carbonate of lime to neutralise the excessive acidity of the water has been apparently successful in some cases. If the contaminated water is filtered through sufficiently active animal charcoal* the lead is removed, probably owing to the formation of an insoluble phosphate. As regards the substitutes for lead piping the following are the chief: lead pipes lined with block tin or a bituminous coating; iron pipes, plain or galvanised or coated internally with Angus Smith's varnish; finally, pipes made of 'rustless iron' by the Barff process, ordinary iron pipes being exposed, whilst hot, to superheated steam, the result being the formation of a thin coating of magnetic iron oxide, Fe_3O_4. A clean fresh surface of lead is most readily attacked, hence new pipes, or pipes much bent and thereby cracked superficially, or pipes which are alternately full and empty, yield most lead to the water. Where leaden pipes must be used the tap should be allowed to run for a little time before the water is drawn for use.

Water containing traces of Zinc, Arsenic or Copper has generally been polluted by accidental contamination and should always be rejected.

The Inorganic impurities in water are, with the exception of lead, mostly impurities of source, *i.e.*, they are present in the water before it is collected. The animal and vegetable impurities are generally added subsequently *i. e.*, impurities of storage or distribution. Water, especially in India, is extremely liable to be fouled during storage with disastrous results to the users of the water. There is perhaps, says Parkes "no point in which the attention of the Sanitary officer should be more constantly fixed than that of the storage of water either on a large or small scale." Where the distribution is by hand from a direct supply situated in a crowded street and common to all users the chances of added impurity are enormously increased. The water carriers of the East including the Indian *pakáli* and

* *v.* Filtration of Water.

bhisti deriving their water as they too often do from polluted sources and distributing it in filthy skins or barrels are undoubted and frequent disseminators of epidemic disease which is by no means confined to their customers, and in this matter their congener is the *dhobi*.

Varieties of Drinking Waters.—According as the source of a water supply varies so will the nature of the water vary.

RAIN water is wholesome by its purity and agreeable because highly aërated, containing from 3 to 30 c. c. of gas in a litre. The proportion of oxygen in the mixed gases is higher than in atmospheric air, amounting to 32—38 per cent. Carbonic acid contributes 2·5 to 3 per cent. Other substances are met in the atmosphere and dissolved or carried down mechanically. Thus ammonium carbonate and nitrate (the latter more especially during thunderstorms), phosphoric acid, hydrochloric acid (near the sea), sulphuretted hydrogen or soluble sulphides, free ammonia, sodium chloride (sometimes even as much as 2 centigrams in a litre) traces of potassium and calcium chlorides, calcium carbonate and calcium sulphate may be found in solution in rain water directly collected. Iron, alumina, silica, particles of carbon, light organic substances (as pollen) are found in suspension. Traces of nitrogenous organic matter derived partly from the atmosphere, partly probably from the surface on which the rain falls, are almost always present, and have been known to amount even to 8 milligrams per litre. The total solids of rain water may be taken at a mean of 32 milligrams per litre, the greatest quantity observed having been 0·0509 grm. The impurities of most importance are ammonia, free and albuminoid, and sulphuric acid, the last being sometimes styled a "measure of the sewage of the air." In India owing to the absence of coal-smoke in the atmosphere the amount of this latter impurity is probably very small. Free ammonia has been found to range from 0·180 to 9·1 mgrms. per litre; albuminoid from 0·034 to 0·4; sulphuric acid from 2·06 to 70·19.

Besides the impurities which rain water derives from the atmosphere through which it passes, it necessarily takes up others, and in larger quantity, from the 'receiving surface' on which it falls. When this is a roof—a flat one more especially—dust, organic and inorganic, excreta of birds, bones and feathers, dead insects, etc., contribute to the impurity of the supply. When the source of supply is a tank filled by surface drainage, all the impurities of the drainage area will, of course, be liable to be present in the water; and in this case rain water is no purer or better than the water of shallow wells. In the former case, where the rain is collected as it falls, the degree of pollution is insignificant, and the probability of the germs or poisons of specific diseases finding their way into the system through the drinking water is reduced almost to a minimum. It is desirable, therefore, that when there is no suitable indirect supply, this source of water-supply should be taken advantage of as much as possible, and that means should be adopted for the collection of all rain falling on the roofs of barracks, jails and other large buildings. Filtration through an oxidizing medium is still necessary before use.

Ice-water is 'flat' and unpalatable, but the usual addition in India of aërated waters to ice lessens this quality. In America the constant use of iced-water, *i.e.*, water frozen solid in vessels and then drunk whilst melting, is the cause of a considerable amount of dyspepsia.

The composition of Well-water depends upon the strata through which a well is sunk, the condition of the neighbouring surface and the measures taken to preserve the water from contamination.* According to circumstances, well-water may be thoroughly pure and wholesome, strongly medicinal, *i.e.*, full of mineral and gaseous impurities, or simply liquid sewage.†

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* *v.* Storage, p. 54.

† "Shallow well-water is the worst of all waters. Some of the shallow wells in or near villages are no better than cess-pools, and the people often drink their own diluted ordure and urine, mixed with those of the domestic

SPRINGS are supplied immediately by subterranean reservoirs which are themselves dependent upon the rain percolating through the strata overlying and surrounding them. The water which they yield is liable to the same kind of impurities as that of wells, though generally in a less degree; and most of the precautions and protection which the latter require are in many cases applicable to springs.

The usual sources of the numerous medicinal waters are deep natural springs from the mouth of which the water wells up continually, at any temperature up to boiling point; often highly charged with carbonic acid or sulphuretted hydrogen and holding in solution various salts such as magnesium sulphate (Epsom Salts) or sodium sulphate (Glauber's Salts), etc.

A STREAM or SMALL RIVER occasionally supplies water to a town or camp. In addition to the ordinary impurities of the springs which flow into it a stream is liable to pollution by surface drainage, dead organic matter, fæcal impurities washed in by floods, and suspended clay, etc., from the same source. The supply is precarious, the smaller streams, as a rule, drying up in the hot season (though water may always be found by digging in their beds). The beds when thus dry are liable to much pollution with organic and noxious material, which subsequently is taken up by the water. It is obvious, therefore, that a stream, especially if villages are situated on its banks above the position, is in general a most objectionable source of water-supply, and one indicating careful filtration or boiling as essential. The water from jungle streams though clear and appa-

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animals, and the washings of their bodies, clothes and household utensils, along with all the other dirt which may find its way into the water from the surface and from the air. What wonder that such people are never free from internal parasites, and that they are debilitated and die by millions from diarrhœa, dysentery, cholera and fevers? What wonder that their soil should be the "breeding ground of cholera"? * * * * * One of the most urgent and primary sanitary measures required everywhere in India is the filling up of surface pools and dangerous shallow wells."—MCNALLY.

rently pure, is considered dangerous by many, as it appears to be the frequent vehicle of malaria. This point is unsettled as yet. It occasionally happens that troops marching through an uninhabited or thinly-peopled country may find in a stream a convenient and wholesome supply. In such a case precautions should be taken to preserve it from being fouled by the cattle of the camp or by washing clothes or persons in it at any points above the most convenient part for obtaining water for drinking and cooking. The spot best suited for this purpose having been selected, another for watering cattle, lower down the stream, should be chosen, and a third, below this, for washing of every kind.*

Many populations are dependent upon RIVERS for their water-supply. In this country the periodical rains and the habits of the people often render this source of supply highly unsatisfactory. In time of flood rivers bring down suspended clay, sand, etc., in large quantities, besides the washings of their beds, fouled with every impurity during the dry season, and of the nullahs which open into them. Dead bodies are often thrown into rivers, and the sewage of towns and drainage from tanneries, slaughter-houses, dye-works, etc., are conducted into them. On the other hand the impurities are largely diluted, while the continual exposure of fresh surfaces to the air promotes the oxidation of putrescent organic matter† and the deposition of carbonates held in solution by carbonic acid. It is evident that water taken directly from rivers, especially in time of flood, should be carefully filtered before use; or, if this be impracticable, it should be well boiled.

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* An excellent plan to obtain good water from a shallow river is to dig small pits or shallow wells some distance from the water's edge. These depressions gradually become filled with clean filtered water.

† The actual amount of oxidation of impurities which take place in running water is still a matter of dispute. It is certainly not so great as was formerly supposed. When the water is very much polluted the effect of oxidation is trifling. Subsidence of suspended matters takes place to a certain extent and the process of purification (oxidation ?) is also assisted by water plants and micro-organisms (?).

The following table* gives a good idea of the comparative merits of the different sources of drinking water (in England).

Wholesome.	1. Springwater.
	2. Deep well water.
	3. Upland surface water.
Suspicious.	4. Stored rain water.
	5. Surface water from cultivated land.
Dangerous.	6. River water to which sewage gains access.
	7. Shallow well water.

As regards palatability	1 & 2 are	very palatable.
	3 & 4 ,,	moderately ,,
	5, 6 & 7 ,,	,,

These tables probably hold good for India with the exception of No. 3 (upland surface water) which is considered dangerous by some as being a favourite vehicle for malaria, save at great elevations, *e.g.*, the Nilgiri plateau (7,000 feet).

Not only the quantity of the water derived from the sources already considered, but also its quality, varies widely with the *season*, and this point has to be considered in judging of the fitness of a tank, well, spring, stream or river for supplying particular wants. In dry weather evaporation concentrates water, increasing the proportion of solid impurities, and the accompanying heat favors putrefaction of organic matters. Inquiries should always be instituted as to the *permanence* of a source of water-supply; analyses should, if possible, be made at two or three different periods in the year, and if one only can be made, the season and its probable effect upon the water should be considered and allowed for.

At sea and in coast towns where the rainfall is scanty and precarious (as at Aden), DISTILLED WATER is often used.†

* From VIth Report of Rivers' Pollution Commissioners.

† *E.g.* In the late Egyptian campaign enormous quantities of water for

Now-a-days nearly every vessel carries apparatus for the distillation of sea water* or for condensing steam from its engine-boilers; but in case of failure of fresh water on board a ship any means of heating salt water and condensing the vapor will afford a supply. The steam may be collected on a metallic surface, or on an earthen dish, changed when it becomes heated; or may be received in a clean woollen cloth, wrung out from time to time as it becomes saturated. Water thus obtained is insipid and perhaps indigestible, owing to absence of aëration. This disadvantage is obviated by exposing it to air in divided streams. It may contain sodium chloride, but not to any considerable degree. Magnesium chloride volatilized and decomposed may contribute hydrochloric acid, which should be neutralized by a little sodium carbonate.

DISEASES PRODUCED BY DRINKING IMPURE WATER.

The question of the production of disease by the use of impure water is one of surpassing interest in this country but space does not permit more than a summary of the present state of our knowledge in this matter. Suspended Inorganic (mineral) Impurities in excess may produce diarrhœa. Dissolved Inorganic (mineral) Impurities in excess, as in the case of waters with a high degree of permanent hardness, may cause dyspepsia and chronic constipation or in other cases, *e.g.*, where large quantities of magnesium sulphate are present, diarrhœa and intestinal irritation, thus weakening the intestines and predisposing to cholera or enteric fever.

The effects of Dissolved Organic Impurities are not supposed to be so formidable as those of Suspended, the latter including such diseases as are propagated by means of organized germs or spores, the former those due to

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the use of the troops on shore were distilled daily from sea-water by steamers fitted with powerful condensing apparatus.

* Zinc must not be used in any part of the condensing apparatus on account of the lead it generally contains; so also red lead is objectionable. In the best forms of such apparatus (Normanbys') the water is aërated artificially before distribution.

irritant poisons. Of the two classes of dissolved impurities of organic origin, the vegetable are certainly the less hurtful; indeed it is doubtful whether any ill-effects can be traced to them. Putrescent animal matters, on the other hand, especially those arising from fæcal contamination, are often productive of serious consequences. The intestinal tract is most liable to disturbance, and diarrhœa and dysentery are not unfrequently due to this cause. The composition of the poison producing these results is not known; and it has often been observed that water abounding in organic matter, having been drunk for months or even years with impunity, has suddenly developed poisonous material. In some cases this may be due to unsuspected communication with a foul drain or cess-pool, suddenly established or enlarged: in others, unusual elevation of temperature may have concentrated the water or set up putrefactive changes or may have favored the formation of the fatty acids which are known even in minute amount to be highly irritating to the bowels. Epidemics of dysentery or diarrhœa recurring annually in the hot season are probably attributable to one or other of these effects of heat upon drinking water. Diarrhœa may, in general, be expected if the water contains from 5 to 15 milligrams of putrescent animal organic matter per litre (parts per 1000,000), although larger amounts may be present in clear and sparkling water without apparent ill-effect, until the obscure putrefactive or fermentative changes mentioned above take place.* No doubt, other impurities are also present, and it is not possible to allocate definitely the share which animal organic impurity contributes to the production of intestinal irritation; but it may be laid down that the use of water containing this ingredient should never be permitted and that water contaminated by percolation through burial-grounds is the most noxious.

* A case is reported in the *Lancet* of April 29th, 1871, in which an epidemic of diarrhœa in a girls' school is attributed to the use for *washing* of water which had stood for two years in a cask.

How far Specific Diseases, as enteric fever and cholera, are dependent upon *dissolved* organic impurities cannot be stated. It is known that the former is propagated by water polluted with fæcal impurities, and that a large proportion of those who drink water containing the specific typhoid poison are attacked by the disease : but whether this poison is a possible product of fæcal sewage simply, or necessarily of sewage including the evacuations of enteric-fever patients, is still an undecided question. It is stated that propagation by water is less common than by air but that the period of incubation is shorter, a large quantity of the poison obtaining entrance to the system and coming more immediately into contact with the intestinal tract. It may be that the specific means by which this disease is communicated is not a dissolved animal poison, but a suspended organized germ ; and in this case putrescent animal products would favor its spread by exciting non-specific diarrhœa and acting as a pre-disposing cause. The same remark applies to cholera. Diarrhœa resulting from the use of water holding animal matters in solution is said to increase the susceptibility to the specific cholera-poison or cholera-germ. Either directly or indirectly, therefore, water thus polluted favors the spread of these specific diseases. It may be added that the diarrhœa resulting from water containing a large amount of putrescent animal matter is frequently choleraic in type and in severity.

As regards malaria and its possible communication by drinking water there is still no certainty either way.

It is probable that vesical calculi are especially common in districts where hard water is drunk.

The causation of goitre is still doubtful but a common idea and, it is believed, a correct one is that the occurrence of this disease is intimately associated with the constant use of water derived from limestone or dolomite ($CaCO_3$ $MgCO_3$) rocks.*

* Goitre is extremely common in Kashmir and the Chin country, either

A large number of animal parasites (with the diseases resulting therefrom) find entrance to the human body by means of impure drinking water.* In some cases the ova pass directly into the alimentary canal, in other cases there is an intermediate host. Severe bleeding from the mucous surfaces of the mouth and throat has been caused by small leeches (*Sanguisuga sp.*) taken in with the drinking water in Algiers and Minorca: it is probable that this also occurs sometimes in India and Burmah. The following are the principal known parasites which find entrance by means of impure drinking water. Some of them are conveyed to the human body more usually by other sources, *e.g.*, food, but impure water is almost certainly one vechicle of infection in the case of all the parasites mentioned.

Tœnia Solium (?)—the common tape worm of man derived fr m eating measly pork. It is possible that pigs get infected by drinking water fouled by human excreta containing the ova.†

Tœnia mediocanellata—the tape worm of man derived from eating measly beef. The cattle derive the ova from water fouled by infected human excreta.†

Bothriocephalus Sp. (?)—probably from fish which have lived in water into which the ova of this tape worm have originally been discharged.‡

Distoma Hepaticum—the liver fluke commonly found in sheep, occasionally in man; intermediate host a small fresh water mollusc.

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of which districts, but especially the latter, from the absence of many disturbing factors, offers excellent material for research in this matter. The disease seems chiefly confined to women, but one sometimes sees male Chins with goitre, and at least one sepoy in the old 38th Regt., B. I. became affected. (*v.* also Neve I. Med. Record, Vol. III, p. 332).

* The subject is by no means worked out in India either as regards human beings or other animals. Tank waters swarm with nematoid worms and other organisms of which the life-history and *raison d'être* are but little understood. For further details of life-history, etc., *v.* the works of Leuckhart, Cobbold, etc.

† The common food of pigs and cattle in many Indian towns during drought is simply dried human ordure.

‡ *v.* Moore, Diseases of India, 2nd ed., p. 556.

Ascaris Lumbricoides—the round worm, extremely common throughout India and the tropics generally.

Anchylostomum Duodenale—produces the disease known as anchylostomiasis in Assam and in various other parts of India.*

Filaria Dracunculus—or guinea worm, formerly supposed to obtain entrance to the human body during bathing. Intermediate host is a cyclops, a small fresh water crustacean abounding in Indian tanks. The introduction of pure drinking water has caused its disappearance in various parts of India, *e.g.*, Perambur (in Madras).

Filaria Sanguinis Hominis—the embryo of which is abstracted by the mosquito from the blood of infected persons, whence, after undergoing certain developmental changes, it is deposited in water and is probably taken directly into the alimentary canal of man along with the water drunk.

Bilharzia Hæmatobia (?)

Tricocephalus Dispar—the common whip worm.

General conclusions†—1. An endemic of diarrhœa, in a community, is almost always owing either to impure air, impure water, or bad food. If it affects a number of persons suddenly, it is probably owing to one of the two latter causes : and if it extends over many families, almost certainly to water. But as the cause of impurity may be transient, it is not easy to find experimental proof.—2. Diarrhœa or dysentery constantly affecting a community, or returning periodically at certain times of the year, is far more likely to be produced by bad water than by any other cause. —3. A very sudden and localised outbreak of either enteric fever or cholera is almost certainly owing to introduction

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* Sometimes called also *beri-beri*, but must be carefully distinguished from the true form of that disease with which it has nothing in common beyond the fact that the patient becomes anæmic in both diseases.

† From Parkes—Notter, p. 81.

of the poison by water*—4. The same fact holds good in cases of malarial fever, and, especially if the cases are very grave, a possible introduction by water should be carefully inquired into—5. The introduction of the ova (or embryos) of certain entozoa by means of water is proved in some cases—is probable in others—6. Although it is not at present possible to assign to every impurity in water its exact share in the production of disease, or to prove the precise influence on the public health of water which is not extremely impure, it appears certain that the health of a community always improves when an abundant and pure water supply is given; and, apart from the actual evidence, we are entitled to conclude from other considerations, that abundant and good water is a prime sanitary necessity.

PURIFICATION OF WATER—FILTRATION.

The purification of water by subsidence of the suspended matters, by filtration through the soil and by exposure to various oxidising media is constantly going on in nature, but almost as constantly, in the case of surface waters at least, fresh impurities are being added. It is necessary, accordingly, in many cases to purify a water artificially before use. One of the four following plans may be adopted, separately or combined with one or more of the others, *viz*:—

1. *Distillation*; 2. *Precipitation*; 3. *Boiling*; 4. *Filtration.* The first method has already been described.†

PRECIPITATION is either *natural* or *artificial.* By the first method the suspended matters are simply allowed to sink to the bottom, as in 'settling tanks:'‡ by the second some substance is added which by means of the formation of a bulky precipitate carries down the impurities in its meshes. Such substances are very numerous. *a.* Alum, especially if calcium carbonate is present, acts very well. Calcium sulphate is formed and a bulky precipitate of aluminium hydrate. Six grains of alum to a gallon of water is a good

* It may be, in the form of ice. † *v.* p. 81. ‡ *v.* p. 52.

proportion. *b*. Lime, if added, combines with the CO_2 and thus causes the precipitation of the $CaCO_3$ already present. *c*. Potassium permanganate; impurities are oxidised, especially if the water is slightly warm, and in addition a precipitate of manganic oxide is sometimes formed which acts mechanically. A good plan is to add the permanganate first and then alum, or else filter the water. *d*. Iron; either as scrap iron or spongy iron* (with agitation of the water)†, or as the perchloride (about 2½ grs. per gallon). In both cases oxidation and precipitation take place. *e*. The 'Anti-calcare' of Maignen consisting chiefly of lime, alum and carbonate of soda. The carbonate of soda acts on lime and magnesia. *f*. Certain Vegetable matters, especially those containing tannin, *e.g.* tea,‡ kino, etc., and in India the fruit of the *Strychnos Potatorum* which swells up and forms a gelatinous precipitate, its action being purely mechanical.

Boiling is a most useful method for the purification of water either alone or as a preliminary. Long continued boiling destroys all living organisms; in addition any temporary hardness is precipitated and suspended impurities partly got rid of.

To sum up then impurities are most readily removed thus§ (exclusive of filtration):

Organic matter by	Distillation, boiling, exposure to air, alum, permanganates, tannin, and by agitation with iron, etc.
Carbonate of lime by	Boiling, or addition of caustic lime.
Iron by	Boiling, lime, and in part by charcoal.

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* *v*. Bischof's filter, pp. 92—3. † *v*. p. 90.

‡ In a strange country it is an excellent rule never to drink water save in the form of tea, unless it has passed through an efficient filter. The action of the tea is threefold:—(1) The water is boiled (should be well boiled in this case). (2) The leaves form a mechanical strainer. (3) The tannin forms insoluble tannates.

§ Allan, *op. cit.*, p. 26.

The effects of FILTRATION are threefold. Suspended matters are retained in the interstices of the porous material of which filters are composed; dissolved inorganic matter is similarly, though to a less extent, separated; and oxidizable organic matter, suspended or dissolved, is oxidized, either by oxygen stored in the filtering material or by such substances as alkaline permanganates added to it.

Artificial filtration is carried out on the large or small (domestic) scale, but the principal is exactly the same in both cases.

On the *large scale,* the water-supply of towns or extensive buildings is, after the subsidence of the coarser suspended impurities in settling reservoirs, admitted to filtering beds composed of sharp sand with underlying gravel increasing in coarseness towards the bottom. The bed will be three feet or more in thickness, somewhat more than a third being sand. The rate at which water passes through such a filter depends upon the pressure, and this upon the depth of the water in the bed, which is usually about two feet. In general the discharge may be estimated at 70 gallons in 24 hours for each square foot of filtering surface. Finely divided clay if present in considerable quantity* will pass through such a filter, but most suspended matters will be retained. The amount of dissolved mineral matters will be considerably diminished in proportion to the thickness of the layer of sand, which also promotes oxidation of organic impurities. Micro-organisms are effectually removed for a short time, by certain sands, but this power is lost in a few days. It must be remembered that the more efficient a filtering bed is, the more rapidly will its interstices become clogged and its power of purification lessened or destroyed; and especially that dissolved matters at first removed will, at a certain point, begin to be restored to the outflowing water. This should therefore be examined

* The turbid water of the Hooghly carries down so much fine clay at some seasons as to block and render useless the sand-filters.

from time to time, and the sand removed and cleaned when necessary. It follows that two filtering beds should always be provided, in order to admit of periodical cleansing. In some water-works a so-called Revolving Purifier is in use. It consists of numerous small cylinders rotating on a horizontal or inclined axis, each cylinder being filled with little angular pieces of iron* lying loose in the cylinder. The water passes slowly through the revolving cylinder and is "churned up" with the iron, which latter continues to offer a bright clean surface owing to the constant friction. Finally the water is filtered through sand to get rid of the coloration imparted by the iron. In yet other cases the 'magnetic carbide' of iron* or Bischof's 'spongy' iron* are used, the water being previously passed through settling tanks and rough sand filters.

For the filtration of water on the *small scale* a great many substances have been used but of these only a few are trustworthy. *Organic filtering media such as sponge, cotton wool or flannel should never be used*: any advertised filter containing them should be rejected. Porous sand-stone filters in the form of jars are largely used by travellers in this country: by them turbid water is rendered clear and of pleasant appearance but their action on dissolved matters is practically *nil*. As a material for the preliminary straining of suspended impurities nothing is equal to closely-woven asbestos cloth. This mineral, as is well known, is unaffected by ordinary heat and the cloth can therefore be purified by washing it and heating it in a fire, by which means all impurities in its meshes can be got rid of. Of filtering media proper there are only two worth considering, *viz.*, *Charcoal* and *Iron*. They may be used separately or in the form of compounds produced by heating them together.

CHARCOAL is derived from the destructive distillation of organic matter either animal—bones, etc., or vegetable—wood,

* *v.* Iron, p. 92.

peat, sea-weed, etc. Coke, derived as it is from the same process applied to coal (*i.e.*, mineralised vegetable matter), may be looked upon as mineral charcoal. All of these, if the layer is sufficiently deep, remove suspended matter from water filtered through them so that the latter passes out clear and sparkling. As regards suspended organic impurities animal charcoal exerts the most powerful influence on dead organic matter but is much inferior to vegetable or mineral charcoal in preventing the passage of micro-organisms. Fresh animal charcoal entirely oxidises dissolved organic matter and removes also dissolved mineral matters, especially lead. But it soon loses its power, more especially as regards the oxidation of dissolved organic impurities.

The conclusions to be arrived at with regard to charcoal as a filtering medium are these* :—" (1) It acts both chemically and mechanically, and is at first both rapid and efficient. (2) With a good bulk of material, water may be passed through nearly as rapidly as it can flow, and be well purified. (3) Water must not be left in contact with the charcoal longer than is necessary for filtration, as it is apt to take up organic matter again. (4) Water filtered through charcoal must not be stored for any time, but must be used immediately, as if kept it is apt to become charged with minute organisms. (5) Since fresh organic matter may pass through it unchanged, animal charcoal cannot be confidently depended upon to purify water from disease poison. (6) The power of charcoal is limited; with a moderately good water it remains efficient for some time, but with an impure water it soon becomes inactive. In all cases it ought to be cleaned or renewed at least every three months, and with impure waters much oftener, say, every week or every fortnight." Having regard to No. 5 it might be advisable in a charcoal filter to have two layers, one of animal and the other of vegetable or mineral charcoal. When charcoal is used it must be pounded and

* Parkes—Notter, pp. 86—7.

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* Parkes—Notter, pp. 86—7.

compressed so as to retain the water for about four minutes in its passage through the filtering medium.

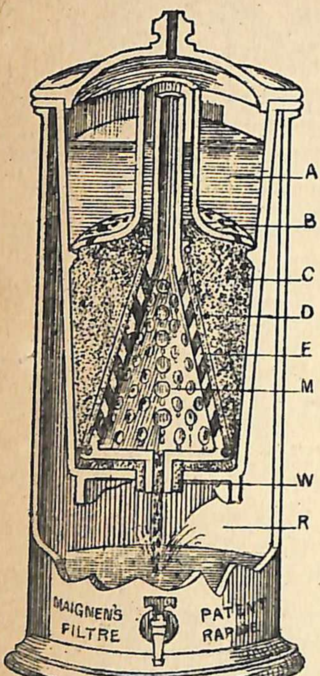
Iron as a filtering material is chiefly used in the form of so-called spongy iron (Bischof's) which is obtained by roasting hæmatite iron ore. It consists chiefly of porous metallic iron. As a filtering medium it ranks very high, its action being both mechanical and chemical. It arrests suspended matter and micro-organisms, oxidises dissolved organic matter and removes lead. Upon dissolved mineral matters it does not have much effect. In all cases its action is slow but water that has been filtered through it does not become deteriorated for a long time.* Besides these there are numerous other materials that have been used from time to time of which the important ones are nearly all compounds of iron (or manganese) and charcoal. Such are magnetic carbide, manganous carbon, carbalite used in Crease's filters in the Royal Navy, polarite or magnetic spongy carbon much used at the present time both on the large and small scale, etc.

A somewhat new idea is the filter known as the Pasteur-Chamberland, where the medium is simply a cylinder of porcelain through the pores of which the water passes under pressure direct from the tap. It effectually removes suspended matters and micro-organisms but has little action except when perfectly new, on dissolved organic matter. The latest filter is the Berkefeld made somewhat after the pattern of the foregoing, but in this latter case the cylinder is made of diatomaceous earth, *i.e.*, of innumerable siliceous 'skeletons' of fossil *diatoms* which form an open or porous structure, the meshes being extremely minute. It is said to possess the following advantages:—(1) It will filter large or small quantities according to pressure; (2) the filtered liquid will be absolutely free from any solid particles and from germs; (3) the filter can be easily cleaned; (4) each filter can be thoroughly sterilised by being boiled in water for an hour, and, moreover, one cylinder will last for years.

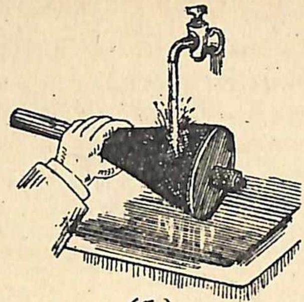
* *Cf.* Charcoal, p. 91 (4).

PLATE IV

I

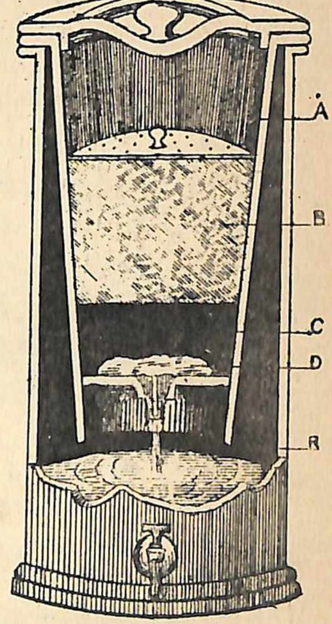


(a.)

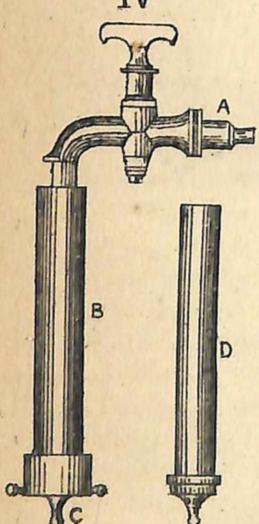


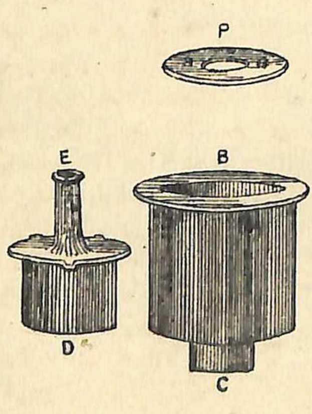
(b.)

II.

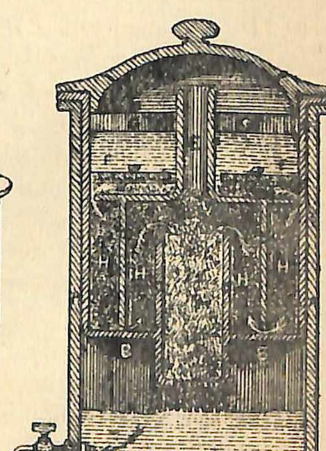


IV





III



LITH: BY ROSS, BROS.

To face p. 92.

PLATE IV.

DOMESTIC FILTERS.

I. (*a*) Filtre Rapide (Maignen), in section. A. Filter case proper; R. Reservoir for the filtered water; M. Filtering frame secured within the case by pure asbestos washer (W); E. Asbestos cloth attached to filtering frame with asbestos cords; D. Layer of *powdered* Carbo-Calcis; C. Layer of *granular* Carbo-Calcis put in loosely to fill space between (D) and the screen (B).

(*b*) Shows method of cleansing the filter by removing the frame (M) and washing away the used Carbo-Calcis.

II. Spongy Iron Filter (Bischof), in section. A. Filter case proper; R. Reservoir for the filtered water; B. Fine Spongy Iron; C. Pyrolusite; D. Abestos cloth bag.

III. Circulating Filter (Morris). An ordinary outer case or vessel, A, is divided into two parts by the division, B, which forms part of a separate vessel dropped into the outer case and hanging by a broad rim. In the centre, and forming part of the division B, is a tube, or chamber, C, the lower portion of which protrudes an inch or two, so as to form—with the aid of the capillary attraction of the material—a siphon arrangement, whereby the filter is drained perfectly dry at each operation.

The lower end, or outlet, of the vessel C, is provided with a strainer of fine holes, the upper mouth, or inlet, being left open. Into this containing vessel, and over the tube C, is loosely placed a second circular tube or chamber, D, with its mouth downwards. This vessel is made to stand higher than the central tube, C, and is also of much larger diameter, so that the interior space of the filter is partitioned vertically at regular distances by the chambers C and D. The upper part of D forms a flat plate, having an open air tube, E, rising from the centre, and the diameter of this flat plate being a little less than that of the containing vessel, leaves an annular space or clearance around it of about ¼ in. at F. Water poured into the upper part, G, of the filter, and around E, must therefore find its way through the annular space at F, down one section of filtering material under the chamber D, up through another section of material till it flows over the top of chamber C, and so down through a third column of medium and through the strainer into the lower compartment of the filter. If now the filtering medium in the central tube or chamber C, be coarse and porous as at J, and that in the spaces H and H′ of a very fine and close nature, it follows that the water will percolate very slowly down the space H and up the intermediate section H′, but will rapidly escape down the central tube or chamber C, and instead of accumulating and flooding the interior of the filter, it trickles down from particle to particle of porous carbon—highly charged with air—thus leaving the mass of material in a semi-dry state, and allowing a supply of fresh air to penetrate down the air tube E, into the very centre of the filter. The action is therefore automatic, the flow of water drawing a current of air down into the carbon, which absorbs it, but gives it up again to the water as it percolates down the central tube. [NOTE.—The letters are, unfortunately, not very clear in the plate, but, if the above description be carefully followed, the action of the filter can be easily understood].

IV. Pasteur-Chamberland Filter. A. Water-tap attached, at A, to water-pipe; B. Outer case of filter; C. Mouthpiece; D. Porcelain Cylinder or 'Candle' (*v.* also fig. 1, pl. v.)

To face p. 93.

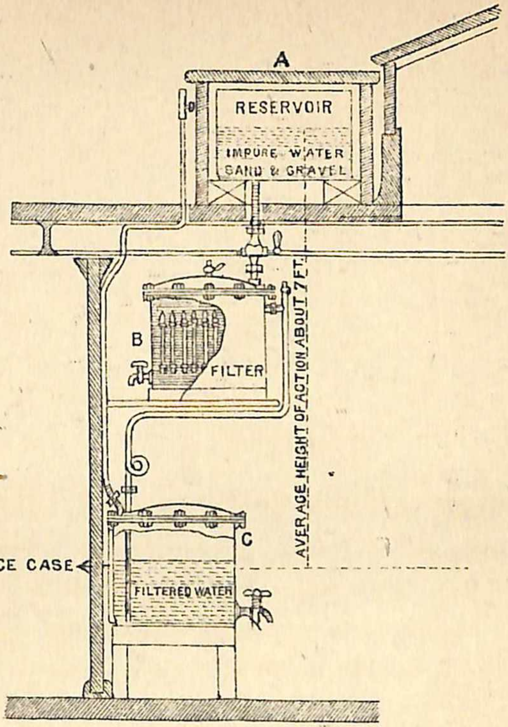
PLATE V.

LARGE FILTERS FOR HOSPITALS, BARRACKS, Etc.

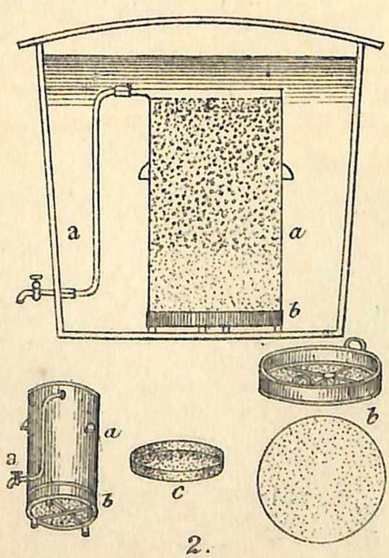
Figure. 1. Large Pasteur-Chamberland Filter for use in Permanent Buildings. A. Covered iron reservoir tank on the top of the building, which can be of any desired size and depth. B. Metal case enclosing the Candles, either Porcelain or *Kieselguhr* (Berkefeld form), from which passes a pipe connecting it with C., the Filtered Water covered receptacle. In India, the filtered water reservoir may have an Ice case surrounding it, if desired, as shewn in the drawing. (For further details *v.* Orig. Art. by Surg.-Col. Roe, I.M.G., March 1893).

Figure 2. Macnamara Filter. *d.* Delivery pipe, *c.* Coarse Sand, *a.* Animal, Charcoal above, Fine Sand below, *b.* Coarse Sand. At *a* and *c* Perforated Zinc Trays are placed, at *b* a Perforated Earthenware Disc. In the left hand corner, the filter (reduced) is shown removed from its cask. (*v.* p. 94).

Plate V.


A
RESERVOIR
IMPURE WATER
SAND & GRAVEL
B
FILTER
AVERAGE HEIGHT OF ACTION ABOUT 7 FT.
C
ICE CASE
FILTERED WATER

1.


a
a
b
a
a
b
c
b

2.

It is believed that one of these two latter filters is to replace the Macnamara filters at present in use in barracks, hospitals, etc., in this country.*

The essentials of a good filter are the following:—

"(1) That every part of the filter shall be easily got at for the purpose of cleaning or of renewing the medium. (2) That the medium have a sufficient purifying power both as to chemical action on organic matter in solution and arrest of organisms or their spores in suspension, and be present in sufficient quantity. (3) That the medium yield nothing to the water that may favour the growth of low forms of life. (4) That the purfying power be reasonably lasting. (5) That there shall be nothing in the construction of the filter itself that shall be capable of undergoing putrefaction or of yielding metallic or other impurities to the water. (6) That the filtering materials shall not be liable to clog and that the delivery of the water shall be reasonably rapid."†

Filters for ordinary domestic use are sold in very many shapes and sizes, but the number of really good ones as judged by the foregoing standard is very small. They are roughly divisible into classes according to the material used for filtering as follows‡:—

(1) Those containing animal charcoal in granules or powder. (2) Animal charcoal compressed into blocks by admixture with silica and other substances. (3) Spongy iron filters. (4) Magnetic iron filters. (5) Cylinders of porous inorganic material such as porcelain. (6) Those containing other substances of varying nature, chiefly mineral. Three of the best known, and most efficient patterns are the Filtre Rapide (Maignen's), the Morris Circulating Filter

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* "The sterilisation of fluids by mere and comparatively rapid filtration must be regarded as a distinct and important advance in bacteriological Science." *Lancet*, 12th September 1891: *v.* also Sanitary Record, 15th November 1892.

† *v.* Parkes—Notter, p. 89, for further information.

‡ *Ibid. loc. cit.*—altered.

and the Spongy Iron Filter (Bischof's). To these must be added the Pasteur-Chamberland and Berkefeld as described above. The construction and working of these various forms are sufficiently explained in the diagrams.

In India a favourite form is the filter made of three *chatties* or *ghurrahs* on a bamboo stand. The uppermost is half filled with pounded charcoal, the middle one with fine sand* and a layer of small stones underneath: both are perforated with small holes in the bottom. The lowest chatty contains the filtered water. It is a good filter *if very carefully looked after.* The filtering media must be as clean as possible in the first instance and any surplus must be stored in clean chatties or boxes. The charcoal should be renewed every fortnight or once a week if the water is very foul; the sand and stones should be taken out, cleaned and dried once a month, also the chatties themselves. Two filters may be kept so that one can always be cleaned when necessary. The chatties should also have removable perforated lids and the lowest one should be renewed when it loses its porousness. The holes should not be quite at the lowest portion nor too large, otherwise the water is apt to run straight through without proper purification. The daily filling of the filter must be superintended by some responsible person; if not, the waterman or bhisti will be certain to pour the water straight into the lowest chatty to save time and trouble.

For large institutions such as barracks, asylums, ships, etc., various special types of filters are in use but they are either imitations on a small scale of the larger sand filters, or else the same in principle as the filters described. One type of filter however, *viz.*, the Macnamara, deserves special mention as it is the filter officially supplied to Military hospitals, barracks, etc., throughout India.† It consists of a stout cylindrical zinc vessel closed at the upper end

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* Both the charcoal and the sand should be well pressed down.
† *v.* I. A. R., Vol. VI., Medical, Madras, 1885.

excepting where the delivery pipe is attached, whilst below it fits into a tray containing a perforated earthenware disc. The interior of the vessel is divided into compartments by removable perforated zinc trays and is so charged with filtering materials that at the top there is a little coarse sand, below this a deep layer of coarse and fine animal charcoal, below this is fine sand and finally coarse sand resting upon the perforated earthenware disc. When ready, the filter is placed in a three-quarter cask the inner surface of which is charred, and the delivery pipe connected with the tap attached to the latter. The cask is then filled with water, the lid fastened down, and upward filtration takes place. The arrangement and working of the filter can be understood from the accompanying diagrams, it being remembered that the filter is turned upside down during the process of charging.

