ON

THE RIGHT USE

OF

DISINFECTANTS.

BY

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PREFACE.

The following paper was not originally intended for publication, but was written merely for consideration and discussion at a meeting of my colleagues, the members of the Society of Medical Officers of Health. It was, however, printed subsequently in *Public Health*, and a few copies were struck off in pamphlet form for private circulation. These have obtained so favourable a reception that I have been induced, at the request of many of my sanitary friends, to permit the paper to be reprinted and published for general use; and in acceding to this request I have revised the original manuscript, and made such alterations and additions as I thought would be acceptable.

London, *September*, 1874.

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BY H. LETHEBY, M.B., M.A., ETC.,

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I AM induced, Gentlemen, to bring this subject under your consideration for the purpose of removing the many dangerous fallacies which beset it, and of arresting, if possible, the unblushing quackery which disgraces it. A glance, indeed, at the so-called sanitary literature of the day will show how boldly and how confidently the use of certain inert bodies is recommended to the public as powerful disinfectors. The danger of this cannot be overrated; for, when by such means undue confidence is placed in the disinfecting power of an agent which fails in its purpose, the result is not merely a waste of materials and a loss of valuable time, but it is also a serious danger to the community. Therefore it is that we should be most careful in the selection of disinfectants, using those only which are known to be effective. It is proper also that we should be thoroughly conversant with their several modes of action, and that in applying them we should be guided by rational principles suggested by the scientific aspects of the subject.

It is hardly necessary to say that the question in all its relations is very large and extensive; for by the term "disinfection" I mean the removal, or neutralisation, or destruction of that which is offensive to the senses or hurtful to the body, limiting it of course to those cases where offensive effluvia, or noxious matters, or specific contagia are the subjects of treatment; and here I may remark that, although the questions before us are undoubtedly connected with the difficult problems now occupying the attention of physiologists, pathologists, and chemists as to the origin of infusorial life, and the cause of specific infectious maladies, as well as of organic decomposition, yet it is at the same time sufficiently independent of these abstruse inquiries to be capable of very effective practical treatment at our hands, without much reference to the conflicting theories of genesis. To us, indeed, it is of little importance, except for the scientific elucidation and explanation of our empirical facts, whether the manifestations of life in a decomposing liquid be the *cause* of putrefaction and fermentation, or the *effect* thereof; and whether life comes "*ex vivo*"—that is, from pre-existing life, as the Biogenists the Homogenists, and the Panspermatists believe; or, "*de novo*," as the Abiogenists, the Heterogenists, and the Non-Panspermatists maintain. Nor does it concern us in our practical treatment of the subject whether each distinct kind of spontaneous organic decomposition, and each specific form of infectious disease, are the results of the vital manifestations of special germs—differing in each case—or whether they are caused by the molecular movements of organic matter in peculiar states of decay; for that which we aim at, and which we undoubtedly are able to accomplish, is the prevention or destruction of the hurtful thing which causes offence or produces disease. And, as in many cases this is associated with the changes incidental to organic decomposition, it may be effected in one of four ways—as, first, by strengthening the affinities of organic substances, and thus enabling them to resist decay; secondly, by so acting upon them with chemical agents as to produce new compounds which are not susceptible of organisation or decay; thirdly, by hurrying on the changes of decomposition and oxidation, so that the particles may quickly arrive at their final stages of decay, and be brought to rest; and fourthly, by the use of special agents which are found to have specific powers of disinfection.

As examples of the first of these methods of preventing decay, I may allude to the effect of cold and to the desiccation of organic matters.

As instances of the second I will refer experimentally to the coagulation of albuminous matters by alcohol, creosote, the mineral acids, and most metallic salts.

Under the third head are the oxidising influences of chlorine, hypochlorous acid, permanganate of potash, and atmospheric air, aided by water and porous substances.

And as examples of the fourth method of disinfection I may allude to sulphurous acid, to carbolic and cresylic acids, and to the volatile oils.

The relative values of these several disinfecting substances have again and again been tested by experiment. As far back as the year 1858 I entered very fully into the question of their action on sewage; but very recently they have been examined by Dr. John Dougall, of Glasgow, and Dr. Crace Calvert, of Manchester, with the view of ascertaining their respective disinfecting powers, as tested by their action on protoplasmic and fungus life, and on vaccine lymph. I have tabulated the principal results of these experiments, and submit them to you for examination. Let us therefore discuss them in the order in which they are there placed:

1. The Mineral Acids.—These are *Sulphurous Acid*, *Nitric Acid*, *Hydrochloric* or *Muriatic Acid*, *Sulphuric Acid*, *Chromic Acid*. This is the order in which Dr. Dougall found they prevented the development of infusoria in infusion of hay, in urine, and in a mixture of beef-juice and egg-albumen, sulphurous acid being the least effective and chromic acid the most; for in the first case as much as one part of sulphurous acid in 117 of water was required to prevent such life during six days, while in the last case as little as one part in 2200 of water was sufficient. A like conclusion was arrived at when a solution of one part of the substance in 500 of water was used with a little beef-juice or egg-albumen. Dr. Crace Calvert, however, found that sulphurous acid was more powerful in its action than nitric or sulphuric acid when used in the proportion of one part in a thousand of solution of albumen, for in the case of sulphurous acid it required eleven days to produce vibrio life, and twenty-one days for fungus life, there being no putrid or mouldy odour for more than forty days; whereas with the like proportion of nitric or sulphuric acid the existence of such life was observed on the ninth and tenth days. In all cases the addition of these acids in small proportions, as from 1 to 2 per cent., to putrid matters swarming with animalcules, immediately

arrested life. In like manner the vitality of vaccine lymph was completely destroyed by the vapours of these acids. It would seem, therefore, that they are all-powerful disinfectants, and this accords with experience; for as far back as the year 1773 Guyton Morveau, one of the most distinguished chemists of France, recommended muriatic acid vapour as a means of disinfecting hospitals; and in 1797 Dr. Carmichael Smith obtained a Parliamentary grant of £5,000 for the successful use of nitrous fumes in the disinfection of our prisons. But sulphurous acid enjoys a reputation of much more ancient date. Homer tells us that Ulysses, after destroying the suitors, fumigated the rooms in which the bodies lay, as well as the rest of the palace, with the fumes of "pest-averting sulphur." Ovid, too, in the "Fasti" speaks of the cleansing and purifying power of sulphur; and Pliny, in his "Natural History," says "that brimstone is employed ceremoniously in hallowing of houses, for many are of opinion that the perfume and burning thereof will keep out all inchantments—yea, and drive away any foul fiends and evil spirits that do haunt the place." The Chinese have always attached considerable importance to the action of burning sulphur as a disinfectant, and have from time immemorial used pastilles of sulphur for internal fumigation, and squibs and crackers for external.

