the air of "close" places a certain index of the organic matter which is likely to be just as hurtful, and is certainly more constantly injurious, than that in water; but it does not show its effects in the outbreaks of epidemics, and so fails to attract attention and cause alarm. It works silently, but in a deadly manner; for the reports of medical men tell us that a very large proportion of cases of phthisis and other pulmonary complaints are owing to the breathing of a vitiated air. The atmosphere, considered as a mere mixture of gases, is of remarkably constant composition; owing partly to its vast extent, partly to its being agitated by the action of winds and imperceptible air-currents, and partly to the decomposition, by means of plant life, of the carbonic acid produced in it by animals. Nevertheless, the air varies constantly and very widely in composition; but the variations are confined within very small limits. An atmosphere containing three volumes of carbonic acid in 10,000 of air in excess of that usually present, commences to be offensive to the nose and loathsome to the senses when entering from the outer air, by reason of the accompanying organic effluvia. This alone renders the importance of breathing fresh air self-evident; but ignorance and negligence too often disregard this. Impurities in water are carried into the stomach, and in a healthy subject may be destroyed by the gastric juice; but impurities in the atmosphere find their way though the lungs into the blood, a much more serious matter. The oxygenation of the blood, and the removal of carbonic acid and other effete products from the body, is the function performed by respiration. All practical experience proves that to breathe air containing as high a percentage of oxygen at all times as Nature will afford, is to insure to a great extent immunity from a certain deadly class of diseases. The researches of Angus Smith have shown that in the air of towns there exists a certain amount of carbonic acid in excess of that usually present in the country. This excess is, on an average, about one volume in 10,000 of air; but it varies in different towns, in different quarters of one town, and even in different streets. The following table, arranged from the figures given in Dr. Angus Smith's "Air and Rain" indicates this:—

November, 1869.	Measures of Carbonic Acid in 10,000 of Air.
Scotland:	
Summit of the Hills	3·32
Average of twenty-six analyses.	
At the Foot of the Hills	3·41
Average of eighteen analyses.	
London:	
In the W. and W.C. Postal Districts	4·115
Twelve analyses.	
In S. and S.W.	4·394
Thirty analyses.	
N. and N.E.	4·445
Twelve analyses.	
E. and E.C.	4·745
Twelve analyses.	
Perth and Suburbs	4·136
Ten analyses.	
Closer parts of Glasgow	5·39
Eighteen analyses.	
More open parts of Glasgow	4·61
Nineteen analyses.	
Manchester	4·42
Average of very many analyses.	
Manchester, during Fogs	6·79
,, about middens (of which there are thousands)	7·74
,, where fields begin	3·69

All experimenters are agreed with M. Felix Le Blanc, who, in 1842, came to the conclusion that the most exact indication of air contamination was the proportion of carbonic acid present. This is found to rise with the proportion of organic matter when pollution is due to vital processes. Organic matter, however, is not so constant in quantity as carbonic acid in the air of open places, except in towns, where it is, to a great extent, the effete matter and refuse cast out by the inhabitants. The various pollutions in town air may be recognised not only by delicate microscopical and chemical analysis, but are seen collectively on looking through a sufficiently thick layer of the atmosphere. The direction of such places as Manchester, Leeds, Birmingham, and London, is indicated at a distance of several miles by the dull grey haze hanging over them, and making a blot in the blue sky on a fine day.

Those who live on Sydenham and Highgate Hills cannot fail to have noticed the vast haze overhanging London, and the change in character it exhibits according to the amount and direction of the wind, the dryness or dampness of the air, and the extent, duration, and recent occurrence of the previous rainfall. It is rarely before or after the months of April and May, during the whole year, that a distinct view of London may be obtained from the hills lying between Sydenham and Croydon, though, during that time, it not unfrequently happens that after a smart shower and a brisk wind the churches and buildings in the heart of the City may be clearly distinguished. The hazy atmosphere of a town is cleared of a crowd of minute solid particles to a remarkable extent by a heavy rain of short duration. The presence of readily oxidisable organic matter in air may be detected by its bleaching action on the pink colour of a very dilute solution of permanganate of potash (Condy's disinfectant). By always taking a solution of the same strength and measuring the quantity of air required to bleach it, a ready means of comparing the air of one place with that of another is afforded. The exactitude of the method is damaged by other kinds of matter than the organic, being oxidisable, such as sulphurous acid in the air of towns; but as these are impurities, it does not affect the utility of the test as a means of measuring the healthiness of the atmosphere. It is my desire to show that the air of such places as indicates a high proportion of carbonic acid also contains a large amount of organic matter, and in order to establish this satisfactorily it will be necessary to refer to figures, derived not only from use of the permanganate test, but from Wanklyn's method for determining the nitrogen in organic substances. The numbers are all quoted from the researches of Dr. Angus Smith, and may be found in his work on "Air and Rain." The following table represents not actual, but comparative quantities of oxidisable organic matter contained in the air of the places named, as determined by permanganate:—

	1859.
Manchester	52·9
"	52·4
"	49·1
"	58·0
"	48·0
In a house kept rather close	60·7
In an uncovered pig-sty	109·7
The Thames, at City, no odour perceptible, 1858	58·4
The Thames, at Lambeth	43·2
" at Waterloo Bridge	43·2
In the streets of London, warm weather	29·2
" " after a thunderstorm	12·3
Fields south of Manchester	13·7
" north of Highgate	12·3
Open air sixty miles from Yarmouth	3·3
Forest at Chamouni Hospice of St. Bernard North Lancashire	2·8
Lake of Lucerne	1·4

The Thames, which was very offensive to the nose from its foulness in 1857, even when it ceased to affect the senses in 1858, polluted the air to such an extent that it gave a very high number, 58. In going out of Manchester the amount diminished till in the fields it was 13, but in passing a sewer stream about one mile from the outskirts the quantity rose to 83.

The influence of heat and moisture increases the amount of organic matter.

Dryness diminishes the organic matter. Rain in hot weather has a very decided influence in removing organic particles from the air.

It is easy to tell by this test, when in the outskirts of the town, whether the air blows from the town or country, also when a room has been inhabited some time, or when the air of a sewer penetrates a dwelling.

From the two sets of data already quoted—the estimation of carbonic acid and of organic matter—we may safely conclude that the air of large cities is sufficiently impure to account for much of their unhealthiness; and the air of the hills, seas, lakes, and moors sufficiently pure to account for their salubrity. This has been confirmed by testing the rain-water of various places with acidified permanganate of potash. As the rain washes the air, the impurities the latter contains will be transferred to the rain-water. The following table shows this :—

Place.	Parts, by weight, of Oxygen necessary to destroy Organic Matter in One Million parts of Rain-water
West Coast, Scotland	0·018
England, inland places	0·466
Towns, Scotland	1·879
" England	2·743
Manchester	3·225
Liverpool	3·896
Glasgow	10·04

Wanklyn's method of determining the amount of nitrogen separable as ammonia from the other constituents of organic substances by means of distillation with strongly alkaline permanganate of potash, serves for a further comparison of the different quantities of organic impurity in air. We give here, first, the matter removed by rain; and then that present in the air :—

Place.	Albumenoid Ammonia in One Million parts of Rain-water.
Edinburgh	0·06
Perth and Aberdeen	0·10
Dundee and Galashiels	0·34
Glasgow and Greenock	0·55
Liverpool	0·159
London	0·205
Manchester	0·217
"	0·285

In London the average numbers for the different postal districts were as follows :—

London District.	Albumenoid Ammonia in One Million parts of Rain-water.
N. and N.W.	0.267
W.	0·283
S.W. and S.E.	0·357
E. and E.C.	0·37

Estimation of Albumenoid Ammonia in the Air.