No filter is self-cleansing though many are stated to be so. The proper management of the various forms of filter on a large scale requires a good deal of experience and technical knowledge. Domestic filters must be most carefully attended to or else they simply become the chief source of impurity to the water passed through them.

Charcoal is best cleaned, so to speak, by renewing it but if this cannot be done it should be heated to redness in the absence of air* if possible, and then washed with clean water; if this is not possible it should be boiled with permanganate of potash solution to which a little dilute hydrochloric acid has been added. *Sand* in large filters should be partially renewed frequently by scraping away the top layer and adding fresh clean sand and should be completely changed at longer intervals of six months or so. In small filters it may be renewed, or taken out, washed and then heated by baking or exposure to the sun and afterwards washed again with permanganate of potash solution. *Spongy iron* lasts for a long time—six months to a year—it

* By placing it in a perforated metal cylinder which is caused to revolve slowly over a fire.

should then be renewed if possible; if not, it must be heated to a low red heat and afterwards well washed with clean water only.*

When travelling in India and obliged to drink doubtful water, if no better means of purification is at hand, the water should be made into tea and drunk in that form only. Travellers, however, if unprovided with a good filter should always carry a small stoneware bottle-filter† and an ounce or two of permanganate of potash. First add a few grains of permanganate of potash and then heat gently; add more potash salt till the pink tinge remains for about ten minutes;‡ boil thoroughly, cool and shake well in some convenient vessel and then, after subsidence of the coarse suspended matters, filter through the stoneware filter. In this way a supply of drinkable water can be easily made and used till the next halting stage.§ It is just within the limits of possibility that Indian Railway Companies will some day provide really pure, cool water in abundance for all travellers.

EXAMINATION OF WATER.

The examination of water will only be considered very cursorily here, for it is a highly technical subject requiring a special training and a fully-equipped laboratory.

The Collection of Samples of Water.—This is a very important duty which may have to be performed by any medical officer. The following directions|| should be most carefully adhered to:—

Analysis of Water.—Before forwarding a sample of water

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* In a filter where the medium is spongy iron, the latter must always be kept covered with water: in the newest form of Bischof's filter this is provided for.

† Obtainable all over India and Burmah.

‡ As judged by pouring a little of the water from time to time into a tumbler or clear glass bottle.

§ The small amount of trouble involved in the above process will be amply repaid by freedom from sickness and in many cases by one or more lives saved. If the Pasteur-Chamberland, Berkefeld or other types of pressure filter come into the Indian market, it is worth while remembering that very considerable pressure may be obtained by hanging the vessel containing the water high up in a tree or on the top of a house and connecting it by rubber tubing with the filter near the ground level.

|| *Extract from G.O.G., Madras, No.* 1062, *Public, dated* 30*th May* 1883, *Chemico-legal Examinations.*

to the Chemical Examiner for analysis, it is necessary to write to the Chemical Examiner and ascertain when it will be convenient to receive the sample or samples which may require to be examined, it being desirable that samples should be examined shortly after they are received at the Laboratory.

(2) The duty of collecting the samples should always be undertaken by a responsible person. The employment of peons or servants for this purpose is strictly prohibited. The bottles used should be thoroughly cleansed, and then well washed out twice with water from the same source it is intended to fill them from, just before finally filling them.

(3) Glass stoppered bottles are best, but if those are not procurable, new corks are to be used with the ordinary quart wine bottle of light colored glass. In filling the bottles a little space should be left between the cork and the water. [The mouth of the bottle should be plunged under the surface, but should not touch the bottom.]

(4) Not less than one gallon of each sample of water is to be forwarded.

(5) Each bottle to be labelled, with the name of the well [or tank, etc.], and date of collection.

(6) On forwarding water for analysis, the Medical Officer should, at the same time, forward separately a letter to the Chemical Examiner. This letter should contain :—

(*a*) An impression and description of the seal used in closing the bottles.

(*b*) Information as to the number of samples sent, and a statement as to how the samples have been forwarded. [By hand, rail, steamer, etc.]

(*c*) An explanation as to the reason for which the examination is required, and information as to by whom it is desired.

(*d*) A statement as to the source from which each sample was collected, and by whom and when each sample was collected.

The information given under 6 (*d*) should be as full and complete as possible, having reference to the geological and meteorological conditions of the place, distance of the well, etc., from possible source of impurity, nature of the collecting surface, supposed connection with outbreak of any particular disease and any other information obtainable. If the water is very bad or if a very complete mineral analysis is desired, two gallons or more should be sent. For the bacteriological examination of a water special methods and precautions are necessary which it is unnecessary to detail here.*

In practice the examination of water for hygienic purposes admits of division into four degrees of accuracy.

I. The very rough and speedy examination which has frequently to be made by a Medical Officer at the end of a long march or journey when many thirsty soldiers or other persons are waiting to be allowed to drink. There may be several sources to choose from—one or more wells or tanks, a shallow stream, the backwater of a large river, etc., etc. From what has been said before a good idea can be gathered as to which is likely to prove the best source of supply. After inspecting these rapidly the Medical Officer should examine samples of the water brought to him for that purpose by sight, taste and smell, remembering that in tasting a water it is unnecessary to swallow any of it.

II. *Physical examination.* This though requiring no chemicals, often gives valuable hints as to the impurity or otherwise of a water and can be made by any educated person when there is a little time to spare, *e. g.*, in choosing the site of a temporary camp which is to be occupied a day

* *v.* Manl. Pratique D'Analyse Bacteriologique des Eaux, Le Dr. Miquel, Chapitre I, Paris, 1891.

or two later. The points to be inquired into regarding the water are as follows:—

1. *Colour.*—This is best examined by pouring some of the water into a tall cylindrical glass vessel one and a half to two feet in depth, which is then placed on clean white paper and the colour compared with a similar vessel filled with distilled water. If no distilled water is available the original vessel may be filled half full and the colour of the water compared with the column of air above it. This test must always be done in a good light. Distilled water is almost colourless; pure waters have a faint bluish tinge. Green waters are very common in India, especially in tanks, the colour being due to minute fresh water algæ. Yellow or brown waters are so coloured by animal or vegetable organic matter or are chalybeate. If there is the remotest chance of the pollution being due to animal matter the water should be rejected, but in this country, save close to towns or villages, such colouration during the rainy season is generally due to vegetable matter.

2. *Clearness.*—Shake up the sample of water so as to divide the suspended matter equally and then pour some into the cylindrical vessel as before. Instead of the white paper put a piece of ordinary newspaper underneath and by gradually adding a little more of the sample ascertain the exact depth at which the printed matter becomes obscured. The latter can easily be read through 24-inches depth of distilled water.

3. *Taste.*—This is not a very reliable test, for though all good waters are practically tasteless and any water with a bad taste is at once rejected, the important fact remains that many of the worst waters are free from any disagreeable taste. If mineral matters are present in large extent the water will probably be objectionable in taste. A small amount of iron will do no harm in water for temporary use.

4. *Smell.*—If the water has a disagreeable smell it should be rejected. Warming the water gently or even boiling

sometimes brings out its peculiar smell, particularly if there is much animal impurity present. In some foul waters the presence of hydrogen sulphide is thus rendered perceptible.

5. *Sediment.*—This if present in large quantity can be approximately estimated by pouring the water into a narrow cylindrical vessel, *e.g.* a long test tube, and allowing it to settle. The naked eye alone or a small hand lens can often detect the presence of numerous animal and vegetable impurities, *e.g.*, crustaceans (*cyclops, daphne, etc.*), worms, algæ, larvæ, etc., but it should always be examined with a microscope if possible. If the number of animalcules and microbes is very great so that the field of the microscope swarms with them the water should be rejected.*

6. *The Lustre.*—The degree of "sparkle" in a water is sometimes recommended to be noted as indicating the amount of aëration but is of no practical value as some of the worst waters, *e.g.* from wells sunk in graveyards, have the most brilliant lustre.

If then on the one hand a water is deeply coloured, very turbid, bad tasting or strongly smelling it should be rejected as unfit for use, but if on the other hand it is colourless, clear, tasteless and odourless it may be accepted provisionally provided that more thorough means of analysis are not available.

III. *Qualitative examination.*—This can be carried out in any station or institution where the ordinary chemical reagents are available and indications of considerable value may be thus obtained. The physical and microscopical examination should first be carefully carried out and if the water is not condemned by these tests the chemical examination may be proceeded with. The following table shows the various tests clearly.†

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* The number of objects, both animate and inanimate, that may be found in water by microscopic examination is so great that it is impossible to give any adequate description of them within the limits of this manual. In addition, the recognition of each form and the probable value attachable to its presence, needs special training and experience not to be gained from any book.

† Taken by permission of the author and proprietors (Messrs. Churchill) from Parkes-Notter *op. cit.*, p. 686 *et seq.*

QUALITATIVE EXAMINATION OF DISSOLVED SOLIDS.

The water may be either at once treated, or, in the case of some constituents, it should be concentrated by evaporation.

Water not Concentrated.

Substance sought for.	Reagents to be used, and effects.	Remarks.
Reaction	*Litmus* and *turmeric* papers; usual red or brown reactions.	Usually neutral. If acid, and acidity disappears on boiling, it is due to carbonic acid. If alkaline and alkalinity disappears on boiling, to ammonia (rare). If permanently alkaline, to sodium carbonate.
Lime	*Oxalate of ammonium.* White precipitate.	Six grains per gallon (9 per 100,000) give turbidity; sixteen grains (23 per 100,000) considerable precipitate.
Chlorine	*Nitrate of silver*, and *dilute nitric acid.* White precipitate becoming lead colour.	One grain per gallon (1·4 per 100,000) gives a haze; four grains per gallon (6 per 100,000) give a marked turbidity; ten grains (14 per 100,000) a considerable precipitate.
Sulphuric Acid	*Chloride of barium* and *dilute hydrochloric acid.* White precipitate.	One-and-half grains (2 per 100,000) of sulphate give no precipitate until after standing; three grains (4 per 100,000) give an immediate haze, and, after a time, a slight precipitate.
Nitric Acid	*Brucine* solution and *pure sulphuric acid.* A pink and yellow zone.	The sulphuric acid should be poured gently down to form a layer under the mixed water and brucine solution; half a grain of nitric acid per gallon (=0·7 per 100,000) gives a marked pink and yellow zone; or, as recommended by Nicholson, 2 c. c of the water may be evaporated to dryness; a drop of pure sulphuric acid and a minute crystal of brucine be dropped in; 0·01 grain per gallon (= 0·0143 per 100,000) can be easily detected.
Nitrous Acid	*Iodide of potassium* and *starch* in solution and *dilute sulphuric acid.* An immediate blue colour.	Add the solution of iodide of potassium and starch, and then the acid; the blue colour should be immediate; make a comparative experiment with distilled water.

Substance sought for.	Reagents to be used, and effects.	Remarks.
	Solution of *metaphenylenediamine* and *dilute sulphuric acid* (Griess's test)—a yellow colour more or less immediate according to amount of nitrous acid.	This is a very delicate test; a yellow colour will appear in the water in half an hour, if there be only one part of nitrous acid in 10,000,000 of water.
Ammonia	*Nessler's* solution. A yellow colour or a yellow brown precipitate.	If in small quantity, several inches in depth of water should be looked down through on a white ground.
Iron	*Red* and *yellow prussiates of potash*, and *dilute HCl.* Blue colour.	The red for ferrous and the yellow for ferric salts.
Hydrogen Sulphide	A soluble salt of *lead.* Black precipitate.	When the water is heated the smell of hydrogen sulphide may be perceptible.
Alkaline Sulphides	*Nitroprusside of sodium.* A beautiful violet-purple colour.	A black precipitate with lead, but no colour with nitroprusside shows that the hydrogen sulphide is uncombined.
Oxidisable matter, including organic matter	*Gold chloride.* Colour varying from rose-pink through violet to olive; a dark violet to black precipitate.	The water, which should be neutral or feebly acid, must be boiled for 20 minutes with the gold chloride. If no nitrous acid be present, the reaction may generally be considered due to organic matter.
Do.	Note the darkening of the *silver chloride* in testing for chlorine.	Compare with a precipitate produced in a pure solution of a chloride.
Lead or Copper*	*Ammonium sulphide.* Dark colour, not cleared up by hydrochloric acid.	Place some water (100 c. c.) in a white dish, and stir up with a rod dipped in ammonium sulphide; wait till colour produced, then add a drop or two of hydrochloric acid. If the colour disappears, it is due to iron; if not, to lead or copper.†

* Sidney Harvey (*Analyst*, vol. vi. p. 146) recommends small crystals of potassium bichromate. According to him $\frac{1}{10}$ of a grain per gallon gives an immediate turbidity, $\frac{1}{20}$ after 15 minutes, and $\frac{1}{50}$ after 30 minutes. These numbers equal respectively 0·14, 0·07, and 0·03 per 100,000.

† Wanklyn.

Substances sought for.	Reagents to be used, and effects.	Remarks.
Zinc	*Hydrogen Sulphide.* A white precipitate. If zinc be in considerable quantity, it is generally present as bicarbonate, and gradually forms a film of carbonate on the surface of the water. This film may be collected and heated on platinum foil. If the residue remain yellow when hot and white on cooling, the presence of zinc is indicated. This reaction is very delicate.*	This test is not possible if there be iron present, should the water be alkaline. It forms, however, in perfectly neutral waters, but not in acid. A little acetate of sodium greatly aids this; or ammonium sulphide with an alkaline solution in excess; or acidulate water with hydrochloric acid and add potassium ferrocyanide; a white precipitate appears, pale greenish if there is iron in the hydrochloric acid.

Water Concentrated to $\frac{1}{50}$ (in a Porcelain Dish.)

Substances sought for.	Reagents to be used, and effects.	Remarks.
Magnesia	*Oxalate of ammonium* to precipitate lime, then after filtration a few drops of *phosphate of sodium*, of *chloride of ammonium* and of *liq. ammoniæ.* A crystalline precipitate in 24 hours.	A precipitate forms in 24 hours, and is the triple phosphate either in the shape of prisms or in feathery crystals.
Phosphoric Acid	*Molybdate of ammonium* and *dilute nitric acid.* A well-marked yellow colour, and on standing a precipitate.	Add the nitric acid, and stir with a glass rod, then add twice the quantity of molybdate and boil.
Nitric Acid	*Brucine* test.	If the nitric acid is in small quantity, it may not be detected in the unconcentrated water.
Silicic Acid	Evaporate to dryness, moisten with *strong hydrochloric acid;* after standing, add boiling distilled	The residue may be weighed, and thus the silica determined quantitatively. A little clay or oxide of iron will be sometimes mixed with it.

* Frankland, *Water Analysis*, 1880, p. 44.

Substances soughht for.	Reagents to be used, and effects.	Remarks.
	water; pour off fluid; dry, ignite; repeat the treatment with hydrochloric acid and water; dry, ignite again, and the residue is silica, or silicate of aluminium.	
Lead or Copper	As before.	If quantity be very small.
Arsenic	*Marsh's* or *Reinsch's* tests.	Water should be rendered alkaline with *sodium carbonate* before concentration, then acidulated with *hydrochloric acid*.
Zinc	Evaporate to dryness; treat rësidue with *caustic potash* or *ammonia*, filter and test filtrate with *hydrogen sulphide*; a white precipitate falls.	This is necessary if the quantity be small, or if iron be present. If a film of carbonate forms on concentration, it may be tested on platinum foil, as before described.

Chlorine is nearly always present but if in considerable quantity giving a marked turbidity or a distinct precipitate its presence is important. It is derived from soil containing chlorides of sodium and calcium, from sea-water, or from contamination by urine or liquid sewage. In the latter case some or all of the following substances will be present in excess, nitric and nitrous acids and ammonia, phosphoric acid, and, if the impurities are recent, oxidisable organic matter.—Ammonia should not be present in sufficient amount to give the Nessler reaction in the undistilled water.—If the phosphoric acid reaction is distinct it is highly probable that the water is contaminated with sewage.—Should it contain any metal other than iron or the alkaline and earthy metals it is unfit for use.—If the water is 'hard' lime will be present in large quantity; if hardness is 'temporary', as $CaCO_3$ which is precipitated by boiling, if 'permanent' as $CaSO_4$, $Ca\ Cl_2$, $Ca\ (NO_3)_2.4\ H_2O$, and is not precipitated by boiling.—If there is an abundant precipitate of magnesia in 24 hours, the water should be rejected. This is a common impurity in India.

IV. *Complete Quantitative examination.*—This really means the accurate determination of the quantity of each basic and acid radical and in addition the quantitative examination of—1. *The dissolved solids*—(*a*) *total* (*b*) *fixed* and (*c*) *volatile.* 2. *The hardness*—(*a*) *total* (*b*) *fixed* (*c*) *removable.* 3. *The free or 'saline' ammonia* and the nitrogenous organic matter (reckoned as '*albuminoid*' *ammonia*). 4. *The oxidisable matter.* In practice the whole of the basic and acid radicals are rarely estimated. The following are the more important as will be understood from what has been said before. 1. Chlorine. 2. Nitrous and Nitric acids. 3. Phosphoric acid. 4. Sulphuric acid.

The only quantitative process that need be referred to here in detail is the *Estimation of the Hardness of a water.* The two bases *lime* and *magnesia* (as well as iron, baryta, alumina, etc., to a lesser degree) with *free acid* (which acts by dissipating a lather already formed and which in this country is only likely to be carbonic) are the causes of Hardness, and, therefore, this quality is a test of their presence and may be made a measure of their amount. Ordinary *soaps* are stearates (or oleates) either of potassium or sodium, soluble in pure water. When dissolved in water and the solution well shaken, a *lather*, or collection of more or less permanent bubbles, is formed. If salts of the alkaline-earth metals (including magnesium) or of iron, etc., are present, the alkaline stearates are decomposed and insoluble stearates are formed instead, appearing as a curdy scum and ultimately as a precipitate. These insoluble stearates are useless for cleansing purposes and so much soap as is thus decomposed is wasted. Hardness, therefore, is a quality of great importance, economically in the first place and sanitarily in the second, inasmuch as any cause which renders cleanliness of clothes, dwellings and persons more expensive and more difficult of attainment is necessarily detrimental to health. Further, as on the addition of an alkaline stearate to water none will remain in solution, and consequently no lather will be possible, until the whole of the calcium, magnesium and iron salts have (in the absence of free acid) been converted into stearates, the quantity of soap which has to be added to a given quantity of water in order to produce a lather is a measure of the amount of calcium, magnesium and iron salts in solution; in other words, of the hardness of the water. The quantity of soap required is ascertained by using a standard soap solution.

A standard solution of barium nitrate* is first required. This was formerly made of such a strength that it contained an amount of barium nitrate equivalent to 16 grs. calcium carbonate in 1 gallon of distilled water—or, as it was called, 16° of hardness on Clark's Scale† (in which therefore, each 1°=1 gr. $CaCO_3$ per gallon of water.)

It is more in accordance, however with modern methods to express the hardness, in common with other quantities, in Milligrammes per 100 cubic centimetres,‡ *i.e.*, parts per 100,000. Accordingly, a solution of barium nitrate containing 0·26 grms. $Ba(NO_3)_2$ in 1 litre of distilled water is made, so that each 1 c. c. of the solution contains 0·26 mgms. $Ba(NO_3)_2$§. Next, a solution of soap|| is made and tested or 'standardised' by the above solution, more of the soap or of the solvent being added, until 2·2 c. c. of this soap solution produce a permanent lather with 50 c. c. of the barium nitrate solution. Now, each cubic centimetre is divided into ten parts and these tenths are commonly called 'measures', *i.e.*, each 1 c. c. = 10 measures, or 2·2

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* Or selenite (hydrated calcium sulphate) may be used; *v. gravimetric analysis* in glossary.

† From Dr. Clark of Aberdeen, inventor of the process v. p. 73.

‡ The so called *centesimal* scale.

§ 1 litre (1000 c. c.) water = 0·26 grm. $Ba(NO_3)_2$.
∴ 1 c. c. water = 0·00026 grm. $Ba(NO_3)_2$ = 0·26 mgm. $Ba(NO^3)_2$.

|| Undried Castile soap (said to contain 60 % olive oil) is the best: 25 grms. of this in 1 litre of weak alcohol will give a solution of almost the exact strength desired. If this cannot be obtained, ordinary B. P. soft soap may be used and standardised by the barium nitrate solution.

c. c. = 22 measures. From this 2 measures must be subtracted as necessary to give a lather even with the purest water. Hence, 2 c. c. or 20 measures are = (*i.e.*, give a permanent lather with) 50 c. c. of the standard barium nitrate solution. From this it follows that 1 c. c. of the soap solution is = 2·5 mgm. $CaCO_3$ and 1 measure is = 0·25 mgms. $CaCO_3$.* Knowing this, all that is necessary is to find out how many measures of soap solution are required to give a lather with a definite amount of the water to be tested and it becomes easy to calculate the amount of hardness, *expressed as calcium carbonate,* that is contained in the water.

The method of procedure is as follows :—

Into a stoppered bottle of about 200 c. c. capacity, which has been previously well rinsed with distilled water, are put 50 c. c. of the water to be examined. Next, a graduated burette is filled with soap solution. From this burette the soap solution is allowed to run slowly into the bottle, the latter being removed, stoppered and well shaken at intervals. When a lather begins to form on shaking, the bottle is laid upon its side and if at the end of five minutes a distinct frothy lather remains it is said to be 'permanent.' The experiment may require to be repeated two or three times with fresh 50 c. c. of water till the exact amount of soap solution necesssary is determined.† Suppose

* Calculated as follows, by the *gravimetric* method (*v.* glossary): 20 measures of soap solution are required for 50 c.c. of the barium nitrate solution

$$\therefore 1 \text{ measure} \quad .. \quad .. \quad .. = \frac{50 \times 0{\cdot}00026}{20} \text{ grm. } Ba(NO_3)_2.$$

Since the basicity of one molecule of $Ba(NO_3)_2$ = one of $CaCO_3$.
260 pts. by weight of $Ba(NO_3)_2$=100 pts. by weight of $CaCO_3$.
260 and 100 being the molecular weights of $Ba(NO_3)_2$ and $CaCO_3$ respectively.

$$\therefore 260 : 100 :: \frac{50 \times 0{\cdot}00026}{20} \text{ grm.} : x$$

$$x = 0{\cdot}00025 \text{ grm.} = 0{\cdot}25 \text{ mgm. } CaCO_3.$$

† It is customary to make longer experiments with 50 c. c. of the water to ascertain the amount required approximately and then to repeat the process very carefully after adding *almost* the required amount at once. For further details *v.* Wanklyn's Water Analysis—Stevenson's and Murphy's Hygiene—Parkers-Notter, etc.

pose 13 measures are required. Then, substracting 2 measures as above-mentioned, 11 measures soap solution are = 50 c. c. of the water. But 1 measure is = 0·25 mgm. $CaCO_3$ and 50 c. c. of the water were taken, ∴ 11 × 0·25 × 2 = 5·5 mgm. $CaCO_3$ in 100 c. c. of the water and *i.e.* 5·5 parts {hardness in terms of $CaCO_3$} per 100,000 parts of the water. To express this result in Clark's Scale, multiply 5·5 by the short factor 0·7 = 3·85° hardness and *i.e.*, 3·85 grains calcium carbonate, *or its equivalent*, in 1 gallon of the water.

The foregoing, of course, gives the *total* hardness of the water. To find the *permanent* hardness, 250 c.c. of the water are taken and boiled over a naked flame for half-an-hour, the loss by evaporation being replaced from time to time by added distilled water so that there are always about 230 c. c. in the bottle. Then filter the water quickly into a graduated flask, washing the filter with a little boiling distilled water. When cold, add as much distilled water as is necessary to make up the amount to 250 c. c. exactly. Take 50 c. c. and titrate with the soap solution as before. Suppose 9 measures of soap solution are required. Then, subtracting 2 measures, proceed as before, *i.e.*, 7 × 0·25 × 2 = 3·5 mgms. permanent hardness expressed as $CaCO_3$ in 100 c. c. of the water. To find the *temporary* or *removable* hardness subtract 3·5, the permanent hardness, from 5·5 = 2 parts per 100,000 or on Clark's Scale (2 × 07) = 1·4. The permanent hardness of a water should not be more than 5° of the centesimal (3·5° Clark's) Scale.* If magnesia is present in the water the amount of hardness *due to magnesia* may be roughly determined by a modification of the above process.†

* Regarding the signification of the results obtained by the above process refer back to the impurities of drinking water. pp. 73-4.

† v. *opera cit. supra.*

CHAPTER III.

SOIL.

It is only of late years that systematic attention has been paid to the study of the ground or soil whereon we live in its relation to hygiene. To the Germans, especially von Pettenkoffer and his school, belongs the credit of initiating such systematic study. In this country, owing to want of encouragement and the absence of facilities, but little has been done by medical officers, save in the special case of Lewis and Cunningham at Calcutta.* The subject is one of extreme interest and importance and it is earnestly hoped that the Government will in future encourage its elucidation by all means in their power.†

Before proceeding to examine into the nature of the intimate connection that is believed to exist between the ground we live on and the occurrence of certain diseases, it is necessary to have a clear understanding as to what is really meant by this term 'soil.'‡ In the first place it is divided into the 'surface soil' and the 'sub-soil', terms which are merely relative and not exact. A perfectly pure soil would consist simply of certain mineral matters the result of the weathering or decay of the subjacent rocks. But, just as we find that in nature the air is something more than a mixture of oxygen and nitrogen and water something more than a compound of hydrogen and oxygen, so also the soil will be found to be a highly complex mixture. It consists then, from the point of view of a sanitarian,

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* *v.* Physiological and Pathological Researches, by the late Surgn.-Major T. Lewis (in concert with Surgn.-Major D. D. Cunningham, Calcutta.)

† *i.e.*, by *systematic* help and encouragement as opposed to the spasmodic appointment of 'Commissions.' It is a subject requiring *years* of study and observation and that not only in one city but in *many cities*. *v. post*, Ground air.

‡ Defined by Parkes as including, in this relation, "all that portion of the crust of the earth which by any property or condition can effect health."

of *mineral matters* of every possible variety, of *organic matter*—both animal and vegetable, living and dead—of *air* and of *water*.

The exact nature of the Mineral constituents does not concern us here save only as regards their general or chemico-physical properties, *e.g.*, the degree of aggregation of the particles, their power of absorbing heat, light or moisture, their solubility or the reverse, etc., all of which will be referred to again.

The Organic matter may be present in any amount from nearly *nil* to constituting the major part of the soil, and it may be of any nature and of any age from living protoplasm up to the stage of incipient mineralisation, as seen in some peaty deposits. The soil, in fact, may be looked upon as a vast underground laboratory in which, under the influence of an almost continuous network of vegetable roots, of myriads of animals,* and, most important of all, of countless micro-organisms, an unceasing series of chemical changes and reactions is for ever in progress. By means of these vital agencies the sub-soil is slowly but surely raised to the surface while the surface soil is as surely carried downwards. Yet again, in the neighbourhood of cities and even villages the influence of man himself is hardly less potent quantitatively whilst qualitatively its power for the production and spread of disease is far greater.

But in addition to the mineral and organic constituents we have the very important ones of Air and Water, by means of which these laboratory products as it were are diffused into the atmosphere or carried ultimately into the water-supply of communities. Not only, it must be remembered, do the various vital forms react upon and change the soil but in its turn the soil by its mineral and

* *v. e.g.* Earthworms, by Darwin. The amount of soil that is annually turned over, raised to the surface and in various ways altered or exposed by burrowing animals, and by ants and other insects in India must be enormous. A study of this subject conducted experimentally on the same lines as Darwin's researches would well repay the trouble expended by a careful observer.

organic nutriment, its heat and its moisture, becomes the most favoured breeding ground of numerous animal and vegetable organisms, some harmless, some of great use and yet others of deadly potency.

The soil on which a house, tent or other dwelling is placed may influence the sanitary condition of the inhabitants, through the *climate,* through the *air* breathed and through the *water* used for domestic purposes. The circumstances which affect the *climate* of a place have reference principally to the chemico-physical properties of the soil and are respectively, (*a*) the conformation of the ground and its relation to the neighbourhood as regards position and elevation, (*b*) the vegetation which it supports, (*c*) the permeability of the soil and sub-soil by water, (*d*) their capacity for absorbing and their power of radiating heat, and (*e*) the color of the surface. Malarious or other miasmatic emanations may contaminate the *air,* and the *water* will be affected by the soluble substances, organic and inorganic, which it takes up in percolation through the soil.

LOCAL INFLUENCE OF SOIL ON CLIMATE.

Firstly then, must be considered the relation which the soil bears to the Climate of any locality.

Conformation.—Both the temperature and the humidity depend, to a great extent, on the conformation of the ground: including, if the place be uneven, the relative extents of high land and valleys; the degree of elevation of the highest parts; the forms, depth, width, slope, and nature of the sides of the valleys; the position and direction of the lines of drainage: and, if the level be uniform, the degree of slope and the capacity and direction of the water courses. Thus, as hills cool by nocturnal radiation more rapidly than lower land, a current of cold air will flow down a valley or ravine by night, depressing the temperature at the outlet. If the outlet be narrower than the main valley or ravine, so that the water draining from above has not sufficient means of escape, dampness will be added to coldness and alternations of temperature. As a rule, positions at the top of a slope will be found best; their temperature being lower and more uniform and free drainage preventing accumulation of water in the soil. As the conformation of the surface of a district is generally a consequence of its geological structure, a knowledge of the latter often affords an indication of the nature of the local climate and its probable effect on health. Thus good sites may be expected where granitic or metamorphic or trap rocks prevail; because these generally imply elevated positions, affording moderate temperature and free natural ventilation, as well as slopes favorable to drainage and consequent absence of excessive humidity. Deposits of clay, on the other hand, are generally flat, so that air stagnates and water lodges.

Relative Position.—Closely connected with the form of the ground itself is its Relative Position with respect to the neighbourhood. In a hilly country a site may be unhealthy, owing to its being so surrounded by hills that ventilation is impossible and the air is stagnant; and, as before observed, narrow valleys or ravines may become channels for currents of cold air, which chills at night a place so situated as to be exposed to its influence. A lower degree of the same cooling effect of elevated land may act beneficially when the more rapid radiation of heat from the latter produces a diffused cool breeze instead of a cold draught. On the other hand a low rocky hill, radiating at night the heat absorbed during the hours of sunshine, often renders places at its foot permanently hot and, if other causes combine, unhealthy.* A site, again, may be sheltered from the action of a prevailing wind by the intervention of a hill or range of hills—a circumstance which may be useful, as when the wind blows over a marsh, or injurious, as when a sea-breeze or other refreshing current of air is intercepted. This power of hills to shelter from, or alter the apparent direction of, the prevailing

* As seen very frequently in Central and Southern India.

wind should be borne in mind when we are choosing a site for temporary or permanent occupation.

Relative position has to be considered with reference to moisture also. A position at the foot of hills may suffer by excess of water flowing from them; either directly through humidity due to deficient drainage or indirectly through malaria produced by exuberant vegetation. In a plain itself a part depressed below the general level may be damp in consequence of the tendency of the drainage: and in this way soils which would under ordinary circumstances be dry and healthy (as gravels) may be in some instances damp and productive of disease.

Vegetation.—So far as the mere process of growth is concerned, Vegetation can be productive of good effects only: but exuberant growth involves excess of decomposing vegetable matter, which, under the influence of heat and moisture, is almost universally believed to be the source of malaria. On the whole, the good effects of vegetation exceed the bad. Herbage intercepts much of the solar heat and, by favoring gradual evaporation, cools and equalizes the temperature. Retaining a large proportion of the rainfall, it regulates the humidity of the atmosphere while, by preventing too rapid drainage, it helps to maintain the water-supply in the soil. Unirrigated crops act similarly, and neither they nor herbage are ever injurious to health. Shrubs and trees have the same effect upon temperature and humidity; but the former always, and the latter, especially the palms, during the earlier stages of their growth, are likely to obstruct seriously the free circulation of air. In the neighbourhood of dwellings, therefore, brushwood is objectionable and should be kept cut low or be altogether removed, while full-grown trees should have all their branches within 10 or 12 feet of the ground cut off; unless, as sometimes happens, a belt of trees shelters a site from a cold wind or intervenes between a place and a source of malaria. Finally, since the sanitary effect of herbage and of forest trees is almost always good, the growth of the former should be encouraged to the utmost, and the latter should be planted judiciously in and about every inhabited place. In districts where the destruction of timber has raised the temperature and diminished the rainfall, the injury done to the climate and sanitary condition of the population should be repaired as far as possible by plantation.*

Permeability.—Almost all soils are permeable in some degree by water; but the power of absorbing and retaining it varies within wide limits, depending on the nature of the surface and of the soil itself. In considering Permeability the chief point, in relation to health, is the retention of water in excessive quantity by the soil; producing dampness of the air and reducing temperature in all cases, and generating malaria if the other conditions necessary to its production, heat and the presence of dead vegetable matter, are fulfilled. Such rocks, as *trap, granite, clay-slate* and the harder *limestones*, and *dolomites*, are practically impermeable and irretentive of moisture, not only in consequence of their structure, but because they generally present a slope which prevents the lodgment of water on their surface. On the other hand, *clays* are commonly flat, so that water lies upon them; and, though they are little more permeable than the harder rocks, saturation proceeds to the utmost. In some cases clays absorb and retain as much as 10 per cent. by weight of water. Through *sandstones, chalk*, and still more through loose *sand*, water passes readily and rapidly; but it must be remembered that the admixture of even a small proportion of clay impairs the permeability of sand and increases its retentiveness. *Humus*, or decaying woody fibre, absorbs and

* This is now being done in many parts of India by the Forestry Department and, in addition, forests already existing are protected from destruction by the ignorant. There is no surer way of ruining a district than reckless destruction of its forests and pollution of the sources of water supply, and, conversely, no one has a greater claim to the title of public benefactor than he who has changed a bare and barren land into a well-wooded country and given a clean and permanent supply of water in place of former scantiness and pollution.

retains from 40 to 50 times as much water as sand.* The old lacustrine deposits, commonly called *cotton soil,* are highly absorbent and retentive; and so also, though to a less degree, is the soil resulting from disintegrated granite, which yields much of our *red soil. Laterite* is permeable and irretentive, and *gravel* eminently so. Lastly, the roots of living *vegetation* impede the passage of water through a soil.

To apply these facts to the effects of permeability on health, it may be laid down, as a general rule, that the soils which are driest, whether because the water which falls on them runs off immediately or because it passes through them rapidly, are also healthiest. Where water lodges, on or in the ground, the air is damp and cold; and, as a consequence, there is a tendency to catarrhs and rheumatic affections, to phthisis and to malarious intoxication. Where the soil is dry the air also will generally be dry, the inhabitants will be free from those diseases and in other respects will be in better health. Hence, the hardest soils, from which the water runs off, and the most permeable, through which it passes rapidly, will (other things being equal) be the healthiest. A gravel hill or slope combines both these advantages. But there is an apparent exception to the rule that permeability of a soil implies healthiness. Gravel, for instance, may occupy a hollow either in hard rock or in clay, which holds the water in: so in this way a material naturally permeable may become saturated with moisture. It may be added that even a permeable soil, retaining water for but a short time, may generate malaria if organic matter be present.†

Heat absorbing power.—The nature of the surface and of theground beneath it determines the power of Absorbing

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* So much so that in Queensland, in seasons of drought, it is customary to cut down numbers of the "bottle-tree" which the cattle eat greedily on account of the moisture they contain.

† The sandy soil of the Deccan illustrates this latter exception. *v. post,* Malaria.

Heat, and in this way affects, either by conduction or radiation, the temperature of the place. The air immediately in contact with hot ground becomes heated, but rises and is replaced by a cooler stratum. The most absorbent soils, therefore, being the hottest, will be most productive of air-currents by conduction and convection. The best absorbents, again, are generally, but not always, the best radiators, giving out most rapidly the heat which they have received. During the day both processes are going on together; but in the evening, when solar heat is diminished, and at night when it is absent, radiation alone proceeds, and those soils which are most absorbent of heat cool most rapidly. In warm weather compact soils are on the average warmer than the loose; in winter, or on a fall of temperature in hot weather, colder. Also, in warm weather compact soils are warmer by day and colder by night than loose soils, and are subject to greater fluctuations of temperature.

The Material of which the soil is composed influences powerfully the degree of absorption and radiation. The following table shows the relative power of heat-absorption possessed by some ordinary soils :—

Sand, with lime	100·0
Pure sand	95·6
Light clay	76·9
Gypsum...	73·2
Heavy clay	71·1
Clayey earth	68·4
Pure clay	66·7
Fine chalk	61·8
Humus	49·0

It follows that in cooler climates clays and cultivated soils are cold; in warmer climates cool: on the other hand, that sandy soils are hot and, as will be seen, hotter in proportion to the darkness of their colour.

Two Ranges of Temperature are observable in soils—one diurnal, the other annual.* The former extends to a depth varying with the solar heat and the nature of the ground, rarely more than four feet in temperate climates. According to Lewis and Cunningham† the temperature of the soil varies directly as the season so that during the hot weather the external air shows the highest temperature, then the upper layer of the soil, the deeper layers being coolest: in the cold weather these conditions are reversed. During the rainy season, again, their relations are naturally somewhat variable. The distance from the surface at which the temperature is uniform and equal to the mean annual temperature is said to range from 57 to 99 feet. Observations on these points in India are much needed.

The effects on health of varying absorptive power are referrable to those of temperature generally; the most absorbent soils being the most freely radiant. In estimating these effects, however, other things have to be considered besides degree of solar heat and radiant power of the soil. Aqueous vapour in the atmosphere absorbs the radiant heat, which through dry air would pass into space; and this again is radiated to dwellings and their inhabitants; so that aerial humidity also has to be taken into account. Water in the soil, again, being evaporated by the heat absorbed, retains much of the latter as latent. Thus marshy soils render latent most of the heat which they absorb: and in this way their poison is not unfrequently antagonized or neutralized by the cold which they themselves generate. In some malarious places the heat is radiated so quickly from the marshes at night that the temperature sinks to freezing point and the malarial poison either ceases to be evolved or is powerless to produce any ill effect. This probably happens in some places in the North West of India.

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* *cf.* the changes in the temperature of the sea, rivers, lakes, etc. *v.* Realm of Nature. H. R. Mill, p. 167, *et. seq.*

† *op. cit.*

Colour.—The colour of the surface affects the power of absorption of luminous, but not of obscure heat, the darker shades absorbing more heat than the lighter; but colour has no effect on radiation.

The colour of the surface may also be important in its result upon the sight. As blindness may be caused by the prolonged effect of snow, so the glare of white or of light-coloured ground may be disagreeable and even injurious in countries of bright sunshine. Green being the hue most refreshing to the sight, trees and grass are to be encouraged in places where quartz or other white rock occupies much of the surface; and buildings, instead of being whitewashed, should be coloured according to the materials available in the locality.

The Slope of the surface also, in relation to the sun's position during the hours of greatest heat, deserves consideration; reflection of heat rays being greatest and, therefore, absorption least, when the angle of incidence is greatest. Herbage is unfavorable to absorption and promotes coolness in this way, besides its action in cooling by evaporation and in converting solar heat into potential energy stored up in plants during the elaboration of the tissues and their contents.*

THE AIR IN THE SOIL—GROUND-AIR.

The air in the soil or the Ground-air varies in amount primarily according to the density of the soil. The very hardest rocks such as basalt contain no air, loose sand may contain 50 per cent. whilst between these are all possible variations in amount. Loose dry soil freshly ploughed such as we see commonly in this country may contain as much as ten times its own volume of air. The air itself is very impure being especially rich in carbonic acid and in organic effluvia of variable and generally unknown composition. In addition it may carry upwards with it,

* *v. post*. Food, introductory.

as noted previously, numerous micro-organisms from their breeding ground in the soil. The degree of impurity of the ground-air, as measured by the amount of CO_2 present, depends upon many factors, the most important being the *composition* of the soil, its *heat, moisture* and *porosity* (which favours decomposition), and the *presence* or *absence of vegetation,* there being less CO_2 in the former case than in the latter. According to one observer* the amount of carbonic acid is greatest when the temperature is high, the moisture great and the diurnal variation in the temperature very slight.