In the act of generating the gas by burning sulphur in atmospheric air, thirty-two parts of it by weight combine with the same weight of oxygen to produce sixty-four parts of sulphurous anhydride, which occupies precisely the same bulk or volume as that of the oxygen consumed. The density of the gas is considerable, for its specific gravity is 2.247, or very nearly twice and a quarter that of atmospheric air; a cubic foot of the gas, therefore, weighs a trifle less than 1,206 grains, and it takes 603 grains of sulphur and a cubic foot of oxygen, representing five cubic feet of air, to produce it. Its chief characteristic is its powerful odour; for as little as one part or volume of the gas in 100,000 volumes of air is readily discoverable by the nose; nine parts of it in 100,000 of air are disagreeable, and provoke coughing; twenty parts of it in that quantity of air are powerfully irritating; and forty-three parts of it in 100,000 of air, or rather more than four parts in 10,000 of air, are actually irrespirable, and a much smaller quantity than this will rapidly kill plants. Sulphurous acid is so deadly a poison to plants and to all the lower forms of living organisms that a mere trace of it will often destroy them. The products of the combustion of gas, containing not more than 20 grains of sulphur in 100 cubic feet of gas, will frequently kill the most vigorous plants in a conservatory; and the potential agent in flowers of sulphur, when used for the destruction of *oidium* in the grape disease, is the minute quantity of sulphurous acid contained therein. The common practice in Devonshire and Herefordshire of "matching" a cask by burning a little sulphur in it before the partially fermented cider is put into it is a certain means of checking fermentation, by killing the *Torula* or ferment cell; and the use of sulphurous acid in all diseases (chiefly of the skin) caused by parasitic (*cryptogamic*) organisms is well known on account of its specific curative power. Water absorbs from forty to fifty times its bulk of the gas, and produces a solution of powerful antiseptic and disinfecting properties. The same is the case with the combinations of the acid with alkalies forming the sulphites and bisulphites.

2. The Organic Acids—as *Carbolic*, *Cresylic*, *Acetic*, *Picric*, and *Benzoic*—are all disinfectant and antiseptic. According to Dr. Dougall, the most powerful of them is benzoic acid, for as little as one part of it in 533 of water will prevent the appearance of infusorial life, whereas as much as one part of acetic acid in 125 of water is necessary for this purpose. Carbolic acid occupies an intermediate position, for it requires one part of the acid in 267 of an organic solution to arrest the development of animalcules for six days; moreover, according to Dr. Dougall, the addition of one part of carbolic acid to 200 parts of a solution swarming with infusoria had no injurious action on them, although the like proportion of picric or benzoic acid was immediately fatal to them. So also with respect to vaccine lymph: air saturated with the vapour of carbolic acid at ordinary temperatures had no destructive effect on its vitality after exposure thereto for twenty-four hours; and even when mixed with the lymph in the proportion of 1 per cent., and allowed to dry, the activity of the virus was not impaired. Pettenkofer indeed has shown that, although carbolic acid will arrest the development of ferment cells, it does not destroy their vitality; for, if after such treatment they are freely diluted with water, they again start into activity. The same is the case with the organisms concerned in acetic and lactic fermentation, and with the agents (diastase, &c.), which transform starch into sugar, and amygdaline into oil of bitter almonds. Its antiseptic power, however, is evidently great; for, according to Dr. Crace Calvert, the presence of one part of the acid in 1,000 of an organic solution will check decomposition and prevent the appearance of vibrio or fungus life for more than forty days. At

the Morgue in Paris, where the acid has been freely used, Dr. Devergie found that in hot summer weather one part of carbolic acid (No. 5, which contains 85 per cent. of carbolic and cresylic acids) in 1,900 of water, freely applied to the dead bodies, completely prevented putrefaction; and even when diluted to the extent of one part in 4,000 of water the effect was most marked. In my own experiments in the City of London I have noticed that a very small quantity of carbolic acid in the sewers prevents decomposition, and that a solution of 1 per cent. of it upon meat arrests putrefaction.

Specimens of the acid are upon the table, there being several varieties of it in commerce for different purposes. The pure acid is a camphor-like solid, which fuses at 95° F. and boils at 366° F—., the boiling point of cresylic acid, with which it is commonly associated, being 397°. It is not very soluble in water—only to the extent of about 3 per cent., but it is freely soluble in alcohol, ether, and glycerine. It has no acid reaction on litmus paper, although it combines with the alkalies to form salts. A good test, indeed, for the purity of carbolic acid is the solubility of five parts of it in one part of caustic soda dissolved in ten of water. You have seen its powerful coagulating action on albumen, and I hardly need say it is an energetic caustic.

The commercial preparations of it are—1, the *pure crystals* for medical use; 2, the *fluid crystals* of the British Pharmacopœia strength for surgical purposes; 3, the *loose crystals* for disinfection; No. 4 and No. 5 for commoner purposes. The last-mentioned variety, as prepared by Messrs. Calvert and Co., is guaranteed to contain 85 per cent. of carbolic and cresylic acids, free from tar oils and sulphuretted hydrogen, and this is well suited for all the commoner kinds of disinfection. It may be used in the proportion of half a pint of the acid to two gallons of water, and, if the odour is objectionable, the purer quality, No. 4, may be employed. Other preparations of it are "*the powder*" (carbolic of lime), which should contain at least 15 per cent. of acid, as shown by the neutralisation of the lime with hydrochloric acid; "*Mc Dougall's fluid carbolate*," which is the acid in neutral combination; "*Cliff's antiseptic liquid*," which is a solution of the acid in soft soap; "*Westerton's patent zymotic fluid*," which is a mixture of carbolic acid, pyroligneous acid, and ether, with a little scent; and there are several kinds of carbolic acid and coal tar soaps,—but it is best to avoid these nostrums and rely on the action of the pure or nearly pure acid.