Place.	Grains per Million Cubic Feet.
London Eighteen experiments, average.	65·94
Glasgow Four experiments.	133·26
Metropolitan Railway	163·16

It will be seen on comparing the foregoing tables, that by four different experimental methods—two on air and two on rain—the albumenoid ammonia or nitrogen, separated from organic matter in the form of ammonia, increases with the proportion of carbonic acid in the air, and that both constituents, organic matter and carbonic acid, increase with the density of the population of a district. The numbers referring to the different London postal districts illustrate this admirably, for they are greatest at the east, and smallest at the west end. The air is a gaseous ocean, serving at the same time as a source of gaseous food and as a receptacle for gaseous excreta and minute solid particles of refuse. It is very evident that the air of towns is polluted by the inhabitants; and if this is the case where the force of the winds can exert their full influence and the supply of fresh air is practically unlimited, or, at any rate, so great that no artifice of man can increase it, what takes place in rooms and other close places where this difficulty of getting fresh air in and impure air out is a very serious consideration.

It is easily seen by this table that the air of Manchester streets contains from seventeen to twenty times as much organic matter, or more strictly speaking, oxidisable matter, than that in the Forest at Chamouni, that near the Hospice of St. Bernard, or on the moors of North Lancashire.

The greater the amount of organic matter the greater the amount of oxygen necessary to destroy it. These numbers show that the rain of Glasgow carries down with it a 1,000 times more oxidisable matter than that descending on the adjacent West Coast. The towns of Manchester and Liverpool contain eight and nine times as much oxidisable matter in the air as other inland districts of England.

The table stating the albumenoid ammonia found in rain water shows that the densely-populated manufacturing towns of Dundee, Galashiels, Glasgow, and Greenock, contain nearly six to nine times as much organic matter in the air as Edinburgh, so far as the ammonia affords an indication, while London and Manchester contain from three to five times as much.

CHAPTER II.

VITIATED AIR.

The amount of Carbonic Acid and Water expired by a Man—Alteration in Air when breathed—Air once breathed is Poisonous—Offensive Nature of the Organic Matter exhaled—Carbonic Acid a measure of the Organic Matter—The Transient Effects of Vitiated Air—The Continued Breathing of Foul Air, its Serious Action—Statistics showing connection between Diseases of the Respiratory Organs and Foul Air—Necessity for Large Supplies of Fresh Air in Hospitals.

A MAN expires on an average, according to Liebig, 0·79 of a cubit foot per hour of carbonic acid, or nineteen cubic feet in the twenty-four hours. His breath contains five per cent. of carbonic acid, and is totally incapable of sustaining life. He thus destroys or renders poisonous 15·83 cubic feet of air per hour, or 380 cubic feet in twenty-four hours. Let us take the average amount of carbonic acid expired by an adult as 0·6 of a cubic foot per hour, measured at 70° Fahr.

This amount of carbonic acid amounts in twenty-four hours to nearly fourteen and a half cubic feet, and such a quantity could only be produced by burning a weight of charcoal equal to nearly half a pound. In addition to this, we have a quantity of watery vapour given off, varying from six to twenty-seven ounces, according to circumstances. In badly-ventilated churches, concert-rooms, school-rooms, and theatres, this moisture condenses on the walls, and may be seen trickling down the windows. As Dr. De Chaumont has forcibly pointed out, an assemblage of 2,000 people, during two hours (or the time of an ordinary concert or service), would give off about seventeen gallons of water from their lungs and by perspiration through the skin, and nearly as much carbon as would be extricated from a hundred-weight of coal : we cannot, therefore, feel much surprise at ill-ventilated apartments having the air they contain rapidly contaminated.

When air has been breathed, it has been altered in the following manner :—

The oxygen has been diminished.

The carbonic acid increased.

The aqueous vapour increased.

The presence of gas or candles affects the air in the same way ; but in addition to these alterations, respiration

Increases the ammonia.

Increases the organic matter, and destroys the ozone.

The lessening of the oxygen is not considerable, compared with what still remains in the respired air, but it is very serious with regard to the loss of its power of aërating the blood. It is in fact, after it has once been breathed, poisonous ; and it must be mixed with a very large amount of fresh air before it can be inhaled again without a feeling of suffocation.

The addition of organic matter to expired air causes a very serious deterioration in its wholesomeness. Its nature has not been exactly determined, but there is no doubt of its offensive character, for the evidence of the nose is sufficient to call attention to the fact. The quantity excreted, probably on an average amounts to 30 grains per diem for each person. It has been collected and examined by various observers, and found to consist of particles thrown off from the air-passages, from the skin, and mucous membranes, and from suppurating sores.

The effect of altered air upon the health is little known; when this is simply a diminution of the proportion of oxygen, probably an increased number of respirations would compensate for any such alteration if slight, and as we can never in the ordinary course of events encounter such conditions, it would be needless to speculate on the probabilities that might arise.

The increase of carbonic acid simply means the addition to air of a poisonous gas, and to a simultaneous diminution of the proportion of the life-giving oxygen. If air be mixed with $\frac{1}{40}$th of its bulk of carbonic acid, it will cease to support life or combustion. This gas, compared with air, is relatively heavier, so that it lies near the bottom in places where it accumulates, such as mines, wells, and brewers' vats. In certain caves in volcanic districts, as for instance, the Grotto del Cane near Naples, it remains below the level of the opening, consequently animals of small size entering therein are poisoned. Their noses and mouths being near the ground are immersed in air so charged with this gas, and so destitute of oxygen, that life cannot continue. Ordinarily carbonic acid diffuses itself so easily, and becomes so mixed up with the general body of the atmosphere, that little evil is to be felt from it alone. In badly-ventilated buildings a very dangerous amount of organic matter accumulates in the air long before the carbonic acid becomes poisonous in quantity. Thus, while it is possible to breathe air mixed with $\frac{1}{50}$th of its bulk of pure carbonic acid, only $\frac{1}{200}$th of this gas mixed with those organic impurities usually present in foul air, will become quite intolerable.