The ground-air is not to be regarded as stationary or nearly so, on the contrary it is in continual movement owing to (*a*) the diurnal temperature variations, which cause differences between the soil and atmospheric temperature so that the air passes from the warmer to the colder medium whichever it may be (*b*) the permeability of the soil, the movement being very free in loose soils up to complete arrest in the case of a layer of cement or frozen ground,* and (*c*) the varying levels of the ground water and the occasional fall of rain, both of which naturally displace air from the pores of the soil. The understanding of these movements of the ground-air becomes of extreme importance when in addition to excess of carbonic acid and ordinary organic effluvia we have added the foul air, from leaky cesspools, defective drain pipes or sewage-sodden ground. Remembering the structure of an ordinary house in a cold climate, *viz.,*—deep foundations excavated, often in close proximity to leaking sewers or cesspools, to form cellars or a basement storey with a perfectly pervious floor of earth, brick, or badly pointed stones through which, owing to the high temperature of the house air, the ground-air is literally sucked in and ascends to supply the various rooms—it is not to be wondered at that many attacks of disease ranging from temporary

* Surgeon Captain Firth, A.M.S., Asst. Prof. of Hygiene, Army Med. School, Netley.

indisposition to a fatal issue are deemed insidious or even inexplicable.*

THE WATER IN THE SOIL—GROUND-WATER.

The water in the soil is divided for convenience into the moisture and the ground-water. Unless the ground is water-logged, as in swamps or temporarily after very heavy rain, there is usually a considerable amount of ground-air between the particles of the soil, which latter are merely damp or moist. This moisture is derived chiefly from rain by simple percolation but also from the water in the deeper layers of the ground by the latter's rise and fall, evaporation from its surface and by capillary attraction. In addition the actual amount of moisture will depend upon the absorptive power of the soil. This absorptive power varies very much with the nature of the soil; even rocks as dense as granite or marble contain one or two per cent.

At the level where the mixture of soil, air and water gives place to one of soil and water only, to the exclusion of air, the Ground or Sub-soil water begins. This is derived from the rainfall, but not necessarily directly, for in some cases the ground-water consists almost entirely of water which has flowed a considerable distance through the soil. It is *not a continuous underground sheet of water*, though such subterranean lakes or reservoirs do occur in nature, but a *network of soil with the interstices filled with water.*† In the same way it is not necessarily a horizontal network for its level varies locally according to the composition and disposition of the soil and the angle of inclination of the underlying impermeable strata. Anyone who has

* *v.* Note on p. 122. In such a case the air being prevented from escaping in a vertical direction travels horizontally till it finds an outlet, such outlet being only too likely to be the previous ground floor of a dwelling house.

† In the same way the soil above which is merely moist, may be looked upon as a network or porous structure of which the fibres or granules are thickened and swollen by moisture but the interstices filled with moisture laden air: *cf.* a cloth dipped in water and 'wrung out,' with a cloth lying *just covered* with water.

had much experience in digging wells knows that water is by no means always found at the same level even at short distances. The depth at which the ground-water lies varies within wide limits from just below the surface in water-logged soil to several hundreds of feet.* Again, the level of the ground-water at any one spot is constantly changing. In this country the level probably varies in ordinary years from five feet during the rains to about twenty feet at the end of the hot weather, but there are doubtless many exceptions to this, and the number of recorded observations is very small. Its level or depth below the surface at any one time depends upon the amount of antecedent rainfall and the ease or difficulty of the outflow: also, the *movement is not merely vertical*; there is *movement in a horizontal plane as well*, for the water is continually flowing, at rates varying from a few feet to several hundred daily, towards the point of easiest outlet, *e.g.*, the sea, a lake, a river, wells, or even the side of a declivity.† The rate of movement is influenced by the ease or difficulty of the outflow, the relative compactness of the soil and the presence or absence of vegetation, the flow of the water being very seriously retarded by the roots of trees and smaller plants.‡

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* When cesspits are dug and left uncemented in such permeable soils, they may be used for very many years and *never become full*, owing to the fact that the liquid matter, carrying with it a large proportion of the solid matter, continually filters into the soil, is thence carried down by the rainfall as it percolates and thus reaches the ground-water; the final result being frequent poisoning of wells situated even some considerable distance away.

† The practice of deep-drainage, so important both from the agriculturist's and sanitarian's points of view, is simply an artificial method of increasing the rate of outflow so that the ground-water is carried away more rapidly than would otherwise be the case. The outflow can also be rendered easier or 'opened' by cross drainage, cleaning water courses, etc.

‡ A point well worthy of closer attention than is given to it in certain parts of India where it would be advisable to conserve the rainfall by obstructing the outflow. In seasons of drought the level of the ground-water in cantonments, etc., may, by the ceaseless and unregulated sinking of wells, be so lowered that the deepest-wells run dry and a water-famine results.

GROUND-AIR IN RELATION TO DISEASE-CAUSATION.

Coming now to the influence which soil is supposed to exert upon health by means of its effect on the air of a place we shall find that this influence may be classified under two main heads, *viz.* :—1. A purely Local influence confined to one or two houses, 2. A more General influence affecting certain parts of a town or village and its neighbourhood.

From what has been said previously in discussing the composition of ground-air it can be easily understood how important a part the latter may play in disseminating disease. Given a soil contaminated with organic impurity due to defective drainage or the accumulation and downward filtration of filth, coupled with a defectively-built house, it is evident that the air-supply of the house is liable at any time to be rendered impure by simple excess of carbonic acid, by organic effluvia from sewage or by the addition of living disease contagia. The degree to which disease is thus spread is probably not so great in this country, considering the extreme impurity of the soil, as in colder climates where the difference between the external and internal temperature of houses is more pronounced, but there is little doubt that it is considerable.*

The more general influence of the soil upon the air of towns and districts is an extremely important question the consideration of which must be omitted for the present save only in connection with one important disease—Malaria. The following diseases have been supposed to be spread by the air from impure soils, *i.e.*, by the 'effluvia' or 'miasmata' of older writers. 1. Malarial fevers; 2. Enteric fever; 3. Yellow fever; 5. Dysentery; 6. Diphtheria.

* *v.* Case reported in *Lancet* (1873, Vol. II, p. 592) where coal gas from a leaky gas-pipe was drawn into a house along with ground air, owing to the frozen-ground preventing its escape elsewhere, and caused poisoning of the inmates. Another case, where the poisoning was due to carbonic acid entering, during hard frost, a house built on soil 'made up' after quarrying, is reported in the B. M. J., 1893, Vol. I, p. 206.

Malaria.—Of the exact nature of Malaria—the poison which produces a disease characterised by paroxysmal fevers, neuralgias, enlargement of the liver and spleen and other well-marked symptoms, and terminating often in profound cachexia and death—not much is known with any certainty. The subject will be afterwards considered.* Most physicians are agreed as to its origin. It is generated by vegetable matter in the soil, undergoing slow decomposition, under the influence of moisture and a certain degree of temperature not less, it is supposed, than 67° F. (19·3° C.) It is probably not gaseous, because it appears incapable of ascending by diffusion to very great elevations, and because a thick belt of trees has been known to shelter from its influence. It can probably enter the blood and produce its poisonous effects, either by the air breathed or by the water drunk.

Although the causes given above are believed to be invariably present in malarious localities, they are sometimes co-existent in places where paroxysmal fevers and other effects of paludal intoxication are unknown. There are two well-marked Exceptions to the rule that sufficient heat, moisture and decomposing vegetable matter in the soil generate malaria. Peaty soils fulfil these conditions, (unless it be supposed that their well-known anti-septic properties prevent the decomposition of the organic matter which they contain); but in boggy countries, as in Ireland and parts of Australia, endemic paroxysmal fevers are unknown. Secondly, tracts regularly covered by the sea at each flow of the tide are not malarious, perhaps because the products of decomposition are washed away before they have reached the stage in which they become poisonous or because the malarial poison cannot live in such a saline soil. Besides these two exceptions, anomalous cases have been observed in various parts of the world where malaria might have been expected to be present but was not.

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* *v.* The Etiology and Prevention of Disease.

Knowing, then, the conditions necessary for its generation, it is easy to infer the places where it is likely to be prevalent. These may be briefly enumerated :—*Marshes*, in hot or temperate climates, whatever be the mineral constituents of the soil, containing dead organic vegetable matter to the extent of from 10 to 45 *per cent.* and abundant moisture, will be generative of malaria. Positions at the *foot of hills* which supply abundance of water are often unhealthy, exuberant vegetation being accompanied by accumulation of vegetable débris in the soil. The most deadly forms of remittent fever occur in persons who have incautiously exposed themselves to the influence of malaria in the jungles of this *terai* country, whether in India or Burmah. The apparently dry *beds of nullahs* and ravines generally have water at no great distance from the surface and often contain much decaying vegetation. *Sandy plains* with an impermeable substratum of rock or clay a few feet from the surface, which holds up water and keeps the soil saturated, may be highly malarious although bare of vegetation, owing to the presence of the decaying remains of previous vegetable growth. In some, vegetable matter, silicious particles and an oxide or other salt of iron become concreted into a nearly impermeable stratum from which the over-lying water slowly dissolves out the organic material and produces malaria. *Alluvial soils*, which constitute nearly one-third of the soil of this country, often consist of permeable beds alternating with impermeable strata of clay, retaining moisture in contact with abundance of decayed vegetation. These are undesirable sites, though it is impossible always to avoid them.* The *deltas* of large rivers are of this nature. *Salt marshes*, if only occasionally overflowed by the sea, are unhealthy. *Newly disturbed soil*, as ground brought into cultivation for the first time or cleared of brush-wood by up-rooting, is very likely, in this country, to be malarious. Even *rocks*, as trap, gneiss and granite, when softened by

* v. p. 128 and note.

disintegration, may admit water and organic matter into their substance by slow percolation and so generate malaria.* It is very improbable that their mineral constitution has any share in the production of this effect; but some have thought differently, and Heyne attributed the Mysore fevers to the decomposition of rocks containing ferruginous hornblende. Lastly, *irrigated lands*, as rice fields, fulfil the conditions for the generation of malaria, and in some countries are virulently unhealthy. In the Southern United States, for example, the rice plantations are almost uninhabitable, except by the black or mixed races, during the heat of summer. In this country Surgeon-General Cornish has pointed out that rice fields exposed to sea air are not sources of malaria, but that irrigation is not innocuous in inland districts. The proximity of rice fields or positions to leeward of them should be avoided for human habitations as far as possible.†

GROUND-WATER IN RELATION TO DISEASE-CAUSATION.

Thirdly, the soluble matters in the soil may affect health though the Water used for domestic purposes. Impurities introduced into the system by this means may be either organic or inorganic. The former include the specific poisons of cholera, enteric fever, malarious diseases, dysentery (?) and epidemic diarrhœa (?). This subject, however, as well as that of the inorganic impurities of water, has already been considered,‡ whilst the exact connection between the ground-water and certain of these diseases, supposed by some to be very intimate, will be discussed hereafter.§

The effects of the movements and of the level of ground-water upon health can easily be inferred from the above

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* This idea is ridiculed by Sir William Moore, with, I think, quite insufficient reason. But, apart from this, his discussion of malaria is well worthy of careful perusal. *v.* Diseases of India, 2nd ed., pp. 259 *et seq.*

† *v.* however McNally, *op cit.*, p. 116, para. 5.

‡ *v.* Chapter II.

§ *v.* The Etiology and Prevention of Disease.

description and from what has been already said about the results of moisture in the soil. The rise of ground-water may make a place damp and cold by saturating the soil above it, causing catarrhal and pulmonary diseases; or it may merely supply the moisture necessary to the generation of malaria or specific miasms. On the other hand its rise may check the production of these poisons by occupying and saturating with water the stratum which contains the organic matter to which they owe their origin. So, too, its fall, after wetting such layers of soil, may stimulate the production of malarious and miasmatic diseases; or its continued depression at a depth below their level too great to admit of their deriving moisture from it may have a highly beneficial effect. If the poison of malaria exists in the ground-air the rise of the ground-water after heavy rain will drive out the poisoned air and produce paludal diseases.*

HEALTHY AND UNHEALTHY SOILS.

From what has been said before, a good idea can be formed of what constitutes a healthy soil or the reverse. One important point remains to be noticed, *viz.*, the use in many towns of "made soils." Under this term is included any soil formed artificially by the deposition in any convenient hollow of earth dug out of the foundations for building and rubbish of all sorts such as street sweepings, house garbage and trade refuse from tanneries and other works. Such a practice is very common in crowded situations where land is valuable. It is objectionable from every point of view† but if permitted no building should be allowed to be erected upon it for at least five years.‡

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* I have noticed a most marked *sudden increase* in malarial fever of the intermittent type at such a time during a period of heavy rainfall in Ganjam.—A. E. G.

† Including the builder's—I remember a row of houses in a Scottish town, which has partly subsided owing to the foundations being sunk in 'made soil'.—A. E. G.

‡ Seven years, even, has been found to be too short a space of time for complete disintegration of rubbish in Madras, *v.* Jones. Manual for District and Municipal Boards, 1888, p. 52. "Where lands have been reclaimed in

Ultimately the soil appears to purify itself but only if it is freely exposed to oxidation and the cleansing action of the rain. Above all things building upon soil which has been used at any time as the site of a cholera or other infectious diseases hospital or as a burying ground should be absolutely prohibited.*

Briefly then :—impermeable rocks as granite, gneiss and clay-slate, are generally healthy : the water from limestone and magnesian limestone strata is often excessively hard and sometimes unwholesome ;† chalk, permeable sandstones, laterite (?) and gravels are healthy, generally yielding a pure water-supply : sands, if free from organic débris are healthy, but many are malarious and the water is often highly charged with saline impurities : clays and marshy soils, unless thoroughly drained, are unhealthy : the worst soil is artificial ground made by the deposit of miscellaneous rubbish.

IMPROVEMENT OF UNHEALTHY SOILS.

In many cases it is obviously impossible to choose a site merely because it would be a healthy one or to reject another site simply because it is unhealthy. The generality of human beings who have a choice at all are governed in their selection of a site by the purely social or commercial advantages it will afford, whilst for the vast majority of people there is no choice about it, they have got to reside where the means of making a livelihood exist. The Burman villagers, who never repair buildings, when their houses and

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the manner above related [*i.e*, by filling in with rubbish and earth in alternate layers], the local authority should place a decided veto against their being used as building sites or bustee settlement for at least four to five years, during which interval they may be used as grazing ground or plantations. After four or five season's cultivation they may safely be built upon by huts or light structures which will not require deep excavations to put in foundations. The local authorities in Bengal have ample powers under the Bengal Municipal Acts to control settlement on such lands and this is a matter that should be insisted upon in all cases." R. C. Sterndale, Vice-Chairman, Municipality of Calcutta, quoted by Jones, *op cit.*, p. 55.

* *v.* Trans. 7th Internat. Congress of San. Sci., Vol xi, p. 27.

† *v.* p. 84, paras. 3 and 4.

their surroundings become defective or markedly unhealthy simply choose a new site and build thereon a fresh village *de novo;* but it must be confessed they do not as a rule travel far enough. Alluvial soils are usually unhealthy owing to the large amount of organic matter present and to the stagnation of the ground-water. A great deal, however, can be done to improve many naturally unhealthy soils.

In order to guard against miasmata proceeding from the soil, the following precautions are advisable:—*drainage,* preventing sudden rises in the level of the ground-water and consequent forcing out of noxious gases, &c.; *raising dwellings from the ground* on poles, arches or solid basements; *exclusion of air from below* by concrete, asphalte or other impervious material in or beneath the floor; and, most important of all, *careful choice of site,* avoiding, if possible, alluvial soils,* and under no circumstances building upon soils artificially made up of rubbish containing organic matter. More especially, the precautions and remedies indicated by a soil which there is reason to believe to be malarious are—thorough drainage; cutting down to the impermeable sub-soil, if there be any, and in all cases deep enough to withdraw moisture from the stratum which contains decaying vegetable matter; raising the dwellings on solid basements three feet or more from the ground, or (better still) on posts or arches, admitting free passage of air beneath; interposing a belt of trees or a piece of water kept at a constant level between a site and an obvious source of malaria; excluding, especially at night, wind blowing from a malarious quarter; (when this is impracticable, as when it is necessary to sleep in the open air, the use of mosquito-curtains is said to be

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* From the sanitary point of view it is to be regretted that by far the larger number of important towns throughout the world are built, of necessity, upon low-lying alluvial soil. In such cases the chances of pollution of the soil, air and water are very much increased and the health of the inhabitants suffers in a corresponding degree.

beneficial);* avoiding disturbance of the soil through clearing away of brush-wood from a temporary position and choosing the hotter hours of the day rather than the morning or the evening for the work if the position is to be occupied permanently; *care to obtain drinking water from a source uncontaminated by decomposing organic matter*;† selection of sites as elevated as circumstances allow—because, though malaria is not unknown even at a height of 6,000 feet above sea-level,‡ its power is diminished by elevation, owing, probably, to the diminution of temperature.

Lastly, it is evident that the remedies for the evils due to changes in the level of ground-water are the improvement of existing and the opening out of new passages for the water towards its natural destination. Deep and effective sub-soil drainage will keep the ground-water below the level where danger begins. "Sanitary and Engineering authorities are all agreed that irrigation without drainage has a most evil influence upon health, and that deep drainage improves the soil as well as the health of the inhabitants. The efficiency of drainage should especially be looked to in irrigated lands. In most parts of Madras the natural drainage is good, but in some parts of Northern India flat tracts of sedimentary soil occur where irrigation water has no sufficient outflows, and in such places malaria prevails to an alarming extent. For instance, in 1885 in the town of Sunpat on the Delhi branch of the Jumna canal

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* From experience gained in very malarious localities in Burmah I believe this to be an undoubted fact. It certainly lessens the risk of chill on cold, misty mornings before taking food or exercise. This practice is recommended also in the valuable and very practical hand-book for travellers issued by the Roy. Geo. Soc.—A. E. G.

† *v.* Instructive paper by Brig.-Surgn. Pringle, in Trans. 7th Internat. San. Congress, Vol. XI, p. 203.

‡ The elevation necessary to secure immunity from malarious influences varies in different countries and in different parts of India from about 400 up to 7,000 feet above sea-level. "Wherever malarial fever is endemic at more or less considerable elevations, the seat of the disease is always a valley with a small declivity, or a basin-like depression in a plateau, while the open levels, except so much of them as lie immediately at the foot of shelving mountain spurs, are, like the mountain ranges themselves, for the most part exempt." Geo. Path.; Hirsch, Vol. I, p. 265.

there were 833 deaths from fever in a population of 13,077, a rate of 63·7 per 1,000 per annum.* * * * The management of irrigation is a most important matter. If an increased volume of water be poured into a district, the channels, natural or artificial, which were previously sufficient for its drainage, may prove insufficient; a general stagnation and rise of sub-soil water and greatly increased unhealthiness may result. Hence when irrigation is resorted to, drainage should receive especial attention."*

EXAMINATION OF SOIL.

A complete examination of the soil of any locality includes an inquiry into the following points:—1. The Mechanical Condition of the soil. 2. The Temperature of the soil. 3. The Moisture of the soil. 4. The Composition of the Ground-Air. 5. The Composition of the soil. 6. The Animal and Vegetable Life in the soil. (2), (3) and (4) are sometimes grouped together under the term Soil-Meteorology, so that we may classify the examination thus:

I. Mechanical Examination of the Soil.
II. Chemical " " "
III. Meteorological " " "
IV. Biological " " "

Mechanical Examination.—Under this heading is included the estimation of the (*a*) Density, (*b*) Friability and (*c*) Permeability of the Soil. The two former can be estimated roughly by any one after a little practice. The degree of Permeability is best noted by having a hole dug about 10 feet deep with vertical sides. After the soil has become fairly dry, water is poured gently on the surface of the ground and the time it takes to percolate downwards is noted. By digging deeper or sinking a tube well the water level can be ascertained, and by digging holes at different

* McNally *op. cit.*, pp. 115-6. *v.* also Evils of Canal Irrigation and their prevention, T. Thornton, C.S.I., Journ. Soc. Arts, March 1888, and Report by Surg.-Major W. G. King on the Influence of Irrigation on the Prevalence of Malaria at Kurnool, 1880, etc.

places a short time after rain has fallen, a rough idea of the natural drainage of the soil can be formed.

Chemical Examination.—Besides the actual analysis, both qualitative and quantitative, the following points are especially important to be determined (*a*) The Percentage of water; (*b*) The Absorption of water by the soil after it has been dried; (*c*) The substances present which are Soluble in water.

Meteorological Examination.—This branch of the subject has received considerable attention in Germany and is undoubtedly of great importance. In this country, unfortunately, with one or two brief exceptions, neither opportunity nor encouragement have been afforded for similar investigations. The principle exception referred to is the series of observations undertaken by doctors T. Lewis and D. D. Cunningham and embodied in a report entitled "The Soil in its Relation to Disease."* The object of the researches was to determine to what extent peculiar conditions or changes of condition in the soil in Calcutta affect the prevalence of disease in general and of certain diseases in particular. Attention was paid to the three following points:—The amount of moisture in the soil; the temperature of the soil; the amount of carbonic acid in the soil-air. Such an investigation requires the very greatest care and technical skill and it is by no means easy to obtain a constant record of the true soil temperature at different depths. "It may be premised that the estimation of the amount of carbonic acid in the soil was not undertaken in the idea that the gas itself exerts much influence on the prevalence of disease but because its amount may be taken as a convenient and fairly accurate index of the degree of the various organic processes taking place between the water level and the surface." To those who have had the benefit of a scientific training it is self-evident that one series of observations is quite insufficient to give reliable

* *v.* Reprint of the report, with charts, etc., in "Physiological and Pathological Researches," by T. K. Lewis.

and useful results—"it is only on *prolonged and continuous observations in various localities** that definite conclusions can be based."

IV. *The Biological Examination.*—This method is also of great importance but requires special training and a good laboratory. There is no doubt that it will ultimately yield, in conjunction with the other modes of examination with which it is inextricably bound up, results of the highest practical importance.†

* The italics are mine (A. E. G.)

† As it has already done in the case of Anthrax, Tetanus, Agricultural Science, etc.

CHAPTER IV.

REMOVAL AND DISPOSAL OF WASTE MATTER.

To a dweller in an ordinary English town it is difficult to realise the enormous amount of waste matter that is being constantly formed and almost as constantly got rid of. But as the traveller passes further east or south to the warmer and less civilised countries he easily enough begins to realise that in and around all the towns he visits there is a plentiful supply of waste and refuse matter of the most varied character, to which constant additions are being made and the removal of which is left chiefly, if not entirely, to the united exertions of crows, kites, pariah dogs, pigs, etc., aided by the powerful desiccating action of the sun and an occasional general clearance, or, it may be, only re-arrangement, during rainy weather. The subject is not a pleasant one, but it is of supreme importance. Given a good supply of water and fresh air the next most pressing necessity for a community is the paying of attention to the thorough and systematic removal of all waste matter.

Sources of Waste Matter.—As to the various Sources from whence such refuse is derived we find them to be as follows: I. Refuse derived from individual members of the general community, *i.e.*, from the Dwellings of men and other animals. Under this heading is included the waste from *latrines*, fæcal matter and urine—, from *kitchens*, food refuse, dirty water and ashes—, from *houses*, house-sweepings, etc.—, from *stables, cowsheds, piggeries, etc.*, fæcal matter, dirty straw, etc. II. Town Refuse. Under this is comprised the waste matter from *slaughter houses, streets, markets, public buildings* of various sorts, and *works* and *factories* of all kinds. Finally, in addition to all this is the question of the disposal of the Dead Bodies of men and the larger animals—a problem which may assume very considerable proportions in time of war or pestilence. It will be separately dealt with hereafter. We have then to consider the following as to removal and disposal. A. Wet material or ordinary *sewage*. B. Dry material or ordinary *refuse*. [C. Dead Bodies of men and other large animals.]

In the same way as the various materials to be removed are divided into wet filth and dry filth, the numerous methods of removal are divided into two great classes, *viz.*: I. Dry methods of removal, *i.e.*, by *scavenging*. II. Wet methods of removal, *i.e.*, by *sewerage* or water-carriage systems. "The advocates of either sometimes argue as if one of these systems alone could be adopted to the exclusion of the other. This, however, is impossible, and both systems must always co-exist in well-ordered towns and villages; foul water has to be got rid of by sewers [or drains], and dry rubbish must be carted away. The only question which can be at issue is whether ordure or urine, or both, should be removed by cartage or by sewerage." * From which it can be seen that certain materials, *e.g.*, road sweepings, are always removed by dry methods, others, *e.g.*, waste water from houses and streets, if removed at all by artificial means, by sewerage, whilst yet a third class, of which human excrement, both liquid and solid, is the best and most important example, is sometimes removed by dry and sometimes by wet methods.

Before adopting any particular system the opinions of those persons chiefly interested must, if possible, be brought into agreement. These are the sanitarian, the agriculturist and the financier. To the former the chief object is effective and *speedy removal* of filth from the neighbourhood of human habitations, etc. The agriculturist wishes to restore to the land as much as possible of the fertilising material which has previously been removed from it in the shape of grain, vegetables, meat, etc., *i.e.*, he wants *manure;* but the manure must be thoroughly good and as free as possible from rubbish, such as glass, old tins, coal ashes,

* McNally, *op. cit.*, p. 98, and many others.

etc., and from excess of liquid which merely adds bulk without adding to the manurial value. Lastly, the financier, who represents the tax-payers, wants the *cheapest* system, whichever that may be. By mutual concessions, agreement is generally possible, but the sanitarian, in the discussion of any scheme of filth-disposal, must adhere firmly to the principle that the health of the people is of paramount importance.

In this country the dry methods of removal of human excreta are most generally suitable so that these will be considered first. A few preliminary observations, however, are necessary. The average amount of fæcal matter passed daily by each member of a *mixed** European population is about 2·5—3 ozs. In India, owing no doubt to the more bulky vegetable and farinaceous diet, the amount is considerably larger, about 7 ozs.,† but of this, about three-fourths consist of water. The daily amount of urine is about thirty-five ounces per head. When the urine and fæces are kept separate, decomposition proceeds slowly; conversely, when they are mixed, it sets in much more rapidly with liberation of ammonia, fœtid organic gases, carburetted hydrogen, carbonic acid, etc. Under a tropical sun fæcal matter passed on open ground very soon dries up into a mass that ultimately crumbles into powder which is partly washed into the soil by rain or blown into neighbouring houses, tanks or wells, etc. The personal ablution which obtains amongst the natives of this country, after obeying the calls of nature, adds about one-third more to the quantity of fluid to be removed and increases but slightly the difficulties in connection with the removal of excreta. Where a wet system of sewage removal has been applied to houses,‡ the squatting posture during the act of defæcation has necessitated the construction of special low-seated closets.

* *i. e.*, a population composed of men, women and children, as distinguished from the populations of jails, barracks, schools, etc.

† 10 ozs., according to some (Dhurandhur).

‡ *e. g.*, in Bombay.

DRY METHODS OF REMOVAL AND DISPOSAL OF EXCRETA.

Under the above system of removal one of two plans may be adopted, *viz.*:—1. The excreta may be removed in the condition in which they are voided. 2. The excreta, before or after removal, are mixed with some substance with a view to deodorisation and the prevention of putrefaction.

Removal without admixture.—This is the plan adopted in many towns in India in connection with public and private Latrines.* The fæcal matter, with or without the urine, is collected for twenty-four hours or so and then removed by hand or by cart. The urine sometimes passes into a separate receptacle from whence it is also removed at intervals; at other times it flows away into the open street drains through a small opening in the outer wall of the house. In the case of European and the larger native houses the solid excreta are collected in a receptacle at the end of the compound and removed once in twenty-four hours by hand or by municipal carts, while the urine is generally emptied on to the ground by the sweeper.

Modifications of this plan are still in use in many European towns under the name of the 'midden' or 'pail' systems of conservancy. Middens† are simply latrines attached to one or more houses of the poorer classes and consist of pits for the reception of excreta only or excreta *plus* dry house refuse. Originally they were simply heaps

* These private latrines, as a rule, are filthy in the extreme. They may be seen, by any one curious enough, in almost any Indian town. The latrine itself is a small room, often just large enough to allow one person to squat. In the centre is a small slit about 6 × 4 inches in size through which the fæces are passed into a dark noisome hole in the ground of uncertain depth. This pit or well is very rarely emptied; when it is, the whole air around is polluted. In some towns a basket is placed for the reception of the solid matter, the urine dribbling away into the ground or into a neighbouring surface drain. Of course, the larger part of the so-called 'solid' matter frequently drains away as well. In other cases the excreta are passed simply on to a smooth surface sloping outwards, down which the urine flows to the open sewer-drain outside the building. The solids, sometimes after the addition of wood-ashes, are removed by sweepers at intervals. *v.* the writings of Kanney Lall Dey, also several papers in Vol. XI of the Transactions of the 7th Internat. San. Congress.

† The terms 'midden' and 'cesspool' are not, as is frequently supposed, synonymous, *v.* Cesspools, *post.*, also S. & M., Vol. I., p. 823.

of decomposing and evil-smelling filth, but in later years it became the practice to dig a hole in the ground so as to conceal these accumulations from the eye at least, if not from the nose. The filth is allowed to accumulate for a certain time, it may be for months, and is then removed by scavengers, a most disagreeable process for all who live in the neighbourhood. If such a midden or privy is allowed to exist, it should be *small*, so that it must be emptied frequently, *shallow* and *watertight*, to prevent leakage, *roofed over*, to keep out the rain and *well ventilated*. In addition, while *easy of access* it must be situated at a *safe distance from the house ;* not placed within the house as is almost invariably the case in this country. As a rule, in English middens sifted ashes or other house refuse are added to the excreta so as to keep them dry and in as inoffensive a condition as possible. This really places them under the next division, *viz.*, removal after admixture.*

In the Pail system, of which there are several modifications, each household is supplied daily by the municipal scavengers with an empty receptacle, the full receptacle being removed at the same time. These pails are made with air-tight lids to abate the nuisance of odour as far as possible, and are sometimes (Goux system) lined with compressed stable-litter or other material which absorbs the urine and thus retards decomposition and prevents spilling of the liquid during transit. The so-called 'bucket' system in use in many towns in India, *e.g.*, Madras, is a modification of the pail system, but in this case the pails or buckets are not supplied to each household. The sweepers

* The student should note that it is impossible to describe or classify all the various methods of refuse removal and disposal in a cut-and-dry fashion. There are so many modifications and combinations of the methods under different conservancy systems that any rigid classification is hopeless. This is well shewn by a reference to the following tabular arrangement of the subject (from Wilson Hand-book of Hygiene, 6th ed., p. 303.)

1. The water system.
2. The privy or midden system.
3. The pail system.
4. The dry system.
5. Lieurnur's and other continental systems.
6. Systems best suited for rural districts.
7. Disposal of slops.
8. Public scavenging.

pull the buckets, which are mounted on wheels, along the streets and into them the house-sweepers empty the privy contents from the houses as the buckets pass along the street.*

Removal with admixture.—Under this heading are included all the various systems in which some substance is added to the excreta with a view to deodorisation, the retarding of decomposition and, in some cases, disinfection (?). As mentioned above, such addition is frequently made in the case of middens, chiefly in the form of coal-ashes from the house fires. Numerous forms of screen-closets are in use, in which there is an arrangement whereby the ashes are automatically sifted so that the finer portions fall through a sieve on to the excreta. Again, coal-ashes or some special deoderant may be added to the pails instead of the absorbent lining mentioned before. It should be noted that coal-ashes have but a slight deodorising power whilst wood-ashes, which are always available in this country for use in small households, have a very strong deoderant and anti-putrefactive action. Pure charcoal of course exercises a still better action in the same direction, but is usually very expensive. It is quite possible, however, that in a town with several large 'destructors'† constantly at work, a sufficient supply of charcoal could be obtained from the 'carbonisers' to permit of its utilisation in the above manner.

In some countries, especially Germany, numerous special deodorising powders have been used, consisting of mixtures of charcoal, tar, carbolic acid, iron salts, etc., in varying proportions and in India McDougall's powder, creolin, Jeye's disinfecting fluid, etc., have been tried. Some of these preparations are but little use, others smell objectionably and nearly all of them are very expensive when used in large quantities. In special cases, *e.g.*, typhoid fever, where the excreta are suspected of containing specific

* *v. post.* Sanitation of Towns. † *v.* p. 145.

poisons the use of carbolic acid or other substance as a *disinfectant* may be very necessary, but that is quite a different thing to the routine deodorisation of large quantities of healthy excrement.

One material there is, however, which is cheap, destroys all odour almost instantaneously, and is nearly always easily obtainable, *viz.*, Earth. With this system of the addition of earth to excremental matters is associated the name of the Rev. Mr. Moule, a clergyman who strongly advocated the practice. All earths are not equally suitable; the best are loamy surface soil, vegetable mould, brick earth and dry clay. Sand is very little good. The earth must first be dried in the sun (or over a special stove in the rains) and then 'sieved,' the coarser portion being rejected. The closet consists of a seat to which is attached a 'hopper' filled with the dry earth. (*v.* plate vi.) Every time the closet is used one-and-a-half pound of earth is discharged on to the newly-passed excrement,* both being received into a movable pail placed under the closet. When the pail is full it is removed and its contents emptied into a trench in the ground and covered up. In a short time the fæcal matter, and even paper, becomes completely disintegrated, the ultimate result being the production of a rich 'garden mould.' Unfortunately, the manurial value of the product is not nearly so great as one might naturally expect, owing to the fact that a large proportion of the nitrogen contained in the voided urine and fæces passes into the atmosphere in a gaseous form. For a like reason it is possible to use the same earth several times over after keeping it for sometime, drying and powdering it, but even then its manurial value does not increase to any appreciable extent. The system is a very valuable one for isolated houses or institutions, *e. g.*,

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* This amount of earth must be increased in this country for the two reasons already noted, *viz.*:—the larger amount of the fæces and the use of water for ablution. In Alipur Jail Mr. Fawcus found 5 lb. of *undried* earth necessary for the fæces and 8 lbs. of the same for the urine of healthy Hindus. If the earth is dried and of suitable quality, as explained above, and the urine and water allowed to drain off into a special receptacle, a much smaller quantity will suffice, say 3 lbs. *v. post.* Practical Sanitation.

jails,* hospitals, temporary camps, etc., but in the crowded portions of large towns it is difficult to work and very expensive, especially during wet weather.†

Disposal of Excreta.—Whether, therefore, the excreta are removed with or without admixture the method of their disposal remains to be considered. There are really only two ways of disposing of solid fæcal matter, whether mixed previously with earth, etc., or unmixed, and these are (1) by returning it to the soil; (2) by destroying it by fire. The final result is the same in both cases, *viz.*, the reduction of the complex organic compounds to simpler and harmless inorganic combinations with evolution of various gaseous substances. But there is one important difference. In the case of fæcal matter exposed to the action of intense heat there is absolute destruction of all living organisms and their spores; in the case of fæcal matter merely returned to the earth there is no such guarantee. If we were sure that all the fæcal matter was derived from healthy individuals this would be a point of no importance, but we know that the contrary very frequently obtains and that the stools of persons suffering from cholera, typhoid fever, etc., are mixed up with those of others. We further know experimentally and practically that many micro-organisms, or

* It is largely in use in Indian Jails. Moule's closets are not used, the excreta being simply passed on to the sloping floor of the latrine or into chatties, but the principle is the same. Lately, an ingenious device, known as Donaldson's 'Night-soil Ejector,' has been applied to several Jails, whereby the excreta and earth are placed in a large hopper on the *inner* wall of the Jail, the hopper being continuous with an iron casing containing an Archimedean screw. The iron casing terminates in an opening on the *outer* side of the wall. By turning a handle attached to the screw the fæcal matter and earth are intimately mixed and the mixture received into baskets in which it is conveyed to the Jail-garden. The advantages claimed for it are (1) That it prevents the *toty* or *mehter gangs* from introducing forbidden articles. (2) That it obviates the removal of night-soil through the Jail, and the consequent trail of pollution in the air. (3) That it saves 30 per cent. of the labour. (4) That it removes any risk of the night-soil being buried in large pits. (5) That it involves more thorough mixing of dry earth and night-soil. For further details and illustrations *v.* Proceedings San. Com., Madras, 1891, p. 228 *et seq.*

† A suitable closet was devised by C. Turner, C.E., Southampton, for use in the ordinary native household, but, like many other improvements relating to India, its expense has prevented its general adoption. For further details regarding the various latrines suitable for use in connection with dry methods *v. post.* Practical Sanitation.

their spores, can multiply, or, it may be, merely lie dormant in the soil and only await a suitable opportunity to become the exciting cause of a dire epidemic.* There is but little doubt that soil saturated with the germs of infectious diseases, has directly—on being disturbed for building purposes, encampments, etc., or indirectly—through pollution of the water-supply, been the cause of many obscure outbreaks of disease.† It is also alleged by some that entozoic diseases may be spread by means of the earth-burial of fæcal matter. This is doubtful.

Though not a perfect system it is better than many others, if the following points are attended to :—(1) The earth must be *dry, well powdered* and of the *proper kind* ;‡ (2) Each individual stool, whether passed into a common receptacle or not, must have a charge of earth applied to it *directly ;* (3) The mixed product should not be allowed to accumulate in heaps but should be *removed daily* or *as often as possible ;* (4) It should not be buried in pits, but in *shallow trenches* about one foot deep ; (5) The spot chosen should be as near as conveniently possible, with due reference to avoidance of contamination of water-supply, and the soil should be of a suitable nature.§

In many towns in Great Britain, the pure excreta or the excreta mixed with straw, etc., impregnated with urine are removed daily and sold as manure. Where coal-ashes or other inorganic refuse is added the resulting product is practically valueless and is disposed of simply by spreading it on waste land along with the rest of the town rubbish, or by fire. The latter method is most conveniently considered under the next heading.

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* *cf.* Earth-burial and cremation: *v.* also Sir W. Moore's paper on Sanitary Progress in India, Trans., 7th San. Congress, Vol. XI, p. 26 *et seq.*

† The following Extract is taken from Sir William Moore's paper *loc. cit.* " * * * A party of coolies employed on a railway cutting near Salem, opened a spring of very clear water. Those who drank of it were seized in a few hours with cholera of a very severe type. In this instance the railway cutting passed through an old burial ground." *v.* also Admin. Report, Madras Municipality, 1891-92, Appendix vii, p. 239.

‡ *v. ante*, p. 139.

§ In many cases, part of the soil removed in digging trenches can be used, after preparation, for application to the excreta.

REMOVAL AND DISPOSAL OF TOWN REFUSE.

By the above title is indicated all the dry refuse which is collected daily by municipal scavenging carts* and brought to certain selected spots or *rubbish depôts* for disposal. In Europe it consists essentially of the ashes, dust, food refuse, etc., from houses, public markets and other buildings, and of the street sweepings, which are made up of road-dust, the excreta of horses and other animals, straw, paper, dead leaves, etc. In this country there is a considerable difference in its composition. The roads and streets are not regularly swept by special machines, partly because they are macadamised and not paved, partly because of the usual absence of mud. They are swept however to a certain extent by hand, the sweepings consisting largely of dead leaves, straw and horse dung. The droppings of cattle are almost entirely collected by private individuals on account of their value as fuel. The house refuse is also different in many ways, consisting chiefly of vegetable refuse, plantain skins, leaf plates and wood ashes.

The ultimate disposal of the enormous amount of refuse-matter thus collected is a very difficult matter. In England all sorts of ways and means are adopted. It is sometimes sold† or given to brick-makers; mixed with lime and used

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* For further details as to removal *v. post.* Sanitation of Towns.