3. THE ALKALIES—*Lime*, *Potash*, *Soda*, and *Ammonia*—are not very powerful disinfectants unless they are used in a somewhat concentrated state, when they are useful for detergent purposes and for the destruction of organic matter. Cream of lime, for example, as well as a strong solution of potash and soda, may be advantageously employed in cleansing rooms, stables, cattle-sheds, and slaughter-houses, and powdered lime, sprinkled freely about cellars, church vaults, and cattle lairs, will absorb moisture, carbonic acid, etc., and assist in the oxidation of organic matters. Added to sewage in the proportion of from ten to twenty grains per gallon, it combines with the carbonic and phosphoric acids, forming a flocculent precipitate, which rapidly subsides, and carries with it all suspended matters as well as a notable proportion of soluble organic matter. It likewise kills the infusoria of

the sewage, and checks the decomposition of it for several days.

4. The Haloids.—The most important of these are *Iodine*, *Chlorine*, *Chloride of Lime*, *Chloride of Zinc*, *Chloride of Aluminium*, *Chloralum*, and *common Salt*. *Iodine* is not of much practical importance, although it has been recommended for use in the sick-chamber. *Chlorine*, however, is a powerful disinfectant, and has been used with considerable success from the time (1791-92) when Fourcroy, the distinguished French chemist, proposed it as a fumigating agent It is easily prepared by adding black oxide of manganese to strong muriatic acid—using about a quarter of a pound of the former to half a pint of the latter in a basin or dish—frequently stirring the mixture, and, if possible, heating it. It is also produced by the gradual addition of muriatic acid to permanganate of potash (Condy's fluid); and this, indeed, is very like the preparation now advertised under the name of *chlorozone*—the muriatic or hypochlorous acid having been added in comparatively small proportion. Chlorine is a heavy gas, its specific gravity being as nearly as possible two and a half times that of atmospheric air. It is extremely irritating, and, like sulphurous acid, cannot be effectively and safely used in a sick-chamber, except to sweeten the air, as the quantity necessary to disinfect is irrespirable. The same is the case with chloride of lime, when its acid (hypochlorous) is set free by carbonic or muriatic acid, as it must be to become an effective aërial disinfectant. In proper proportions, however, both of these agents are powerful disinfectants, as they do not only check putridity and the development of animalcules in organic solutions, but they also kill such creatures when added in the

proportions of about 4 per cent., and they destroy the vitality of vaccine lymph. Like other agents which favour oxidation, they actually promote decay and the generation of infusorial life when used in small proportion. To disinfect with chlorine, therefore, or with hypochlorous acid, the chamber must be vacated, so that the air may become charged with at least 1 per cent. of these agents, and then the destruction of the miasm or contagium is insured. A solution of chloride of lime in the proportion of one pound to two gallons of water (5 per cent.) is useful for washing floors, etc., but it must be used cautiously for the disinfection of clothing, as solutions of this strength act injuriously on animal tissues, although they are not so hurtful to vegetable fibres.

Chloride of Soda (Labarraque's liquid) is a compound homologous with chloride of lime, and it enters into the composition of Watts's chlorinated soap; but, as it rapidly undergoes decomposition, the disinfecting power of the soap is *nil.*

Chloride of Zinc (Sir William Burnett's fluid) is a liquid which ranges in its specific gravity from 1·309 to 1·594—the former containing about 30 per cent. of the chloride, and the latter about 54. Its action is evidently due to its power of coagulating albumen, and of absorbing ammonia and sulphuretted hydrogen. Used in the proportion of one part of the chloride to 300 of water, it instantly destroys infusorial life; and even when diluted so as to contain but one part in 1,000 of an organic liquid, it checks decomposition, and prevents the appearance of animalcules and fungi for more than forty days. Its chief use, however, is as a disinfectant of fæcal matters; for it has no power as an aërial disinfectant, and is too corrosive in its action for textile fabrics, unless it is largely diluted with water.

Chloride of Aluminium, or the solution called *Chloralum*, which contains about 15 per cent. of the salt, appears, from the researches of Dr. Dougall, to be powerfully antiseptic, for when used in the proportion of only one part of the substance to 933 of water, it prevented the development of animalcules for six days. Dr. Crace Calvert also found that an organic solution containing one part of the chloride in 1,000 of the solution did not exhibit vibrio life until after ten days. In another experiment, however, with albumen and starch-paste—each containing 2 per cent. of the substance—decomposition with offensive odour began in nine or ten days; and in my own researches I found that putrefactive decomposition could not be prevented with less than 4 per cent. of the substance. In illustration of this I direct your attention to the ineffective action of the salt in checking the putrefactive changes of the organic liquids before you. Moreover, it is not an aërial disinfectant, and is therefore worthless in a sick-room; and, with regard to its deodorizing power, it manifestly does not contain anything which is capable of absorbing putrid miasms. Like common alum, however, and crude sulphate of alumina, it is a good precipitating agent for sewage, and, when combined with the action of lime, it thoroughly defæcates such matters. This, in fact, is its only effective use, where its cost is of no consideration.

5. Mineral Sulphates—as *Sulphate of Zinc, Sulphate of Iron, common Alum, and Sulphate of Copper*, as well as the waste solutions of metallic salts from wire-working, iron-galvanising, lacquering, etc.—are useful disinfectants

when the object is to coagulate albuminous matters and to destroy living organisms, as well as to neutralise offensive miasms. Each of these substances will prevent the manifestation of infusorial life in organic solutions containing from one to four parts of the salt in the 1,000; and a solution composed of from one to two pounds of the substance in a gallon of water is a good disinfectant of fæcal and other matters directly they are discharged from the body. *Mudie's disinfectant* is sulphate of iron or green copperas, which is the cheapest of all these substances. None of them, however, can be advantageously used as aërial disinfectants, as they are not in any case volatile.