It has been experimentally proved that when the *heat is not excessive, the organic matter charging the air of crowded places rises in amount as the carbonic acid increases,* so that in the estimation of carbonic acid we have a measure of the foulness of the air or, as it may be termed, want of ventilation. When the heat becomes uncomfortable, the organic matter rises in a still greater proportion. The immediate effects of vitiated air are to cause an unpleasant "closeness," or "stuffiness," to be felt in the rooms ; this is generally detected by the nose when entering from the outside. It causes headache, languor, and lassitude, which come on gradually, the first symptoms of which are sighing, yawning, and listlessness. A feverish state is felt by many persons, even after so long an interval as twenty-four hours. The immediate effect is to weaken and decrease the rate of the pulse, and at the same time to quicken the respiration. The sensation of being wide-awake after retiring in a sleepy condition to one's bedroom is, more frequently than not, caused by having left a badly-ventilated apartment and moved into a cooler and purer air.

Such symptoms of the physiological action of foul air as these, are as nothing compared with the results arising from constantly breathing from day to day an atmosphere vitiated in a slight degree, and having a scarcely perceptible action. Pale cheeks and lips, want of energy, partial loss of appetite, lowering of the spirits, and decrease in muscular strength, are found to be gradually induced. Unless a corrective, in the shape of fresh air and exercise, is resorted to, things go from bad to worse, till such affections of the respiratory organs as bronchitis and consumption result. This last most-dreaded disease is more frequently than not contracted by persons who continually breathe foul air. Dr. Parkes has quoted statistics which show this in a very marked manner. In the badly-ventilated prison of the Leopoldstadt, in Vienna, in the years 1834 to 1847, the proportion of deaths was 86 per 1,000; out of which number 51·4 per 1,000 were due to phthisis or consumption, while in the well-ventilated House of Correction in the same city, the deaths were 14 per 1,000; of which 7·9 were occasioned by phthisis; it follows then that 43·5 cases per 1,000 were deaths attributable to nothing else but foul air. Perhaps no more instructive examples can be drawn from such perfectly trustworthy statistics as those which the history of the army and the police force of this country offer.

Before the Crimean War the health of the army was very bad, at least two soldiers died for every policeman, and the deaths were not traceable to service in tropical countries, since this source of fallacy in the numbers was eliminated by taking into account only such troops as never served abroad. The following table indicates the number of deaths per 1,000 men:—

	Death-rate.
Foot Guards	20·4 per 1,000
Infantry of the Line	17·8 ,,
Metropolitan Police	8·9 ,,

Soldiers are well-selected men; those with physical defects or of unsound health are not enlisted, the medical examination being very strict. It cannot be said that they are more severely worked than policemen, and in comparison with other persons of the same age and sex they apparently have greater chances of long life, still their mortality is nearly twice as great. With the worst lives in the community they are seemingly better fed, clothed, and lodged than the class whence they are derived. The chief causes of mortality appear to have been enteric fever, to which reference has been made, and consumption, or destructive lung diseases. The only difference which could possibly affect the health, was the unwholesome condition of barracks as a dwelling-place. With air-tight walls, and tightly fitting doors and windows, the air-space allotted to each man was found on investigation to be very insufficient. The air in the barrack dormitories was foul to a disgusting degree. When changes were made to remedy this, a marked improvement in health was soon manifested, and at the present day the death-rate amongst soldiers is no more than that of the civil population under like conditions of age and sex, and not more than half what it was prior to the year 1867. Precisely similar experiences in the French army have led to improved ventilation in barracks, resulting in an improved sanitary condition of the army. With domestic animals, like conditions yield like results.

During the outbreak of cattle plague in 1866, in sheds containing twenty or thirty cows—which the owners kept closed to such an extent that all chinks in the doors and windows were stuffed with straw and matting, under an ignorant belief that thus the plague could be kept out—very frequently the entire stock died in two or three days after the first appearance of disease; while in other cases, where animals were housed in a well-cleaned and tidily kept shed, with a plentiful supply of fresh air, not only did some of them escape the disease altogether, but the deaths were reduced to one-third of the number of beasts attacked.

The large supply of fresh air necessary in hospitals for contagious diseases is fully recognised by medical men, and more especially so in America. Wounds carefully protected from contact with impure air do not suppurate, and organic fluids do not putrify. On the other hand, in a bad atmosphere sores become unhealthy, and are difficult to heal, erysipelas and hospital gangrene frequently set in; while [the best prevention and the best means of cure for such afflictions is the greatest possible exposure to fresh air.

Overcrowding aids the spread of measles, scarlet fever, and the much-to-be-dreaded small-pox ; it brings on ophthalmia, a troublesome inflammation of the eyes, and is not unfrequently the cause of the ricketty and scrofulous condition of children, Although exposure to cold does cause such afflictions as bronchitis, pneumonia, cold in the head, sore throat, and other affections of the respiratory organs, it is more frequently the case that they are the result of a sudden change of temperature, such as is experienced on coming out of a crowded assembly in a close, badly ventilated building, than by actually cold weather. This is decidedly and strikingly shown by the fact which Dr. De Chaumont has quoted, that the British army when in the Crimea when lodged in tents during extremely rigorous weather, experienced a wonderful condition of health, such a thing as a cold being an unknown complaint; but, when some of the men were placed in huts which were much warmer, and into which there was a smaller circulation of fresh air, the sick rate increased, and coughs and colds began to put in an appearance. Persons who during summer and winter sleep with their bedroom windows more or less open, cannot endure a night spent in a chamber with the chimney closed, and the window shut. A less refreshing sleep occupies the night, and a somewhat feverish sensation is felt next morning. If, in cold weather, the window be opened only one inch at the top, the difference in the air of a bedroom is something quite beyond comprehension to those who have not paid attention to these things.

CHAPTER III.

VENTILATION.

The Circulation of Air in Houses, or Natural Causes of Ventilation—The Effect of Heat—Calculation as to Heat given off from the Human Body—Gaseous Diffusion—Exchange of Air through a porous medium between a Cold and a Warm Atmosphere—Passage of Air through Walls—The Unwholesomeness of Low-Ceilinged Rooms—Limits of Allowable Impurity in Air—Necessary Supply of Air per hour for each Person—Reckless Opening of Windows not good Ventilation—The Rate of an Imperceptible Breeze—The Neglect of Ventilation in Public Buildings, Offices, Workshops, and School-rooms—Examples showing the amount of Carbonic Acid in the Air of London Buildings—Test for the Purity of Air.