† "The ultimate disposal of dustbin [dry] refuse is a matter for the serious consideration of local authorities. The old system still obtains at many places of carrying the refuse to a large sorting yard, often in close proximity to inhabited houses. Here men and women are employed in sorting the refuse and separating it into *breeze* (cinders and small particles of coal), *hard core* (bottles, bones, crockery, metal pots and pans,) and *soft core* (animal and vegetable organic matters and textile substances). The breeze is sold to brickmakers; the hard core, or such parts of it as are worthless, is used in road-making; and the soft core is mixed with fish offal, market sweepings, and horse droppings, and sent into the country to be sold as manure. The whole process of sorting is a noxious one, and degrading to the work people; and the foul odours given off during the process, and also from the heaps of refuse awaiting removal, whilst fermentation and decomposition are at work, often prove a most serious nuisance to the surrounding neighbourhood." (Murphy and Stevenson, *op. cit.*, p. 809). In many towns in Great Britain and the continent there is a miserable class of people known as 'rag pickers' (in France as *Chiffoniers*) who earn a scanty livelihood by coming out of the horrible dens they live in after dark, spending the night in 'sorting' the dustbins placed in the street

as manure for stiff clayey soils; mixed with the 'sludge' from sewage farms* and dug into the soil; used for filling up hollows and depressions in the soil;† or lastly, taken out to sea in hopper barges‡ and sunk in deep water.§ "The universal manner of disposal of town refuse in this country is by throwing it into pits, tanks, ponds and low grounds."|| This unfortunately is only too true and the process may be seen on any scale, commencing with the small mounds of household refuse deposited daily by the careful housewife around her dwelling, in immediate proximity to the shallow well or tank which constitutes the water-supply. The usual custom is to empty the carts, laden with town refuse, day by day on the selected bits of waste ground and then, after levelling the rubbish, to add six inches depth or so of earth. In practice the layer of earth is usually very much less and, if the supervision of the sweepers is not very thorough, there will be no earth added at all. In some towns the excreta are here intentionally deposited as well; in all towns there are sure to be excreta mixed with the rubbish. Such a 'made soil' is certain to be chosen by enterprising persons as a good site for building upon and stringent regulations are required to prevent this for a long time. In Madras seven years have been found insufficient for thorough disintegration of the waste material.¶ Such land should be brought under cultivation as speedily as possible, preferably by utilising it as a sewage farm, as has been done in Madras.** Even if such a place does not become a focus from which epidemic disease radiates,

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and abstracting from them anything eatable (!) or saleable before the scavenger's cart arrives. They may be seen in plenty in Edinburgh or Paris. In the latter city they have lately been disturbed in their occupation and ordered to quit the wretched quarter where they live amidst the filthiest possible surroundings.

* *v. post.* Disposal of Sewage. † *v.* Soil, p. 126.

‡ Large flat boats with moveable bottoms.

§ In New York, U.S.A.—about 800,000 tons of refuse are thus annually disposed of. For further information on this matter and many interesting details. *v.* Mun. and San. Engineer's Hand-book, Boulnois, 2nd ed., chap. XIX.

|| Manual for Dist. and Mun. Boards, Jones, Madras, 1888, p. 52.

¶ *v. Note* p. 126.

** *v.* Appendix, Madras Sewage Farms.

it is certain to be a nuisance to all who are unfortunately obliged to live in the neighbourhood.

After all, there is only one way of satisfactorily disposing of the enormous dry refuse accumulations of large cities, and that is by Fire. The proposal to do this apparently originated with Mr. Hickey, of Darjeeling, though his proposal had reference, strictly speaking, to the *distillation* of the excreta in retorts, with or without previous admixture with charcoal. Soon afterwards Mr. Stanford, in England, proposed much the same thing, the charcoal to be derived from the carbonisation of sea-weed which abounds along the littoral in that country. The charcoal is primarily added to the excreta when they are passed in the closets, to act as a deodoriser, etc.* This entirely does away with all offensiveness but does not disintegrate the fæces, as in the case of dry earth. The mixture is afterwards distilled, the charcoal being thereby recarbonized and fitted for use in the closets again, whilst the final condensed products of redistillation are ammoniacal liquor and tar, from the former of which sulphate of ammonium and acetate of potassium are obtained. The charcoal ultimately becomes charged with potash and phosphates and, after the addition of the ammoniacal products of distillation, forms a valuable saleable manure. The initial expense of the apparatus and materials and the difficulty of finding a sale for the chemical products have militated against the success of this plan of 'carbonisation' in India.†

Following this idea of carbonisation came the proposal‡ to expose all kinds of refuse matter to the action of fire, whence there have gradually come into use those somewhat elaborate buildings known under the generic terms of Destructors or Incinerators. The methods now adopted in the latest patterns of these structures have only been

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* ½ lb. only of charcoal is necessary (*cf.* dry earth, p. 139.)

† *v.* Parkes-Notter, p. 131.

‡ By Messrs. Meade & Co. *v.* Boulnois *op. cit.*, p. 270.

arrived at after many failures and determined opposition.* Those of Messrs. Fryer and Harrington are probably the best known.† One great difficulty, which has now been successfully evercome, was that owing to careless feeding of the furnace and to the excessive draught created, the process of combustion was incomplete, and noxious and evil-smelling vapours, along with small particles of unconsumed refuse, etc., were carried up the chimney into the open air. By the introduction of Jones' 'Fume Cremator' in which all the products of combustion are exposed for a second time to the action of a bright fire, this objection has been obviated.‡ A modern Destructor consists essentially then of the following :—(1) A *destructor* proper in which the bulky inorganic refuse such as cinders, broken earthenware and glass, old tins, etc., is exposed to the action of fire and reduced to 'slag'; (2) A *carboniser*, which receives street sweepings, vegetable refuse, offal, etc., and reduces them to carbon; and, in some cases, (3) a *concretor*, wherein the excreta are collected and dried, the ammonia being 'fixed' by sulphuric acid fumes derived from the carboniser and destructor. The slag or 'clinkers' is largely used for

* *e.g.* in Calcutta. In Madras, Ootacamund and other Municipalities may be seen disused examples of these ancient crematoria, which undoubtedly, owing to imperfect combustion, etc., were a decided nuisance when in action.

† Garlick's incinerator is being erected in Bombay and will shortly be put upon its trial.

‡ Experiments which were made in connection with this invention gave the following heats of the vapour :

Temperature in the Flue	...	... 610° F.
...	... Fume Cremator	... 1270° F.
...	after leaving the Fume Cremator	1100° F.

"At these temperatures and in presence of the accompanying air (about 13 tons of air are required to burn 1 ton of refuse), all septic poisons are destroyed, and organic compounds resolved into carbonic acid, water and nitrogen gas; only the minutest traces of empyreumatic products could survive and pass into the atmosphere. No harm to the health of the community is to be expected or feared from these products." W. Warner quoted by Boulnois, *op. cit.*, p. 269. The 'Smoke-Scrubber' in Harrington's incinerator is something of the same nature. In this case the smoke is drawn into a 'fan water wheel' into which water plays. The smoke is whirled round in the fan and washed by the water. It afterwards passes through a tatty screen against which water is playing. The soot, etc., from the smoke being deposited on the tatty work is washed away by the water which flows away into a drain. Finally, if desired, the smoke, as in Jones' Fume Cremator, is passed over several bright coke fires and is thus rendered imperceptible as it issues from the chimney.

roads and foot-paths, filling up holes and depressions in the ground, etc., or is ground into powder, mixed with lime and made into mortar, or mixed with cement and made into artificial stone for street paving, etc. The charcoal from the carboniser has many uses in connection with municipal and manufacturing operations, while the product of the concretor forms a valuable manure of moderate bulk. There is little doubt that this system for the disposal of dry refuse is very suitable for large towns, whether the excreta are included or are disposed of along with the sewage. It is at the present time in successful operation in Calcutta, and will in all probability be applied in Madras shortly, in which city the quantity of dry refuse removed daily is enormous. The heat generated during the combustion of the refuse has been utilised in various ways and it is at present under consideration to utilise it for generating steam for the engines required to drive the dynamos of the Madras Electric Tramways Company.*

REMOVAL OF REFUSE BY WET METHODS—WATER-CARRIAGE SYSTEM.

It has before been stated that even if the solid refuse of a town, including the excreta, is removed by a dry method, there still remains the waste water (*sullage*) from cooking, bathing, washing, trade operations, rainfall, etc., to be dealt with and that some system of removal of the impure fluid *must* be adopted in every town.† Great stress is laid upon the above fact as it is so frequently overlooked. It is necessary also to pay careful attention to another point. The waste waters from houses, stables, streets, markets, etc., contain a very large amount of foul organic matter of an easily-decomposable nature, such as grease or fat, soap, dirt from clothes and the bodies of men and other animals, urine, slaughter-house and market offal, etc.,

* *v.* Letter from the Health Officer to the President, Municipal Commission, Madras, 30th November 1892.

† *v.* p. 134. Conversely, even though the excreta and liquid waste of a town are removed by a sewerage system it is absolutely necessary to have some method in force for the removal of dry refuse.

etc. In addition, in towns where the excreta are not added to the drains, the sewers are not constructed with the same care and expense; the removal of the sewage is therefore not so rapid and complete and the consequence is that the sewage undergoes more extensive decomposition or fermentation. It is then said to be 'stale,' in which condition it is very offensive and dangerous to health. It has been proved* that there is a "remarkable similarity of composition between the sewage of midden towns [*i.e.*, excreta removed by dry methods] and that of water-closet towns [*i.e.*, excreta added to the sewage.] The proportion of putrescible organic matter in solution in the former is but slightly less than in the latter; whilst the organic matter in suspension is somewhat greater in midden than in water-closet sewage." It follows, therefore, that even though the excreta of the population are excluded—with open sewer-drains there never is any certainty that they *are* excluded—there *still remains a large volume of highly impure waste water to be disposed of, and no method of disposal can be considered suitable, which is not equally applicable to the sewage of towns having a complete water-carriage system :* in other words, the sewage in the former case is as impure, as objectionable and frequently as dangerous as in the latter.†

It is evident from the foregoing that sewage may have

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* *v.* First Report of the Rivers Pollution Commissioners.

† To any one who is sceptical about this matter, my advice is as follows :—Go to some town where there is a wet system of removal in force but in which the excreta are not added to the sewage and, paying a visit to the outfall of the main sewer, watch the black, greasy fermenting liquid pouring out ceaselessly. Then imagine for the moment that no such sewerage-system existed and that that enormous volume of liquid filth was allowed day by day, year by year to sink into and pollute the soil whereon the town was built. Which method of getting rid (*sic*) of waste 'water' is likely to be most beneficial to the health of the inhabitants? Yet the latter method has been in force for hundreds of years, if not longer, in ninety per cent. of Indian towns. What *does* flow away into the nearest watercourse or tank under such a *natural* system of drainage is not the original sewage, but the effluent after the sewage has undergone a process of 'downward filtration' through the soil of the town; the *immediate* result being a filth-sodden soil, a filth-laden atmosphere and a water-supply from the town wells of the nature of liquid sewage. The *final* result is best indicated in the death-roll, of the town.

a very variable constitution and as a matter of fact it may consist of any of the following mixtures :—

(*a*) Waste water.

(*b*) Waste water + Excreta (*liquid only* or *liquid and solid*).

(*c*) Waste water + Rainfall (*ordinary*, including sub-soil water).

(*d*) Waste water + Rainfall (*total*, *i.e.*, including 'storm water.')

(*e*) Waste water + Excreta + Rainfall (ordinary or total).

But whatever its nature, it has to be got rid of in much the same way, *viz.*, by causing the *sewage* to flow along *sewers* or drains,* which latter, taken collectively, form a *sewerage system.*

The sewerage arrangements of a modern town such as London or Paris are very elaborate and costly, but, like the methods of water-supply and artificial ventilation now in use in such towns, they were originally highly primitive. From such a primitive condition the ordinary Indian village has not yet emerged, and in this country we may see examples of the sewerage system in all stages of development up to the latest and most ingenious of all, *viz.*, the 'Shone' system as adopted by Rangoon and which will be afterwards described.

In its simplest expression a drain consists merely of a small channel scraped in the earth alongside a dwelling and is exactly the same as the drains used by cultivators for irrigating their gardens. It is of course totally inadequate for carrying off liquid refuse efficiently. The suspended matters are soon deposited, owing to the slow rate

* The word 'drain' will be used principally in this work to denote open or uncovered sewers as distinguished from covered drains and sewers proper. There is considerable confusion in the writings of various authors in this respect. In England, where open sewers are now almost unknown, except in country districts, it is becoming customary to restrict the use of the word drain to pipes or channels used for draining land whilst *all* channels carrying sewage, whether open or closed, large or small, are known as 'sewers.'

of flow, and the liquid rapidly sinks into the ground through the porous soil out of which the channel is formed. The next stage of advance is seen in those drains made by digging channels of various depths, with rectangular or sloping sides, and paving them with bricks or slabs of stone laid in mortar. Such drains may be seen in any Indian town in abundance and in most military or police 'lines.' They are well shown in the illustrations on the annexed plate. As a rule they are badly laid with respect to gradients, the bricks used are sun-dried country bricks which soon break and crumble, the mortar drops off and leaves interspaces in the sides and bottom through which the sewage percolates into the subsoil, and they are altogether inefficient.

In many towns, however, a much better class of drain or open sewer has been introduced, consisting either of good brick or stone slabs set in cement or else made entirely of concrete, as illustrated. In such cases the levels are carefully taken beforehand and the gradients properly adjusted so as to secure a flow that is neither too slow nor too rapid, sharp corners are avoided and the junctions of the drains are curved and in the direction of flow.* Being faced with cement which forms a smooth, even surface there are no obstructions to the flow of the liquid, the drains are easily kept clean by simple mechanical devices† and, if properly looked after, there are no cracks or fissures through which the sewage can escape into the soil beneath. To such drains there is one great objection, principally on æsthetic grounds, *viz.*, that being open, the sewage is visible to the eyes and appreciable by the nose.‡ This is a perfectly

* *v. post.* p. 162.

† In Madras, a wooden instrument with a head that fits the section of the drain is used. Sometimes a ball of straw is pushed on in front of the wooden cleaner.

‡ It is quite possible that there are far more serious grounds of objection, for it is at least doubtful whether the foul and sluggish-flowing liquid undergoing rapid evaporation and decomposition under the rays of a tropical sun, and in immediate proximity to the verandahs of the shops and houses in the bazaar, is not a direct and exciting cause of serious disease. The subject is discussed, from the engineering point of view, in Wallace's San. Engineering in India, Chap. V., *q. v.*

legitimate objection and the question comes to be whether closing the drains will lead to the creation of greater evils than those complained of. This question has long been answered in the negative by sanitary authorities in Great Britain and other civilised countries and the practical result is that from beginning to end the sewers in all large towns are closed, save for special openings for ventilation and inspection. In the early part of this century, when sanitary engineering was in its infancy, the knowledge of sanitary reformers was not commensurate with their zeal, so that in their hurry to remove all sewage from sight and smell they constructed elaborate and costly sewers on very defective principles. As a result very serious evils were produced and the plan of closing all sewers became discredited. During the last twenty years, however, enormous improvements have been made in the construction of sewers and all appertaining thereto and the consequence is that for large towns situated in countries with a temperate climate there is really no other system worth considering practically.* In India, however, it is a very different matter owing to climatic, social and other local conditions: and the subject will be discussed later on. Apart from this, it is quite necessary that every one who pretends to a knowledge of hygiene should understand at least the rudiments of a modern sewerage system and, accordingly, such a system will be described briefly from its commencement in the dwelling house to its termination at the outfall of the sewer.

Cesspools.—Before doing so, however, we must study the connecting link between simple drains or *gutters* leading into the nearest tank or nullah, and a modern sewerage system where the sewage is completely disposed of at the point of discharge. This connecting link we shall find in Cesspools or Cesspits as they are variously called. Such cesspools formerly existed in great number in England, in fact they

* The excreta of the population in these towns are not *necessarily* added to the sewage: it is only stated here that practically all large towns have a system of closed sewers.

were almost universal in connection with the better class of houses. In certain parts of India they are in common use and in Rangoon, before the introduction of the Shone system of sewerage, the ground was literally 'honey-combed'* with them.

A primitive cesspool consists simply of a hole dug in the ground, into which the excreta and waste water from a house or collection of houses pass directly or by means of drains. In England many of the cesspools were formerly constructed directly under the basement of the house, the air of which, as a consequence, was fearfully polluted and was the direct means of conveying disease to the inmates. In other cases the cesspit was situated at some distance from the house, to which, however, it was connected by an unventilated drain. Such a drain simply acted as a ventilating shaft *from* the cesspit to the house. In addition, the walls of the cesspit being porous, the liquid matter escaped into the subsoil and polluted any wells in the vicinity.† Sometimes the cesspool had an overflow

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* *v.* Trans. viith, Internat. San. Sci. Cong., vol. xi, p. 179. "Cesspools constructed in brick, stone and other materials are in common use, and large earthenware jars sunk in the ground are also used as cesspools, and are emptied at periods more or less remote." Baldwin Latham. "For the disposal of sewage and other filthy liquid, a system of cesspools, called 'khalcoovas,' prevails in Allahabad. A 'khalcoova' is in construction like a dry well. On a wooden kerb a steining of bricks is built dry without mortar in the joints, so that water may easily find its way through it, and this brick cylinder is sunk to within a few feet of the subsoil water-level. The top of this well, about five feet below ground-level, is arched over with a brick and mortar dome; a connection with the house drain being made, earth is filled in over the dome. All the sullage water of the house is run off into the 'khalcoova'—all the bathing water, the kitchen water, the urine, the washings of the privies, and every conceivable liquid filth. All the liquid thrown into this khalcoova or cesspool filters through the sandy soil at the bottom and sides and finds its way into the subsoil water, and thus these khalcoovas are kept in working order, without opening and cleaning out, for more than 30 or 40 years. But the result of the system has been that the water of all the wells in the city is so much polluted as to be quite unfit for drinking. Most of the wells in the city are so badly affected by these khalcoovas that their water is too brackish to be drinkable in any form whatever; however, this water is freely used for washing, bathing and all other domestic purposes." Runchorelal Chotalall, President, Ahmedabad Municipality. *v. op. cit., supra*, which contains many other references to the same subject.

† *v. supra* and note, p. 121.

pipe which discharged the liquid matter into a neighbouring stream or into a sewer. In the former case the pollution was just as great as if the house drain opened directly into the stream; in the latter case it would have been much better to have no cesspools at all, the house drain itself being connected with the sewers.

If cesspits must be constructed for isolated houses or small villages, great care must be taken to see that the following conditions, which have reference to the prevention of leakage and to the backward passage of foul air, are complied with in detail. The walls of the cesspit must be made of brickwork set in cement; the interior must be lined with cement; the exterior must have a backing of clay-puddle all around and beneath of from 9—12 inches depth. The roof and bottom must be arched, not flat, and the roof must have a ventilating manhole. The bottom must be built with a fall at the distant end so that the sewage can gravitate or be pumped if necessary. Between the house and the cesspool must be situated a ventilating disconnecting trap on the house drain and the latter must be constructed air and water-tight.*

With regard to disposal of the contents, they may either be allowed to flow away directly into irrigation drains in the proximity of the cesspool, or else a *strainer*, or screen of galvanised iron wire, may be inserted in the higher portion of the cesspool so as to separate the liquid from the solid contents. The liquid is then allowed to gravitate from an overflow pipe into subsoil irrigation drains, whilst the solids are removed daily by hand and dug into the soil.

On the continent in Europe the cesspool system is still largely in use. Large cement-lined spaces are constructed in the immediate neighbourhood of the houses, and are emptied three or four times a year. The pipes from the closets lead directly into them and are never properly flushed. The emptying is done by means of barrel-shaped

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* *v.* p. 159.

carts (*tonneaux*) which act as receivers. In addition, there is a small engine which works a steam vacuum pump for exhausting the air in the receiver. This latter is connected by a hose with the cesspit and its air exhausted. Then, by turning a valve, the receiver is put in direct connection with the cesspits and their contents are drawn into the receiver. The whole system is unsound in principle and disagreeable in practice.*

According to modern sanitary principles it is essential to *remove all decomposing or decomposable matter at once* from the neighbourhood of dwellings. Cesspits do not comply with this principle and should only be permitted therefore in special cases and after absolute compliance with the aforementioned rules of construction.

A MODERN SEWERAGE SYSTEM FROM HOUSE TO OUTFALL.

Baths, Sinks and Closets.—In Great Britain the ordinary system of closed sewers may be said to commence within the individual houses of which the town is composed, but it does not necessarily do so.† Inside the house there are, respectively, *baths* for ablution of the entire body and in some cases *fixed basins* for washing the hands and face, *sinks* or receptacles for receiving waste water of all kinds, and finally *water-closets*‡ or receptacles into which the excreta are passed or emptied as the case may be.

The Baths and Sinks are made of various materials, *e.g.*, lead or zinc painted with enamel paint, enamelled stoneware, porcelain, etc., and are of various shapes and sizes.

There are also many kinds of Closets of which the lead-

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* It matters little what precautions are taken in emptying cesspits, a nuisance is almost certain to be created, as any one who has walked about the streets of a continental town at night or in the early morning well knows.

† It is quite possible, as will afterwards be seen, that for towns in India some system of sewerage is advisable in which there is no direct continuity between the houses in the poorer quarters of the town and the sewerage system itself.

‡ And in large houses or schools, etc., *urinals*, in addition.

ing types are shown in the accompanying plate (vi).* Formerly they were made of metal and were surrounded by a wooden casing, but in the most modern closets all parts are made of china or earthenware and the wooden casing is done away with, thus ensuring greater cleanliness and the easier detection of any defects. Such a closet, as the 'Unitas' shown in the illustration, consists essentially of a basin or receiver placed directly under the seat, into which the excreta are passed and which leads directly to the second portion. This is usually an ordinary siphon trap as described in the next paragraph. After use, by an automatic arrangement, or by pulling a plug or handle, a regulated amount of water from a small flush tank or cistern overhead is discharged into the basin with considerable force, either as a jet of water or as a flush from perforations round the rim of the closet. In some closets, as the 'Carmichael,' there is both a jet and a rim flush. The contents of the basin are thereby driven into the trap and from there they pass down the pipe leading from the trap. When the flow of water ceases, the excreta have disappeared entirely and the basin and trap are full of clean water. Three to four gallons of water are necessary to flush the closet properly. In the case of baths and sinks the discharge opening or outlet leads directly into a siphon trap. All the above points are illustrated in the annexed plates. It is to be noted especially that the cistern for supplying water to the closet must be quite distinct from the general water supply of the house and, if the intermittent method of water supply† is in use, special precautions must be taken to avoid contamination of the drinking-water cistern by leakage from a closet placed over it in an upper storey of the house.

Traps.—Originally, the pipes for carrying off waste water of any kind opened directly into the bath, sink or closet at one end and into the sewer at the other end.

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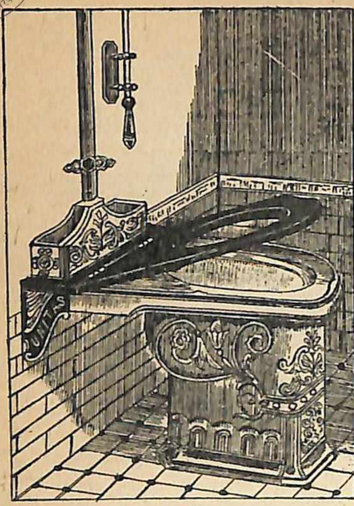
* In connection with a wet system of removal of excreta a very useful form of closet for the poorer class of houses is the *trough* closet, *v. post.* Sanitation of Towns.

† *v.* p. 57.

Plate VI.



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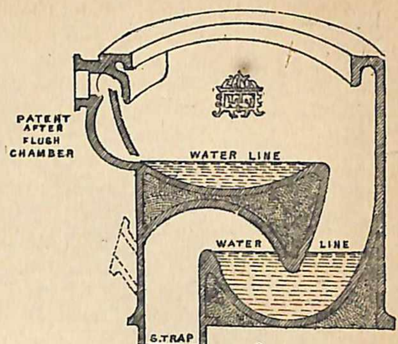

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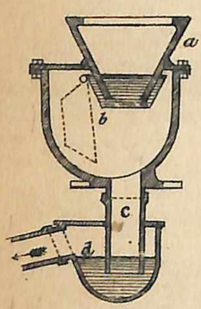

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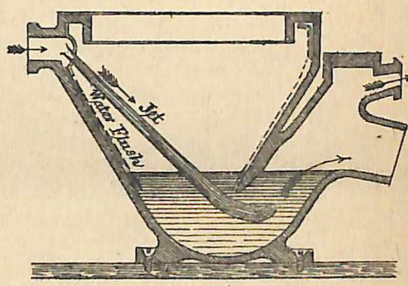

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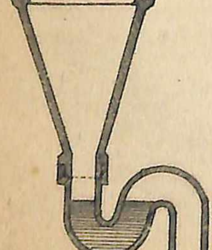

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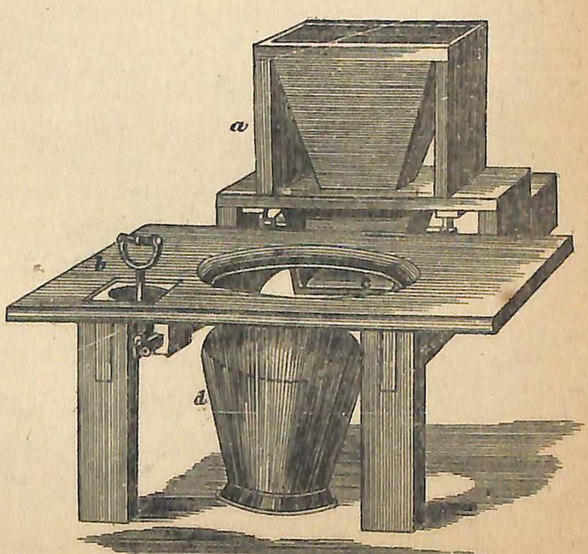

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G. PACZENSKY LITH:

PLATE VI.

CLOSETS.

Figure 1. Diagram of 'Pan' Closet with D-Trap attached: formerly in almost universal use in Great Britain, and by no means extinct yet. *a*. The Basin, which is closed (?) by a shallow metal Pan containing a little water. When the Plug or Handle is raised, after use of the closet, the excreta fall into the Receptacle or 'Container' *b*. which is quite useless and soon becomes fouled. From this the water and excreta pass into *d*. a D-Trap connected with the soil pipe, as indicated by the arrow. This form of closet and trap are both thoroughly defective and their use should be entirely prohibited. (*v.* also pl. vii, fig. 1.)

Figure 2. Diagram of 'Long Hopper' Closet with Siphon-Trap attached. It is a simple form of closet, which requires, however, a powerful flush of water after use: in addition to which the basin, from its narrow shape, is certain to become fouled, and requires frequent cleaning. An improved form, is the Short Hopper Closet, in which the cone is shorter, has a rim flush, and the back is nearly vertical, so that the excreta fall directly into the water.

Figure 3. (*a*) Twyford's 'Unitas' Wash-Out Closet: (*b*) same in section. A good representative of the modern type of closet, in which the only part made of wood is the hinged seat. This latter can be lifted at will when any vessel is emptied into the closet or when it is used as an urinal. The whole closet can be easily and quickly inspected since it is not boxed in with a wooden casing. In (*a*) is shewn the handle communicating with the flushing cistern, which when pulled causes the latter to discharge three or four gallons of clean water into the closet, whereby every thing is carried down the soil pipe: only enough clean water being retained to fill the receptacle and seal the siphon-trap, as shewn in (*b*). At the lower part of (*b*) is indicated the air pipe situated on the *distal* side of the trap, and which opens into the ventilating pipe carried up 'full bore' beyond the ridge of the roof. (*v.* pp. 157—8, and plate viii.)

Figure 4. Diagram of Buchan's 'Carmichael' Wash-Down Closet, consisting of one piece (closet and trap combined), and with the trap in the form of a P-Trap (a modification of the S-Trap). It will be observed that it possesses a *double flush* of water to ensure speedy and complete emptying of its contents. The upper right-hand arrow indicates the Ventilating Pipe on the *distal* side of the trap (as in fig. 3, (*b*) .); the lower arrow the entrance to the soil pipe.

Figure 5. Moule's Earth-Closet—*a*. Dry Earth Box, *b*. Handle or Plug which, when lifted, causes the discharge of a regulated quantity of dry earth from the mouth of the hopper (*c*) into the Pail or Receptacle (*d*). The latter, when full, is removed and emptied. (*v.* p. 139).

This, however, was found to be both dangerous and obnoxious on account of the constant backward passage of sewer gas from the sewers into the pipes and ultimately into the house, thereby poisoning the air of the rooms. To what an extent this can occur is easily realised by travellers on the continent where the closets frequently open directly into a straight drain or tube terminating in a cess-pool at the bottom of the house.* Accordingly, it has become the custom to insert a Trap of some description between the original receptacle and the pipe, and between the pipe and its opening into the sewer. The principle of these traps is the same in all cases, *viz.*, the interposing of an efficient barrier to the backward passage of sewer gas whilst the onward flow of waste water into the sewer is unimpeded. This result is obtained by means of a *water-seal,*† *i.e.*, the last portion of the water which flows away is retained at a certain point and forms the barrier above alluded to. The original traps were all exceedingly defective and as a matter of fact the ideal or perfect trap has yet to be invented.‡ Various traps which have been given up as obsolete by all modern sanitarians are shown and explained in the illustrations: unfortunately, many of them are still in common use. They have nearly all two faults in common—the water-seal is too shallow and is liable to become dried up, and they are apt to retain the heavier matters in the sewage, which form a foul and evil smelling mass at the bottom of the trap, from which offensive and, it may be, dangerous emanations are given off and pass back into the dwelling.

With the exception of certain traps for special use, all modern traps are made on the principle of the siphon or

* As also in many two-storied native houses in this country.

† Certain traps are constructed by interposing a sheet of metal or a ball of metal at the beginning or end of a pipe, so regulated that the mouth of the pipe is kept closed save when waste water is running down the pipe. They are not a good form of trap and require no further notice here. In one form of trap the siphon trap is combined with a ball trap made of India-rubber or wood, *v.* Plumbing by W. P. Buchan, p. 231.

‡ As also the 'perfect' ventilating cowl, *v.* note, p. 40.

ᔕ-trap. Of this there are many modifications, one of the best known being Buchan's trap (*v.* pl. vii.) In reality they are not siphons at all but simply pipes "bent in such a way that there is always a water-seal between the inlet and the outlet."* If properly fitted and carefully looked after they are valuable adjuncts to a good system of house sewerage, but *they must not be looked upon as perfect preventives of all danger from sewer gas.*† As will be seen later on, in a good sewerage system there should be very little sewer gas present at all in the sewers‡ and it is quite *possible* that some day traps will be found to be unnecessary.

There are one or two points which require especial attention. If a pipe is too seldom used the water in the trap will evaporate, the trap becoming 'unsealed' and useless for the time being. Again, if the trap is too small in calibre, especially if there is a sudden drop in the pipe below the trap, the waste water as it rushes through the pipe fills the latter entirely so that it 'runs full' as it is called; the consequence is that all the water is sucked out of the trap and the latter is left empty. The same thing may happen where there are several siphon traps situated at different levels but connected with the same pipe. As a rush of water takes place down the pipe the latter is completely filled (runs full) and the lower traps are unsealed in turn as the water flows past them. Both these accidents are preventible by proper ventilation on either side of the traps. Some have even supposed that a trap may become unsealed by the backward pressure of sewer air combined with the aspirating effect of the warm house-air: it is at least doubtful if such an accident ever does occur. Below every bath, sink and closet, as before stated, a trap is securely fixed, and from its lower end begins the house pipe. The traps are most frequently made of lead on account of convenience,

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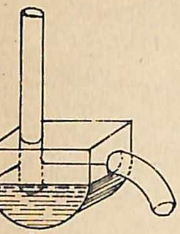
* S. and M., *op. cit.*, p. 769.

† Even the siphon trap, which is so generally suitable in a temperate climate, has been found by experience to be unsuitable in many cases in a tropical climate. *v. post.* Sewerage of large towns in India.

‡ *v.* Ventilation of sewers.

PLATE VII.



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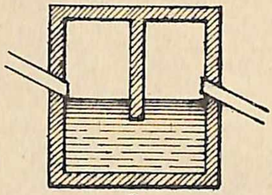

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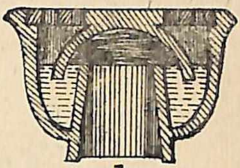

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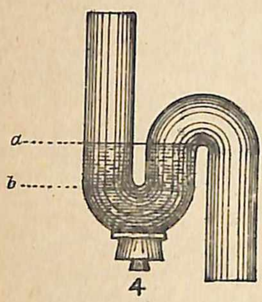

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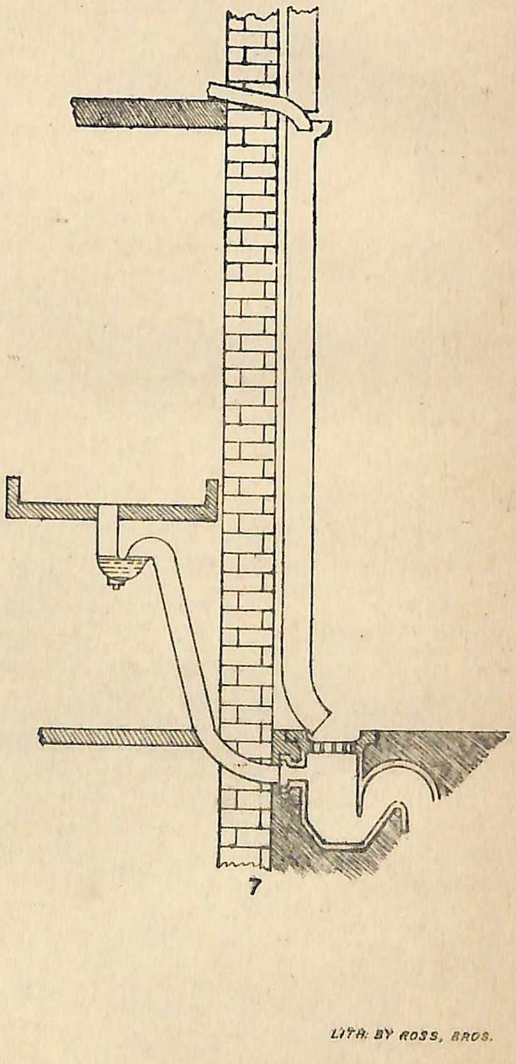

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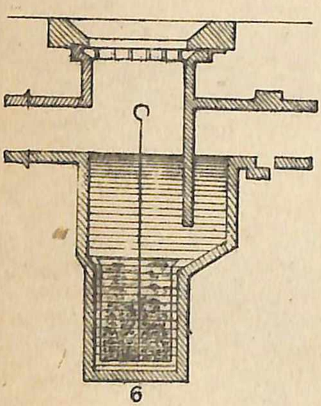

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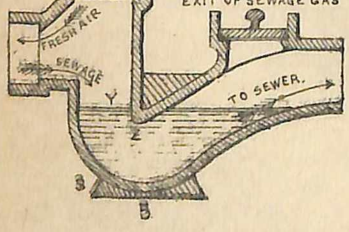

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LITH: BY ROSS, BROS.

To face p. 156.

PLATE VII.

TRAPS.

Figure 1. D-Trap, an obsolete form. It soon becomes fouled from the deposit of solid matters, and cannot be flushed properly.

Figure 2. Dip-Trap, an obsolete form. The tongue is made of stone or metal. If not in constant use it becomes 'unsealed' from evaporation of the water, and it cannot be flushed properly owing to its rectangular shape.

Figure 3. Bell-Trap, an obsolete form. The top is removable for inspection, but it is certain not to be inspected sufficiently often. In addition it is liable to become choked, and the water seal soon evaporates if the trap is not frequently flushed.

Figure 4. S-Trap or Siphon trap, with removable screw plug for cleaning purposes. The depth of water between *a* and *b* constitutes the 'seal' of the trap, and is considerable in this case. In some cases a smaller seal is advisable (*v.* fig. 5).

Figure 5. Buchan's Patent Disconnecting Ventilating Siphon-Trap. It is a simple and effective form of trap. The 'water seal' *i.e.*, the dip of the tongue (Z) below the surface of the water is 1″·5. Owing to the drop of 2″ which the water gets in flowing from the drain branch (W) into the well (Y) of the trap, it washes out the contents completely, instead of flowing *under* the floating matter as in the old fashioned Siphon. (For trap in position *v.* pl. viii.)

Figure 6. Dean's Gully Trap. It is really a modified dip-trap and is only intended for waste water from kitchens, backyards, etc. It contains a bucket with a handle, into which stones, etc., fall, and which is removed and emptied at intervals. (Gully traps are shown at fig. 7 and at pl. viii., D. *q.v.*)

Figur 7. Disconnection of Combined Rain and Waste Water Pipe over Siphon Yard Gully. [After L. Parkes.] In this case the rain water pipe is utilised as the waste pipe as well. The basement waste pipe discharges into the gully by a special side inlet, the upper waste pipes into the open head of the rain water pipe at each storey of the house. Here the rain water pipe, which is carried 'full bore' above the roof, acts as ventilating pipe to the branch waste pipes, while it discharges its contents on to the iron grating of the gully. The above arrangement is quite distinct from the soil pipe (for which *v.* pl. viii.) It is not an arrangement to be commended, for the waste water fouls the rain pipe with grease, etc., and gives rise to offensive smells which penetrate into the house through the windows. The proper plan is to keep soil pipe, waste pipe, and rain pipe quite distinct.

but in other cases, *e.g.*, water-closets, they are usually of porcelain or coated cast iron.

House or *Sullage Pipes.*—Under the above heading only those pipes carrying waste or sullage water are included here, though of course there are several other sets of pipes in most English houses, for carrying water, gas, etc., with which we have no concern here. The former are often called the *waste pipes* and the latter the *soil pipes*. Careful distinction is made in modern houses between the pipes for conveying waste water from baths and sinks and the pipes which carry only the sewage water from the closets, and the two systems are kept quite separate, though the ultimate destination of their contents is the same. Soil pipes are either made of drawn lead or of iron (cast iron or galvanized iron—never wrought iron). Great care must be taken in fitting the various lengths of the iron pipes and they should be coated internally and externally with pitch or Angus Smith's preparation or by Barff's process.* The pipes are usually carried outside the house, one set for waste water and the other for sewage water from the closets, as explained above. They do not open directly into the house drains.† The waste pipes are made to discharge into the *open air* and this result is frequently brought about by making them open into the rain water pipe as it passes down the outer wall of the house. The rain water pipe is disconnected from the drain below by opening on the grating over a siphon trap leading to the drain (*v.* pl. vii). If a separate waste pipe is carried down the outer wall of the house it is made to end in the same way, *i.e.*, over a trap, and is carried up full bore above the ridge of the roof, its end being left open or covered with netting. The soil pipes themselves are brought down *outside* or inside the house, the former being the more usual, but they always end in one way, *viz.*, by opening directly into a

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* *v.* p. 76.