6. *Permanganate of Potass* and *Chlorozone* are both oxidising agents, and do not appear to exert much action on vital manifestations, but they are very active in the destruction of dead organic matter. The use, therefore, of these agents in the sick-room as disinfectants is altogether fallacious, for we have no reliable evidence of their power of destroying contagia. The sheet, indeed, saturated with Condy's fluid, which is recommended to be hung up in the sick-chamber, will quickly, like other dead organic matter, decompose the fluid and render it inert. This property, however, of attacking and oxidising dead and decaying organic matter gives it value as a means of purifying potable water, and for this purpose it is chiefly useful. The same may be said of chlorozone, for the small quantity of free chlorine present in it is not capable of much energy of action.

7. The Volatile Oils—as *Camphor*, *Turpentine*, etc. —are probably effective to some extent, for we not only perceive that they hinder the development of animalcules and fungi, but they also generate ozone: for ages, indeed,

these substances have enjoyed a high reputation as trustworthy disinfectants and deodorisers. They are the correctives universally employed in religious worship, and from time immemorial they have entered into the composition of the ointments of the high priest, and the incense of the altar. Among eastern nations the practice of fumigating the house with costly spice and rich-smelling drugs has been contemporaneous with history. During the middle ages, when the plague, the black death, and the sweating sickness decimated the cities of Europe, immense importance was attached to these agents as disinfectants. The advice of the learned Dr. Caius, who wrote of the sweating sickness in 1552, was to "have always your handkerchief perfumed with a mixture of spices for your nose and your mouth, both within your house and without, and in your mouth a piece either of setwel or of the root of *Enula campana* well steeped before in vinegar roseate, or a mace, or berrie of juniper. In want of such perfumes, as before said, take myrrh and dried rose-leaves, of each a like quantity, with a little frankincense, for the like purpose, and cast it upon the coals, or burn juniper and their berries." Until very recently, too, the practice in our criminal courts was to lay a bunch of rue on each side of the prisoner to guard the court against danger from the infected jail. Now, it is a curious fact, as I will show you experimentally, that the oxidation of volatile oils is generally accompanied with an active ozonization of the atmosphere; indeed, Professor Paolo Mantegazza, of Padua, who has carefully investigated this subject, says that this is a very convenient method of obtaining ozone, for under the influence of light, especially solar light, and air, the essential oils, even in small quantity, will ozonize comparatively large proportions of atmospheric oxygen. It may well be, therefore, that the volatile oils and essences deserve the reputation they have so long enjoyed as purifying agents, and that the recommendation of Empedocles to plant aromatic and balsamic herbs about your houses as preventives of pestilence, is supported by scientific as well as empirical facts. Moreover, as benzoic acid is a large constituent of the incense used in the Latin and Greek churches, it is possible, looking at its antiseptic powers, that it may be useful as a disinfectant.

8. Charcoal and other Porous Substances are powerful oxidising agents, and they owe their action to the property which they possess of condensing upon their surface and within their pores large quantities of vaporous and gaseous matter, which by the very force of condensation they bring into contact with atmospheric oxygen, and thus by a process of slow combustion burn up organic miasms almost as thoroughly as if they were passed through the ignited coals of a furnace. In the case of wood charcoal it will absorb about nine times its volume of oxygen, and ninety times its volume of ammonia.

This property of absorbing offensive effluvia was described by Löwitz, a German chemist, at the close of the last century, and in 1805 Giraud proposed to use it as a means of disinfecting night-soil. In 1814 the subject was further investigated by Theodore de Saussure, who ascertained the exact volumes of different gases and vapours which wood charcoal would absorb. Since then the question has been further explored by Figuier, Bussy, Thénard, Allen, and Pepys, Count Morozzo, and others; but it was not until the year 1853 that the facts of the inquiry began to acquire practical importance. In that year Dr.

Stenhouse, pursuing an experiment of Mr. John Turnbull, of Glasgow, found that putrid organic matters, when covered with a layer of charcoal, were quite free from offensive smell, notwithstanding that they putrified and decayed with more than usual activity.

The sole condition necessary to this is the free access of atmospheric air, which the charcoal uses in oxidising the putrid miasms. It is useless therefore to expect a beneficial action of the charcoal unless it can obtain oxygen; but, getting this, it will carry on its *eremacausing* power for an indefinite time. The applications which have been made of this power are numerous:—1. There is the respirator of Dr. Stenhouse, which arrests putrid miasms, and enables us, as I know from experience, to work comfortably in the most filthy atmospheres. 2. There is the air-filter, which I shall presently describe as applicable to the purification of the air of sewers, etc. 3. There is the charcoal water-filter, which, with water containing oxygen, or worked intermittently, will purify water from the foulest matters; and other applications of it will occur to us presently.

Again, everyone is familiar with the purifying power of common earth: the graveyards, indeed, of every large city, testify to the enormous quantity of organic matter which may be disposed of through its agency; and, looking at the magnitude of the subsoil filth of this city, it is surprising how little it has affected the virgin gravel a few feet below the surface. All this is referable to the catalytic action of the porous soil, whereby the countless tons of decomposing matters buried in it have been oxidised and converted into harmless nitrates, which abound in the City wells, and which might, in case of an invasion, furnish our volunteers with abundance of "villainous saltpetre."

The substances which are chiefly concerned in these remarkable changes are the alkaline and ferruginous matters of graveyard soil; for in the presence of alkaline compounds ammonia, which is a product of organic decomposition, is rapidly oxidised, and converted into nitric acid and water. Peroxide of iron, also, will part with some of its oxygen, and will recover it again from the air—thus serving as an active purveyor of atmospheric oxygen to putrifying organic substances. Mr. Spencer has utilized this power in the construction of his well-known filters.

9. Air and Water are likewise powerful agents of destruction, and show their beneficial action in the one case in the effect of good ventilation, and in the other in the disintegration of organic substances as they flow along in our polluted rivers—thus giving them the means of rapid self-purification. A heavy storm of rain, too, is a great purifier of the air, and is often the turning-point in the progress of an epidemic; but besides this, water, by reason of endosmic action, is inimical to the corpuscular structures of many specific contagia, for, by bursting their cell-like envelopes, it destroys their vitality.