In all dwelling places there are conditions constantly presented which give rise to an entrance of fresh air, to dilute and to expel in part that which is foul. These may be called causes of natural ventilation. The first and most potent of these is difference of temperature. When a gas is heated it expands enormously, it therefore becomes proportionately lighter, and it naturally rises with the greater rapidity the more it is heated. If we take a glass shade and hold beneath it a roll of smouldering brown paper, or a lighted cigar, it becomes rapidly filled with a quantity of smoke, which remains imprisoned; invert the jar, and the smoke speedily becomes lost in the surrounding atmosphere. At least so we say. The case is not exactly what it appears; the smoke is carried up into the jar by currents of heated air, when the jar is inverted this heated air rises rapidly through that which is colder and denser, and takes up its position near the ceiling. But in its progress it warms the air with which it comes in contact, turning it over and over in eddies and currents, which causes such a mingling that the smoke is spread over a large cubic space in a way which we express by saying it is dissipated. So powerful is the effect of hot air, that a heavy fire-balloon may be raised to a great height by no other means than a fire lighted below it. Such is the power it has of thoroughly mixing and distributing itself, that the smell of a cigar lighted in the hall of a house of moderate size, may be smelt distinctly in the attics. This is in reality due to the movements of the air, which carries the smoke along with it, and not to the motion of the smoke by itself. By bearing this in mind, the extraordinary way in which still air circulates is readily comprehended. When not a leaf stirs, nor a breath of air ripples the surface of the water, constant and active air currents, quite imperceptible to us, are playing about, and from the very heat of our own bodies an upward stream of air is constantly rising. A good candle will produce 0·31 cubic feet of carbonic acid per hour while burning, and will by this act increase the temperature of 150 cubic feet of air 118°4 Fah. I have calculated from unquestionable data that the bodily heat of one man will cause a rise of temperature in the same quantity of air equal to 173° Fah. Hence the great heating effect of a mass of human beings packed closely together in a well-lighted and badly ventilated building. Hence the complaint of heat in such places. But we cannot, as is usually the case, lay the cause of faintness to the high temperature; it is due to the want of fresh air. The second cause of natural ventilation is the tendency of gases to mix with each other, notwithstanding great differences between their relative weights. This is called gaseous diffusion, and it is due to the operation of a natural law. The instances which might be cited of the diffusion of gases are very numerous and very striking, but it would be entering too much into details to enumerate them. Special instances of diffusion, however, are of importance, and these are dependent on the fact that cold air passes through a porous medium, such as earth or a brick wall, into a warmer space. Even through a wall which is plastered this is the case, but the effect of papering is in a great measure to obstruct the passage of gases.

Houses which are not provided with well-ventilated cellarage, are constantly liable to an influx of air which has passed through the soil up through the boards of a kitchen floor and into the room. When the place is not properly drained, and the ground is soaked with sewage, this fact is made evident in a dangerous and offensive manner. Concerning the passage of air through walls, no experimental facts can give so striking an instance as the following remarkable case in point. A London house, of the light brick and mortar construction, contained a small room which was only occasionally used. Sometimes there was noticed in it an unbearably bad smell, which was never perceived in summer, and only indeed in winter when a fire was lighted in the room. The drainage was of course first suspected, but found to be faultless, yet here was this extraordinarily foul air making its way into the room whenever the interior was warm and the exterior cold. The cause turned out to be a dust-bin built against the outside wall, and the filtration of air through this and the house wall. Diffusion from the cold to the warm atmosphere took place through the porous bricks and mortar. The large houses with lofty rooms in which many of the wealthy people in this country generally live, contain so large an amount of air that only a small quantity coming from the outside, or from the staircase and hall, is necessary to keep up a healthy atmosphere. In old manor houses, and other country residences, which are amongst the most picturesque, quaint, and pleasing features of many an English landscape, the ceilings are so low, and the windows so small, while at the same time the walls are so thick, that some means of artificial ventilation is necessary. Bedrooms without chimneys are by no means uncommon, and these are most unhealthy. In the overcrowded town-dwellings of the poor, one is prepared to encounter unhealthy air, and its effects are seen in the pale faces of the inhabitants, and their generally sickly condition; but where least expected, in secluded spots, surrounded with exquisite undulating park or meadow land, garnished with the fine old caks and such other foliage as constitutes the great charm of English scenery, there stands here and there an ancient ivy-covered building with rooms quite unwholesome for the use of the family to which it belongs.

What is the amount of space necessary for each person to breathe in? It has been already stated that the air of the open country does not contain less than three volumes of carbonic acid in 10,000 of air, and that this amounts to four or even five volumes, under ordinary circumstances, in towns. It is not advisable to breathe air containing more than six volumes of carbonic acid in 10,000; and, indeed, such air is pronounced by those entering from the outside to be close, that is to say it has a disagreeable smell—its impurity is detected by the nose—our senses warn us not to breathe it. We cannot, therefore, safely increase the amount of carbonic acid in buildings by the act of respiration beyond this quantity, that is, we may not add more than two volumes of carbonic acid to each 10,000 volumes of the air of the room. A person does not inhale and exhale more than 18 cubic feet of air per hour; but the supply of fresh air necessary, according to General Morin, of Paris, is 2,120 cubic feet per hour for the use of each person, and this amount has been more recently fixed at 3,000 cubic feet per hour. In addition, every two candles would require a similar supply, or for every gas-burner burning 3 cubic feet of gas per hour, an additional quantity of 5,400 cubic feet of air would be necessary. Generally speaking, in this country, the change of air in a room cannot be effected oftener than three or four times in the course of an hour, so that a space of 750 to 1,000 cubic feet per head must be provided in each apartment.

It is necessary to lay emphasis on the fact that the reckless opening of windows does not constitute good ventilation, though it may give a good supply of fresh air. If the rate of an almost imperceptible breeze be measured, it is sure to be found travelling at a higher speed than 18 inches per second. Every one knows what the effect of a draught is from having experienced the chilling sensation caused by its continued action, but it is, strictly speaking, a current of air moving at a greater rate than 18 inches per second, or 1 mile an hour. Ventilation in temperate climates is the art of supplying fresh air at a rate not greater than this, and in quantity sufficient to prevent the carbonic acid from increasing beyond the proportion of six volumes in 10,000 of air. The conditions under which we generally live at home, if carefully examined, will be found to be unwholesome,—either that we inhabit rooms which are too small, or that there is an insufficient supply of fresh air admitted to them. In bedrooms this latter defect is very frequent. But, although in dwelling-houses the sanitary conditions are not strictly adhered to, the great damage to health is committed in offices where men sit for hours earning their daily bread in an atmosphere like that of a common sewer; in workshops where the low ceilings and the pollutions of gas-lights, oil, dust, cotton waste, and metallic filings, the air which enters the lungs seems to be of such a consistency that one might cut it with a knife; and in school-rooms, to enter which just before twelve at noon, is to encounter a sickening, fetid air. In theatres and concert halls, places fortunately of only occasional resort, there is scarcely ever any systematic method of ventilation in practice. There are commonly a few holes in the roof, or in the walls, which are called ventilators, but which are nothing of the kind; when they are in any way effective it is by sending an avalanche of cold air on to the heads of the people. The ventilation of ordinary dwellings is comparatively a simple matter; but in considering the case of public buildings and workshops, where the numbers of people crowded together is very great, and the amount of gas consumed very large, the conditions are such as to be almost beyond the control of natural ventilation.