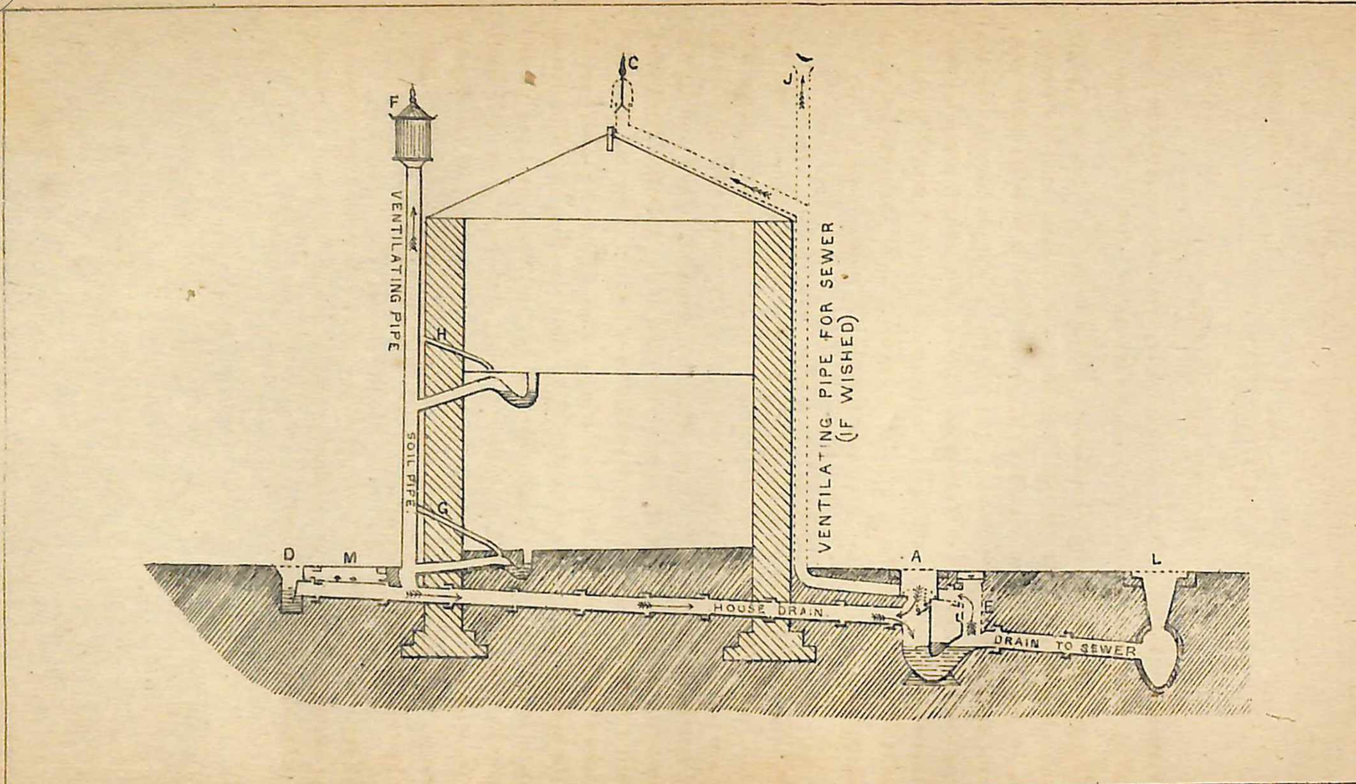
† The term house drain as used in this and the following para., is applied to the commencement of the sewerage system *outside* the house. It is in reality a small sewer.

siphon disconnecting trap (*v.* pl. vii). The soil pipe itself is always carried up full bore to the top of the house above the ridge of the roof, its top being left open or covered with a ventilating cowl (*v.* pl. viii). The sizes of these pipes vary under different arrangements: as a rule, the soil pipes have an internal diameter of about four inches, the waste pipes one-and-a-half to two inches. Very many other details have to be attended to with regard to the house pipes which it is unnecessary to further allude to here.

House Drains.—These may be looked upon as the feeders of the small sewers which run down the middle of the streets between the rows of houses. Between the waste and soil pipes of the house and the house drain is placed a disconnecting, ventilating siphon trap, as mentioned before, so that the house drain starts at the distal end of the trap. In most cases, where there are special waste pipes distinct from the rain water pipes these house drains receive only the waste water and water closet sewage, the rain water from the roofs and ground surface being conveyed away separately. The drain is usually constructed of two-foot lengths of circular pipes made of glazed stoneware, which are very carefully jointed together with cement of various kinds. The drain should be laid perfectly straight so as to be open from end to end for inspection and its interior should be quite smooth and free from obstructions of all sorts. If the soil is loose and sandy, cast iron coated pipes are preferable, or the stoneware drains may be laid in a thick bed of concrete. In Germany cement and silicated concrete pipes are extensively used and are said to be less brittle, more capable of withstanding extremes of climate and of resisting the chemical action of sewage, to improve with age and to withstand the jarring effect of heavy traffic overhead.* The pipes vary in size from four to nine inches in diameter according to the size of the house they drain.

* These pipes would probably be very suitable for use in India. The author of Sanitary Engineering in India, Mr. John Wallace, C.E., Bombay, is a strong advocate for the use of iron pipes for the removal of sewage, as in the Shone and Berlier systems (*q. v.*), in India.

PLATE VIII.



LITH: BY ROSE BROS.

To face p. 158.

PLATE VIII.

HOUSE DRAINAGE.

Vertical Section of a House, showing the arrangements adopted for house drainage in connection with a modern sewerage system (after W. P. Buchan).

[NOTE.—The house drain is here shown passing *under* the house, an arrangement only permissible when absolutely necessary, as in crowded parts of towns, etc., (*v.* pp. 158-9). Note, also, that in this case there is no waste water pipe shown distinct from the soil pipe; that the soil pipe leads directly into the house drain; that there is only one disconnecting and ventilating trap between the house and the sewer; and finally, that here the 'drain to sewer' is what is usually designated the 'house drain'—*i.e.*, in those cases where the soil pipes and waste pipes are trapped as described in the text (*v.* Summary, p. 168)].

D. Gully Trap (*v.* figs. 6, 7, pl. vii..) M. Inspection Manhole. G. and H. Ventilating Pipes carried from the crowns of the siphon-traps and opening into the soil pipe, which latter is carried up 'full bore' above the ridge of the roof and ends in a Fixed Cowl, F., for ensuring an up-draught. The house drain is shown opening into a Buchan's trap (*v.* fig. 5, pl. vii.). At A. is a Perforated Grating which allows of fresh air entering the house drain, passing along the latter and up the soil pipe, to be discharged at F., carrying with it any foul air in the house drain or in the soil pipe. The Ventilating Pipe shewn in dotted section, and which is intended to ventilate the 'drain to sewer' beyond the Buchan's trap, may be used when there is a danger of sewer gas forcing itself by pressure past the dip or tongue of the siphon-trap. The foul air may be arranged to discharge at J. or at C. as desired. L. Manhole, and Ventilator (if desired), for the street sewer.

[NOTE.—Many other arrangements of the house drainage are possible, and even advisable, but are too complicated for the present purpose. For these, special works must be consulted].

The drain *should not pass under the house* unless absolutely necessary (as shown in illustration); where it does do so there must be inspecting manholes placed at intervals on the drain so that it can be opened and thoroughly examined if possible. In such a case if the house drains are badly laid or if the joints are not air and water-tight there is great risk of poisoning of the occupants of the house by sewer-gas.*

Sewers.—The house drains lead the sewage into the *street drains* or *tributary sewers*, but should not do so directly, as is still frequently the case. There should be efficient disconnection by some suitable form of trap which prevents backward passage of sewer-gas, provides for ventilation and allows of thorough inspection and cleaning. The smaller sewers are sometimes made of circular pipes of much the same kind as the house drains, only larger; the same precautions in laying and construction are necessary. These smaller sewers open into larger ones, the *mains*, and these again into the *outfall sewer*.†

It will be seen that under this 'separate' system, as it is called, only waste water and sewage with *possibly* the surface water from the immediate neighbourhood of the houses is permitted to enter the sewers. The latter are therefore made air and water-tight and of small size. Special provision must be made for the carrying off of rain-water and for the drainage of the subsoil, a very important point, particularly where the subsoil is so completely filth-sodden as it is in Indian towns. There are several ways of doing this which may be mentioned here. (1) If the town possesses an old system of brick drains and sewers, which are porous and therefore permit the subsoil water to enter them from without, they can be utilised for collecting the rain

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* For much useful information on this and kindred subjects, *v.* Mr. Pridgin Teale's pictorial guide—Dangers to Health.

† Under this system the only sewers made of brick are the mains (in large towns) and the outfall sewer. Their construction is explained afterwards, *v.* p. 161.

and subsoil water and the main sewer can be directed to the nearest river or other outlet without fear of harm. (2) The combined drain and subsoil pipe known as Brooke's may be used. The drain or pipe carrying the sewage rests upon an invert block under which is a ⋒-shaped subsoil pipe for draining the soil (*v.* pl. x). (3) The pipe sewer is laid as usual and over this are laid open-jointed agricultural tile drains, surrounded with gravel, into which the subsoil water flows and is carried to any convenient outlet apart from the sewage.

This plan of separating the sewage from the rain and subsoil water is comparatively modern. Sewers as originally constructed were "underground channels destined to receive and convey away by gravitation the rainfall and waste waters of the town."* At a later period the overflow from cesspits and middent was allowed to enter them, and finally, when the water carriage system of excreta became general, the whole sewage of the town was received by them—such a method being known as the 'combined' system. It is not necessary here to go into any details regarding the original construction of such a combined drainage and sewerage system. Suffice it to say that it is practically obsolete and that the discredit into which the practice of the removal of excreta by water carriage at one time fell was largely due to the rash attempt to make one set of drains perform two radically different functions. The relative advantages and disadvantages of the separate system as compared with the combined may be thus stated :—

(1) Under the separate system the *total volume of sewage is very much less*, from which it follows that the sewers need not be made of such an enormous size as under the combined system and, in addition, the sewage is more easily disposed of.†

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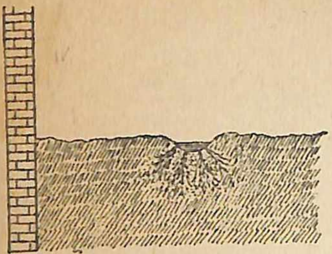
* E. A. Parkes, Hyg. and Pub. Health, 2nd ed., p. 149.

† *E.g.*, the two towns of Romford and Slough, near London, with same population and same amount of water-supply per head. The sewage farm at the former received in one year over 100,000,000 gallons of

Plate IX.



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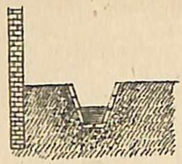

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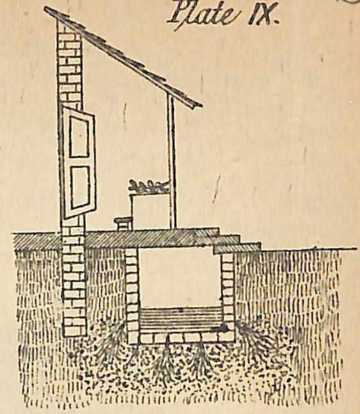

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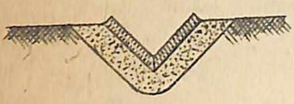

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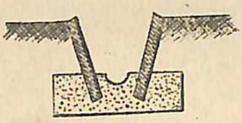

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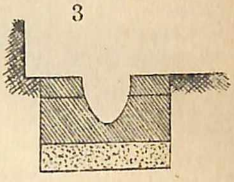

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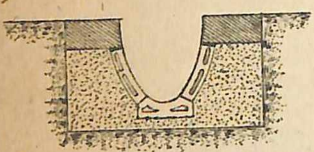

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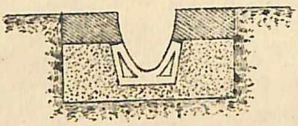

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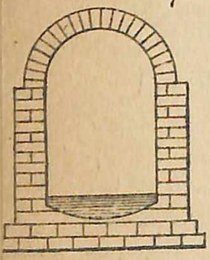

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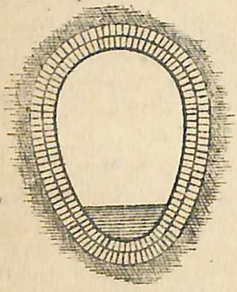

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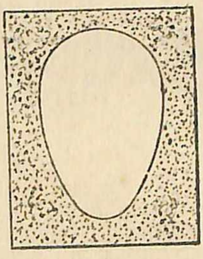

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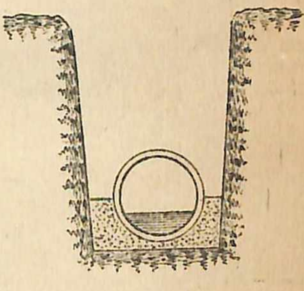

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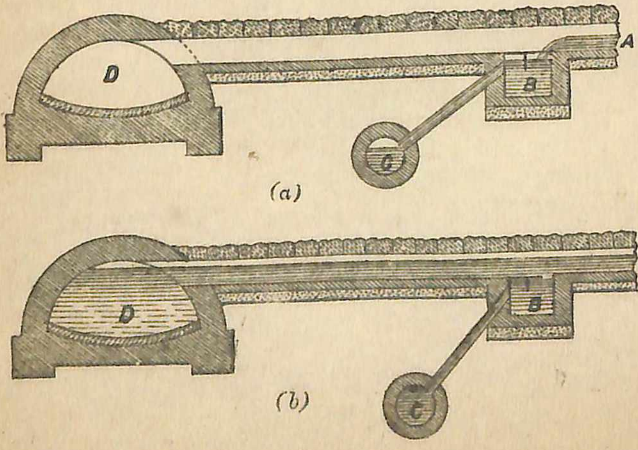

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PLATE IX.

DRAINS AND SEWERS.

Figure 1. Rudimentary form of Drain made by scraping a channel in the soil. (*v.* pp. 148-9, 179).

Figure 2. Flat Bottomed Drain formed of slabs of stone or of bricks set in mortar.

Figure 3. Rectangular Drain, of large size, built of country bricks. Such drains are commonly seen running along the side of a street, in immediate proximity to houses, shops, etc.

Figures 4, 5, 6. Improved Drains for use in India, made of slabs of stone set in concrete, or of cement (after A. M. Jones.)

Figures 7, 8. Improved Drains (designed by Jennings of London from suggestions by Surgeon-Major W. G. King, I.M.S.) The essential point is the use of accurately made bricks of glazed fire clay, either in three pieces (fig. 7), or in one piece (fig. 8), which can be rapidly laid 'true' by unpractised workmen: whereas the accurate construction of the ordinary drain (*e.g.* fig. 4) requires considerable skill and experience. They are not expensive.

Figures 9, 10, 11. Sewers, shown in section. 9. Obsolete form of Brick Sewer. 10. Modern Egg-Shaped Brick Sewer. 11. Egg-Shaped Sewer of Concrete; for use in soft soil.

Figure 12. Stoneware Pipe Sewer in Trench, as used for house drains, etc. (*v.* also plate x). If the soil is soft or yielding the pipe should be laid in a concrete bed.

Figures 13, 14. Diagrams to illustrate the Interception System of Drainage as applied to Blacktown, Madras (after A. M. Jones). In (*a*) the ordinary condition of things is shown, where the sewage passes into the gully and from thence to the main sewer. In (*b*) is seen the condition of matters during heavy rain, shewing the branch sewer 'running full' with mingled rain water and sewage, the greater part of which passes into the old Blacktown sewer and thence to the sea or the canal, whilst the smaller portion is carried off by the main sewer to the pumping station and thence to the outfall at the sewage farms.

A. Branch sewer which collects the sewage from the open drains that run along the sides of the streets. B. Gully, into which the sewage falls and, under ordinary conditions, passes by the lower opening into the main Blacktown sewer, C. D. Obsolete Blacktown sewer which is only used for carrying off 'storm water' during heavy rain.

(2) The *daily amount of sewage* and its *composition* are *both fairly uniform,* points of great importance in the chemical treatment of sewage or its disposal on land.

(3) The sewers on account of their shape and size and smooth walls are frequently running full, which of necessity means that they are *well flushed,* and there is *very little deposit of foul matter.* On the other hand in the ordinary brick sewers it is only after a storm of rain that they run full and are properly flushed; hence there is generally, and more particularly in dry weather, an accumulation of foul matter within them; the walls are rough and uneven and, as a result, are covered with a deposit of sewer-slime from which offensive emanations are given off.

(4) There are several other practical advantages, *e.g.*, the exclusion from the sewers of a large quantity of road detritus washed into ordinary sewers during rain time and which may choke the sewers; finally, the cost is much less.

(5) The only alleged disadvantage of any magnitude is that it is a more expensive system for householders since two sets of drains are necessary for each house, but this disadvantage is more than compensated for in other ways. As a matter of fact it is often found impossible and, it may be, inadvisable to exclude the rain water that falls on the roofs of buildings and round the houses. This addition to the sewage will rarely incommode the pipe-sewers in England but in India it would certainly be inadvisable.*

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sewage to be disposed of, whilst the farm at the latter received only 30,000,000 gallons. Romford is sewered on the combined system, Slough on the separate system. *v.* also *post.* Sewage Disposal.

* A compromise between the two systems called the interception system has been introduced in India, as at Berlin, etc., in Europe. It will be afterwards noticed. *v.* p. 171.

Whether therefore the separate or the combined system be adopted by a town, large sewers will have to be constructed; the only essential difference is that in the latter case they must be porous and of greater size. Now-a-days such sewers are nearly always made of oval shape, though occasionally the large outfall sewer is circular. It can be seen from the accompanying illustrations (*v.* pl. ix) of what varied shapes they were formerly made. The egg-shaped sewer is by far the most suitable where the volume of sewage is liable to undergo fluctuation: there is greater depth of sewage and less contact with the walls of the sewer, and hence less friction. Up to eighteen inches diameter circular sewer pipes are most convenient; above that size, egg-shaped brick sewers should be used. These may be twelve feet in diameter or more. They are constructed of well-burnt impervious bricks or glazed firebricks and the floor of the sewer is frequently made of suitably curved stoneware blocks or inverts. They are laid as far as possible in straight lines, with manholes for inspection and cleaning at every change of direction. Such a manhole is shown in section (*v.* pl. x). The gradients are very carefully laid, being uniform except at certain places, *e.g.*, when smaller sewers join the main sewer or when there is of necessity an abrupt change in the direction of the sewer. In such case the gradient is temporarily increased in steepness. As stated before, all junctions must be made in the direction of flow, *i.e.*, at acute angles, so as to offer no obstruction (*v.* pl. x). The rate of flow should ordinarily be from two to three feet per second, the gradient running from 1 ft. in 250 ft. to 1 ft. in 750 ft. according to the size of the sewer.*

* In calculating the discharge from sewers the following formula is generally used.

$$V = 55\left(\sqrt{D \times 2F}\right)$$

Where V = Velocity of flow in feet per minute.
D = Hydraulic mean Depth.
F = Fall in feet per mile.

If A = Sectional Area of current of fluid, V × A = discharge in cubic feet per minute. The hydraulic mean depth is the sectional area of the current of fluid divided by the wetted perimeter (that part of the

PLATE X.

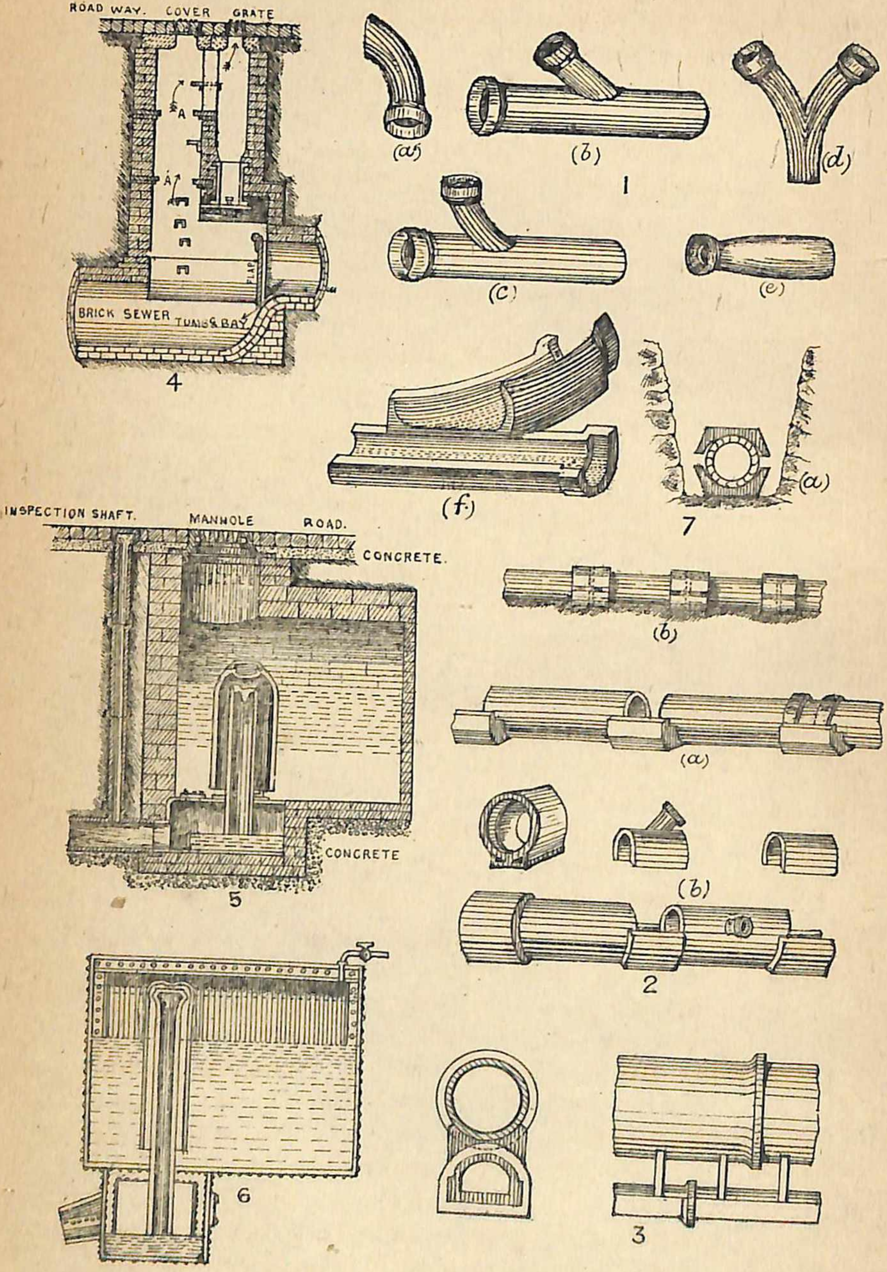

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PLATE X.

PIPES, MANHOLES, FLUSHING TANKS, Etc.

Figure 1. (*a*), (*b*), (*c*), (*d*), Various forms of 'Junction' for use in the joining of pipe sewers. (*e*) Taper-Pipe, for connecting pipes of different calibre. (*f*) Winser's Channel Bend. At the point of junction the afferent pipe has a 'straight channel', as shewn in the diagram, with a bend specially adapted for concentrating the sewage as it rises and flows round the bend.

Figure 2. Glazed Stoneware Pipes, as used for house drains, small sewers, etc., (*v*. pp. 158-9). (*a*) Patent Chair and Saddle Pipe (Geo. Jennings), (*b*) Improved Registered Drain Pipe (Stiff). Of such pipes there are very many varieties in use, the differences chiefly consisting in the methods of jointing. It is most important that the joints be absolutely air and water-tight.

Figure 3. Brooke's Patent Subsoil Drain and Pipe Rest. Above is seen the ordinary pipe for conveying sewage, resting on an invert block; below is the subsoil drain for draining away the subsoil water.

Figure 4. Means of Ventilation and Inspection of a Brick Sewer (3′ 9″ × 2′ 6″). At certain points in the course of sewers with a steep gradient a 'Tumbling Bay' is constructed, and in connection with this there is a Manhole giving access to the sewer from the roadway, and a Ventilating Chamber opening on to the street by a grating. The 'Flap Valve' allows the sewage to flow into the tumbling bay, but prevents the backward passage of sewage or sewer air to the higher levels of the sewer and compels the air to rise and escape at the ventilatory grating. The horizontal line indicates 'higher water level' in the sewer. (After Rawlinson—reduced and slightly modified.)

Figure 5. Large Automatic Siphon Flushing Tank or Cistern for scouring sewers, etc. (Rogers Field). The principle of these tanks is that of a siphon in which the long arm is placed within the short arm. The long arm dips into a small amount of water (retained in position by a weir). As the tank fills, the water rises at the same rate in the short arm and when it reaches the level indicated in the diagram it is directed, by means of a projecting lip, to the centre of the siphon, so that in its fall it carries with it sufficient air to create a partial vacuum and start the siphon action. [Note.—In this figure, the broken shading indicating water should be continued to the bottom of the tank as in fig. 6.]

Figure 6. Small Automatic Siphon Flushing Cistern for use with water-c losets, etc. Here the action is automatic; in other cases the action is started by pulling a handle, as shown in plate vi. fig. 3 (*a*). In both cases a *definite* amount of water, usually 3 or 4 gallons is discharged, and the closet, etc., properly flushed, but *without waste* of water. [NOTE.—These flushing tanks (figs. 5 & 6) can be made of any desired capacity and their rate of filling regulated to a nicety by the tap that fills them, (shewn in fig. 6). Thus they can be made to discharge every five minutes or once in twenty-four hours, and so on. The siphon is easily accessible for cleaning, etc. The tank shown in fig. 5, is much larger than that in fig. 6 but is reduced here for convenience.]

Supposing then that a good system of sewers has been built, the following things must be carefully attended to, *viz.*, Inspection, Cleaning, Flushing and Ventilation. In the original badly-constructed sewers once they were brought into use they formed practically an underground series of tunnels unevenly laid, with rough interior walls, only accessible by breaking open the crown of the sewer, and never properly cleaned.* In a modern sewer the construction and means of inspection, as before noted, are such that these evils have been almost entirely done away with. From end to end they can be inspected and if from any cause partial or complete chokage (very rare) should occur, the obstruction can easily be removed.† Periodic flushing by means of a rush of water is extremely useful. This was formerly done by playing a hose attached to the water-main into the sewer or by damming up the sewage for a certain time and then allowing it to rush forward suddenly. Now the same result is achieved much more thoroughly by means of automatic siphon flush tanks (*v.* pl. x) placed at 'dead-ends,' *i.e.*, the commencement of the branch sewers, or any other convenient spot. These tanks discharge their contents of one or two hundred gallons automatically, at intervals regulated by the supply pipe to the tank, and produce a most effective scouring action on the sewers. Very small sewers can be scoured by simply emptying an ordinary water-cart into a manhole, as is done in this country.

The ventilation of sewers is an extremely important

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circumference of the sewer wetted by the fluid flowing through it); in circular sewers it is constant and equal to one-fourth the diameter. For simple explanation of hydraulic mean depth, etc., *v.* Jones' Manual, p. 168.

* The cost of removing deposits from the former stagnant sewers in London amounted to £30,000 or 3 lakhs of rupees *per annum.* Sir J. Bazalgette—quoted by S. and M., p. 837.

† The chokage in pipe sewers generally arises from one or more of the following causes:—(1) Improper gradients. (2) Insufficient flush. (3) Foreign articles finding their way into and choking the sewer. (4) Defective joints through which the liquid runs, leaving solid matters behind. (5) An excess of road detritus or ashes finding their way into the sewer. (6) Improper bends in the line of sewer. (7) Right angle or improper junctions being formed with the sewer. (8) A collapse of the sewer. *v.* Boulnois *op. cit.*, p. 296.

thing but is hardly yet understood.* "To know that the infective agents of such diseases as cholera, typhoid fever, many cases of diarrhœa, and probably other diseases, are passed out of the body in the excretions of the patients suffering from them, that they probably have the power of self-multiplication outside the body in sewers and sewer deposits, and can infect the air in contact with them, is to understand the importance which sewer ventilation has in relation to public health, and to impress the necessity for the closest attention to this subject on the part of those who are entrusted with local sanitary administration."† A large amount of sickness and disease has been proved to be due to defective sewerage systems in Great Britain, so much so that many who have not followed the subject closely or who have been absent from that country for many years are still persuaded that these evils are as great as they formerly were. This, of course, is not the case, and it may be confidently stated that in a modern well-sewered house connected with a good separate system of sewerage the dangers are reduced to a minimum and are far less than they were in the days of privies and cesspits, of shallow, porous drains for the nominal removal of waste water, of heaps of decomposing food refuse and general rubbish in the immediate neighbourhood of each house.

The various theories which have been held in connection with the movement of air in sewers and the various means adopted to ventilate the latter are foreign to the scope of the present work. Suffice it to give a few plain statements. Firstly, as regards the movements of the air in sewers. These are *extremely irregular and their direction depends on many factors, e.g.*, the relation of the temperature of the air inside the sewers to that of the external atmosphere, the direction and strength of the prevailing

* "The whole subject of scientific and sanitary sewer ventilation is beset with difficulties," (Boulnois, 1892). If this is true in England with years of experience, how much truer is it in India!

† S. and M., *op. cit.*, p. 889.

wind,* the steepness of the sewer gradient, etc. Formerly it was customary in manufacturing towns to discharge the waste steam or hot water from different works into the sewers, thus hastening the decomposition of the sewage and setting up strong currents in the sewer air. This is now forbidden by law.

As regards remedies the most generally applicable one is the leading of a shaft from the crown of the sewer to the road above, covering the opening with a grid and placing a dirt box immediately inside the opening to prevent road débris gaining access to the sewer. They are generally placed at intervals of about one hundred to one hundred and fifty yards. Sometimes the ventilating shaft is placed alongside the manhole (*v.* pl. x). Whether the shaft acts as inlet for fresh air or as an outlet for foul air depends as above stated on many factors. It is not a perfect system, and in hot, dry weather the nuisance may be considerable to dwellers in the street along which the sewer passes. The very tall chimneys attached to chemical and other works have been utilised as sewer-ventilators but not with much success†. In sewers where the gradient is steep the foul air tends to pass from the lower to the higher levels and to accumulate at the latter places, constituting a danger to the houses in those neighbourhoods. This backward current can be prevented to a large extent by means of a tumbling-bay and flap valve placed at each combined manhole and ventilator. The sewage can flow onwards but the valve prevents anything passing backwards (*v.* pl. x). As mentioned before, the air in a good sewer is not particularly foul; in the old-fashioned brick sewers it was often extremely impure.

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* In a long series of experiments, Santo Crimp found that the wind, by its varying force and direction, was by far the most important factor in causing movements of the air in sewers.

† As also the street lamps. The object in sewer-ventilation should not be the disguising or destroying of foul odours so much as their prevention by means of cleanly sewers and plenty fresh air.—It is desirable also to equalise the pressure inside and outside the sewer, as nearly as may be, to prevent the escape of sewer gas through the water seals of the traps. (Wallace.)

The sewage is now removed so quickly and there is so little deposit in the sewers that before decomposition has advanced much the sewage has left the sewers and been disposed of. Of course, as in the case of the air of a dwelling room, the chemical composition of the air forms no trustworthy guide to the quality of its biological or living impurities, still, as a general rule, the purer the air the less likely is it to be laden with dangerous organic impurities. It is probably only in sewage which is undergoing rapid fermentation and on the surface of which bubbles are constantly bursting that numberless micro-organisms are given off, many, no doubt, harmless, but others of a distinctly pathogenic or disease-producing nature.*

Outfall Sewers.—These, as before remarked, may be ovate or circular in shape. Originally, they discharged almost without exception directly into a river or other watercourse a short distance below the town or into the sea. The former is now illegal under the Rivers Pollution Act.† If sewage has to be discharged into a river it must first be treated by some of the purifying processes to be described in the next section, so that the effluent, *i.e.*, the water flowing away after purification, may attain to a certain standard degree of purity. In some cases the sewer has to pass across a river or valley and in such cases the

* The scientific study of sanitary problems being practically unrecognised officially in India, no experiments of any note have been made in connection with the subject of sewer-ventilation. The result is that in Bombay, where the air in the sewers is extremely foul, there have been numerous deaths amongst the sewer men, when working in the sewers. Great precautions are now taken to prevent the occurrence of such accidents. The conditions in this country are in many ways different from those in a temperate climate. (*v. post.* System of Refuse Removal Suitable for India). "The quality of the sewage varies in different districts of Bombay, according to the prevailing style of diet used by the inhabitants. Hindus, whose diet is fish, rice and vegetables, produce, in the refuse of cooked and uncooked fish, rice water and other vegetable remains, an exceedingly foul smelling sewage; and the sewers of the quarters inhabited principally by them are said to be unusually foul." Wallace, San. Engineering in India, p. 96. Properly conducted experiments, by trained and capable men, on sewer-ventilation, under official recognition and sanction, are urgently required.

† *v.* Disposal of sewage.

outfall is generally at too low a level to admit of bridging. This difficulty is got over by laying the sewer, in the form of an inverted siphon, in the bed of the river or valley, a ventilating pipe being attached to the descending arm of the siphon in order to allow of the escape of air which might interfere with the siphon action.

When the outfall is into the sea directly or into a tidal river it is necessary to have tanks wherein the sewage can be stored until the commencement of the tidal ebb. If the outfall is carried directly into the sea great trouble and nuisance is apt to be caused at certain seasons by the rush of the tide into the sewers whereby the sewage may be carried back a considerable distance and even flood the ground floors of houses situated at a low level.* In any case, stagnation with resulting deposit and decomposition is very apt to take place in outfall sewers and great trouble must be taken to prevent such an occurrence. The position of the outfall must be such as not to give rise to any nuisance.

Summary.—Such then is the construction of a modern sewerage system on the 'partially-separate' system as it is called, *i.e*, where the sewage at the outfall consists of *waste water, excreta and a small portion of the ordinary rainfall* from the roof and immediate neighbourhood of the houses, but does *not* include the larger portion of the rainfall nor any subsoil water. The details of such a system may be summarised as follows :—

(1) *Baths, sinks* (and *basins*) for the reception of ordinary waste water.

Water-closets (and *urinals*) ... ... liquid and solid excreta, and flushed with clean water from *special cisterns*.

* This objectionable state of things used formerly to occur at St. Andrews on the E. Coast of Scotland. It is not likely to occur in this country as the tides are much smaller, but great trouble may arise through the sewage being carried by currents and re-deposited along the foreshore, as has happened at Bombay.

Underneath every bath, sink, water closet, etc., is a *siphon trap.* In the case of water closets the trap is ventilated. Below the traps the *house pipes* begin. Of these there are two sets—(*a*) the waste-water pipes from baths, etc., (*b*) the soil pipes from urinals and water closets. Both sets of pipes pass down the *outside* of the house, if possible, their upper ends being open and carried above the ridge of the roof for ventilation. The waste-pipes end below in the open air over a *trapped grating,* through which the waste water enters the house drain. The soil-pipe ends below in direct continuity with a *ventilating disconnecting trap.*

(2) Between the house and the sewer is placed the *house drain,* in reality a small sewer, constructed of carefully-jointed and cemented pipes. This is trapped and ventilated at both ends, is laid in a straight line, and has small manholes for inspection and cleaning. It should, if possible, be placed at the back of the house :* if it must pass underneath the house it should be made of coated cast iron. The house drain opens into a *ventilating disconnecting trap and manhole combined* which is placed at its junction with the street sewer.

(3) These *street* or *tributary sewers* join the larger or main sewers and are of the same nature as the house drains, only larger (*pipe sewers.*) They open into the *main sewers* at suitable angles. These latter are large pipes in small towns; in large towns they are brick sewers. Finally, the main sewers open into the outfall sewer which ends at some spot, situated at a suitable distance from habitations, where the sewage is disposed of. The construction of and means for inspecting, flushing, and ventilating sewers have already been described.

* *v.* Boulnois, *op. cit.*, p. 292.

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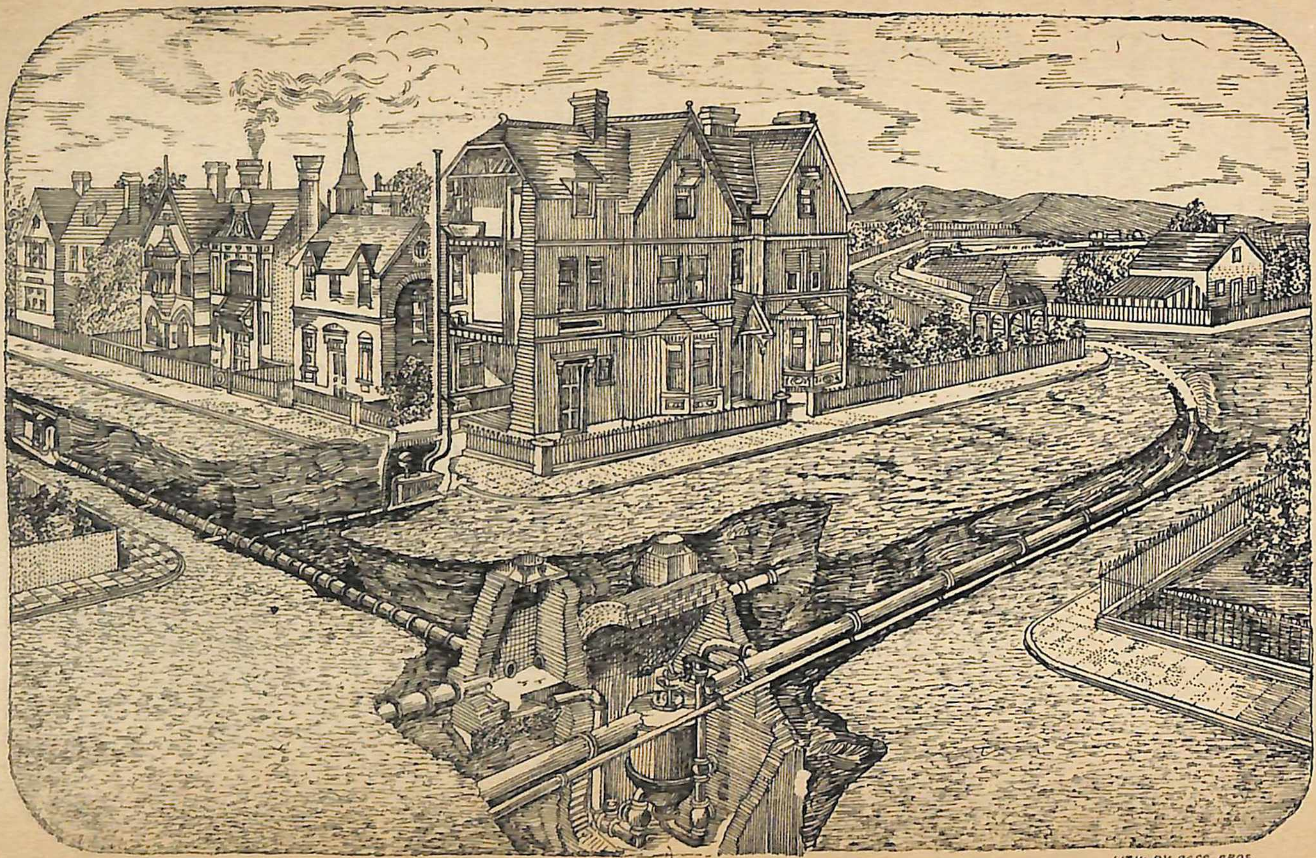
PLATE XI.

THE HYDRO-PNEUMATIC SYSTEM OF SEWERAGE (SHONE AND AULT.)

In the centre of the illustration is seen the 'Ejector' placed underground in a special brickwork chamber. The Afferent and Efferent Sewers are seen at the lower part of the ejector, the efferent sewer opening into the Cast Iron Main which conveys the sewage to the outfall. Running beside the main is seen the Small Pipe bringing the Compressed Air from the Central Compressed Air Station (not shewn), and connected with the Valve at the top of the ejector.

PLATE XI.



LITH: BY ROSS, BROS.

OTHER SYSTEMS OF SEWAGE REMOVAL.

There are three other methods for the disposal of sewage which must be mentioned, *viz.*, The Shone, Liernur and Berlier systems, all named after the inventors, and also a modification of the ordinary methods, termed the Interception system. In the Shone system *propulsion* by means of compressed air is the essential feature, in the other two systems *extraction* by means of a partial vacuum is the means adopted.*

Shone's Hydro-Pneumatic System.—This method is especially suitable in the case of low-lying towns where the sewers cannot be laid with steep enough gradients to carry the sewage to the outfall. There are plenty such towns in the Indian Empire, and one of these, Rangoon, has already adopted this system. Its object is to give, by means of compressed air, an 'artificial head' to the sewage and the effect produced is the same as if the sewage had been pumped up from a lower to a higher level. Careful study of the accompanying plate (XI) will enable the system to be understood in all essential details. The town is first divided into so many blocks or divisions. The sewers converge from each block to a common point where there is placed underground a hollow chamber, the *Ejector*. This has three openings into it—two main openings at the lower part and one small opening at the top. The small opening at the top is kept closed by a valve from which depends a rod carrying a float. The two main openings are simply those of the sewer bringing the sewage to the ejector (afferent sewer) and of the sewer which carries away the sewage (efferent sewer.) The former is closed by a hinged valve opening inwards, the latter by a hinged valve opening outwards. At a certain spot is constructed a complete set of machinery for supplying compressed air at any desired pressure (compressed-air station.) This compressed air is conveyed by a small pipe to the top of each ejector but cannot get into the ejector on account

* c.f. Artificial ventilation, p. 24.

of the closure of the valve guarding the upper opening. Suppose now the sewage from a block of houses is gradually flowing into and filling the ejector by gravitation. As it does so, the float is carried upwards and when the fluid in the ejector has reached a certain level the pressure exerted opens the floating valve. The compressed air immediately rushes in at a regulated pressure of so many pounds, the inward-opening flap-valve is closed, the outward-opening flap-valve is opened, and the sewage is forced out and *propelled* to a higher level. It then enters an ordinary gravitating sewer in most cases; or, if the rise has to be more gradual and the sewage carried a long distance, it enters a 'sealed' sewer of cast iron pipes. If the air is compressed 15lbs. to the square inch (1 atmosphere) the sewage will gain an artificial 'head' equivalent to a height of 34 feet. In Rangoon about 7lbs. (or just under 0·5 atmosphere) is usually sufficient.* It is worth noting that in this system the air is compressed at one station, the ejectors acting automatically. This means a saving of labour as compared with pumping stations of which there are ordinarily several.