10. Disinfection by Heat.—The power of fire as a disinfectant is well known, and has been recognised from the remotest time. The sacrificial altars of early nations were the rude methods by which this agent was employed; and so fully did the ancients believe in its salutary effects that in time of pestilence it was often resorted to as the only effective means of purifying the air. Caius, in his "Boke of Counseill against the Disease commonly called the Sweate or Sweating Sickness," (1552,) advises the use of "fyres either in houses or chambers, or on that side the

cities, townes, and houses that lieth toward the infection and wynde commyng together, chefely in mornynges and eueninges, either by burnyng the stubble in the felde or windfallynges in the woodes, or other wyse at pleasure. By which pollicie," he says, "skilful *Acron* deliuered Athens in *Gretia*, and diuine *Hippocrates Abdera in Thratia* frō ye pestilence, and preserued frō the same other the cities in *Greece*, at diverse times coming with the wynde fro *Ethiopia*, *Illyria*, and *Pæonia*, by puttyng to the fyres wel smelling garlandes, floures, and odoures, as *Galene* and *Soranus* write. Of the like pollicie for purgyng the aier were the bonfyres made (as I suppose), frō long time hetherto vsed in ye middes of summer, and not onely for vigiles." In the popular mind there has always been a notion that the plague of London was exterminated by the Great Fire.

The temperature at which infectious matter is rendered inert has lately been a subject of keen controversy, chiefly in relation to the temperature at which the vitality of living germs and minute infusorial creatures is destroyed. The late Dr. Henry, of Manchester, demonstrated experimentally that the vitality of vaccine matter is destroyed at a temperature of 140° Fahr., and that the virus of scarlet fever is inert after being exposed to a heat of 204° Fahr.; but some of the lower organisms appear to be more tenacious of life, for, according to Dr. Crace Calvert, the common vibrio will bear a temperature of nearly 300°; and his black vibrio, which appears to be a very salamander of animalcules, is not killed by a heat of less than 400° Fahr. After a long investigation, however, before the Académie des Sciences of Paris, it was unanimously agreed by all parties to the controversy of spontaneous genesis that none of the lower organisms or their germs would resist in air a temperature of 130° C. (= 266° Fahr.), and in liquid a temperature of 110° C. (=230° Fahr.). This, indeed, was the temperature fixed by Pasteur himself, although many of the members thought that 100° C. (=212° Fahr.) was sufficiently high to destroy all vitality. In most cases, in fact, a temperature of 180° Fahr. is sufficient to destroy infusorial life, for that will coagulate albumen, of which they are made. Assuming, however, that it is desirable to use as high a temperature as possible for disinfection, it is important, as a first question, to know what is the effect of heat on textile fabrics. Up to a temperature of 250° Fahr. most of these fabrics are unchanged, unless the exposure is maintained for many hours, when they become discoloured and slightly brittle. Above this temperature the change is more marked, for with a dry heat of 300° Fahr. cotton fabrics are slightly charred, and therefore spoilt. At 400° they become dark brown, and crumble into powder when rubbed. At 500° gaseous hydrocarbons are produced, and at 600° all vegetable and animal tissues are converted into charcoal, with the evolution of empyreumatic oil and gas. It would seem, therefore, that, for practical purposes, a heat of 250°, aided by a jet of steam, for the purpose of diffusing the temperature and helping its action, may be safely applied to textile fabrics.

In the case of noxious vapours, however, as the fetid effluvia from tallow-melting, bone-boiling, soap-making, etc., the organic miasms must be destroyed by actual combustion, and to this end they must be conveyed into and through a large body of fire. In many cases it is necessary to remove aqueous vapour from the miasms by means of a scrubber or condenser before they pass to the fire, and in all cases the products of their combustion should be conveyed into a tall chimney, in order that a good draft may be secured for the delivery of them to the furnace fire.

The employment of heat for disinfecting purposes should be taken advantage of on all possible occasions. Foul linen from the sick chamber should be immediately boiled in water, or steeped in boiling water. Milk, whether tainted or not, should always be boiled before using; and in cases of suspicion as to the contamination of drinking water, it should be boiled and filtered through animal charcoal, for there is no reliable evidence that any of the common agents of infection will resist a temperature of 212° Fahr. applied in this manner for a few minutes. Lastly, meat should be thoroughly cooked, so as to destroy parasitic and other infection.

And now, having broadly examined the several powers and modes of action of the leading disinfectants, we will briefly consider the way in which they may be most advantageously applied, taking as examples the common cases which present themselves in actual sanitary practice.

First and foremost of these cases is the *disinfection of the sick-chamber and of the articles contained therein.* This is avowedly a difficult matter, for the presence of the sick person and his attendants prevents the use of volatile or aërial disinfectants in such quantity as to be of undoubted service; chlorine, for example, or hypochlorous acid, or sulphurous acid, or carbolic acid vapour, must be present in the atmosphere in the proportion of at least one part per 1,000 to be effective, and in this proportion they are so irritating as to be irrespirable. While, therefore, the room is occupied by the living, we must rely on other means of disinfection, and must take every precaution for the immediate destruction of all tainted articles. Matters discharged from the body should be received into a vessel containing active disinfectants, as about half a pint of either of the following solutions, namely :—A solution of two pounds sulphate of iron (green copperas) in a gallon of water (=20 per cent., specific gravity 1·096) ; or a solution of one quart of chloride of zinc (Sir William Burnett's fluid) to three quarts of water (=about 8 per cent. solid chloride, specific gravity 1·077); or a solution of four fluid ounces of carbolic acid (Calvert's No. 5) to a gallon of water (=2·5 per cent.). All articles of clothing, bedding, etc., should be boiled in water or plunged into boiling water before they are taken from the room, and in addition to this they should be steeped in a solution of carbolic acid of the above-mentioned strength. Special agents of infection—as the desquamated cuticle in scarlet fever, and the phagedenic discharges of ulcers and foul wounds or sores—should be the subjects of constant attention ; oil, pomades and other matters being freely employed to the surface of the body in the former case, and antiseptics and disinfectants in the latter. Besides this, all superfluous articles of furniture, as carpets, curtains, etc., should be removed from the room early in the case, and free ventilation and the utmost cleanliness should be always practised—every thing like soiled rags, dressings, &c., being immediately burnt. As regards the use of aërial disinfectants, I am inclined to think that acid vapours are the most effective—as chlorine, or chloride of lime, or acetic acid,—for these only are capable of destroying the vitality of vaccine lymph, and therefore, by inference, of other contagia; besides which they sweeten the atmosphere and make it more pleasant for respiration.