Fresh air should be provided by well-devised means, and the greatest possible care should be taken that natural ventilation should have full play. How seldom this is the case the following tables will show:—

Carbonic Acid in Close Places in London, according to Dr. Angus Smith:—

1864.	Parts in 10,000 of Air.
Chancery Court, 7 ft. from ground, closed doors, March 3	19·3
Same, 3 ft. from ground	20·3
,, door wide open	5·

	Parts in 10,000 of Air.
Strand Theatre, gallery, 10 P.M.	10·1
Surrey Theatre, boxes, ,, ,,	11·1
,, ,, 12 ,,	21·8
Olympic, 11.30 P.M.	8·17
,, 11·55 ,,	10·14
Victoria Theatre, boxes, 10 P.M.	12·6
Haymarket, dress circle, 11·30 P.M.	7·57
Victoria Theatre, boxes, April 4	7·6
City of London Theatre, pit, 11.15 P.M.	25·2
Standard Theatre, pit, 11 P.M.	32·0
St. Thomas's Hospital, Queen's ward, 3.25 P.M.	4·0
,, ,, Edward's ward, 3.30 P.M.	5·2
Lambeth Workhouse wards	·1
St. Luke's (Chelsea)	7·6
East London (Homerton)	7·6

In law courts, where it is more than ever needful that every one should have his wits about him, where judge and jury are confined for hours sometimes, even days without intermission, and where people of all kinds congregate, it is of the utmost importance that proper heed should be taken that they be provided with air fit to breathe. It is, however, by no means unusual in such places to find the atmosphere as bad as that which existed in the Chancery Court quoted at the head of the list. In the upper boxes of some theatres the breath of those in front is passed on from mouth to mouth till it reaches those sitting at the back; a listlessness is induced, headache follows, and people may be seen constantly sighing and fanning themselves, complaining of the closeness of the place, which they attribute to heat, and not to what it really is, the presence of foul air.

The following table states the amount of air which it is necessary to supply to each person hourly in the various buildings specified. These numbers, which were drawn up by General Morin, are considered by Dr. De Chaumont to be even too small:

	Fresh Air in Cubic Feet.
In Hospitals for Ordinary Patients	2,000 to 2,400
In Hospitals for Epidemics	5,000
Workshops, Ordinary Trades	2,000
Workshops, Unhealthy Trades	3,500
Prisons	1,700
Theatres	1,400 to 1,700
Meeting Halls	1,000 „ 2,000
Schools for Children	400 „ 500
„ „ Adults	800 „ 1,000

In children's schools the breathing of vitiated air day after day is most disastrous to the health, especially in crowded towns where the play hours cannot be spent in such healthful exercise as in the country. Many a poor lad has been blamed for idleness when, in fact, his seeming listlessness arose from ill health, aggravated, if not caused, by the vitiated air in which he lived most of his time. His weakly health made him extremely susceptible to the effects of what he was breathing.

TEST FOR THE PURITY OF AIR.—In cases where some proof of the foulness or purity of the atmosphere is required beyond that which is given by the sense of smell, a ready test is afforded by proceeding in the following manner.

Take a wide-mouthed stoppered bottle, obtainable from any druggist, capable of holding 10½ measure ounces of water. This should be cleaned and wiped carefully dry inside and out. On entering the apartment, the air of which is to be tested, a dry linen glass-cloth should be crammed into the bottle and withdrawn rapidly ; this changes the air of the bottle for that of the room. Take a bottle of clear lime-water and a clean dry measuring glass, pour the lime-water carefully down the inside of the glass until half an ounce is measured ; this should be emptied into the bottle, the stopper should be replaced and the bottle violently shaken for a few minutes. If the air be pure, the lime-water will remain clear, but if it be foul it will become turbid, and if very bad, even quite milky in appearance. When a measuring-glass is not at hand, a table-spoon will roughly answer the purpose. Precise directions are given as to pouring out the liquid because if it be agitated the air of the room in addition to that in the bottle will affect the lime-water.

CHAPTER IV.

METHODS OF VENTILATION.

The value of Ventilation established by Antiquity—Sketch of the History of Ventilation—Useful Methods of Ventilation.

THE actual value of ventilation as a means of preserving health and assisting in the curing of disease is now universally acknowledged by scientific men, but its real importance is not appreciated by those who have not given thought to the subject. The art of ventilation, nevertheless, is exceedingly old. It was practised by the ancient Egyptians, and at the present day the inhabitants of Cairo pursue the plan of their forefathers. The appliances in vogue may be described as shafts connecting the apartments with the roof of the house; the shaft is open only in the direction of the prevailing north-west wind, and it operates in conducting and distributing currents of air into the rooms below. According to Marco Polo, the Chinese at Ormus were provided with ventilators which conveyed air to the different floors of their houses. Agricola, in the sixteenth century, first advocated the means of ventilation which at the present day is found to be most successful, namely, causing currents of air by means of a fire; this is not only applied in every coal mine, but is the method now in use in the Houses of Parliament and in the lately completed Grand Opera House of Paris, and in all dwellings with open fire-places. Agricola also advocated the use of rotating fans for the mechanical propulsion of air into close places. Sir Christopher Wren recognised the necessity for some further means of ventilation than existed in doors and windows, and he constructed rooms in the corners of which were openings communicating with the outside air by shafts for the escape of vitiated air, but these had the disadvantage of admitting a down draught. The villa of the Trenti family at Custozza, described by Palladio, was ventilated by means of channels leading from a grotto near the palace and closed by valves when not wanted. A gate closed the entrance to the cave, and the admission of fresh cool air was regulated by the opening of the valves. In the years 1723 and 1736 Dr. Desaguilliers ventilated the then House of Commons, firstly by drawing off the foul air by the draught of a furnace-fire, and secondly by the application of a centrifugal exhaust fan. In 1784 Mr. Whitehurst, of Derby, ventilated St. Thomas's Hospital by the following admirable plan. In every second window about an inch and a half of each pane in the bottom of the upper sash was cut away. A frame of glass, nearly two feet in width, was set across the window resting on the top of the lower sash, and fastened to it by hinges. The frame moved on the hinges so as to make a greater or less angle with the window, and by that means admitted more or less air at pleasure, and the air which entered between the sashes was directed by the frame towards the ceiling, and diffused through the room. A great advance in the principles of ventilation was suggested in 1836 by Clanelin, who recognized the importance of subdividing incoming currents of air into many small streams so as to avoid draughts.

Dr. Neil Arnott, in 1855, fixed valves into the walls of rooms near the ceiling, which valves allowed heated and vitiated air to escape into the chimney,—

these valves in various forms are now well-known appliances. In the same year McKinnell patented an exceedingly useful method of ventilation, consisting essentially of two tubes, arranged concentrically, and opening at their lower ends into the space or apartment to be ventilated. The tubes communicate with the external atmosphere at different levels, the vitiated air rising up the central tube and passing off at the higher level, whilst the fresh air enters the annular passage between the inner and outer tubes at a lower level, and descends into the space or apartment below. Both passages are provided with suitable valvular mechanism for regulating the currents, that of the outer passage at the same time serving to deflect the downward current of fresh air, and spread it out horizontally, so as to prevent partial draughts.