Liernur and Berlier Systems.—Under the Liernur system the waste water, rain and subsoil water are disposed of by ordinary sewers. The system proper commences in air-closets—as distinguished from water-closets. These are simply iron receptacles of the same shape as a hopper-closet (*v.* pl. vi) with a siphon trap underneath. The excreta, liquid and solid, are passed direct into the closet, but no water is added. It is unnecessary to describe the construction and size of the pipes in detail. They are connected with reservoirs placed at certain spots below the ground, like the Shone ejectors. Instead of a compressed-air station there is in this case machinery for producing an air-vacuum. A vacuum is

* As noted on p. 56, in a town where the Shone system is in use, separate ejectors supplied from the central compressed-air station, but connected with the water mains instead of the sewers, can be laid for giving a 'head' to the water-supply, so that the latter can be distributed, without pumping, to the upper stories of the houses. This has been already done in Rangoon.

produced in the reservoirs and the valve connected with the street sewer is then opened by hand. The sewage rushes in and nearly fills the reservoir, thereupon a little air is admitted and the whole contents of the reservoir drawn away along the outgoing sewer to the central works where the sewage is dried in revolving cylinders and the resulting powder sold as manure. There is a great difference of opinion as to whether the system is an obnoxious one or not; it certainly appears on the face of it as if there were several valid objections to the plan. It will be noted that it does not do away with the necessity for other sewers, for not only rain and subsoil water have to be removed but all waste water except that from closets. As shown before, such waste water is almost quite as impure as when the excreta are added and is quite unfit for direct discharge into a watercourse.

The Berlier system* is a modification of the foregoing and is in use in Paris, the chief distinction being that it works automatically by a floating-valve arrangement, whereas in the Liernur system the valves have to be worked by hand.

Interception System.†—This system has been adopted in this country in the Blacktown sewerage works in Madras. In some cases, as at Berlin, in Germany, the sewers are composed of two parts, as it were (*v.* pl. IX), the lower and smaller part being the channel along which the sewage ordinarily flows in dry weather, and which leads to the ordinary sewer outfall at the sewage farms or other place of disposal. When heavy rain falls this channel is quite insufficient to carry off the stormwater which pours into the sewers in enormous volume. The result is that the entire sewer becomes filled with very much diluted sewage the greater part of which is 'intercepted' and carried off as storm overflow to an outfall into the nearest river or the

* For a good account of this system, *v.* Wallace, *op. cit.*, p. 135, *et seq.*

† The name 'Interception' is sometimes given to systems by which the solid are separated from the liquid excreta. As applied here it has a different significance, *viz.*, the 'interception' and carrying away of storm water to a separate outfall.

sea. In Madras, the arrangement is somewhat different. There the open drains are led into large gullies which have two openings, an upper and lower. Ordinarily, the sewage flows away by the lower opening into the sewers. In storm time the greater part of the mixed rain water and sewage enters the upper opening and is carried by the old drains to the sea on the one hand and to the canal on the other, whilst the remainder, which contains a relatively larger proportion of the sewage, enters the closed sewers through the lower opening in the gully (*v.* pl. IX). When the diluted sewage enters the sea or a tidal water the system is probably a good one and, from the engineering point of view, well suited to a country like this where enormous falls of rain occur suddenly. Where, however, the dilute sewage is conveyed into a river which is a source of water-supply it cannot be considered a very good plan. In addition, it fails to deal with that important thing—the subsoil water. As noted before, sewers should carry sewage only, whilst the rain and subsoil water are removed by drains. Of course, in a low-lying city like Madras the difficulty of doing this is very great. Where an interception system is in force, the best way would probably be to set apart a suitable piece of low-lying waste land near the river and to erect a *band* between this and the river. The dilute sewage, for such it really is, should be made to flow on to and flood this land into which it would gradually sink and be filtered downwards, the considerably purified effluent finding its way into the river. Such a system is at best a modification of the combined system and nothing but urgent pecuniary difficulties could justify its adoption in place of a good separate system. Even in this latter case, however, the original cost and extra taxation would almost certainly be more than repaid by improved general health and freedom from epidemics of filth-diseases.

DISPOSAL OF SEWAGE.

This is one of the most important and most difficult problems of the present day, its importance and difficulty being chiefly owing to the enormous aggregations of human dwellings which constitute the great cities of the world, *e.g.*, London, Paris, Berlin, Bombay, Calcutta, Madras, etc. In those towns which are properly sewered the amount of sewage to be disposed of daily is almost beyond belief, and in those which are not properly sewered it is absolutely certain that the subsoil of the town daily receives an immense amount of liquid impurity, which forms a hot-bed and nursery for many deadly diseases.

As a result of countless experiments and reports made in connection with this subject a very large number of processes for the disposal of sewage have been invented. These can be classified under several heads as follows :—

(1) The crude sewage is passed directly into the sea or tidal river.—*Direct Disposal.*

(2) The sewage is allowed to 'settle' in large subsidence tanks, the effluent being discharged into a river or the sea.—*Disposal by Subsidence or Mechanical Precipitation.*

(3) The sewage is subjected to mechanical filtration, with or without previous subsidence, the effluent passing on to land or into a river.—*Mechanical Filtration.*

(4) The crude sewage is made to flow over a large area of land whereon suitable plants are grown.—*Irrigation.*

(5) The crude sewage is made to flow over and through small tracts of land previously prepared by deep drainage.—*Intermittent Downward Filtration.*

(6) The sewage is introduced into tanks and some chemical precipitant added, the effluent, after subsidence of precipitate, passing on to land or into a river.—*Chemical Precipitation.*

(7) The Sewage is first treated with a precipitant and then filtered, the effluent passing on to land or into

a river.—*Combined Chemical Precipitation and Filtration.* (International or Ferrozone Process.)

(8) The sewage is exposed to the action of electricity.—*Electrolytic Process.* (Webster).

1. *Direct discharge into Tidal River or Sea.*—Formerly, as before remarked, when sewerage systems were first introduced into Great Britain, the whole of the sewage, waste water from manufactories, etc., were discharged direct into the nearest watercourse or into the sea. The result of this was the creation of a nuisance on a stupendous scale. Rivers which had formerly been the chief ornament of the towns situated on their banks, became nothing more nor less than open sewers, *e.g.*, the River Irwell at Manchester, the Thames at London and countless other rivers. At many seaside places, also, the sewage which was discharged into the sea was carried back by the returning tide and deposited along the beach in front of the town. In 1876 the Rivers Pollution Act was passed making it illegal to discharge crude sewage into streams, which term included rivers, canals, lakes and most watercourses; also the sea and tidal waters, except under certain restrictions and conditions. Unfortunately, owing to powerful opposing interests, the Act has been to a large degree inoperative, but there is reason to believe that it will be administered with greater strictness in the future.

For a long time it has been a disputed matter to what extent sewage, if discharged direct, or after partial treatment, into running water, becomes purified. Many interesting experiments have been made and reports submitted but the matter is by no means completely settled yet.* It is certain that river water which has been polluted may, in process of time, regain its purity so far as any available tests can show. But, to bring about such purifi-

* Even now, the authorities in the town of Aberdeen in the north of Scotland are undecided, on account of this difference of opinion, as to whether they can safely take water for the supply of that town from the river Dee, this same river receiving sewage from towns situated higher up in its course.

cation many conditions are necessary, *e.g.*, a course of many miles of the river free from any fresh or additional contamination, a rapid current, suitable temperature, etc., and it is impossible, in any river, to ensure that these conditions will always be fulfilled. As a matter of fact a river passing through an inhabited country is almost certain to be fouled at frequent intervals. In England "rivers which are once polluted with sewage so continually receive fresh accessions of sewage from towns situated lower down on their banks that the processes of self-purification are brought to a standstill, and the contamination of the water gradually but constantly increases from the source to the mouth of the river."* In this country, of course, the chief rivers are larger and longer, and though large towns are not so closely placed along their banks and they do not receive the same quantity of waste water from manufactories, still they are continually being polluted by filth of all sorts from towns and villages. In fact the smaller rivers are so foul already that in many cases they are in much the same condition as if large sewer outfalls opened into them. It will be seen then that many rivers are ordinarily so impure that any additional sewage purposely discharged into them would render them hopelessly foul. Finally, it must be remembered that many rivers, except the largest, dry up almost completely during several months of the year and could not therefore be used to carry off sewage from any town.†

The actual process of purification which sewage undergoes in running water is brought about chiefly through oxidation of the impurities by the oxygen dissolved in the water.‡ There is little doubt that certain kinds of bacteria

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* S. and M., *op. cit.*, p. 851.

† In Madras may be seen the horrible sight of sewers discharging their liquid filth into the more or less dried-up salt backwater named the Cooum. The sewers open many feet from the nearest water, and, as the water from the sewage which trickles out of the drains evaporates quickly, there is left a daily-increasing foreshore of black and most offensive slime. It is almost beyond comprehension that such a state of matters has been permitted to arise and continue in the capital town of a Presidency.

‡ *v.* p. 66.

and other micro-organisms play an important part in bringing about this oxidation. Additional oxygen is partly derived from solution of fresh atmospheric oxygen as the water runs over shallows and partly from the vital processes of the numerous water plants which grow in running water. The sewage matters also serve as food for certain fishes and for the countless low forms of animal life, *infusoria entomostraca*, etc., which flourish in impure water and which, apparently, may play a very important part in disseminating disease.* Subsequently, if fresh additions of sewage are made to the already impure water, the total available oxygen is quite insufficient, the fishes and plants die, and the number of putrefactive micro-organisms becomes greatly increased. Active fermentative processes are then set up and the river becomes simply an open sewer from which most offensive odours are given off. It is extremely difficult to trace outbreaks of particular diseases directly to such a state of things, unless such foul water is used for drinking purposes, but there is abundant evidence that it produces a low state of vitality in those who are forced to reside in the neighbourhood, so that they are only too liable to fall victims to any prevalent disease, *e.g.*, cholera.

With regard to the discharge of sewage into tidal waters there are many interesting points which cannot be dealt with here. The proper way, as before mentioned, is to store up the sewage in suitable tanks at the outfall and discharge it just as the tide begins to ebb. When salt or brackish water, however, comes in contact with fresh sewage, active chemical changes take place and the organic matters in the sewage are largely precipitated. If this goes on day by day a very considerable amount of offensive matter is deposited and in time may form a bank of sufficient size to interfere with navigation. The sewage may be carried back a considerable distance by the flowing

* *v.* p. 85, *et post.* Parasites of Man.

tide, or by variable currents, and cause a grave nuisance.* A peculiar and disagreeable smell, due to the formation of a chlorinated compound, is noticeable when crude sewage and salt water meet.

If then crude sewage is to be discharged into a tidal water or into the sea direct, many precautions must be taken and careful study made of the tides, currents, relative position of the town, etc., etc. It is very doubtful if it should ever be allowed, more especially in this country where it is so urgently needed for irrigation and manurial purposes. Under no circumstances should crude sewage be discharged into a river above the tidal reach.

2. *Mechanical Subsidence in tanks* and 3. *Mechanical Filtration, with or without previous subsidence.*

These two processes belong to the period when attempts were first made to purify sewage ere discharging it into a river. In the first case it is to be noted that large and costly 'settling tanks' are necessary and that the suspended matters are only very slowly deposited. In the second case the filters, made of gravel, charcoal, etc., soon become blocked and are costly to renew. The effluent in both cases is still highly impure and quite unfit to discharge into a river. Both processes are practically obsolete and need not be further described. Partial subsidence or straining, however, are still employed in many cases, ere allowing the sewage to flow on to land.†

4. *Irrigation.*—There are two methods of irrigation in use, *viz.*, *Broad* or *Surface* Irrigation and *Subsoil* Irrigation. The first method is by far the commonest and is undoubtedly of great importance in connection with sewage disposal in this country. It will be considered first and in considerable detail. Careful distinction must be drawn between this process and that known as Intermittent Filtration.‡ It is defined as the *distribution of sewage over a*

* As at London, or Loch Fyne in the W. Coast of Scotland.
† *v. post.* Irrigation and Intermittent Filtration.
‡ *q. v.* p. 183.

large surface of ordinary agricultural ground, having in view a maximum growth of vegetation (*consistently with due purification*) *for the amount of sewage applied.* That is to say, the sewage is allowed to flow over the ground, into which it sinks and is filtered, its products being oxidised and utilised as food for the crops grown on the land, whilst the filtrate or effluent passes into drains laid at a suitable depth and is carried along an outfall for discharge into a river or into the sea. The first essential in starting a sewage irrigation farm is a piece of ground *with a gentle slope towarde the outfall,* if possible, situated at a *convenient distance from habitations, moderate in price* and with a *soil of the proper kind.* The best kind of soils are light sandy soils with, if possible, a subsoil of gravel. The 'poorer' the soil the better, and pure sand is much preferable to a rich soil which is naturally damp and retentive of moisture.* As regards the amount of land which is necessary that depends primarily on the population of the place and secondarily on the kind of soil. In England it is generally stated that 1 acre should be allowed to every 100 persons; no rule available for all circumstances is possible. The number per acre will vary from 50 to 200 according to the nature of the soil and the average amount of sewage per head. In India, owing to the general absence of water-closets and to the rapid evaporation, the amount of land required for a given number will probably be less than in a European town.

The sewage is conducted by the main sewer to the highest spot on the farm.† From here it may be allowed to pass at once on to the land or may be roughly strained so as to remove any large solid matters.‡ The main

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* *v.* pp. 114-5. Almost any soil can be rendered more or less suitable by a little expenditure; careful under-draining is most essential save in the case of very sandy and porous soil immediately adjoining the sea.

† It is preferable to choose a piece of ground with a good natural slope so that the sewage can gravitate over the soil and be carried away by the under-drains. If the land is low-lying, pumping must be resorted to and this, being expensive, takes away a large amount of any profit otherwise accruing.

‡ In some cases irrigation is secondary to mechanical or chemical pre-

carriers are simply open channels of brick and cement or concrete, and are easily flushed and kept clean. The land itself is usually laid out in broad ridges from 30 to 50 feet across which slope away from the main carrier on either side. The ridges are parallel to each other and between each pair is a furrow or shallow channel in the earth. Down the centre or crest of each ridge there is also a grip or shallow channel. The sewage is applied intermittently* to various portions of the land; if applied continuously, the ground becomes water-logged, oxidation processes are at a standstill, and the land is said to be 'sewage-sick.' When any piece is to have sewage applied to it, a sluice is lowered in the main-carrier, or a piece of wood called a 'stop' is placed across it, thus damming back the sewage. The main-carrier then overflows, the sewage running down the grip in the crest of the ridge. This is blocked at intervals with earth and opened again† so that the sewage is made to flow by degrees all over that particular ridge. On the ridge is grown some suitable crop. Any sewage that does not sink into the soil on the ridge, runs into the furrow between the ridges. Ultimately, if the farm is properly managed, the whole sewage is absorbed by the soil and disposed of as before mentioned.‡

A great deal depends upon whether the town which

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cipitation, in other cases it is combined with intermittent filtration as will be explained afterwards.

* The number of hours or days during which sewage is allowed to flow on to a particular piece of land varies according to the absorptive power of the soil, the crop which is being grown, the weather and climate. In this country, probably, owing to the very rapid evaporation of moisture exposed to the direct rays of the sun, the period of flow may be rather longer than in colder countries.

† As is done by ryots in irrigating rice fields. Notice also that here the channel scooped out of the earth fulfils its proper function of *allowing* the sewage to sink into the subsoil: *cf.* the use of similar channels in the neighbourhood of houses in this country, where their proper function is to carry away the sewage and to *prevent* its sinking into the subsoil. *v.* p. 148, and Plate VII.

‡ The above is generally known as the 'ridge and furrow' system. There are many other plans adopted according to varying circumstances, but the principle is the same. The system in use in Madras is slightly different, the most important being that there is no under-drainage. For full description of the same, *vide* appendix, Madras Sewage Farms.

supplies the sewage is sewered on the separate or combined systems. In the former case, as explained before,* the amount of sewage to be dealt with is very much less than in the latter case which includes, in addition to the sewage proper, the greater part of the rainfall and all the subsoil water. Again, at certain times, *e.g.*, the Indian rains, the amount of sewage to be disposed of under the combined system would be enormous and would interfere very seriously with the working of the farm. Either the soil would become completely water-logged and the effluent only be half purified, or else a large part of the sewage would have to be disposed of elsewhere.† As a matter of fact there are several ways of dealing with an excess of sewage, which farms connected with a combined system have been forced to adopt. When the soil is almost pure sand and there is abundance of cheap land, it would be sufficient merely to turn the excess of sewage on to fresh waste land and let it gradually sink in, provided that there was no possibility of its contaminating any water-supply. Another plan is to choose a piece of land adjoining the irrigation fields, where the soil is as porous as possible, and to prepare it for intermittent filtration as described under the next heading. The proper plan, however, is *only to bring real sewage to the land,* as much rain water as possible and all subsoil water being excluded.‡ Of what use then are these sewage-farms from other points of view? As a rule they are merely utilised for raising one or two crops of grass in this country but in the near future there is little

* *v.* Table comparing separate and combined systems, p. 160.

† It is to be noted here that in India, typically in Madras, the sewage farms are on a relatively small scale. In Madras there are many farms each dealing with only a small portion of the town. Owing to the enormous falls of rain in this country, in a short time, the combined system of sewerage is quite unsuitable. A modification of it, known as the Interception system, whereby the storm waters are carried direct to the nearest outfall in rainy weather, is in use in Blacktown, *v.* p. 171. I believe it to be a most dangerous error to say that sewage diluted with rainwater is harmless and can be discharged into a possible source of drinking water; especially in India where the sewage always contains excremental impurities.

‡ In fact, the oft-quoted maxim 'The rain to the river, the sewage to the soil,' applies correctly.

doubt their uses will be considerably increased. They afford excellent grazing for cattle of various sorts and it is very doubtful whether there is any chance of disease being communicated to the animals, and thence to man, from such a practice; although at one time the danger was regarded as considerable. In Madras the chief crop raised is *hariali grass* for which there is considerable demand. It grows most luxuriantly and forms a marked contrast to the stunted and earthy bundles brought in from the country by the grass-cutters. *Guinea grass* and *lucerne* grow well,* but there is not such a demand for them. In England many different sorts of plants are grown and find a ready sale. At Craigentinny, near Edinburgh, irrigation has been carried on for many years, the formerly barren ground yielding many crops of well-grown rye-grass every year. With care, wheat, oats and other cereals can be raised and, in this country, rice. Tap root vegetables, such as turnips, beet-root, rabi, etc., do well, likewise potatoes, if not over-sewaged, and many other crops. If there is any surplus of sewage, it can often be sold to cultivators with land in the immediate neighbourhood, care being taken that proper restrictions are put in force with reference to the working of the sewage-cultivated land.

Subsoil Irrigation is a process allied to the foregoing and is specially suitable for isolated institutions like jails, barracks, etc., where the drains do not connect with any sewerage system and the sewage has to be disposed of at a short distance from the buildings. The usual way of getting rid of the sewage in such cases is by the use of cesspools or by discharging the sewage into a neighbouring stream which probably receives sewage from numerous other farms or houses and is simply an open sewer. Subsoil irrigation, if properly carried out, is much preferable in every way. It can be applied also to villages but, in this

* They are growing well at the present time at Government House, Ootacamund, the crops being irrigated with sullage water from the dwelling lines and stables.

country, broad irrigation is likely to be more generally adopted.

A piece of ground is chosen, as in the former case, situated at a lower level than the buildings and with a gentle slope. The sewage is conveyed to the ground by the ordinary water-tight pipe sewer from the house or houses and flows into under-ground porous drain pipes,* about two inches in diameter, which are placed at a depth of half to one foot under the soil, their joints being open. These pipes are laid in rows about six feet apart and ramify through the selected piece of ground. Their ends are laid upon cradles made of half pipes and are covered above in a similar manner so as to allow the sewage to escape, whilst preventing earth falling into them (*v.* pl. vii.) In a loose, porous soil this is all that is required; when it is denser and more retentive, a catchwater drain should be laid at the lowest point to convey the effluent to the nearest stream. If the amount of sewage is small, it may be necessary to use an automatic siphon flush tank (*v.* pl. x) which allows the fluid to accumulate for a certain time and then discharges the total amount with considerable force.†

The process of purification is much the same as in surface irrigation, the sewage, as it passes out of the open pipe joints, being exposed to the action of the roots of growing plants—grasses, vegetables, etc., and to oxidation processes in the soil.

It is, of course, of extreme importance that the effluent in sewage farms, when there is any, should be of sufficient purity to ensure its being safely discharged into water, so that there may be no risk of its contaminating a water-supply. Now, its purity depends upon several things which

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* Ordinary agricultural drain-pipes will do. If excreta or other solid matters are added to the sewage, it is customary to strain the solids off, first and to dispose of them by spreading on land and digging them in. *v.* p. 152.

† This practice is much the same as that alluded to on p. 152, only here the sewage itself fills the tank and scours the sewer, whilst in the case of large sewers the scouring is done by clean water from the water-main.

may be included under the management of the sewage farm. If the ground is properly prepared and of suitable nature, the under-draining carefully done and the sewage not too continuously applied to any one part, then the effluent is wonderfully pure. The organic impurities, estimated as so much nitrogen, are very much reduced in amount. The suspended organic impurities should be completely removed, whilst the nitrogen in the dissolved impurities is almost entirely in the form of harmless nitrates and nitrites.* In other words, by bringing the sewage to the soil the latter is supplied with a most valuable and easily-assimilable† manure, whilst the former, which is otherwise a continual menace to health and a standing nuisance, is completely got rid of.

5. *Intermittent Downward Filtration.*—By the process to which the above name is given is meant the *concentration of sewage, at short intervals, on an area of specially chosen porous ground, as small as will absorb and cleanse it; not excluding vegetation, but making the produce of secondary importance.* In other words the soil is here the principle purifying agent, the action of the roots of growing plants being an additional and non-essential, though usual, part of the process. A suitable piece of ground is chosen, as in surface irrigation, only in this case the amount required is much less. It is divided into 'lots' of equal size. As regards the proper sort of soil, what has been

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* "All the constituents of sewage are greatly reduced by irrigation, with the exception of chlorine, which is very slightly reduced, or even sometimes apparently increased, owing to the concentration produced by evaporation: but the constituents which are most effectually removed from sewage are especially the putrescible organic matters—those, namely, which it is essential to remove both from an agricultural and sanitary standpoint. Nitrates and nitrites do not exist in sewage, but are usually found in the effluent water to some extent, and are evidence of the oxidation processes to which the sewage has been exposed in the soil." S. and M., p. 883.

† It should be noted that in the case of liquid sewage the nourishment supplied is mostly brought to the roots of growing plants already dissolved and is quickly assimilated. Where excreta and general dry refuse are dug into the soil and buried, the crops have to be sown afterwards, and it takes some considerable time for the organic matter to be brought into an easily assimilable form for plant nourishment.

said of surface irrigation applies equally here. The best soil is a sandy loam with a small proportion of gritty gravel to quicken percolation. The soils most unsuitable are very dense clays, bog peat and very coarse gravels. Any soil which cracks during dry weather, *e.g.*, black cotton soil, is thoroughly unsuitable, as the sewage simply flows down the cracks and reaches the effluent outfall quite unpurified.*

The sewage is brought to the highest part of the ground and is roughly screened of its larger solid matters. It is then ready for distribution which is so arranged that it can be made to gravitate slowly over the various plots of land in order. For six hours each plot receives the sewage and for eighteen hours the flow is intermitted. By this means the soil has time to recover itself, so to speak; in other words, it becomes re-aërated and is able to re-commence the purification of fresh supplies of sewage. First of all, the ground is very carefully levelled to ensure even distribution of the sewage and is then dug into small ridges and furrows. On the ridges vegetables or other crops are planted and the sewage flows along the furrows. At the commencement, it mostly sinks into the furrows, but after a time, when the furrows have become lined with a deposit of the suspended matters known as 'sludge,' the sewage does not sink readily into the furrows, which resist the infiltration, but is "driven into the ridges on each side." In this way the liquid sewage is brought

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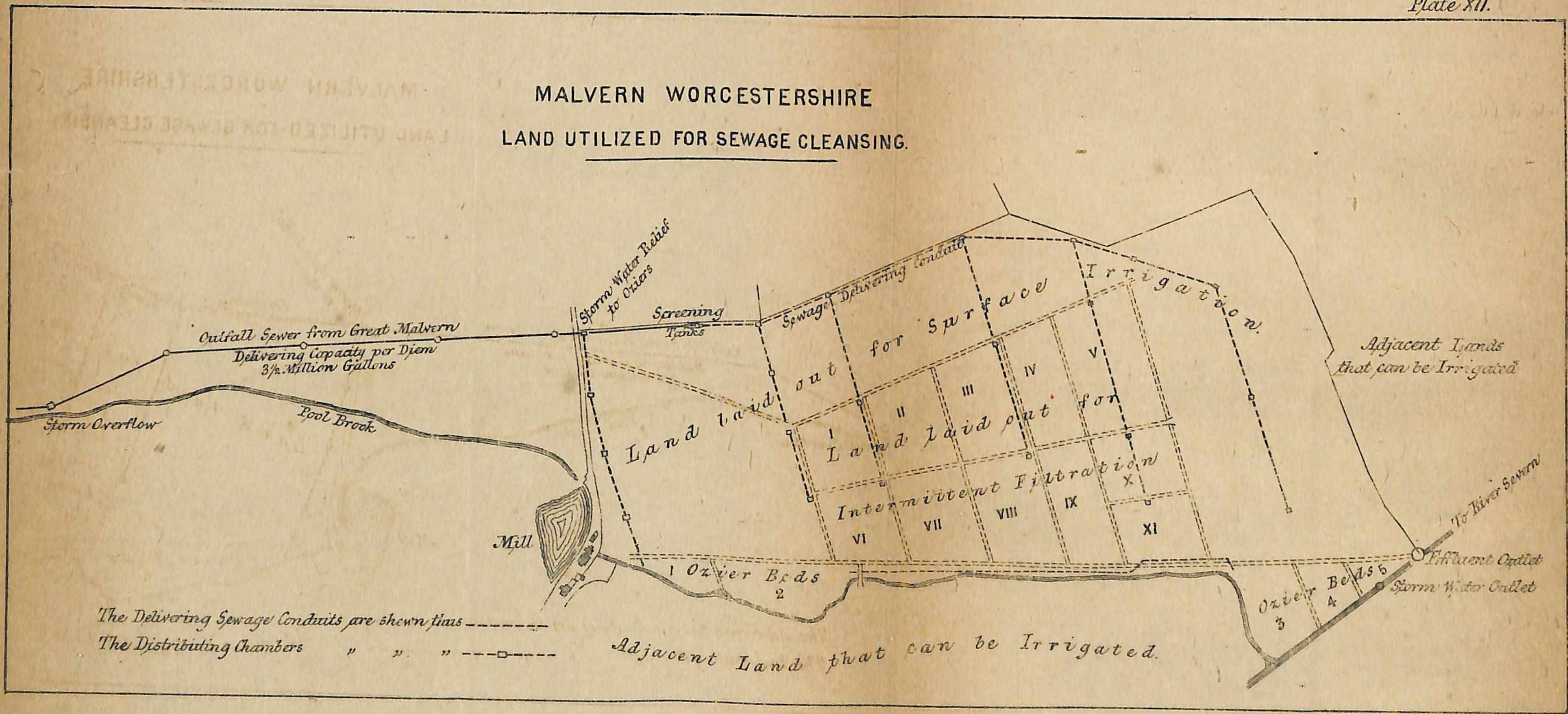
* Note also that the capacity of soils to absorb water is no criterion whatever of their cleansing capability, whilst their *retentive* powers exercise great influence on the rate of percolation and the quality of the effluent. A coarse gravelly soil thoroughly drained, for instance, will absorb and discharge liquid almost as quickly as it reaches the surface and will give out an effluent but imperfectly purified, whereas a loamy soil, having a sufficient proportion of sand to render it free and to fill it with close interstitial spaces for aëration, will discharge a satisfactory quantity of purified water by under-drains and maintain a very superior effluent. Closely related to the absorptive and retentive powers of soils is their evaporating property, the effect of which at certain times of the year is so great that in cases where there is no subsoil water to dilute the effluent, the quantity discharged has been less than half the quantity of the sewage distributed over the surface. *v.* Sewage Disposal, Bailey-Denton, 2nd ed., p. 49, *et seq.*

Plate XII.



G. PACZENSKY LITH:

To face p. 184.

PLATE XII.

PLAN OF SEWAGE FARM AT MALVERN, IN ENGLAND.

(After Bailey-Denton).—The Plan shows the Land Laid Out for the Cleansing of Sewage by Intermittent Downward Filtration, and by Surface Irrigation, with Storm Water Reliefs to Ozier Beds; the Effluent passing into the River.

into contact with the *roots* of the vegetables only and does not contaminate their stalks and leaves. Afterwards, when the furrows are filled with sludge, the latter is allowed to dry partially and is then lifted out and dug into the ridges.

The soil is under-drained precisely as in surface irrigation, the drains being very carefully laid at a depth of about four feet from the surface. If the process is properly carried out, the effluent will be very pure, as in surface irrigation, and can safely be discharged into a water-course.

The preparation of the land for intermittent downward filtration is more expensive than for surface irrigation, but much less land is required. Some authorities advise the previous clarification of the sewage by chemical treatment (precipitation processes); (*a*) because the slimy matters in crude sewage tend to block up the pores of the soil by forming a thin pellicle on its surface and (*b*) because the sewage does not putrefy to such an extent after chemical treatment and therefore undergoes nitrification more easily. In this country it is very unlikely, save possibly in the largest towns, that any such chemical treatment will be adopted. If precipitation is resorted to in the first instance, it means that an enormous amount of 'sludge' will be accumulated, the disposal of which will be a matter of extreme difficulty. Careful arrangement of the ground, so that the crude sewage *gravitates slowly* along furrows, the latter being cleared at intervals and the deposit dug into the ridges, appears much simpler and more suitable in every way for adoption by Indian municipalities.

Intermittent downward filtration is very rarely, if ever, adopted to the exclusion of surface irrigation. This latter is nearly always combined with it so that part of the farm is laid out for intermittent filtration, the remainder, and larger portion, for broad irrigation. In most cases there is also a special piece of ground, laid out in ridges and furrows and planted with osiers,* set apart for storm overflows in time of very heavy rain. It is not underdrained and merely serves to check the rush of storm water, which is prevented from flowing into the ordinary filtration area until most of the suspended matters have subsided in the furrows and the liquid has undergone a certain amount of clarification by flowing over the ridges and amongst the osier roots.

6. *Chemical precipitation.*—This method of purifying sewage is essentially the same in principle as that sometimes adopted for removing the suspended impurities in drinking water.† It consists in the addition to the sewage of one or more substances that form a precipitate which carries down in its meshes the greater part of the suspended matters and sometimes a small portion of the matters in solution. An enormous number of processes have been patented from time to time, but of these only very few need be noticed here and very briefly. *Lime,* as milk of lime,‡ or simply as lime water, has been largely used for a long time and is the chief or only precipitant in a number of cases. *Aluminous* substances, in one form or another, are also in great favour. Impure sulphate of aluminium, the refuse of alum works, aluminous earth with sulphuric acid added to it, alum and powdered clay mixed, have all been tried. A favourite mixture is milk of lime and sulphate of alumina.

Lime, when added to sewage, exerts the same action as when added to water in the process of 'Clarking,'§ the insoluble carbonate of calcium carrying down the greater part of the suspended matters in the sewage. If too much lime is added, the effluent is rendered distinctly alkaline and, although the precipitation is very rapid and the

* Osiers are plants with thin flexible stems which are used in basket-making, etc., as cane and bamboo are used in this country. They are not an essential feature of such storm overflow reserves (*v. ante*, p. 172), but help to retard the flow of water by their long twisting roots much as mangrove roots do in a swamp. No doubt some other plant, such as oleander (?), could be utilised in the same way in this country.

† *v.* p. 87. ‡ *i.e.*, lime slaked and added to water. § *v.* p. 73.

effluent clear, it has been found that the excess of lime causes solution of some of the previously suspended matters. Thus the effluent is really made more impure and, being strongly alkaline, undergoes secondary fermentation or decomposition* more readily. Now, one great object of the chemical treatment of sewage is to prevent this secondary decomposition taking place, in order that the effluent, when discharged into a river or other watercourse, may not give rise to nuisance. The lime process, then, cannot be considered sufficient of itself.

Sulphate of aluminium has likewise the same action on sewage as when added to drinking water†, a bulky, flocculent precipitate of aluminium hydrate being formed, whilst the sulphuric acid combines with the calcium in the sewage to form sulphate of calcium. The effect on the sewage is much the same as in the lime process, save that the impure aluminium sulphate being slightly acid the effluent is neutral or even acid. This tends to prevent secondary decomposition taking place, but an acid effluent is unsuitable for irrigation of growing plants. It has, therefore, become customary to use these two substances, *viz.*, lime and sulphate of aluminium, together, the special object being to produce an effluent and precipitate which are neither acid nor alkaline, or, in other words, as nearly as possible neutral.‡

Amongst other substances which have been used as pre-

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* By secondary decomposition is meant the fermentation which takes place in the effluent—which contains nearly all the original dissolved impurities—after it is discharged into a stream or otherwise disposed of.

† *v.* p. 73.

‡ To sewage of average strength the amount required of each substance is about 5 grains per gallon of sewage. The Corporation (Municipality) of the city of Glasgow have recently determined to adopt this process for part of the sewage of that town. The new works will deal with the drainage of an area of 26,035 acres, representing 10,000,000 gallons of sewage *per diem*, from a population of 265,000. The sewage will be treated with sulphate of aluminium and milk of lime: after precipitation it will be aërated, to promote oxidation, and then filtered, the clear effluent being passed into the river Clyde (not used as a water supply for domestic purposes). The sludge will be compressed by air into cakes and, in conjunction with other refuse, may be available for manurial purposes. *v.* Brit. Med. Jour., 18th March, 1893, p. 598.

cipitants are charcoal, bone ash, black ash, chlorides of sodium and calcium, sulphate of zinc, magnesian and iron salts, tar, creosote and many other things, most of the processes being known by the name of the inventor. It is unnecessary to describe any of them in detail here.

In dealing with sewage by such 'chemical' processes, there are several things to be kept in view. (1) The process must be made to pay the whole or part of the cost if possible. (2) Care must be taken to prevent the possibility of a nuisance being caused. (3) The effluent must be rendered so pure, if possible, as not to interfere with the use of the river as a drinking water supply, or at all events so as not to interfere with the animal and plant life in the river. For consideration of these points, it is best to divide the subject into two parts, discussing the precipitate first and then the filtrate.

The disposal and utilisation of the precipitate or *sludge*, as it is called, is a matter that is by no means satisfactorily settled. When the sewage is brought fresh to the works, the larger solid matters are removed by straining. Afterwards the chemicals are added to the sewage as it flows along, so that the two are well mixed ere arrival at the precipitating tanks. In order to permit of periodical emptying and cleansing, a double set of two or three tanks in line is usually provided. The sewage is allowed to flow slowly but continuously through one set of tanks for several days, and then, after all the effluent has flowed away, the sludge is allowed to settle. Thereafter, being more or less in a fluid condition, it is forced up in pipes to the filter presses, where it is compressed by air into cakes, the excess of liquid, which is still very impure, flowing away for treatment again. It still contains over 50 *per cent.* of moisture and it takes about 850 tons of sewage to produce one ton of such sludge. Consisting, as it does, chiefly of water and mineral matter its manurial value is very small, hence its market value is almost *nil* and in many cases farmers actually demand payment to remove it. In one process, known as General Scott's or the 'sewage-cement' process, lime and clay were used as precipitants, the resulting sludge being dried, burnt in kilns, ground into fine powder and sold as cement.*

As regards the filtrate or *Effluent*, it is of extreme importance to note that, though the major part of the suspended matters are got rid of, the dissolved organic matters are untouched. Now, these dissolved impurities are just those which are most valuable from the agricultural and most hurtful from the hygienic point of view. Wherein then lies the advantage of the chemical treatment of sewage? In the case of a city like Glasgow where the chief object is to prevent the creation of a nuisance in the Clyde and neighbourhood, where the river is tidal above the point of discharge of the effluent and is not used as a source of drinking water, it may be sufficient to remove the suspended matters and to take means to prevent the effluent undergoing secondary decomposition. But in the case of inland cities the conditions are different and chemical precipitation processes are of themselves quite incapable of dealing satisfactorily with large volumes of sewage. The only reliable method, and one which is being adopted more and more, is to treat the sewage first of all by chemical precipitation, *if necessary*, and then to pass the effluent on to prepared land either for surface irrigation or intermittent downward filtration.

7. *International* (*Ferrozone*) *Process.*—This is a somewhat novel process which has been tried near London with a considerable degree of success. The sewage is first treated with a precipitant called ferrozone,† the whole of the suspended and some of the dissolved matters being thrown down. The effluent is then passed through two

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* *cf.* treatment of material produced by burning dry refuse in incinerator, *v.* p. 145.

† Called 'magnetic ferrous carbon' and consisting largely of protosulphate of iron.

filters by intermittent downward filtration, the filters being composed, from above downwards, as follows:—

Nine inches of sand.
Ten inches of mixed sand and polarite.*
Six inches of sand.
Four inches of gravel the size of peas.
Coarse gravel, which is intersected with catch-water drains laid on the floor of the filter.

The filtration is conducted slowly, the filter beds being used intermittently to allow of fresh aëration. The polarite can be used for a long time, but the sand must be changed at fairly short intervals. The resulting effluent is wonderfully pure and contains nitrites and nitrates, showing that a considerable amount of oxidation takes place. It is claimed that one acre of such a filter bed will purify from one to two million gallons of clarified sewage daily. From a hygienic view the process seems to be a success, but it is a costly one. It appears suited for well-to-do towns situated on inland rivers, where land suitable for irrigation or downward filtration is not available.

8. *Electrolytic Process.*—The application of electricity to the treatment of sewage is the idea of Mr. Webster, F.C.S., who remarks—"The oxidation of organic matter can only be obtained by one mode of chemical action, whether it be by filtration accompanied by the action of micro-organisms, the addition of chemicals or mechanical force represented by the electric current." The sewage is made to pass through two 'electrolytic shoots' or brickwork channels divided into cells containing iron plates. Every alternate plate is connected respectively with the positive and negative poles of the generator.† During the passage of the sewage through the shoot, a flocculent precipitate of hydrated ferrous oxide (?), produced by the action of the electric current on the iron electrodes, is formed. The

* Called 'magnetic spongy carbon,' and consisting largely of magnetic oxide and carbide of iron.

† A dynamo driven by a steam engine.

resulting effluent is very considerably purified and, apparently, all living organisms destroyed, so that it does not readily undergo secondary fermentation. Very little extraneous matter is added to the sewage and this means that the amount of sludge is relatively small. The process, however, is a costly one both on account of initial outlay for plant and the waste of power, and the resulting sludge has no great value. Its use will probably be confined to certain towns where the amount of manufacturing refuse is very great and not easily amenable to other treatment.*

HEALTH IN RELATION TO REMOVAL OF REFUSE MATTER.