When, however, the room is vacated, disinfection of it may be practised with the most perfect success.

In the first place, all the articles contained in it should be spread out, so as to receive freely the sulphurous acid fumes which are to be generated therein; and, having closed the windows and stopped up as completely as possible every aperture and outlet from the room, measures should be taken for producing the needful quantity of sulphurous acid. This should not be less than one per cent. of the air of the apartment. Now, as a cubic foot of sulphurous acid is produced from 603 grains of burning sulphur, it is evident that every 100 cubic feet of space will require at least this quantity of sulphur for disinfection. To be certain of the results, however, it is advisable to use the sulphur in slight excess—say an ounce and a half for every 100 cubic feet of space. The sulphur may be safely burnt in a shallow pipkin or coarse earthenware saucer containing some live coals or a little spirit of wine, or bisulphide of carbon; in fact, this latter compound, if accessible, is the best form in which the combustion of sulphur can be effected, for it contains about 84 per cent. of sulphur, and is very combustible. The pipkin or saucer should be supported upon a pair of tongs laid across a pail of water, so that in case of accident the burning sulphur may fall into the water and do no injury. After a period of six or eight hours the room may be opened for ventilation and the several articles be spread out for an airing, or taken to the disinfecting chambers for still greater safety. The floor and painted parts of the room should be then thoroughly cleansed and the ceiling treated with limewash.

2. *Infected Clothing and Bedding* should be subjected to a further process of disinfection in the chambers provided by the local authorities for that purpose. These are a room or chamber for exposure to the concentrated fumes of burning sulphur (from 4 to 5 per cent. of them in the air); and next a chamber for disinfecting, and for killing parasites by heat. This should be so constructed that its temperature can be uniformly maintained, at from 240° to 250° Fahr., for about five or six hours, as it takes that time for the heat to penetrate to the centre of a pillow or bed. It should be self-regulating and self-registering in this respect, and, therefore, be easily managed. The apparatus in use in the City of London for this purpose was constructed by Mr. Leoni, and it is very effective in its action, for during the last two years we have disinfected 2,583 articles of clothing, bedding, etc., with the most perfect success. In fact, during the recent epidemic of small-pox, nearly 2,000 articles were thus treated, and I am not aware of a single case in which it was not successful. This accords with the experience at the several small-pox and fever hospitals of London, and shows that, whatever may be the effect of such treatment upon Dr. Crace Calvert's black vibrio, it is abundantly efficacious in the case of common contagia, be the virus what it may.

3. *The Treatment of Dead Bodies.*—This is a matter which frequently demands attention, as when bodies are kept in rooms occupied by the poor, or are brought to the mortuary for safe custody. I have already told you that carbolic acid has been most successfully employed by Dr. Devergie at the Morgue in Paris for the preservation of the

dead. As little as one part of the acid in 2,000 of water, freely applied to the corpse, will prevent putrefaction. A sheet, therefore, saturated with a solution of one per 1,000 of the acid and applied to the body will preserve it. So also will a couple of pounds of good carbolate powder, containing 15 per cent. of carbolic acid, placed in the bottom of the coffin. Metallic salts also will preserve the dead, and in some cases they are preferable to carbolic acid, as they are without odour; thus sawdust, nearly saturated with a solution of chloride or sulphate of zinc (specific gravity 1·077), may be placed around and over the corpse when in the coffin, and in this manner decomposition will be arrested.

I might here mention that the diseased and putrid meat seized in the City, amounting to nearly two tons per week, is disinfected with crude carbolic acid before it is sent away from the markets; and this not only prevents decomposition, but it also prevents the use of the meat for improper purposes.

In the case of old burial-grounds which are offensive, as well as church vaults, the best means of disinfection is the covering of the ground with fresh earth to the depth of several inches, and the planting of trees and sowing of grass. In this way we have dealt successfully with the city grave-yards—26 in number, and covering a superficial area of about 48,000 square yards, in which, according to a moderate computation, there are not less than 48,000 tons of human remains. Church vaults should be disinfected by first opening the vaults, exposing them freely to the external air, and throwing into them a quantity of quicklime. The coffins should then be rearranged cross-ways, like bricks in a building, and filled in with dry earth or masons' rubbish, with which from 5 to 10 per cent. of vegetable charcoal has been mixed. Ventilation should then be brought into connexion with the vaults by means of an upcast and downcast shaft of the size of a rain-water pipe, and the whole closed in. It was thus in 1860 that the late Mr. Grainger and myself proceeded to disinfect all the vaults, amounting to 250 in number, of the 71 City churches. These vaults contained the coffins and remains of many thousand dead bodies,—at least, 11,000, in a very offensive condition; and the effect of it has been most successful. When bodies are removed from the vaults to other places of burial they should be enclosed, coffins and all, in cases containing carbolate of lime powder in good quantity.

4. *Sewage and Sewer Gases.*—The best disinfectants of sewage are the mineral salts, as the salts of iron and alumina in conjunction with lime. Ordinary sewage subjected to the action of from one to two parts of either of these agents per 7,000 of sewage is immediately disinfected, the flocculent matters being rapidly precipitated, leaving a clear supernatent water which may be safely distributed upon land, or allowed to flow into a running stream of moderate volume—as from ten to twelve times that of the defæcated sewage. So effective is this operation that it ought to be universally applied to the sewage of towns when it is not discharged into the sea. The matters of cesspools and privies require the application of large quantities of metallic salts—the best being sulphate of iron (green copperas) or chloride of zinc—either of which should be used of the specific gravity of about 1·100.