McKinnell's arrangement was afterwards modified by Davies, by placing tubes of unequal lengths in different parts of a room instead of fixing one within the other. They were placed at the upper part of the wall of the room, the heated and vitiated air escaped through the upper tube, and the fresh air entered through the lower one. This invention in reality contains the principles of all true ventilation, provided the incoming draught is not delivered on to the heads of the occupants of the room. It works admirably in some cases, and one instance in which it has proved of great benefit I can quote with all particulars appertaining to the arrangements. The apartment was an office measuring 30 feet in length, 13 feet in breadth, and 12½ feet in height. Only at an extremity of the room could there be any communication with the outer air, and, in this part, directly over the window, the two apertures are placed, side by side. The incoming air is carried along by a zinc tube to the other end of the apartment, where it is delivered in such a manner through perforated zinc at a distance of about a foot from the floor that no cold draught is felt. At the outlet the draught is generally so great as to put out a candle placed there. The dimensions of the pipes are the following :—

				Inches.
Section of Inlet-pipe, measures	....	8	×	14
Ditto Outlet-pipe ,,	....	8	×	14
Ditto Perforated Opening	....	31	×	14

According to well-known principles, the greater the difference between the inside and outside temperatures the greater the current of incoming air ; hence, sometimes this arrangement will be ineffective unless a gas flame be lighted in the exit tube in order to create a draught, but the weather is at such times generally warm enough for the windows to be opened. A former occupant of this office before it was ventilated was disabled by ophthalmia, and there can be little doubt of the disease having been caused by the foulness of the air in which he worked and the gas-light he was obliged to use.

Boyle, in 1863, used mica in the construction of ventilators for windows and for chimney breasts. The form of ventilator known as Boyle's valve is a useful outlet for the heated air in the upper part of a room. A thin flap of mica is so poised in a frame that the slightest current causes it to fall outwards and permit the air to escape; an inward draught is prevented by reason of the flap being exceedingly light and at the same time so flexible that the slightest impulse causes it to fall by its own weight and cling close to the frame when an air current moves in an opposite direction. Boyle's inlet for air is an admirable arrangement, consisting of an aperture in a wall opposite to which is a circular plate of metal, movable by a screw placed at its centre, so that its distance from the opening can be easily regulated; its motion being parallel to the wall of the building, the entering air strikes the plate and is spread around, moving in all directions parallel to the walls, thus preventing violent draughts. Jennings' air-brick is a useful form of inlet. In a wall 1½ brick in thickness there is fixed on the outside a perforated brick communicating with a hollow space; this, in turn, is in communication with the air of the room by means of an obliquely perforated brick. Thus, the entering air passes into an intermediate chamber before gaining the apartment, and, in spite of the varying force of the wind, its velocity on that account is tolerably constant.

Captain Douglas Galton, F.R.S., describes the method by which the Herbert Hospital at Woolwich is ventilated:—"The flame, heated gases from combustion, and smoke are compelled, by the form of the back of the grate and the iron part of the smoke-flue, to impinge upon a large heating surface so as to extract as much heat as possible out of them before they pass into the chimney, and the heat thus extracted is employed to warm air taken directly from the outer air. This air is warmed by the iron back of the stove and smoke-flue, upon both of which broad flanges are cast, so as to obtain a large surface of metal to give off the heat." The construction of the heating surface was such as to prevent the back of the grate getting sufficiently hot to burn the organic matter in the air entering the room. The unpleasantness in rooms heated by stoves, which is common in Germany, is due partly to the charring of organic matter by over-heated iron flues. An important feature in these arrangements consisted in causing the entering air to be passed into the room near the ceiling, because at that point it flows most easily into the already existing currents. In rooms where there are open fires a draught travels from the doors and windows along the floor towards the chimney, up which one portion passes, but the remainder rises, strikes the ceiling, and, passing in a direction opposite to its previous course, descends near the end of the room farthest removed from the fire-place.

There is a ready means of ventilating a room with an ordinarily constructed window which is worth describing. It consists simply in raising the lower sash and placing inside the window-frame a piece of wood long enough to reach from one side to the other, about three or four inches in height, and an inch or so in thickness; the window is then closed upon this so far as the breadth of the wood will allow. The inside sash-frame is thus raised three or four inches above the place where it should meet the outer one, and as there is an open space between the two sets of window panes, a current of air moves inwards and upwards towards the ceiling of the room, and thus no draught will be felt. This admirable arrangement, which is, at least, twenty years old, answers well in small bedrooms where the window cannot be opened without causing a cold draught, and it is so simple and costless that those who may be doubtful of the comfort it will afford can have no excuse for not giving it a trial. There is yet another method, which consists in perforating with perpendicular holes the thick wood of the frame where the two sashes meet. The excellent plan which has been recommended by Mr. Tobin for use in private houses, differs from this only by cutting the wood away on each side right and left of the spring fastener. In case at any time the supply of air should be too great through such a wide opening, a flap or lid of sheet zinc is hinged on so as to close it when desirable.

DISINFECTANTS.

Dirt and Disease—Presence of Zymotic Organisms in the Air—Communication of Disease through the Air—The Meaning of Disinfection—The Description of various Disinfectants—Heat—Corrosive Gases—Tar and Tar Products—Common Chemicals—Charcoal—Directions for the Use of Disinfectants.

It is a fact generally allowed by all but a few obstinate or ill-educated people that filth engenders disease, and there is a very general feeling abroad that decomposing matter is connected with the spread of communicable diseases. We hear much agitation about sewer gases and their poisonous nature, the danger of their coming in contact with the drinking water, or gaining access to houses. If we examine the products of the decomposition of organic matter we find them to consist of marsh gas, hydrogen, nitrogen, ammonia, and carbonic acid, together with small undetermined quantities of suphuretted hydrogen and hydro-carbon gases. These compounds are perfectly incapable of causing such diseases as are known to occur from breathing air emanating from foul places. Sulphuretted hydrogen,—one of the most deadly, poisonous, and, at the same time, one of the most offensive of gases,—has not been known to produce any disease; it cannot act in any way like infection or contagion. Continual exposure to its influence, even when diluted with large quantities of air, lowers the health, and to inflate one's lungs with it would be to meet with instant death; its action is quite specific. As with this gas, so in a lower degree is it the case with the other products of putrefaction. They are unwholesome certainly as substances with which to aerate the blood, but they cannot operate in such a manner as to cause anything resembling the specific diseases, typhoid fever, small pox, scarlatina, or cholera. The short account of M. Chauveau's experiments, which is contained in a preceding chapter (p. 48), makes it sufficiently evident that small particles of living matter detached from diseased persons transfer or sow disease in healthy individuals. But many communicable diseases are transmitted through the air. How can this take place? By studying the nature of mould and mildew, and the ways in which they are propagated, and likewise the life history of the zymotic organisms of which mention has already been made, we may easily account for the communication of disease through the air.