This, of course, is the most important part of the subject now under consideration. It is quite right that pains should be taken to ensure that no accumulations of filth shall be allowed to pollute the air or offend the eye, and it is also quite right that the removal of all refuse be done at a reasonable cost, if possible, and that it be disposed of at a profit likewise, if possible. But *the* point for consideration of sanitarians is—*How best to remove and dispose of all refuse so as to minimise the risk of disease being caused by it, directly or indirectly?* Before taking up this point, however, it must be seen what is the experience of India and other countries in this relation.

The most important enquiry in England in this direction was that carried out by Dr. Buchanan, but, of necessity, it did not deal merely with the introduction of sewerage systems, but with sanitary works as a whole.†. It is extremely difficult in most cases to assign accurately to each sanitary factor its part in lessening disease, but it can sometimes be done: the result is, in many cases, sufficiently startling. Buchanan chose twenty-five towns of varying size where sanitary improvements had been instituted for some time, and the general result was that of

* For an account of the process in considerable detail, *v.* paper by Dr. MacLintock. Brit. Med. Jour., 30th August 1890.

† Including improvements in house, subsoil and surface drainage, improvements in water supply, in removal of town refuse generally, and in the ventilation, etc., of lodging houses.

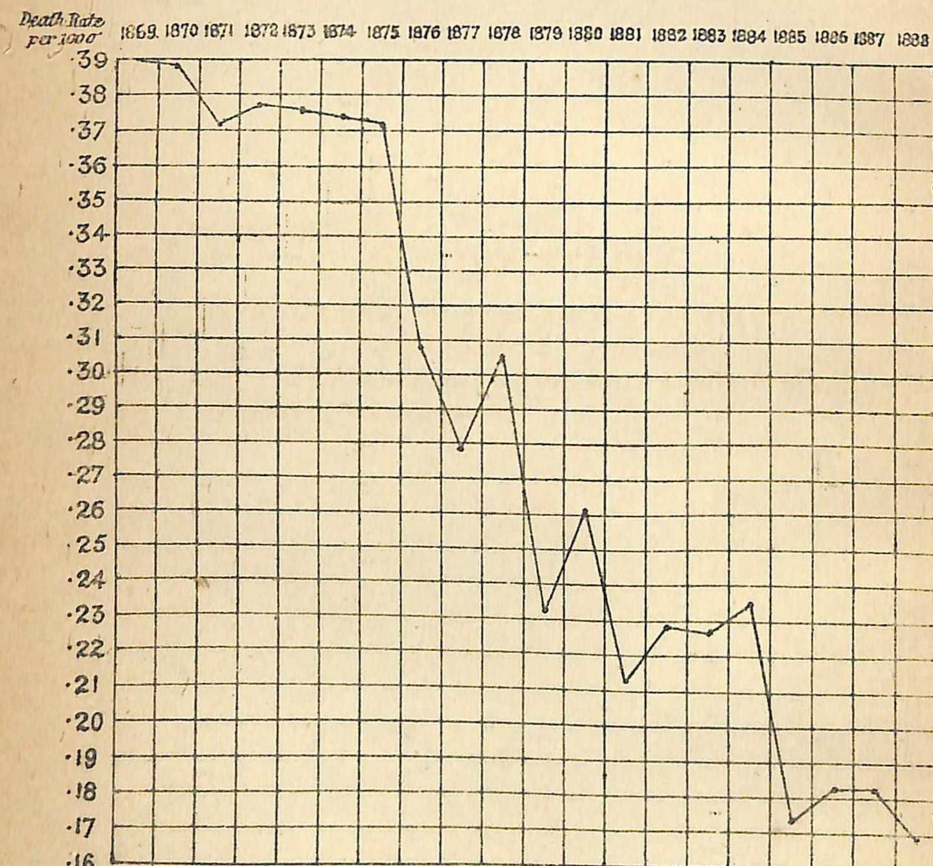
these towns twenty showed a reduced death-rate since the completion of the sanitary reforms. This reduction was especially due to the diminished mortality from enteric fever and cholera, as also, no doubt, to a generally-improved condition of health leading to a greater resistance to attacks of disease. For further details the original report may be consulted.* In the town of Munich, in Germany, since the introduction of a sewerage system in place of the former porous cesspools, the average annual number of deaths from enteric fever has fallen from 208 to 40. The accompanying table (pl. xiii) shows clearly the wonderful diminution in enteric fever mortality which has taken place in England and Wales from the year 1869 onwards, the decrease being specially marked in the years 1876-77.†

Coming now to this country, it may at once be stated that the available information and experience are far from what they should be. The cause of such a state of matters need not be discussed here, it will be remedied in time to come and with results that will appeal to the most sceptical. Of one thing there is absolutely no doubt, and that is *to the present ignorance and apathy concerning the significance and means of effective removal and disposal of the refuse of towns and villages, and especially the excreta, is due to a very large proportion of the diseases which decimate the inhabitants.* "It has long been," says Sir John Simon, "among the most fixed of the certainties which have relation to civilised life, that wherever human population resides, the population cannot possibly be healthy, cannot possibly escape recurrent pestilential diseases, unless the inhabited area be made subject to such skilled arrangements as shall keep it habitually free from the excrements of the population." It cannot be denied that there is, at

* *v.* Ninth Report of the Medical Officer to the Privy Council. *v.* also extracts from the same in Public Health Reports, Sir John Simon, Vol. ii, p. 262, *et seq.*

† The Public Health Act was passed in 1875, leading to the appointment of District Medical Officers of Health and consequent great improvement in sanitary matters, especially those relating to refuse removal and pure water supply.

Plate XIII


Death Rate per 1000
1869 1870 1871 1872 1873 1874 1875 1876 1877 1878 1879 1880 1881 1882 1883 1884 1885 1886 1887 1888
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To face p. 192.

PLATE XIII.

TO ILLUSTRATE STEADY DECLINE IN TYPHOID FEVER MORTALITY, IN ENGLAND, FROM THE YEARS 1869 TO 1888 INCLUSIVE.

(STEVENSON AND MURPHY.)

present, no single town in India habitually free from the excrements of the population. Most praiseworthy efforts to bring about such a state of things have been made by sanitary authorities, but as yet the lions of ignorance and sloth have barred the way. Individual effort and example are wanted and until the people as a whole are shown that carelessness with regard to the disposal of refuse of all sorts, and of excreta in particular, is a *crime*, it is hopeless to expect much improvement in the present condition of matters throughout the Empire.

In the larger towns efforts have been and are being made to deal effectively with the subject, but they are, as a rule, partial and incomplete. "Rangoon is now the only city in the Indian Empire which can boast of a scientific system of drainage which fulfils all the requirements of sanitarians." Previous to 1873 the land was honeycombed with cesspools and the drinking water correspondingly polluted. Thereafter the cesspools were closed by order and the night soil collected by carts and thrown into the river. This horrible system obtained till 1890 when the Shone system was adopted at a cost of more than twenty lakhs of rupees. With thorough conservancy of dry refuse, a good water supply and efficient subsoil drainage, supplementing the effect of such a system of sewage removal there is little doubt that this great and rapidly-increasing city will take the lead in healthiness from her more conservative and poverty-stricken Indian neighbours. Bombay is likewise making a laudable attempt to deal with her enormous mass of liquid and solid refuse. Up to 1891 about 56 miles of sewers had been laid. "The main principle on which the sewerage works have been designed is to secure segregation of storm-water from the sewage, a necessity consequent upon the concentration of the annual rainfall within a short period of the year, and on the inability to construct channels to do the dual duty of sewers and drains under the variable conditions of flow during the dry and wet seasons. Before the new works were commenced, the city was drained by flat-bottomed masonry drains, many of vast dimensions, which received both storm-water and sewage, and which during fair weather became merely elongated cesspools. Under the present project, the main sewers have been constructed on the most approved and modern principles of sanitation. The sewerage works when completed will cost probably not less than £1,000,000," or more than 130 lakhs of rupees. Calcutta and Madras have also made attempts to provide themselves with good sewerage systems but, for various reasons, with not conspicuous success. In all these cities and in many others the question of effective disposal of dry refuse by fire is also being considered, so that, given rapid removal and disposal of both dry and liquid refuse, one great evil will have been abolished.

As said before it is too soon to attempt to reckon the good which will result from such reforms, added to which is the very imperfect registration both as to the number and causes of deaths in these towns. If these remarks are true for the chief towns in India much more are they true for the smaller towns and numberless villages. At present sanitary reformers can but continue quietly and persistently the great work of cleansing these Augean stables, confidently leaving the justification and approval of their doings in the hands of their successors.

WHAT SYSTEMS OF REMOVAL AND DISPOSAL OF REFUSE ARE BEST FOR INDIA?

Having thus briefly described the various methods for removal and disposal of waste matter, including excreta, and considered very shortly the influence exercised on the health of towns by such rapid and systematic removal, it is necessary to examine and compare together these methods with reference to their relative merits for adoption in the towns and villages of this Empire.

Firstly, then, let these two axioms again be carefully noted :—In adopting any conservancy system whatever, provision has to be made for the removal of both wet and dry refuse, and,—Whether the excreta are added intentionally to the waste water (sullage) or not, the latter is highly impure and, unless quickly and suitably disposed of, becomes a nuisance and a danger to health. There are thus three things to be considered :—

(1) The best methods of removal and disposal of dry refuse in India.
(2) ... ... liquid " "
(3) ... ... excreta. "

1. *Removal and Disposal of Dry Refuse.*—Very little need be added to what has already been said on this subject. Sometimes a distinction is made between 'organic' and 'inorganic' dry refuse,* but in practice, with rare exceptions,† the two are intimately mixed. There is no better plan, at present known, for the destruction of the organic matter in dry refuse, than exposure to heat in an incinerator. It is not, of course, really *dry* refuse when brought to the incinerator for it contains a very large amount of moisture which interferes with the process of combustion and special devices are necessary to overcome this difficulty. It now appears, however, to have been successfully surmounted and, if so, there is no doubt that in a few years nearly every town in India of any considerable size will avail itself of this method for the disposal of its dry rubbish. In the smaller towns and villages the disposal will still have to be by incineration or by removing it to a safe distance and spreading it on land, with due precautions, as already described. If sold to contractors as manure,‡ stringent regulations are necessary to prevent the creation of nuisance and pollution of water-supplies.

2. *Removal and Disposal of Liquid Refuse.*—This is a very important and somewhat neglected branch of the

* *v.* McNally, *op. cit.*, pp. 106-7.

† During the destruction of large buildings condemned from age, a large amount of so-called inorganic dry rubbish may be available but this is not common. In such cases the safest plan would be to spread it on land, cover with a foot of earth and leave undisturbed for several years.

‡ In 1885 nearly Rs. 85,000 were realised from the sale of dry refuse in the Punjaub, principally consisting of excreta, however. It is only when excreta are added to dry refuse that it is saleable to any extent.

subject under consideration. Dry-refuse and excreta are so much *en évidence* that their removal and disposal is early looked to by sanitarians. To many of these latter in this country, however, the sewage, unless it includes the excreta, seems a small matter. They are so firmly persuaded and grounded in their belief that 'dry' methods are essential for a tropical climate that they overlook or ignore the existence, or at all events the importance of, house sewage. The amount of such liquid refuse that really needs disposal may be faintly realised by a visit to the lines of a native regiment where each house has in front of it a large receptacle sunk in the ground, into which the waste water from the house trickles along an open drain. From the usual condition of the drain and from a knowledge of the habits of the people it may be safely inferred that not more than one-half, at most, of the waste water reaches the receptacle, yet these require emptying every two days, if not oftener, and in spite of the rapid evaporation under a tropical sun.*

At present in most towns and nearly all villages there are two ways in force for the getting rid of this sewage. One is the more general, but hardly more hurtful, plan of simply making no provision whatever for its removal, reliance being placed merely on the absorptive power of the soil and surface evaporation.† The other, and more ostentatious method, is the construction of a series of shallow, and in every way imperfect, open drains, ending nowhere in particular or in a tank or watercourse used for bathing and drinking. And all this is harmless because the sewage does not contain added excreta, or is not *supposed* to! There is no greater error possible. A moist subsoil saturated with organic matter is undoubtedly a favourable nursery for disease contagia and what is more likely than

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* *v.* also note p. 147.

† As illustrated in perfection in the immediate neighbourhood of 90 *per cent.* of the kitchens (*sic*) belonging to the bungalows of the wealthier classes, European and otherwise. *v.* Chap. v. Buildings.

that such a breeding ground should become inoculated with the poison of enteric fever and other diseases.*

It is necessary then to realise clearly that this house sewage is a waste product for the removal and disposal of which definite and sufficient provision must be made. For very small villages or for isolated houses all that is necessary is a well-laid open drain of proper shape and material† leading to a garden where the sewage can be daily utilised.‡ The drains must be kept clean and flushed with water occasionally if necessary. In time of heavy rain the liquid flowing along the drain will be almost pure water and can be safely diverted into the ordinary surface channels or, better still, run on to waste ground. For larger villages and most towns there should be a proper system of such open drains *very carefully laid and constructed, great attention being given to proper gradients.* If necessary, liquid excreta may be allowed to enter these drains but any attempt to use the drains, morning and evening, as a substitute for latrines should be at once punished.§ Having constructed such a system it should be made to end in some spot where the sewage can be harm-

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* Not long ago a lady, resident in an official bungalow at one of the finest hill-stations in India, was attacked with severe enteric fever. On examining the waste water pipe from the bath-room, it was found to open into a brick drain that ran about four feet and then terminated abruptly. In addition, there was no catchwater drain for the water dripping from the hill above so that the ground at the back of the house was always damp. On digging up the soil round the termination of the drain, which latter had apparently 'silted up,' it was found to be saturated and discoloured with greasy organic matter and the stench emitted was fearful. No other cause for the attack could be discovered and it was quite an isolated case. It was almost certainly attributable to the above-noted defective state of things. The general health also, of the other occupants of the house was by no means good. Since the introduction of a proper system of open drains carrying off all rain and sullage water, there has been no further sickness.

† *v.* pl. ix. If cheapness is essential the drains can be built of good bricks laid in mortar, pointed with cement and the whole thickly tarred.

‡ *v.* Chap. v. Buildings.

§ In the case of adults by fining at first with imprisonment on subsequent conviction: in the case of children by the cane. If due notice of such being a punishable offence has been given to all and sundry, there is no earthly reason why punishment should not follow a breach of the rule. It is done with admirable success in military lines, as also under military rule in Burmah, and if the police were compelled to arrest every translessly and, if possible, usefully disposed of by irrigation or otherwise.* In the largest towns the disposal of the sewage forms part of the question of disposal of excreta and will be considered under the next heading.

3. *Removal and Disposal of Excreta.*—From the description of the various methods of removal and disposal given in the earlier part of this chapter it is easy to gather a general idea of those which are most suitable to this country. For small towns and for villages there is no other known plan of any efficacy save the dry method of removal, with or without admixture, followed by disposal in shallow trenches which are covered in with fresh earth when full. The removal must be *regular and thorough* and the ground where the disposal takes place *frequently inspected* to see that the operations are conducted so as to bring the excrement into contact with fresh earth and to prevent its burial *en masse* in pits.† It is in the case of large towns that differences of opinion as to removal and disposal of sewage and excreta really begin. Are the excreta to be added to the sewage or not? There may be some difference of opinion as to whether open drains are suitable for the removal of waste water, etc.; there is no doubt as to their

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gressor, or severely punished for not doing so, the same degree of prevention in the case of the civil population could certainly be obtained. Various pecuniary penalties can be inflicted for committing such a nuisance in the street, under different Municipal and District Acts, but they are never properly enforced.

* Of course there are apt to be many difficulties in the way of such disposal, and these will only be overcome when the local medical officer or other sanitary authority takes an active and genuine interest in the matter. There are few places in India where prejudice against the use of sewage or excrement as manure will long withstand vigorous and kindly effort: such excellent fertilising material is too valuable to be wasted. In Japan and China the use of human excrement for manure is universal and it is a substance of very considerable pecuniary value.

† As is done at Cawnpore. "The pits are about 20 ft. square and 4 ft. deep, and are filled up with the liquid nightsoil, which is left to heat up and ferment in the sun. The ground being of clay, there is very little combination between it and the sewage, which putrifies so freely as to be covered like beer with a head of foam, due to the gas bubbles rising through it. The stench is indescribable and lasts at least two years. The residue, when dry, is sold to cultivators as poudrette, having lost the greater part of its fertilising powers in the gases of decomposition. Wallace, *op. cit.*, p. 161.

entire unsuitability for the removal of sewage *plus* excreta. Hence it is first of all necessary to compare together the dry and wet methods of removal and to weigh their relative advantages and disadvantages.

Numerous objections have been urged from time to time against the plan of having a system of underground sewers connected with houses by means of pipes leading to water-closets, etc. Every one of these objections having any weight has reference to *faulty construction*. (1) The system is defined as a network of underground channels containing foul, decomposing material, in immediate connection with dwelling-houses, so that the house pipes act as ventilators along which the poisonous sewer air can and does pass into the interior of the houses. Now, such a definition of a sewerage system was and is only too true for certain towns in Britain and elsewhere, but is about as accurate in the case of a modern well-sewered town, on the separate system, as the ordinary definition of a volcano.* There is certainly an underground series of channels in mechanical connection with houses, but efficient means are taken to prevent the backward passage of sewer air and, in any case, the sewage is so quickly removed that decomposition proceeds but slightly ere the sewage reaches the outfall. Hence, as before explained, the air† in a modern sewer is wonderfully pure. (2) It is urged that at any time the pipes may break or the jointing prove defective, the surrounding soil becoming polluted as a consequence. Even with proper pipes and good foundations and workmanship such an accident *may* happen occasionally, but, under systematic inspection it would soon be detected, sewers being now engineered specially to facilitate such inspection. (3) The water supply is said to be in danger of contamination. The various ways by which this might

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* *viz.*, a 'burning mountain giving forth flames and smoke.'

† Some insist upon careful distinction between sewer air and sewer gas. Of course the latter implies the gases given off during decomposition of sewer-slime, etc., and these in their turn help to render impure the natural sewer-air.

take place cannot be described in detail,* suffice it to say that here also such an occurrence could only be due to faulty construction or a breakage in the pipe-sewer coupled with the use of a shallow well as a water supply.

These then are the objections so called. There are one or two other points requiring attention. Where there are water-closets in connection with a sewerage system, a large and unfailing water supply is necessary to flush the closets and to keep the traps sealed. Without this the system is unworkable. Again, the use of water-closets means so much extra fluid added to the sewage and requiring disposal. Suppose these are used once daily by a population of 30,000, with an average flush of two gallons only, it will be seen that about 60,000 gallons of fluid are added to the daily sewage discharge for disposal at the outfall. For the same reason, the original cost of the system will be greater than where the sewers simply carry waste water. Finally, if the town is low-lying, so as to prevent the sewers being laid with good natural gradients, the sewage must either be pumped or the Shone system adopted. This means considerable extra expense.

In favour of the water-carriage system is the important fact that sewage and excreta are thereby removed as nearly *immediately* as may be. Sewage water must be removed anyway and the addition of the excreta and extra water from the closets does not perceptibly add to the impurity whilst the initial extra cost is more than compensated by careful construction and the saving of plant and labour in removal of excreta by dry methods.

Coming now to dry methods the most obvious advantage is *not* the non-necessity for sewers of any sort, but that no system of *closed* sewers is necessary. In addition the amount and permanence of the regular water supply is not so important.

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* The commonest cause of such a serious mishap is the wilfulness of builders in leading an overflow pipe into the sewer instead of making it end in the *open air* just beyond the outside of the wall.

The chief disadvantage is *delay in removal of the excreta*, a small matter perhaps, in the case of healthy people, but of great importance in diseases like cholera and enteric fever. If admixture with earth before removal is practised, as is frequently the case in this country, the carriage and storage of a large quantity of earth is a very expensive matter, as also the removal by hand or cart of the mingled earth and excreta.* Æsthetically it is objectionable on the large scale compared with a *good* water-carriage system.† Suitable earth is not always obtainable, and besides, the amount of fæcal matter to be removed from a large town is so enormous that the town would become surrounded after a time with buried deposits of filth.‡ Finally, and most important of all, it is only a partial system and leaves entirely untouched the question of disposal of sewage and the whole or greater part of the liquid excreta.

It remains, then, to consider what are actually the best methods available *in this country*. At once there arise a number of objections to be considered and difficulties to be overcome, due to two great and ever present factors, *viz*:—the *tropical climate* and the *existence of caste*.

The climatic peculiarities are principally those due to a

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* Save in the case of isolated institutions, like jails, where free labour is obtainable, and which are not comparable to towns.

† In the otherwise admirable work by McNally, so often referred to, there are one or two points in this matter that require notice. In favour of a dry system of latrines he says that "foul water not containing latrine waste being so inoffensive may be passed into ordinary drains," *i.e.*, into surface drains, which empty themselves into the nearest watercourse or allow their contents to sink into the soil. This, as before stated, I believe to be a dangerous error. Again he says "the same earth can be used over and over again after drying, and the return latrine carts would carry earth instead of going empty." I have before (p. 139) alluded to the fact that the same earth *can* be used several times so far as its deodorising powers go. It is extremely doubtful, however, whether such a plan is advisable, and certainly the same carts should not be used for removing excreta and bringing fresh earth. "Quite recently," says Sir William Moore, "Surgn. Capt. Nichols, Surgn. Capt. Battersby, A.M.S., and also Dr. Hare, of the Brisbane Hospital, Queensland, have condemned the dry-earth system (B. M. J., 1890); especially when, as the officer first-named remarks, the cart which takes the mixture of earth and fæcal matter to be buried brings back dry earth for use." Trans. VIIth Internat. San. Sci. Congress, vol. xi, p. 27.

‡ "As military stations are now being surrounded." (Moore, *loc. cit.*)

powerful sun, and alternating seasons of drought and heavy rainfall, with occasional failure of the latter. In the hot weather, from March to the middle of June, there may be barely sufficient liquid to run in the drains, whilst in the wet months the drains may be running full and carrying pollution to every neighbouring water supply. Again, the hot sun causes the water of the sewage to evaporate rapidly and the sewage itself to undergo rapid fermentation, so that most offensive odours, and probably micro-organisms and other minute organic particles, are given off. On the other hand, the heat causes desiccation of the solid refuse matters so that they become 'mummified' or dried up and do not give rise to a nuisance. This, certainly, is apt to be but a delaying of the evil, for when the rain comes, all refuse lying about speedily begins to decompose and putrefy. Lastly, if from long continued drought the water supply should fail, any system of closed sewers becomes an unmitigated evil.

The existence of caste with its peculiar train of social beliefs and customs makes this problem of ten-fold greater difficulty than it would otherwise be. If indeed caste prohibitions, as believed in and practised, were thoroughly rational, and pollution really meant pollution, the difficulties of framing sanitary measures and of inducing the people to live sanitarily would not be nearly so great.* In most districts in India, the caste population is more or less completely at the mercy of the sweepers (*mehters* or *toties*) whose occupation is hereditary and each of whom will only work in certain houses, perhaps situated far apart.† Again, there are many other social customs, such as the

* "The sanitary appliances for the removal of the refuse of the population by water-carriage in India must not only prevent the waste of water, but must be of such a character as not to even splash with water the person using them, for fear he is polluted; yet these same natives ordinarily bathe in common, and use waters for all purposes of the vilest character, to which there has been access of all those matters which are looked upon as a cause of pollution to the particular individual when he has to use sanitary appliances within his own residence." (Baldwin Latham. Trans. VIIth, Internat. San. Sci. Congress, vol. xi, p. 201.)

† With regard to this difficulty, there are many graphic descriptions in the volume above quoted.

segregation of the women in special quarters, the almost universal custom in small towns of going outside in the morning to any piece of unoccupied ground, *e.g.*, the bed of a dried-up tank, for the purposes of nature, etc., etc., which make it extremely difficult or impossible to carry out the removal of excreta thoroughly and systematically.

Like other sanitary problems, this must be solved differently according to the nature and circumstances of the population concerned.

Isolated houses and very small villages.—In this case the best means at present available is the setting aside of certain pieces of waste ground, remote from the water supply, as a site for moveable latrines consisting simply of screens or *taties* surrounding shallow trenches.* Any excreta passed in the houses must be carefully removed and buried in these trenches. Vegetable and other house refuse should be destroyed by burning in the fields or spread on the ground and ploughed in. There should be a good, *packa* built open drain to remove all waste water, and urine if necessary, from the neighbourhood of the house.†

Large villages and small towns.—These are perhaps the most difficult places of all in which to carry out a good system of conservancy. If some inexpensive and simple form of incinerator could be invented, as no doubt it will, all solid refuse should certainly be disposed of by fire.‡ The liquid waste should be conducted by a good series

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* Or the jungle itself may be preferable as well as customary, *v.* Moore, *loc. cit.*, p. 28, line 4 from bottom. The ancient Israelites were directed (Deut. xxiii, 12-14) to cover the excrement, when passed, with earth. It is a pity that such a custom does not obtain in India. The spectacle presented to the passer-by outside most towns in India, morning and evening, is insanitary and disgusting to the highest degree.

† *v.* p. 149. For further details on this subject *v. post.* Sanitation of Towns and Villages.

‡ Since writing the above, I see advertised the "Silchar Patent Cinerator and Rubbish Furnace," *especially suited for small communities.* It is said to cost about Rs. 400 only and to burn and completely destroy all kinds of organic refuse from gardens, stables, kitchens and latrines, also the bodies of dead cattle, both during monsoon and dry weather. It has been adopted by the Assam Government and several municipalities, Simla

of open drains to a proper outfall for disposal by irrigation of land. If possible, the solid excreta, whether passed in public latrines* or in private houses, should be disposed of by drying in a special part of the incinerator and used as manure, or else removed direct to the fields and buried in shallow trenches, the land being shortly afterwards ploughed and cropped. The urine, if the drains are well-made and frequently cleaned, may pass into the open drains.

Jails, Hospitals, Lines, Cantonments, etc.—In such cases as these the conservancy is usually easier and much more thorough: the great difficulty is the question of disposal. The earth system, with admixture before removal, is almost universal but is by no means perfect. At present there is no efficient substitute. In time to come the destruction of refuse matter by small and easily-managed incinerators will probably be the favourite method. All liquid should be utilised for cultivation in the case of jails, cantonments, etc. In hospitals it should enter the general drains of the town or be removed to a suitable spot by hand.† In this latter case also there should always be abundant means of thoroughly *disinfecting* the motions in cases of enteric fever, etc., *under responsible supervision.*

Large Cities.—In all towns of any size there is only one proper way of disposing of the dry refuse or ordinary

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Silchar, Kohima, Naraingunj, etc. It is certainly worthy of trial. J. Wallace, C.E., Bombay, is sole agent for India (excepting Bengal and Burmah).

* Moore (*loc. cit.*) considers that the publicity and unavoidable odour of public latrines is a drawback to their use. It is certainly so, but these are lesser evils than others. Again, he says, the value of land makes the reservation of special plots difficult and there is a complaint of want of privacy here also. But surely the value of land is not so great as to prevent the town or village collectively paying a small rent. As regards the complaint of want of privacy behind tatty screens the experience of the writer is that in very many instances the people seem to go out of their way to choose the most conspicuous place possible.

† At the General Hospital, Madras, the sullage water used formerly to be discharged into the already polluted Cooum backwater. It is now, under arrangements made by the present S. M. O., Bde-Surgn. Lt.-Colonel W. Price, M.D., utilised for irrigating the grounds of the hospital, which are thus kept perpetually green and neat. There is no sign of a nuisance, and the amount of grass that is grown and cut for forage is considerable,

rubbish and that is by fire. *The* question to be decided is whether there should be a system of closed sewers or not. Until a town has got a thoroughly abundant and permanent water supply the answer must be in the negative. If the town lies on a good natural slope the laying of sewers is easy and a comparatively simple matter. If, on the other hand, the land is very flat it becomes necessary either to pump the sewage from a lower to a higher level or to adopt Shone's Hydro-Pneumatic System. Again, how are the rain and subsoil water to be disposed of? Certainly not by admittance to the ordinary sewers. Whatever system be adopted it should be partially or completely *separate*. If an old system of brick sewers exists it may be made to carry off the storm-water and drain the subsoil. If not, special provision must be made for draining the subsoil. This is not always an easy matter, but is quite essential for the health of the population in many Indian towns. "Drainage is not, however, the universal panacea which some consider it to be. Subsoil drainage is not applicable to those sandy countries where only a few inches of rain fall, for the sand immediately absorbs the rain like a sponge, and although it remains damp and cold a very short distance from the surface, this would not be much altered by drainage, the moisture not being sufficient to escape from the holding sand by oozing. Surgn.-Genl. Cornish, C.I.E., has also pointed out that subsoil drainage is not applicable to certain districts in the Carnatic, where they do not suffer from too much moisture, but from excessive dryness of the soil. During the long period of drought, subsoil pipes become blocked by deposits of ants, lizards, rats, etc., so that when they are really required, no water flows through them. This it may be said is a matter of supervision, and so it is to a considerable degree. But to ascertain the patency of any large extent of subsoil drainage is no easy matter, and deposits of the nature mentioned occur very suddenly. As a matter of fact when the Indian monsoon bursts, and heavy rain falls, many subsoil drains overflow." "The greater my experience," says Dr. Simpson, the

Health Officer of Calcutta, "of the effects of the network of underground drains in busties, the greater is my distrust of their utility and freedom from danger. It would be safer and more conducive to the health of the busties to restrict underground drains to the broad roads, which should intersect." "All tributary drains," continues Sir W. Moore, "should be open, or should be covered with moveable iron gratings, which would ensure the condition of the drains being readily seen, while the drain being exposed to the influence of the sun* and air, injurious gases would not be elaborated."† A large amount of storm water can be removed by surface drains, ere it sinks into the ground.

In time to come the inhabitants of the larger cities will become habituated to the use of water-closets‡ and abuses and prejudice be done away with. The result will be a large saving of labour and a considerable gain in health for the population. Where house connections and water-closets are not desirable, then the excreta, liquid and solid, should be removed in air-tight receptacles and emptied at special openings, morning and evening, into the main sewers. The waste water can be got rid of by good open§ or closed drains, connected, in either case, with the sewerage system. The following extract is noteworthy as being written by a native and medical graduate of this country.‖ "In the case of the larger towns, where sufficient money and an ample supply of water are available, the water

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* It has been proved that direct sunlight in the presence of oxygen, has a distinctly retarding and even destructive influence on micro-organisms of various sorts. This fact may hereafter be proved to have important bearing in reference to the use of open drains for sullage water, etc.

† *v.* Trans. VIIth Internat. San. Sci. Cong., vol. xi, p. 31.

‡ Not necessarily water-closets in *every* house but probably trough-closets for common use in the poorer parts of the town. *v. post.* Sanitation of Towns.

§ Of course, if open drains are used it means that a large amount of storm water will gain access to the sewers. In such a case the only method in this country is to 'intercept' the storm water as much as possible and discharge by a separate outfall (*v. ante* p. 171).

‖ K. V. Dhurandhar, L. M. and S., Medical Officer and Superintendent of Vaccination, Baroda, (*v.* Trans. VIIth Internat. San. Sci. Congress, vol. xi, p. 141).

carriage system of removing excreta is the best. The experience of that system in Calcutta and Bombay, though even now the sewers are incomplete, justifies the conclusion that water-closets of simple construction best suit the prejudices of the natives of this country. Natives have an aversion to the person of a scavenger, and suffer in consequence a good deal of filth to collect in and about their dwellings. The system of removing excreta by waterflow in underground drains and sewers is the cleanliest and most economic in the long run. It is pleasant to find that the foolish opposition that once threatened to be formidable against the system of underground drains is fast dying out. It had its origin in overdrawn descriptions of outbreaks of typhoid from badly constructed sewers in England which now and then appear in the newspapers. Some of the Native States, such as Baroda and Hyderabad (Nizam), and some municipalities, have wisely voted large sums for the sewerage of their towns. The designs must be made only by sanitary engineers with the most recent drainage experience." With the above quotation all whose knowledge of the subject is up to date must agree. Regarding the disposal of the refuse matter, the products of the incinerators may be utilised as before described;* the sewage should certainly be disposed of by irrigation, combined with intermittent filtration if necessary, or, in the case of towns situated on the sea-board, if no suitable land is available or if there are other obstacles to its utilisation in this way, by discharge, at a carefully selected spot,† into the sea. In all drainage schemes of any magnitude it is absolutely necessary for true economy and efficiency that the very best advice and personal supervision be obtained.‡

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* *v.* pp. 145-6. † *v.* p. 177.

‡ This subject cannot be considered in further detail here. The latest contribution to it will be found in Wallace's 'Sanitary Engineering in India,' chaps. IV—VII inclusive. He shows that the chief difficulties to be overcome in applying a complete sewerage system, as in common use in England, to an Indian town, are (1) the 'human factor' of ignorance and prejudice; (2) the failure of siphon traps owing to loss by evaporation and the throwing of improper articles into the down-take pipe

DISPOSAL OF DEAD BODIES—HUMAN.

In this country there are various ways in force of disposing of dead bodies. Amongst the Hindus, who form by far the larger portion of the population, disposal by burning is the more usual method. In certain special cases earth or water burial is used instead. Europeans, Mahommedans and Burmese bury their dead in the ground; Parsis, in Bombay at all events, expose the bodies to be eaten by vultures in the Towers of Silence.

Cremation.—Of these various practises there is absolutely no doubt that cremation is by far the most sanitary and is equally preferable on æsthetic grounds. But it must be thorough cremation and not a merely partial destruction of the soft structures. If properly carried out, the whole body should be reduced to a fine powder which, being of a purely mineral nature, is clean and harmless and can be disposed of in accordance with the religious scruples of any particular sect. One* who has studied this subject carefully and has had much official experience of earth burial in England writes thus, with reference to the introduction of cremation in that country:—"I am so deeply convinced that cremation should be substituted for it [earth burial] for many weighty reasons, that I feel it necessary for me to give a few of them:"

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on which the siphon is situated; (3) the accumulation of a peculiar and objectionable 'silt' in the main sewers, very troublesome to remove; (4) the difficulty of ensuring that the discharge of sewage at the outfall into a river shall take place well into the stream during the period of smallest volume of the river. He suggests several outlets to suit various states of flood, the lower ones being dug out once a year if they become silted up. This latter idea, of course, is comparable to the in-take pipes which are sometimes constructed at different levels, (in place of a water-tower) in water reservoirs, and used in turn according as the water level in the latter is high or low. Mr. Wallace is a strong advocate for the use of iron pipes as sewers and it is possible that they may be adopted to a considerable extent, at all events experimentally. Indeed the whole question is still in an experimental stage, but of the *ultimate* adoption of three things in most towns there can be little doubt, *viz.*, *incinerators* for the destruction of all dry refuse or *cutchra*, properly built *closed sewers* (with or without house connections) for the removal of all liquid refuse (and possibly excreta as well), and the disposal of sewage by *irrigation* (with or without intermittent filtration).

* Boulnois, *op. cit.*, p. 410, altered.

(1) Nothing can be more unsanitary or dangerous to the living than the burial of the dead. This has been enlarged upon over and over again by men who have well studied the subject and are competent to give an opinion, and to that opinion I add my testimony.*

(2) Nothing can be more loathsome and degrading to the dead bodies of our friends, or more revolting to our feelings, than the horrible practice of placing the remains of those we love in the soil of a churchyard or cemetery, to be devoured with other bodies by worms.

(3) In placing a dead body under ground we can never be sure how long the remains will be left undisturbed, a new road or railway will soon destroy all traces of its resting place.

(4) In the event of friends or relations dying abroad or at a distance their remains cannot be sent home for burial except at great expense: on the other hand, cremation would reduce the body to a few

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* In 1843 when a parish church near Stroud in Gloucestershire was in process of re-building, the superfluous soil of the burial ground was disposed of for manure (!) to the villagers, and the result was nearly a decimation of the place. The outbreak of the plague in Egypt in 1823 was traced to the opening up of a disused burial-ground about 14 miles from Cairo, and thousands perished in consequence. An investigation was made in the cemeteries of Rio de Janeiro, about five years ago, upon earth taken about spade deep from graves where victims of yellow fever had been buried some twelve months previously, and this soil was found to contain 'myriads of microbes,' self-same with those present in persons stricken with the same pest at the time of the excavation. A healthy guinea-pig was incarcerated in a space over which earth taken from a grave was sprinkled, and in five days the animal was dead, its blood being found to be 'literally crammed' with the germs of the disease in various stages of growth." Boulnois, *loc. cit. supra*. "Some years ago a body of prisoners were employed in making a road in the Guntoor district, and in cutting away the soil, they came upon the remains of a number of persons who had died of cholera in 1838; cholera immediately broke out among the workmen. A party of coolies employed on a railway cutting near Salem, opened a spring of very clear water. Those who drank of it were seized in a few hours with cholera of a very severe type. In this instance the railway cutting passed through an old burial ground." Sir W. Moore, *v.* Trans. VIIth, Internat. San. Sci. Cong., p. 27. And so on, the list might be extended *ad infinitum*.

silvery ashes which could easily be brought home and secured on arrival in a suitable and safe position.

(5) Cremation is the most respectful and beautiful manner for the disposal of dead bodies, as fire is the most perfect purifier and type of purity with which we are acquainted, and need not alarm (on religious grounds) any more than the practice at sea of lowering dead bodies overboard.

(6) Cremation is merely a *more speedy means of burning a body than burial,* decomposition being only a very slow and loathsome combustion.

(7) A large amount of valuable land is rendered useless for building or agricultural purposes.

(8) The expenses of earth burial are proportionately very large. Public crematories for the different sects or castes should be instituted. For a very small cost, sufficient heat could be maintained to consume almost any number of bodies, whilst the present great expense of maintaining large cemeteries would be dispensed with.

The only objection of any weight* ever urged by the opponents of cremation is the difficulty of detecting cases of poisoning. This is certainly an objection that is worth considering. In England it could be met by instituting a scientific and independent enquiry as to the cause of every death which occurs. This is so much required at the present day for the sake of the public health, that even if cremation is never introduced, it should be at once en-

* Some have pretended that in burning bodies the soil is deprived of a natural manure! Against this are the facts that cemeteries are not used and are not meant to be used as farms, and secondly, that the very existence of large cemeteries means valuable land diverted from its natural use. *v.* (7) *supra.*

forced, so that those who have charge of the public health could have exact and reliable knowledge of the causes of all the deaths throughout the United Kingdom, and thus obtain such valuable information as would greatly assist in the daily fight to subdue and overcome deaths from preventable causes.* Several large crematoria have been built in England and it is only a matter of time till the practice becomes general †

In India, as has been stated, the burning of bodies is no new thing, but, with rare exceptions, cremation in its proper sense is almost unknown. Poverty no doubt is the chief reason for such a state of things and this can only be remedied either by public crematories under municipal control or else under immediate control of the various castes with general supervision of the municipal authorities. The sites for burning-grounds should be most carefully chosen so as to be distant from all dwellings and sources of water supply. Cremation, in large towns, should be conducted in the absence of air in proper furnaces, the process being essentially one of destructive distillation, as in a closed retort. In such a furnace an ordinary adult body is destroyed in about two hours, the resulting mineral ashes weighing only about three pounds. For small towns and villages efficient burning on a pile of wood or with cow-dung cakes may be permitted at the

* The danger of concealment of cases of poisoning is much exaggerated with reference to Great Britain. The extra number of cases that would escape detection if cremation was adopted generally, would be but a very *slight* increase on the number that escape under present conditions. The above proposal to carry out a scientific examination into the cause of every death would not be easy to carry into practice, but is now being considered in England. Anyway the good of cremation far outweighs any possible evil.

† Some of the sentimental objections urged by the opponents of cremation are most curious and amusing, but cannot be quoted here. They are strictly analogous to many of the so-called religious scruples advanced in this country to resist any sanitary innovation and owe their origin to the same fountain heads of ignorance and superstition. The great argument formerly used and one which still has weight amongst a certain order of persons, was that if the body was destroyed by fire how could it be raised again at the Judgment Day? Such depths of ignorance and superstition in a country like England should make us more charitable towards the beliefs of others.

selected site and under supervision.* The use of such a place as the bed of a dried-up river should be strictly prohibited.