Sewer gases are easily disinfected by vegetable charcoal in the manner already explained—the charcoal being placed upon trays in boxes which are situated in the course of the ventilating shafts from the sewers or drains. Many years ago I advised the adoption of this plan in the City of London, and there is a large district, eastward of Bishopsgate-street, where all the sewer ventilators are fitted with charcoal air-filters. The district is in the filthiest and most densely occupied quarter of the city. It contains 1,700 houses, occupied by about 14,000 inhabitants, and the total length of the sewers of the district is about 25,587 feet. Along these there are 104 air-shafts fitted with these ventilators, 265 trapped gullies, 15 flushing tanks, and 26 side entrances. The air-filters consist of an iron box eighteen inches deep and fourteen inches square, containing a movable frame of six trays or sieves, upon each of which there is a layer of wood charcoal, in pieces as large as filberts, about two inches deep. Our experiments were commenced in 1860, and they have been maintained with perfect success until the present time, for they are still in action. I have repeatedly submitted the charcoal from the ventilators to chemical examination, and have always found that it contains abundance of nitrate, together with a peculiar alkaline salt of a nitrogenous nature, associated with hydrocarbon. These ventilators are best fixed where they are protected from actual wet, as against the sides of houses, or in the course of a shaft or pipe carried up from the soil-pipe of the closet. In such situations their action is continuous for many years, and they should always be thus used where foul gases escape from the soil-pipe, the drain, or the closet of a house. Air-filters of this description have been adopted and applied with more or less success by Mr. Rawlinson, Mr. Baldwin Latham, and Mr. Bazalgette.

5. *The Offensive Gases and Infected Air of noxious and unwholesome trades* are easily destroyed by fire—there being contrivances for conveying the foul gases first through scrubbers or condensers and then into the back part of the ash-pit of the furnace fire. In this way moisture and other condensable matters are removed, and the residual gases and vapours are consumed by the glowing fire through which they must pass before they reach the chimney-shaft. By carrying the vapours to the back of the ash-pit of the furnace we insure their combustion, for, when the ash-pit door is closed (as it ought to be), the draft is so powerful that it draws the vapours from the chambers or boilers in which they are generated and insures their passing through the furnace fire.

In some cases the air becomes so loaded with minute particles of dust, etc., as to be extremely irritating. This is so in cotton mills, and with flock workers, feather cleaners, stone and steel grinders, chloride of lime makers, millers, firemen, and others. The remedy is easy, for a pocket-handkerchief over the face, or a respirator packed with cotton-wool, will shut out all noxious solid particles—in fact, the power of cotton-wool is so great in arresting the minute particles of matter, germs and others, which float in the atmosphere, that, according to Professor Tyndall, it is capable of producing an atmosphere absolutely free from dust, which will bear the severe test of his electric beam. Schroeder and Pasteur say that air filtered through cotton-wool is deprived of the power of producing infusorial life. Here is an experiment which is very striking in this particular: in these flasks I have a super-saturated solution of sulphate of soda, which, while in a state of active ebullition, was closed with a plug of cotton-wool, and in this state it has been allowed to cool. Atmospheric air, of course, has entered the flasks to take the place of the condensed steam, but in so doing it has been strained by the wool, and the solution has failed to crystallise. When, however, I remove the plug of cotton-wool, you will remark that the liquid instantly becomes solid, in consequence of the rapid formation of a mass of crystals. This is no doubt due to the falling in of a few particles of atmospheric dust, which were floating by at the time of the withdrawal of the cotton plug, and which immediately became nuclei for the growth of the crystals.

A still better respirator than cotton-wool is that of Dr. Stenhouse, which consists, as I have said, of a layer of granulated wood charcoal. I have used one of them successfully on many occasions when analysing dead bodies and other putrid matters in cases of suspected poisoning.

With respect to street dust, attempts have been made to keep down the nuisance by means of deliquescent salts dissolved in the water used in street watering, but such contrivances are exceedingly objectionable, as they not only keep the roads at certain times in a dangerously slimy and slippery condition, but the dust, charged with these salts, will, when dry, be blown about, and, falling upon delicate goods, spoil them by its deliquescent property. Cooper's Patent Salts in this country, and Marcus' Patent Salts in America, are examples of this kind of thing. They are solutions of common salt and chloride of calcium or magnesium in water, the specific gravity of the solution being from 1·040 to 1·085. Both of the patents have been tested in America and on the Continent and have signally failed.

6. *Shambles, Slaughter-houses, Cattle-lairs, &c.*, should

be kept sweet and wholesome by strict attention to cleanliness, and by the frequent use of cream of lime, with a little chloride of lime as whitewash.

7. *Breweries, Brewing Utensils, and Distillers' Vats* are easily and effectively cleansed and disinfected by means of sulphurous acid or a strong solution of bisulphite of lime, aided in the case of fungoid casks by a jet of steam.

8. The purification of *Water* is insured by a few drops of permanganate of potash solution (Condy's fluid) or of chlorozone, leaving them to act for a few hours, and taking care that the pink colour is distinctly maintained to the very end of the process. Boiling the water for several minutes, and, after allowing it to cool, filtering it through animal charcoal, is also a safe method of disinfection. The filters of the London and General Water Purifying Company are admirably adapted for this purpose, as they contain a large volume of charcoal, which can be aërated by intermittent filtration. I find, indeed, that water thus filtered is absolutely free from organic taint—looking blue like distilled water when examined in large volume, as in a glass tube two feet in length; and the action of the filter is so enduring that it is maintained in the case of ordinary water for more than a year. A little alum or sulphate of alumina added to the water before filtration aids in the separation of organic matter.

And now, gentlemen, in leaving the subject and inviting you to a discussion of it, I have only to say that I have carefully avoided a controversial treatment of it, not merely in respect of the possible or even probable causes of contagion, but also in respect of the many kinds of disinfectants which are daily advertised for public use. It is true that most, if not all, of these have come under my observation, and have been the subjects of experiment; but I have not dwelt on this, for my principal object has been to show you what, in my individual experience, I have found to be the most effective means of dealing with the several kinds of infection which almost daily occur in our sanitary practice.

Note.—Upon the next page will be found a summary, which I have prepared, showing the nature and results of the experiments made by Dr. John Dougall, of Glasgow, and by the late Dr. Crace Calvert, of Manchester, on the action of various antiseptics upon protoplasmic and fungus life, and upon vaccine lymph.