From the earliest times until very recently all facts led to no other conclusion than that grubs, maggots, and the lower forms of life were evolved out of dead matter; that the sun, as Hamlet says, could breed maggots in a dead dog, or, according to Lord Bacon, that substances, as flesh and cheese, by putrefaction are converted into animalculæ. In the year 1638 an Italian philosopher, Rédi, first corrected this misconception by showing that so far from maggots being the result of the decay of flesh they were in reality the larvæ of the common blow-fly. When the meat was covered over with gauze the flies deposited their eggs as near to it as they could, but upon the gauze. It was ingeniously suggested that all the living things of which the origin was doubtful, and which were still found to be of constant occurrence in Nature, were derived from pre-existing eggs or germs to be found floating in the air. It was shown that heat could destroy the fertilizing effect of the air, and that if fresh air could not gain access to organic matter, the latter would not putrefy or ferment. A further step was made when Schrœder and Dusch proved that if air admitted to organic matter was passed through cotton wool it had not the power of causing change of any kind. Further progress was made by Schwann, who found that oil of vitriol and potash, being two very corrosive chemicals, when allowed to act upon air they deprived it of all putrefactive or fermentative properties. The researches of Pasteur, one of the greatest philosophers of this or any age, have given us distinct proof—1st, That there are constantly in ordinary air organized particles which cannot be distinguished from the true germs of the lowest organisms, such as are found in air poisons; 2nd, When these and other particles associated with them are found in suitable liquids which have been previously boiled, and which remained unchanged in air previously heated, there appear in these liquids exactly the same forms of life as arise in them when exposed to the open air. It is thus established that all organised productions of infusions previously heated have no other origin than the solid particles which are always to be found floating about in ordinary air, and are deposited upon everything exposed to it. This atmospheric dust has already been mentioned, and its existence may be easily understood by giving consideration to the following facts. Water, which is, bulk for bulk, 800 times heavier than air, remains suspended in it in the form of very fine spherules, causing a mist or fog, and solid particles of carbon are discharged into the air from chimneys, and remain floating in it in the form of soot or smoke. It is, therefore no wonder that the dust we see playing in a ray of sunlight is nothing more than finely divided particles of such solid materials as are found in most abundance around us. To illustrate how noxious matters may become attached to the mucous membranes of the human body, and so exert their baneful action, it is only necessary to refer to the effects of certain powerful poisons. Aconitine, the active principle of the poisonous plant Monk's-hood (*Aconitum Napellus*), is a white crystalline substance, and if a small portion, even a few grains, of this be pounded in a mortar, or simply transferred from one bottle to another, an imperceptible quantity detaches itself and gets into the air. Persons in the room, not necessarily near the operator, are liable to a violent irritation in the nose, eyes, and throat which is almost beyond endurance, and which sometimes is accompanied by more serious symptoms of poisoning. We can smell organic matter from the human body in the air of close places, and there is every reason to fear that matter capable of communicating disease may be amongst this. Acting on the assumption that such is the case, we escape the effect of disease; our experience therefore justifies such a belief. Now, disinfection is the destruction or rendering harmless of organic matter capable of communicating disease. This matter may be :—1st, In the air we breathe; 2nd, In the water or other food we take; 3rd, In the clothes we wear; 4th, In the house we live in; or, 5th, In the excreta or on the person of the patient.

Disinfectants are of various kinds, and no single substance can be used with advantage in all cases. It will be best to describe those which are known to be efficient in their action, and then to explain how they should be used.

HEAT.—In remote ages the power of fire as a purifier was very commonly credited, for in times of pestilence it was resorted to as a means of disinfection. In the middle ages it was customary to light fires around infected houses. In the streets of London during the visitation of the Plague fires were lighted, and it is commonly believed that the Great Fire of 1666 was the cause of the disease being exterminated. This may have been effectual,—partly as a process of disinfection, and partly by the destruction of crowded and filthy streets of wooden houses, which compelled the inhabitants to camp out in the neighbouring fields. Very precise directions, however, have been laid down by writers in the 16th century for preventing the spread of the sweating sickness by lighting fires in houses in those parts of towns where it was raging.

In the 17th century, Boyle seems to have studied the effects of heat and cold on the progress of decay; but to the late Dr. Henry, of Manchester, we owe the very important discovery, that the peculiarly active character of vaccine lymph was destroyed by exposure to a temperature of 140° F., for a period of three hours, though at a temperature 20° lower it still retains its properties unaltered. The virus of scarlet fever is rendered harmless by exposure to 204° F. It is now a generally accepted truth, that none of the lower organisms can resist a dry heat of 266° F., and that, if they be immersed in a liquid, the fatal temperature is 230° F.

MINERAL ACIDS.—When sulphur is burnt, it gives off suffocating fumes, sufficiently well-known to every one who has used the old form of lucifer matches tipped with brimstone. These fumes consist of sulphur dioxide, or sulphurous acid, a gas of an irrespirable nature. It is extremely soluble in water, and it is, therefore, readily condensed on all moist surfaces. It has been used for ages as a purifier. Ulysses employed the fumes of burning sulphur as a disinfectant after the slaughter of the suitors of Penelope, therefore its purifying power must have been well known in the days of Homer.

In the year 1773, Guyton Morveau, a French chemist, first employed muriatic acid gas, made by pouring oil of vitriol on common salt, as a means of preventing or arresting the action of contagion. The most recent researches of Dr. Angus Smith and of Dr. E. B. Baxter, however, show that the fumes of burning sulphur constitute the most easily producible and efficient agent amongst the many corrosive gases which are applicable. Its presence is easily detected by the sense of smell; thus 1 volume in 100,000 of air may be perceived, 9 volumes in 100,000 provoke coughing, and rather more than 4 volumes in 10,000 of air are irrespirable. Air containing proportions so small as to be scarcely perceptible, is fatal to minute forms of life, and even to healthy growing plants.

Tar and Tar Products.—The virtues of tar and tar water have been extolled by Bishop Berkeley. They are regarded as specifics against pestilential disorders by some of the peasantry of this country at the present day, but their application of them is peculiar. In some parts of the Midland Counties during the outbreak of cattle plague in 1866, when the poor people were at their wits' end to know what to do, tar was kept in barrels in the cow-sheds, and stirred up two or three times every day. The sign of the cross was marked in tar on the walls before the noses of the cows as they stood in the byres, and a cross of tar was painted on the doors. In addition to these precautions, every hole and crevice in the cow-houses was carefully closed with bricks, pieces of wood, and old sacks, to keep out the plague, as if it were an evil spirit. The consequence was that the beasts suffered severely from breathing a foul atmosphere; when contagion gained access to them in ever so slight a degree, perhaps from the clothes of a farm servant, the mortality and the rapidity with which the animals were killed was frightful. Pliny is said to have described the uses of creosote for the preservation of bodies, and the curing of skin diseases in cattle. The latter purpose, and the destruction of parasites in domestic animals, is one of its greatest uses at the present day. Chemists have extracted the active substances from coal-tar, and these have most beneficial uses as disinfectants. They are commonly called carbolic and cresylic acids. The former is a white crystalline solid when pure, and the latter a liquid substance; but a crude commercial article, employed as a rough disinfectant, is a brown disagreeably smelling liquid, and contains a mixture of these two substances.

Common Chemicals.—Chloride of lime, chloride of zinc, Condy's fluid, sulphate of zinc or white vitriol, sulphate of iron or green vitriol, quick-lime, and washing soda.

All these substances are disinfectants, and have applications for special purposes. The first, known as bleaching powder, may be termed the popular disinfectant. In this country it is the one thing that people send for with the idea of preventing the spread of sickness. It is a powerful deodorant or destroyer of bad smells, and it is itself a strong-smelling substance. As soon as its own odour predominates, when it has been mixed with offensive matters, we know that foul emanations are destroyed. This is a valuable property. It may be kept in a sick-room, when not disagreeable to the patient, to sweeten the air, and its power may be temporarily increased by liberating chlorine from it, by adding a little vinegar to the powder placed in a saucer ; but it must be remembered that to cause complete disinfection of the air, sufficient of the gas must be liberated as to render it impossible to remain in the room. Its use is apt to cause a false sense of security. Chloride of zinc (Sir William Burnett's disinfectant), and white vitriol, or sulphate of zinc, are dangerous substances, because they are colourless and very poisonous ; they are, nevertheless, powerful liquid disinfectants when dissolved in water. Condy's fluid, the permanganate of potash, is a very elegant and useful preparation, but its application is limited, because of its ready decomposition by organic matter, and the fact that it leaves a brown stain upon linen. It is a very powerful deodorant, and is a very useful dressing for foul sores ; but it cannot be used for purifying the air, because it is not itself a gas, and, therefore, cannot sufficiently come into contact with it. There are two kinds, the green and the red liquid, and the substance may now be obtained in bronze-coloured crystals, as crystallised permanganate of potash. It is only slightly soluble in water, to which it imparts an intense and very beautiful colour. Sulphate of iron or green vitriol is a cheap substance, and a disinfectant much recommended by Pettenkofer, a great authority on these matters. It is possessed of an inky taste, and as in small quantities it is harmless if swallowed, there is no danger attending its use. It will, however, iron-mould linen, and therefore its uses are limited. Good thick lime-wash over ceilings and walls acts, to some extent, as a useful disinfectant after other cleansing processes have been employed. Scrubbing wood work, and cleansing clothes in boiling water containing plenty of soda, is an effective process.

CHARCOAL.—In the year 1853, Dr. John Stenhouse made use of previously known facts concerning the power of charcoal to absorb gases and destroy those of an offensive nature by using air-filters of charcoal. It has numerous applications. 1st, As a respirator for the nose and mouth, by which means an atmosphere of the most offensive nature may be entered without perceiving any annoyance. Deadly vapours such as arise in chemical operations are arrested in the charcoal, so powerful is its action. 2nd, As a ventilator or air-filter, by which air from a foul source may be purified before it gains access to a room, or from a sewer into the street. 3rd, As a means of destroying the organic matter in water when used as a water-filter. The way to use it for this purpose has already been referred to (see p. 67).

Directions in the use of disinfectants :—

All matters, articles of clothing, bandages, evacuations, &c., immediately after their removal from the sick person, should at once be subjected to the action of disinfectants before being taken out of the chamber.

Matters discharged from the body should be received in a vessel containing about half a pint of one of the following disinfecting solutions—

(*a*) A solution of two pounds of sulphate of iron or green vitriol in a gallon of water.

(*b*) A quart of Sir William Burnett's disinfecting fluid (solution of chloride of zinc) in three quarts of water.

(*c*) A solution of one pound of sulphate of zinc in a gallon of water.

(*d*) A solution of four fluid ounces of carbolic acid to a gallon of water.

It is important to be sure that matters are thoroughly incorporated with the disinfectant, so that no solid substances may shield particles of contagion. Whenever it is possible, unhealthy discharges should be buried in the earth at a depth of eighteen inches to two feet, *far away from any pump, or well, or other water supply.*

To destroy offensive smells permanganate of potash or chloride of lime may be used; but it is not safe to recommend the use of these substances as actual disinfectants, because the former is readily destroyed by organic matter, as has already been pointed out, and thus the noxious substance might escape destruction, while the latter is not readily soluble in water, and it is therefore not easy to get it thoroughly mixed in sufficient quantity with the substance to be disinfected. When the carbolic acid is preserved dissolved in water, constituting solution (*d*), this and the liquid (*a*) are the safest materials to keep in the house. Cases of poisoning by carbolic acid have occurred only when the undiluted liquid substance itself was swallowed.

The towels, sheets, articles of clothing, &c., should be boiled in water, or plunged in boiling water containing one or two handfuls of soda to the gallon before being taken from the room, after which treatment they should be steeped in the carbolic acid solution (*d*).

Soiled bandages, rags and dressings, and things of no value, should be immediately burnt, or if there be no fire at hand they may be treated as above.

All superfluous furniture, especially table-cloths, carpets, pillows, curtains, and all unnecessary garments, should be removed as soon as the disease declares its nature.

All aërial disinfections of the apartment must be postponed until it is vacated; before such a time, thorough disinfection is impossible, and the smell of carbolic acid powder or chloride of lime is, if not disagreeable to the patient, likely to be objectionable by causing a false sense of security.

For the disinfection of a room the best agent is sulphurous acid. All articles within should be spread out as freely as possible, and the windows and doors should be closed, and the chimney stopped.

The cubic space should then be calculated by multiplying the height, length, and breadth together, and taking an ounce and a-half of sulphur for every 100 cubic feet. For a small bedroom one pound of sulphur would be sufficient. Indeed, eighteen ounces would suffice for a room measuring 12 ft. × 10 ft. × 10 ft. To burn the sulphur with safety take a flower-pot and saucer, invert the flower-pot in a large flat pan or a bucket containing four or five inches of water, this forms a stand upon which the coarse earthenware saucer can be placed. A few live coals and the sulphur are put into the saucer, and the room is closed for six or eight hours. Bedding, &c., should be further disinfected by heat. After the room can be entered, a thorough draught of air by opening the window and removing the obstruction from the chimney, will soon remove the sulphurous smell; plenty of soap and water to scrub the floor, the wood and iron-work, and lime-wash for the ceiling, will soon render the place wholesome.

Infected bedding, &c., should be removed in the boxes made for the purpose, and subjected to the heating process. In most towns provision is made by the Board of Guardians, and under the direction of the Medical Officer of Health, for the disinfection process to be efficiently carried out.

The disinfection of articles of food is accomplished by thorough cooking, boiling in the case of milk, boiling and filtration in the case of water, and complete roasting, stewing, or frying of meat.

By burning bisulphide of carbon in a metal bowl placed in a basin of water, the sulphurous disinfection is most satisfactorily accomplished. This substance being a highly inflammable and volatile liquid, is not a safe material to be handled by inexperienced persons.

To quote the words of Mr. Simon, lately the Medical Officer to the Privy Council, "It is to cleanliness, ventilation, and drainage, and the use of perfectly pure drinking water, that populations ought mainly to look for safety against nuisance and infection."

Artificial disinfectants cannot properly supply the place of these essentials; for, except in a small and peculiar class of cases, they are of temporary and imperfect usefulness.

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