Summary of the Experiments made by Dr. J. Dougall, and by Dr. Crace Calvert, on the action of various Antiseptics on Protoplasmic and Fungus Life, and on Vaccine Lymph.

Substances used.		Experiments made by Dr. John Dougall, of Glasgow.											Experiments by Dr. Crace Calvert.			
		Reaction of the Solution	Quantity required to prevent animalcules in six days.				Effect on animalcules in Putrid Beef Juice and Egg Albumen, when added in proportion in 3rd column.	Number of days before life appeared in a solution containing 1 of substance in 500 water and ½ drachm of following—				Effect of the Vapour or Gas during 24 hours on Vaccine Lymph.	Number of days before Vibrio Life appeared in a solution of Albumen containing 1 of substance in 1,000 of solution.			
			Infusion of Hay	Human Urine	Beef Juice and Egg Albumen.	Average of all.		Beef Juice.		Sol. of Egg. Albumen.						
								Animalcules.	Fungi.	Animalcules.	Fungi.		Animalcules.	Putrid Odour.	Fungi.	Mouldy Odour.
Acids. Mineral.	Sulphurous	Acid	1 in 250	1 in 50	1 in 50	1 in 117	Death	24	4 P.	8	over 100	killed	11	over 40	21	over 40
	Nitric	do.	400	400	200	333	do.	18	4 P.	15	5 T.	do.	10	50	10	23
	Hydrochloric	do.	500	400	100	333	do.	28	4 P.	9	over 100	do.	—	—	—	—
	Sulphuric	do.	800	500	100	467	do.	over 100	over 100	30	10 T.	—	9	—	9	11
	Chromic	do.	4000	1400	1200	2200	—	78	38 P.	over 100	over 100	—	—	—	—	—
Acids. Organic.	Carbolic	Neutral	300	300	200	267	None	12	50 T.	38	36 P.	none	over 40	over 40	over 40	over 40
	Cresylic	do.	—	—	—	—	do.	—	—	—	—	do.	do.	do.	do.	do.
	Acetic	Acid	350	25	10	125	—	—	—	—	—	killed	30	—	9	50
	Picric	do.	350	350	350	350	Death	44	11 P.	over 100	44 P.	—	17	over 40	19	over 40
	Benzoic	do.	700	700	200	533	do.	over 100	over 100	do.	over 100	—	—	—	—	—
Alkalies	Lime	Alk.	—	—	—	—	—	—	—	—	—	—	13	19	over 40	over 40
	Potash	do.	300	50	10	120	Death	—	—	—	—	—	16	—	—	—
	Soda	do.	—	—	—	—	—	—	—	—	—	—	23	31	18	29
	Ammonia	do.	—	—	—	—	—	—	—	—	—	—	24	50	20	over 40
Haloids	Iodine Tincture	Neutral	400	400	50	283	Death	1	80 T.	15	over 100	—	—	—	—	—
	Chlorine Gas	Acid	—	—	—	—	—	—	—	—	—	killed	7	21	21	—
	Chloride Lime	Alk.	200	200	25	142	Death	27	27 T.	40	over 100	do.	7	18	16	—
	Chloride Zinc	Acid	200	300	300	300	do.	4	over 100	18	do.	—	over 40	over 40	50	over 40
	Chloride Aluminium	do.	2000	500	300	933	—	19	4 P.	over 100	8 P.	—	10	do.	21	50
Sulphates, &c.	Bisulphite Lime	Acid	100	50	25	58	Death	4	92 T.	9	over 100	—	11	21	14	over 40
	Sulphate Zinc	do.	300	300	200	267	do	30	4 P.	90	70 P.	—	—	—	—	—
	Sulphate Iron	do.	500	500	100	367	?	14	5 T.	35	40 T.	—	7	over 40	15	—
	Common Alum	do.	800	500	100	467	—	14	3 P.	38	15 T.	—	—	—	—	—
	Sulphate Copper	do.	1000	1000	800	933	Death	86	20 P.	over 100	over 100	—	—	—	—	—
	Permanganate Potash	Neutral	500	200	125	275	None	—	—	—	—	—	9	50	22	over 40
	Alcohol	do.	350	50	20	140	Death	4	4 T.	10	over 100	—	—	—	—	—
	Camphor	do.	300	150	50	167	None	—	—	—	—	none	—	—	—	—
	Turpentine	do.	—	—	—	—	—	—	—	—	—	—	14	over 40	42	over 40

Note.—In the *first* set of Dr. John Dougall's experiments 3 drachms of a solution of the strength mentioned were treated with 1 drachm of a filtered infusion of hay, or with half a drachm of urine or half a drachm of the mixture of beef juice and egg-albumen. In the *second* set of experiments equal parts of a putrid solution of beef juice and egg-albumen, full of living animalcules, and of the solution of the various substances of the strength known to be preventive of life (as in 3rd column), were mixed together, and the results immediately noted. In the *third* set of experiments 3½ drachms of distilled water, containing 1 in 500 of the substances named, were treated with half a drachm of filtered beef juice, or half a drachm of a solution consisting of 1 part white of egg to 4 parts water. In the *last* set of experiments, separate portions of vaccine lymph were exposed to the several vapours for 24 hours, and the dried spot in each case was moistened with glycerine and water, and sealed in a capillary tube until an opportunity for vaccination occurred, when the whole of the diluted lymph was used in one insertion so as to ensure its full effect.

In Dr. Crace Calvert's experiments, 0,026 of a gramme of the substance was added to 26 grammes (1 to 1,000) of a solution of albumen containing 1 part white of egg to 4 parts pure distilled water.

The Animalcules observed were Monads (microphymes), Vibrios, and their cell segments (microerphymes), Bacteria (microzymes), Amœbæ, &c.; and the Fungi were Torula, Mycelium, Penicilium, &c., indicated in Table by letters T & P. Putrefaction was always characterised by a putrid odour, an alkaline reaction, and the presence of Animalcules: whereas Mouldiness and Fermentation were distinguished by a mouldy or musty odour, an acid reaction, and the presence of Fungi.

FOLD OUTS MAR

BY RED CARD.