Earth burial.—In this case even stricter precautions are necessary than in the case of cremation.† The selection of land suitable for a cemetery in not always easy. "The soil of a cemetery should be of an open porous nature, with numerous close interstices, through which air and moisture may pass in a finely divided state freely in every direction. In such a soil decay proceeds rapidly, and the products of decomposition are absorbed and oxidised. The soil should be easily worked, yet not so loose as to render the work of excavation dangerous through the liability to fall of earth. It should be free from water or hard soil to a depth of at least 8 feet. If not naturally free from water, it should be drained if practicable to that depth: to this end it is necessary that the site should be sufficiently elevated above the drainage level of the locality, either naturally or, when necessary, by filling it up to the required level with suitable earth. Loam, and sand with a sufficient quantity of vegetable mould, are the best soils; clay and loose stones the worst. A dense clay is laborious to work and difficult to drain; by excluding air and moisture it retards decay, and it retains, in a concentrated state, the products of decomposition, sometimes to be discharged into graves opened in the vicinity, or sometimes to escape through cracks in the ground to the surface. A loose, stony soil, on the other hand, allows the passage of effluvia."‡ Further, the cemetery must be situated con-

* "It is the duty of Municipal servants at the burning grounds to see that the corpses are completely consumed, and that in those cases where the ashes are not carried away, they are prevented from accumulating in heaps, to the inconvenience of persons attending following ceremonies." (Jones, *op. cit.*, p. 87). The ashes are buried in some part of the ground. The cost of cremation in Madras varies from Rs. 4 to Rs. 1-6. The average price is Rs. 2.

† "Speaking broadly, the effect of the proximity of a burial ground upon health is the same as that of any other accumulation of putrefying animal matter."—Whitelegge, Hyg. and Pub. Health, p. 204.

‡ *v.* Eleventh Ann. Report, Local Government Board.

veniently, if possible; certainly not near any source of water supply nor near any inhabited spot.* The ground must also be firm and not exposed to the danger of land-slips, flooding by storm-water or encroachment by a river or the sea.† In some places it is very difficult to find a place at all suitable for inhumation, and in some it is quite impossible.‡

Many sorts of material are used as coffins for enclosing the dead body in Europe. Of these the worst is lead, the best thin wood, wicker-work or *papier-mâché*.§ In the case of noble or wealthy people, their bodies, in former times, were buried in brick-lined graves or in graves dug in the church itself or in underground rooms connected with the church.|| Such practices are all equally insanitary and opposed to the first postulate of earth burial, which is that *the body shall be so circumstanced after death as to be dissolved into its elements as speedily and inoffensively as possible.* These conditions can only be fulfilled by the choice of a suitable soil, as described above, a grave of proper depth,¶ a thin, easily-destructible coffin and the growth of suitable plants in the immediate vicinity. Above all, over-crowding, a constant evil in most town grave-yards, must be absolutely prevented.

The changes undergone by the human body buried in

* Above all, not on an elevated site from which the foul subsoil water can reach and contaminate a tank, well, or the foundations of dwellings situated at a lower level.

† Every one of these conditions has been many times violated and it is by no means easy to fulfil them all. In some cemeteries choice is made, apparently, of the *most unsuitable* piece of ground simply because it is prettily situated or near the town!

‡ *e.g.*, at Kalémyo in Upper Burmah it was found quite impossible to dig a grave *anywhere* (!), the whole ground being completely water-logged during the rains.

§ Layers of paper compressed by machinery into a wood-like material.

|| Vaults, catacombs, etc.

¶ Not less than six feet deep, nine long, and four broad for adults, so as to surround each body with clean earth. Under the Madras Municipal Act there must be 5 ft. between the ground level and the upper surface of the coffin and a margin of 2 ft. round the grave. The present M. O. H., Dr. J. Nield Cook, makes the burial-ground peons test the depths of the graves by means of 6 ft. staves which are pushed through the ground.

earth are the same as take place in any decaying organic material, *viz.*, through the agency of various animals, micro-organisms, and plants, the destructive process is carried on. At first carbon dioxide, carburetted and sulphuretted hydrogen, ammonia, nitrous and nitric acids and other complex and fœtid products are evolved, which are eventually oxidised into simpler combinations. The salts go to enrich the soil and are used up by plants or dissolved and removed by the ground water. The harder structures, especially the mineral framework of the bones, remain for long periods unaltered. When bodies are buried in unsuitable soil, *e.g.*, clay or peat,* they may remain unaffected for a long time and in some cases are transformed into the curious fatty substance named adipocere.†

In India there is the greatest need for speed in burial on account of the rapidity of decomposition and, except in really *cold* weather, no dead body should remain unburnt or unburied for more than twenty-four hours at longest. It should certainly be made illegal to bury the bodies‡ of cholera patients, even if disinfectants, so-called, are used, and proper arrangements for cremation of all classes and sects should exist. Such a furnace should consist of a closed chamber or retort in which the body is placed and and the whole heated to 1,500° F. In one hour the operation is complete. Whenever any place has been used as a burying ground, temporary or permanently, for one or more people, the spot should be suitably and distinctively enclosed, and this both on hygienic and social grounds. Such a practice as simply throwing out cholera bodies or others on to waste ground or into water should be made a crime and the offenders punished by imprisonment.§

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* *v.* p. 110. † *v.* Works on Medical Jurisprudence.

‡ As also the excreta.

§ The extraordinary supineness of the authorities, municipal and otherwise, in this matter seems almost inconceivable to those who have not seen it. The author remembers, in Ganjam, seeing a dhoby washing clothes in a nullah, about fifty yards from a floating cholera body, whilst the peon stationed there to prevent such an occurrence, carried on a leisurely conversation with the dhoby!

Dead bodies being carried through the streets should be decently covered up from head to foot and it should be illegal to expose them.*

Water Burial.—The custom which prevailed and still prevails, of carrying the dying to the banks of sacred rivers and, after death, partially burning the body which is then thrown into the river,† must formerly have been a most fertile source of disease. It is a thoroughly insanitary practice and should be strictly prevented. When the cremation is properly carried out, and the body reduced to mineral ashes, there is no objection whatever to the ashes being scattered on the water.

Burial at sea is but rarely resorted to save when death occurs on boardship. It is in many ways preferable to earth burial as ordinarily carried out, and far better than the exposure of bodies to be eaten by loathsome vultures. When a body, wrapped in sail-cloth and with heavy shot attached to it, is dropped over the side of a ship in mid-ocean, it is practically certain that it sinks with comparative rapidity to the depths below and, becoming embedded in the 'ooze' formed of the calcareous coverings of myriads of marine organisms, has a more suitable and more innocuous resting-place than in any town cemetery. In any case it is better that the corpse, the worn-out earthly covering, should be rapidly and harmlessly disposed of under water than left to decay slowly and, it may be, spread disease, a few feet below the earth's surface.

Many other methods have been, and are, in force amongst different tribes and nations, for the disposal of their dead, and the various rites and customs form a most interesting chapter in Comparative Ethnology. Amongst these are embalming, as practiced by the Egyptians under an erroneous idea of the connection between the body and

* It is illegal to do so under the City of Madras Municipal Act (*v. post.* Sanitary Legislation) but, like most other Municipal enactments, no proper attempt is made to enforce it.

† Or, what is worse, throwing the body into the river direct.

soul after death, exposure to wild animals or to dogs specially trained to devour the corpses, exposure on platforms or in trees, etc., etc., all of which are opposed to true hygiene and most of them utterly barbarous.*

DISPOSAL OF DEAD BODIES—LOWER ANIMALS.

This subject is only liable to assume important proportions under one of two conditions, *viz.*, an outbreak of contagious disease amongst a particular class of animals, or during war or famine time.

Epidemics.—At such a time, if proper precautions for the disposal of the dead bodies of animals are not taken, a very considerable increase in the spread of the disease coupled with a dangerous nuisance to human beings is apt to occur.† In the case of an outbreak of anthrax it is of especial importance that the bodies of all horses, etc., be

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* The following extract concerning the burial of Sannyâsi Brâhmans is taken from the interesting and accurate work of the Abbé Dubois, 'A Description of the People of India.' After preparatory ceremonies, "the body is placed in a sitting posture, cross-legged, in a large basket; which is suspended with straw ropes upon a strong pole of bamboo and carried by four Brâhmans. They proceed, without noise or tumult, to the trench which has been prepared on the bank of the river, if there be one in the neighbourhood. It is dug so as to resemble a well, about six feet in depth, and is filled one-half with salt, on which the body is placed, in the posture that has been described. "It is then covered up to the neck with the salt, which they press closely all round, so as to keep the head immoveable. This is succeeded by the strange ceremony of breaking cocoanuts upon the head of the deceased, which is continued till the skull be quite shattered; after which, more salt is thrown into the pit, and the head covered out of sight. Earth is then accumulated over the trench, to the height of several feet; and upon the heap so raised a *Lingam* is erected." The presiding Brâhman then "collects all the bits of the cocoanuts which were broken on the head of the deceased, and distributes them amongst those present, who eat them as a sacred and well-boding morsel." v. p. 265, *et seq.* The bodies of all other Brâhmans are, of course, burnt, not buried.

† The writer has seen the most fearful nuisance and danger caused by such an outbreak amongst buffaloes in Burmah. Along the river banks the animals lay dying or dead in great numbers whilst crows, kites, adjutant birds, dogs, etc., attacked them before death had actually taken place and after. The dead bodies lay about amongst the villages and floated in scores down the rivers Mitthya and Chindevin, decaying as they went. On these dead bodies, the Burmese, who will eat any thing, feasted. The smell, etc., was most disagreeable, and destruction by ordinary fire most difficult. I have known Burmese eat a miserable, diseased pony; also take the body of a self-dead deer out of the river, as it floated towards them, and shortly after breakfast off it! In the same way the *chucklers* and other low-caste people in India will eat almost anything, horse meat being a favourite morsel.

at once completely destroyed by burning. Burial is quite impermissible. Indeed, as a general rule, it may be said that *destruction by fire* is the only safe and proper means to be adopted in all cases. Great vigilance is necessary, especially in Burmah, to prevent the bodies of animals dying of disease from being used as food. The ordinary rubbish incinerators, which will doubtless soon come into general use, will be quite sufficient for the destruction of the bodies.

War and Famine.—Under these circumstances even greater neglect is liable to ensue, for people are disheartened and will not take the trouble to do anything save what is an absolute necessity. The proper disposal of the dead bodies of the horses, etc., as well as those of human beings killed in war is a most difficult thing, and depends on many varying factors. Various devices have been tried.* If no special means are available, the only plan is to issue peremptory orders for proper earth burial to be carried out with the least delay possible in every case; and to take means to have the order carried out effectively. In future wars between civilised (*sic*) countries, cremation will almost certainly be the method of disposal for both human and other bodies as well.

Famine in India raises a peculiar difficulty in many districts, inasmuch as the people, though starving themselves, will not eat the flesh of the cattle dying from starvation, neither will they bury the bodies. The local sanitary authority should see that the dead bodies of animals are buried with due precautions, or better, burnt completely.

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* *v*, Parkes-Notter, pp. 394-5.

CHAPTER V.

BUILDINGS.

Into this subject it is impossible to go in detail here; all that can be attempted is to indicate the *principles* which must be borne in mind if buildings are to be suitable for human occupation, and to note some *practical points* to which special attention should be paid. It must be carefully remembered that in India and Burmah the actual construction of dwellings is almost universally done by ignorant native workmen upon whom the unwritten rules by which their forefathers worked are equally binding, and this in spite of official 'supervision.' The latter is often extremely perfunctory and is perforce carried out in many cases by men who have never had opportunities of seeing first class work. This state of matters is gradually being remedied, but the mass to be leavened is out of all proportion to the amount of leaven available.* Things being so as regards official buildings, it can easily be imagined how much worse they are with respect to houses built purely as a commercial speculation. It is not to be denied that in England the same charge of greed on the part of speculative builders, without the possible excuse of ignorance, holds perfectly good, as the rows of 'jerry-built' houses in the suburbs of London and other large towns, only too clearly show. The poorer classes being the chief sufferers in both countries, it is the duty of the municipal authorities (some of whom, however, are the worst offenders), to act upon

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* Many volumes might be filled with accounts of the extraordinary and perverse blunders made under the very noses of so-called supervisors. The amount of money spent annually on alterations and re-construction, through originally defective work, is enormous. A certain amount of this 'pulling down and building up' is, it is to be feared, somewhat intentional and follows apparently as a necessary sequel to 'estimates,' and 'contracts.' It is probable that here, as in other cases, an increase in the number of high-grade public works officials, with consequent more effective supervision, would prove to be the truest economy.

the advice of their sanitary advisers in prevention or mitigation, so far as possible, of these evils, and to enforce rigorously the utmost penalties upon the offenders.*

The extent and power of epidemics in former ages are largely to be attributed, amongst numerous other predisposing causes, to the very imperfect nature of the dwellings occupied by the mass of the people.† Then, as in India but a few years ago, the nobles and grandees occupied palaces and forts whilst all below them were housed in miserable hovels crowded together and surrounded by damp and filth. Even now it cannot be said that things are much improved in Indian towns.

With reference to the influence on health necessarily produced by such defective conditions of living, an eminent authority‡ has thus written: "Ill-contrived and closely-packed houses, with narrow streets, often made winding for the purposes of defence; a very poor supply of water, and therefore a universal uncleanliness; a want of all appliances for the removal of excreta; a population of rude, careless and gross habits, living often on innutritious food, and frequently exposed to famine from their imperfect system of tillage,—such were the conditions which almost throughout the whole of Europe enabled diseases to attain a range, and to display a virulence, of which we have now scarcely a conception.§ The more these matters are

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* If anyone built a ship so carelessly that it capsized immediately after leaving harbour, or sold a gun with a barrel that burst on its being fired for the first time, enquiry would certainly be made and the offender probably punished by a heavy fine or imprisonment. On the other hand a builder may build a house which is nothing more than a death-trap, and will consider himself aggrieved if his tenant should dare to get ill and die as a result of its faulty construction.

† A favourite argument with the opponents of hygiene is that, in spite of such a state of things, countries like England were enabled to produce and rear a splendid class of men, who were the pioneers of discovery and the heroes of battles throughout the world. Such a fallacious argument hardly deserves notice. It is merely an example of the well-known law of 'the survival of the fittest' and entirely leaves out of account the enormous death-rate and amount of preventable sickness.

‡ The late Edmund Parkes, *v.* Parkes-Notter, p. 220. So also many other writers—Froude, Green, Kingsley, Simon, etc.

§ Those, however, whose memories go back to the famine and cholera in India sixteen years ago, can easily form such a conception.

examined, the more shall we be convinced that we must look, not to grand cosmical conditions, not to earthquakes, comets, or mysterious waves of an unseen and poisonous air; not to recondite epidemic constitutions, but to simple, familiar and household conditions, to explain the spread and fatality of the mediæval plagues." And so it is true for this great country, that disease will continue to claim its victims in excess until, by slow degrees, the narrow streets are cleaned and widened and the wretchedly-built houses replaced by others of suitable form and construction.

Attempts have been made in the large towns to remedy this state of matters as far as may be, but it is an evil of such magnitude as to make the task seem almost hopeless. Poverty, that bar to sanitary progress in India, is here the chief obstruction, but a great deal can be done by improving the *design* of even very small houses without much increasing the cost. It is to be hoped that natives of this country, graduates in engineering and sanitary science, will take up the question energetically and design dwellings which, whilst conforming to local taste and customs, will be constructed as far as possible in accordance with the canons of hygiene.

What then are the requisite conditions for a healthy habitation? They are chiefly these, as defined by Parkes:—

1. *A site dry and not malarious,* and an aspect which gives *light and cheerfulness.*
2. *A pure supply and proper removal of water;* by means of which perfect cleanliness of all parts of the house can be insured.
3. *A system of immediate and perfect sewage removal,* which renders it impossible that the air or water shall be contaminated from excreta.
4. *A system of ventilation which carries off all respiratory impurities.*
5. A condition of house construction which insures *perfect dryness of the foundations, walls and roof.*

Now, let the reader think for a minute how many of the houses he is acquainted with fulfil these conditions: the answer will probably be—'not one'!* Yet there is nothing out of the way in these five postulates, save perhaps the demand for a non-malarial site. Even in this case, a little care in choosing and preparing the original site of any place would obviate this objection almost, if not quite entirely.

Not only, then, is it very exceptional to find a dwelling house or group of houses fulfilling all these conditions; it is the general rule to find that every one of them is violated. An undrained, malarious site; a water supply of extreme impurity; no proper system for removal of excreta and none for removal of impure water; ventilation practically *nil;* unsuitable materials used in the building and a thoroughly defective method of construction,—such are the almost invariable conditions of Indian houses. Is it any wonder that the people die by thousands of fever, cholera, phthisis, etc., and are at best a poorly developed race lamentably deficient in stamina? It is not denied that many other of the essentials of healthy living are wanting, such as good food, temperance in all things, regulated physical exercise and proper clothing, all of which will be discussed under Personal Hygiene,† but the fact remains that imperfect and insanitary dwellings are a powerful factor in aiding the virulence and spread of disease.‡

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* Let him remember also that an 'unhealthy dwelling' is invariably an *expensive one* and a bad bargain. People generally realise this when it is too late; when the favourite child has died of diphtheria or the chief bread-winner been carried off by cholera or enteric fever, or when half the family begin to suffer from malarial asthma.

† *v.* Part II, The Hygiene of the Individual.

‡ *E.g.*, Dr. Ballard, reporting recently to the Local Government Board in England, upon the annual mortality from diarrhœa, points out, among the more important conditions influencing diarrhœal mortality, that aggregation of population favours, and dispersion over area disfavours, diarrhœa; that density of buildings (whether dwelling-houses or other) upon area promotes diarrhœal mortality; and that restriction of and impediments to the free circulation of air, both about and within dwellings, promote diarrhœal mortality. Quoted by S. and M., p. 657. In all eastern towns which, in the close aggregation of their houses and the consequent narrowness and tortuosity of their streets, resemble the towns of Europe in the

In considering this subject attention must be paid to the different classes of buildings inhabited by human beings in this country.* They may be thus classified :—1. Houses, (*a*) of the Wealthy, (*b*) of the Poor, (*c*) of the Nomadic tribes or castes, and (*d*) Camp life in Tents : 2. Hospitals, (*a*) for General or Special diseases, (*b*) for Infectious diseases : 3. Jails : 4. Barracks : 5. Schools : 6. Shops and Offices, Courts, etc.† The two latter classes, 5 and 6, are not, strictly speaking, dwellings, but as a large number of human beings pass a considerable portion of their lives in these buildings they require to be noticed.

HOUSES—OF THE WEALTHY.

By this heading is not meant that all who live in large houses are necessarily wealthy and *vice versâ,* for it may be that owing to special circumstances a comparatively poor person may live in a large house, whilst, contrariwise, nothing is commoner in this country than for a man who is really wealthy and could easily afford to live in a proper house, to prefer instead a tumble-down hovel in a back lane off a bazaar, so that he may save a few more rupees ere he quits this earthly scene—and leaves them all behind him! The houses referred to here are the detached bungalows occupied by well-to-do Europeans and Natives and the larger houses in the streets of the chief towns.‡

By far the greater number of these are built either as a pure speculation or else by people who have prospered in life and wish to settle down, in which latter case the work

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middle ages, the rapid and fatal spread of epidemics is very largely due to the concentration of the impurities on a very small area.

* The consideration of the *collections* of huts or houses which go to form villages and towns, in their relation to external ventilation and the general health of the inhabitants will be found under Part IV, Practical Sanitation.

† There are many other classes of buildings such as Hotels and Hostelries, Churches, Public Halls, etc., which require equal care in construction and subsequent supervision, but space forbids mention of them.

‡ The scope of this work does not permit nor require reference to the palaces of Rajahs and other Nobles nor to the official residences in the various presidencies.

is almost invariably entrusted to an ignorant contractor. In some cases the houses have been built under official supervision and in these the work is generally of a better nature. In every way, save in point of size of the rooms, Europeans in India are worse housed than those of a corresponding class in Great Britain and this is partly due to the fact that, with rare exceptions, their Indian dwellings are only temporarily occupied by any one family, and partly to the fact that the same class of work and material is not procurable here without disproportionate expense. The large bungalows standing in several acres of ground, seen typically near Madras and Calcutta, which were formerly the usual dwellings of Europeans, offer, no doubt, many advantages of comparative distance from dirty bazaars and *parcherries* or *busties*, quietness, fresh air, etc., but the day when the tenants could well afford to keep them clean and in repair, and pay a proper rent for their occupation, has gone by. Hence is commonly seen the insanitary and disagreeable sight of a half-empty, ruinous bungalow in a dirty, unkept compound, through which latter is a 'right of way' in any direction and, apparently, free grazing for the cattle of all and sundry. There are few pleasanter dwellings to look upon than a clean, handsome bungalow in a well-wooded compound, but such is daily becoming a rarer sight.

1. Referring once more to the requirements of a healthy dwelling, as instanced at the commencement of this chapter, the first necessity is a dry and non-malarious Site and a good Exposure. These have already been discussed.* The site of a large bungalow is frequently the best available in any particular place and, if malarious, it is generally owing to the existence of swampy, undrained ground in the neighbourhood, coupled, it may be, with defective foundations of the house itself. These latter will be alluded to afterwards.†

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* *v.* Chap. III, p. 111, *et seq.*, and p. 126, *et seq.* Exposure will again be referred to under 'ventilation' of houses, hospitals, etc., in this chapter.
† *v.* 'Foundations', pp. 230-1.

2. The arrangements for Water Supply and the removal of dirty water have already been described,* but a few points remain to be noticed. Except in bungalows situated in the largest towns, the water supply is almost invariably from a well in the compound. This well is frequently situated in a bad position and not seldom is merely a *shallow* well, although its actual depth is considerable. When the water level is high the pressure within the well may keep back the surface soakage to a large extent, but during dry weather any impure water which dribbles through the cracks and fissures in the upper layers of the soil meets with no resistance and may often be seen oozing through the sides of the well and dropping into the water below.† In large towns with a proper water supply there should be a stand-pipe available in every compound for watering the garden, flushing drains, etc. If the natural pressure or 'head' is too small to deliver the water to the upper stories of the house, the municipality should certainly make use of Shone's ejectors as before described, erecting a small compressed air station if necessary.‡ Water should be laid on to the pantry, kitchens, stables, etc., and the waterman abolished. Otherwise, cleanliness of the house is almost impossible.

For the removal of Dirty Water, in most cases, there is practically no provision whatever. When a house is first constructed a few miserable channels, lined with country bricks and chunam, are built, chiefly with the intention of carrying off rain water. In a short time these become completely choked or destroyed, with the result that the whole of the dirty water from the house and the rain water from the roof sink into the ground, which is

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* *v.* Chaps. II and IV.

† When the writer was acting as Chemical Examiner in Madras, a gentleman sent a sample of water from the well in his compound and wished to know if it was fit for drinking. Analysis showed that it was practically sewage!

‡ *i.e.*, in a place where the hydro-pnuematic system for the removal of excreta is not already in use. All that is required is two small engines and two sets of air pumps, with a small supply pipe for conveying the compressed air to the ejectors.

thus saturated with moisture and filth.* In some cases hollow, and usually porous receptacles, of limited capacity, are placed at the foot of the pipes from the bath-rooms and pantry. These receptacles constantly overflow and, under any circumstance, are only emptied at the leisurely convenience of the sweeper and after the liquid has been exposed for many hours to a tropical temperature. The proper remedies for such a state of things cannot be applied unless the landlord is forced by the authorities to *make and keep in order* suitable drains, and the tenants of the houses take a personal pride in seeing that all is clean and sweet. All sullage water could be quite easily and harmlessly disposed of by leading it to one or more points in the garden for use in irrigation, the drains being flushed daily, if possible, with a few gallons of clean water and occasionally scraped by the sweeper.† The arrangements for the removal of rain and house water will be alluded to again under construction of houses.

3. The third condition, immediate and perfect Sewage Removal, has been fully considered in the last chapter and in the preceding paragraph. As regards the Removal of Excreta proper, the very simple method adopted in this country has been alluded to already.‡ It is fairly satisfactory, when properly carried out, but might be considerably improved. In the first place the practice of using the bath-room, which is in immediate connection with the bed-room, as a privy is a mistake. In each house there should be two partially-detached rooms§ for exclusive use as privies, one for males and one for females, the bath-rooms

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* *v.* Chapter IV, p. 197, and footnote.

† *Ibid.* At first sight it appears as if the European tenants of these houses coming, as they do, from the most hygienic country in the world, are largely to blame for such a state of matters. And so they are to a considerable extent, in most cases, but it is to be remembered that they are constantly changing their residence and servants, and it is very disheartening to have to keep on complaining to every landlord and trying to train fresh servants. The first essential is to *compel* landlords to make proper provision for the removal of all rain and dirty water.

‡ *v.* p. 136.

§ With thorough cross ventilation between them and the house.

being used exclusively for purposes of ablution. By a slight re-arrangement this could easily be managed in the design of a new house without adding to the expense. A little water, containing, if desired, a few drops of a deoderant such as sanitas fluid, should be placed in the pan before use, or else a box containing dry earth and a scoop should be at hand and the motion covered with dry earth* immediately. For the reception of the excreta, both liquid and solid, the sweeper should be supplied with a water-tight, metal receptacle, tarred inside and out. This should be kept in a place easy of access by the municipal scavengers, but invisible to the ordinary passer-by.†

4. Coming next to the subject of Ventilation, which has already been dealt with,‡ there are still some practical points to be noted. It is not too much to say that the ordinary Indian house is built without any regard whatever for ventilation, the only idea being to obtain a certain degree of shadiness and coolness. Unless the greatest care is taken in designing the house, these two conditions, *viz.*, good ventilation and coolness, will not be obtained, the result being a cool house in which the air constantly stagnates, or *vice versâ*. When a house is completely shut up during the day in hot weather, there must be some special means of ventilation in action if the air is to be kept pure.§ In a one-storied bungalow, which is the usual type throughout India, the area covered by the building is very large, and though the vertical height of the rooms in the centre of the building may be considerable, the eaves project all round the outer edge of the verandahs to within a few feet from the ground. In addition, there are commonly no vertical openings through the roof such as are naturally

* Note, once more, that sand is quite useless; on the small scale, suitable earth can always be obtained and prepared for use.

† The ordinary practice of having an old leaky kerosine tin with no handle, placed in as conspicuous a place as possible, is neither sanitary nor decent.

‡ *v.* Chapter I.

§ Under any condition pure air is necessary, but itis especially so in the case of people who are obliged to pass the greater part of the day in partial darkness, for months together.

made for chimneys in colder climates. The result is that when the doors and windows are closed the house is like a box with the lid shut down and the ventilation is almost *nil.* If it were not that the fittings in Indian houses are invariably defective owing to bad material and workmanship, and warping from the heat and damp, the air within the house would soon become unbreathable.

In the heat of the sun there exists for utilisation a source of ventilation almost, if not quite as powerful as a good fire. By the use of shafts of wood, brick, or iron, painted black and with a curve, if necessary, to prevent the direct passage of the sun's rays, placed in the highest point of the roof and projecting upwards several feet, a most efficient outlet can be made.* To compensate for the out-going air efficient inlets must be provided. They are best placed over the doors or windows as a general rule, and may be simple openings covered with wire-netting or gauze, or may be more elaborate and artistic. It is very desirable that there should be some means of cooling and filtering the in-coming air which is nearly always hot and dusty. This might be managed by making the inlet in the form of a metal box or short metal tube of zinc or copper, somewhat after the nature of a Tobin's tube, but projecting outwards for two or three feet, and covered with felt or cloth kept constantly moist by a simple automatic apparatus, such as a water container perforated with holes through which wicks are passed, and placed over the tube. The outer end of the tube should be covered with metal gauze to prevent the entrance of birds, etc., and near the inner opening a removable screen of Jute cloth could be placed. Such a plan would only work well in a comparatively dry atmosphere, where the metal inlet was kept well in the shade but exposed freely to the movements

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* In connection with this subject Mr. Wallace made experiments with a bit of thin sheet iron, 22 inches square and 10 feet high, left black and unpainted. The velocity of the current through the tube was found to be 133·2 ft. per minute, which multiplied by the area of the tube (3·36 sq. ft.) gave 447 cub. ft. per minute, or 26,853 cub. ft. per hour. For further details, *v.* Wallace, *op. cit.*, p. 194.

of the air.* When the air is warm and moist, and at the same time very still, it is by no means easy to ventilate a house satisfactorily. Reliance must be placed on simple openings which will act as inlets or outlets on occasion, and on simple perflation by opening doors and windows.† The whole subject of the ventilation of Indian houses in the plains needs to be studied scientifically and carefully, and practical use made of the knowledge thus obtained. On the hills there should be no difficulty in securing sufficient ventilation, but there the houses are, if anything, worse off than those in the plains in this respect.‡ Many of the rooms are very small and absolutely unprovided with means of ventilation, save a chimney. Sometimes even that is wanting. Such carelessness is quite inexcusable, more especially when it is remembered how essential fresh air is to the worn-out or invalid toilers from the great heat of the plains.§

With regard to the larger houses situated in the streets of Calcutta, Bombay and other towns, there are many objections as regards site, drainage, and especially ventilation. The external ventilation is so bad that it is impossible to get pure air in the houses, and the general surroundings are in every way defective, not the least drawback being the constant noise from the street traffic,

* The only doubtful point is whether the length of the tube would not have to be considerably greater. It might be bent or in the form of a short spiral, though in that case there would be considerable friction. *v.* Suggestion by Wallace, *op. cit.*, p. 191.

† "The semi-hexagonal layer of the Allahabad system (*v.* note, p. 236) serves the purpose of ventilation. In flat roofs circular openings are generally made in the terrace and surmounted by a cap slightly raised above the roof surface, the air escaping through the joints between the flat tiles into the channel formed by the hexagonal."

‡ Exception must be made of some houses built under the personal superintendence of retired medical officers and others, and of some official residences.

§ All houses on the hills, and elsewhere, should be periodically inspected, and compliance with at least the rudiments of sanitation insisted upon. No railway can be opened till every part of the permanent way, rolling stock, etc., has been inspected. It is quite as necessary that the same precautions should be taken for the health of people powerless to defend themselves. This subject will be referred to later.

etc.* It is possible that in time to come Anglo-Indians may be obliged to live in tenement houses situated in or quite near to the town, but if this is so there must needs be great improvement in many directions.

Regarding the use of punkahs, to which reference has already been made,† Mr. Wallace, C. E., has made interesting experiments‡ as to the most suitable form for producing a downward current. "A punkah curtain is a ship's sail reversed. It is drawn through the air in order to produce a current in a desired direction. It must curve or 'belly' as the sail does, in order to facilitate the movement of the air, and the rod§ at the lower edge must be of such a weight as to produce a curve on the curtain like that of the blade of a revolving fan. The curtain should be perfectly plain, and of the thinnest possible material, such as muslin or fine silk, and the suspending cord should never exceed $\frac{1}{4}$ of an inch in thickness. Lightness in appearance should always be the object of the designer. Round bar iron, $1\frac{1}{4}$-inches in diameter, covered with leather or leather cloth, makes a very effective swing-bar with

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* *E.g.*, the noise from the steam whistles of the Jute and other mills near the suburb of Cossipore, at Calcutta, is most distracting, especially to those who sleep lightly or are sick. There should be only one steam whistle at a central spot, and this should only be blown at fixed hours.

† *v.* note, p. 30.

‡ "Twenty-five pulls per minute represent the economical speed of working of an average coolie, so all suspended punkahs should work at this rate, however high the roof may be.—The simplest way of finding the length of the suspending cords is to hang the punkah temporarily with cords going over the hooks and fixed within reach, or held by hand. The length may then be altered till the right speed is found. Ceilings up to 16 feet high will give a fair approximate length to punkahs, which must be hung 6 feet clear off the floor. Twenty-five pulls of three feet will give a speed of 150 ft. per minute to the punkah bar. The pull should be in a downward and not in a horizontal direction, and to make the work as easy as possible, the swing-bar should be made heavy enough to lift the arm of the puller during the return movement.—If the roof of a room be too high for the proper swinging of punkahs, they may be hung in the ordinary manner, and the centre of suspension may afterwards be altered by attaching a light bar of wood across the suspension cords, horizontally, but at such a height from the swing-bar as to give the right length for speed of movement. The bar is next fixed by thin wires to opposite ends of the room so that it cannot swing; it thus becomes the true centre of suspension of the punkah."—Wallace, *op. cit.*, pp. 185, 187.

§ A light piece of wood.

polished hard wood ends. When hung with 3-inch iron rings on the suspending hooks, the rubbing is transformed into a rolling motion and the punkah is noiseless.

5. The last condition for a healthy dwelling, demanded by Parkes, is Proper Construction, insuring perfect dryness of the foundations, walls and roof. In this country must be added another condition, *viz.*, construction such as will be amply sufficient to protect from the direct heat of the sun's rays and to insure reasonable coolness of the house at all hours.

Under various local acts, such as the Madras Municipal Act and the Madras District Municipalities Act, notice has to be given of any new building or restoration, with plan of foundation and of ground floor, statement of means of ventilation, drainage and privies, and such further particulars as may be required under bye-laws. So far as can be seen the supervision exercised on the strength of the above clause is by no means thorough and houses continue to be erected on the old plan with nearly every possible fault in their construction. The greater number of bungalows occupied by Europeans have been built for some time* and as a consequence it is not possible to do much in the way of improving the original design. Of late years there has been a considerable improvement in buildings erected under official supervision and a higher class of work insisted upon, so it is to be hoped that in time to come a corresponding betterment in the houses in which ordinary human beings are compelled to reside may occur.

In the construction of a house the following parts require separate consideration—(*a*) The Foundation; (*b*) the Walls; (*c*) the Floors; (*d*) the Roof and Ceilings; (*e*) the Out-houses, including the Kitchen.

Foundations.—Before starting the actual erection of any building careful attention must be paid to the choice of a

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* *E.g.*, in Madras the larger bungalows were mostly built from 30—40 years ago or longer and are nearly all in a state of impending dissolution.

site, if possible, and also to the nature of the soil on which the building is to be erected. This latter point is chiefly a question for engineers, but if there is any reason to suspect that it is 'made soil'* or that the ground is in any way unsuitable from a hygienic point of view it should be carefully examined by a sanitary expert. The object of carrying the foundation of a building below the surface of the ground is to guard against the soil under the bottom of the masonry being softened and exposed or undermined by rain, etc.; also, where the top soil is easily compressible, or loose, to obtain a firm footing. In soft ground the foundation is made very broad at the bottom or better still, a good, continuous bed of concrete or asphalte is very carefully laid down.* In addition, to prevent damp from rising in the walls by capillary attraction,† a 'damp proof course' should be inserted. This consists of a continuous layer or course of impervious material such as slate, glazed earthenware, vitrified bricks, or hydraulic cement, etc., laid horizontally for the entire thickness of each wall, above the point where the wall leaves the earth, but below the level of the floor. Efficient ventilation, with resulting dryness of the floors, may be obtained by leaving a clear space between the foundation and the floor, with occasional openings to the outer air, but it must be very carefully done so as to exclude all chance of the entrance of insects or vermin. A still better plan is to elevate the house on pillars or arches, care being taken to keep the spaces thus left perfectly clean and dry.‡

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* In preparing the bed of the foundation careful search must be made for white ants, and if found, they must be completely destroyed by tracing down the burrows, till the queen ant is secured and killed. For further details on this and subsequent sections, *v.* Roorkee Treatise on Civil Engineering, sections II, III and VI.—Jones' Manual, etc.

† The amount of moisture that can be absorbed by the walls of a building is very great. An ordinary brick will hold about 16 ounces of water, and during monsoon weather the walls of mud huts are like sponges saturated with water.

‡ In Burmah and other countries it is customary to raise the houses on poles or on arches, but the benefits thus derivable are largely neutralised by the ground surface being allowed to remain constantly wet and filthy; in fact, it is made the receptacle for dirty water, scraps of food, etc.

Walls.—Walls in India are mostly built of brick. The bricks are generally the common 'country' sort, which are made of poor material, sun-dried or dried in rude kilns, and most erratic in shape. The result of this latter failing is that it is impossible to get proper 'bond'* in the wall, which thereupon begins to crack in a short time and allows the passage of moisture, insects, etc. Where good chunam mortar or cement are used with well-baked ('P. W. D.' or 'Government') bricks, properly laid, a thoroughly suitable wall can be constructed of the thickness of a brick and a half.† Various other materials are used for the houses of the poor, temporary structures, etc., which will be described afterwards. Double walls, with a ventilated space between, are very good and keep a house dry and cool, but the constant presence of squirrels, rats, etc., makes it difficult to prevent a nuisance arising from this cause.

The outsides of the walls in nearly all houses are plastered and whitewashed.‡ The former is done merely to hide the *kucha* brickwork, but the whitewashing has undoubtedly the effect of preventing the absorption of a large amount of heat. It is becoming the custom in the case of officially built houses, etc., where good bricks and neat work are employed, to leave the outside walls with the bricks exposed, in other words of a red colour. It certainly looks well and is refreshing to the eye, but the buildings are

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* Bonding is the arrangement of the bricks in respect to one another, so that no joint in any course shall be in the same place with any other joint in the course immediately above or below it; the object being to preserve a transverse and longitudinal tie between every portion of a structure, so that its stability should be practically independent of the mortar.—Jones, *op. cit.*, p. 135.

† "A brick and-a-half wall of *pucka* masonry will carry almost anything. As a rule, there is much unnecessary masonry in Indian houses," and this means waste of money that might be much more usefully expended in proper surface drains, etc.

‡ The plaster used in India is really finely-ground mortar being made of chunam and river sand or chunam and white sand in varying proportions. Sea sand must never be used, on account of the hygroscopic salts that it contains. Whitewash is made by adding slaked lime to a solution of gum, glue or rice-water. Sometimes blue or yellow washes are used, but they are not so useful in preventing the absorption of heat. Dark blue is especially bad.

proportionately hotter, as anyone who has to live in them soon finds out.*

The inner sides of the walls are generally plastered and whitewashed also; this being required on account of the rough nature of the work. Where the wall is well made of good bricks, properly 'pointed,' this is quite unnecessary, the inner surface being simply painted with oil paint and therefore washable. As to whether the walls should be built of or covered with some impermeable material, there is a difference of opinion. Some consider that the porosity of the wall is a good thing as being an extra source of ventilation, but this is an error and a tacit acknowledgment of failure to ventilate a house by the proper means. What is really wanted is a smooth, washable and non-absorptive surface, which is in addition impermeable, so that it can be cleaned periodically and will prevent the entrance of heated air or moisture from without. For this purpose nothing is better than the beautiful plaster of Madras with its polished surface resembling white marble.† But the process, if done properly, is a lengthy and costly one‡ and repair after injury is difficult. Encaustic tiling or cement are excellent for kitchens, bath-rooms, etc., and will probably be used largely some day. At present the best available method for general use is good hard plaster covered with oil paint. The papering of inner walls, almost universal in England, is comparatively uncommon in India and is not to be recommended, save possibly for reception and dining rooms. Care must be taken that arsenic is not mixed with the 'size' used for making the paper stick to the wall.§

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* The tendency to make Indian houses conform to European styles of architecture is certainly a grave mistake. Given materials and workmanship of European goodness, elegant and hygienically suitable buildings, adapted from various oriental patterns, should be designed and built as standing examples for the native builder to copy.

† *E.g.*, St. George's Cathedral, Madras, where the plaster, about sixty years old, is smooth and beautiful still.

‡ *v.* Jones, *op. cit.*, p. 128, *et seq.*

§ It is commonly added in large quantity by the native workmen to prevent insects destroying the paper, but there are other harmless sub-

Floors.—In a cold climate like that of Great Britain the floors of houses are almost invariably made of wood, but in India the practice is neither advisable nor necessary in an ordinary house. Here the flooring may be made of a variety of materials;—bricks, stones, tiles, broken bricks and mortar (terraced floors), cement, asphalte and wood are all used. Like many other things in India, the custom of the place or district largely determines the use of any particular material. A terraced floor,—made of a layer of broken brick (or *kunkur*) and a little mortar well beaten in, followed by a layer of *súrkhí* mortar well beaten in, and finished with a layer of fine shell lime or, better still, cement,*—makes a very good floor for use in houses. The great drawback of such a floor is that it is difficult to repair; indeed the whole floor must be taken up and relaid if a good job is to be made of it. For large houses, the most suitable method of flooring would probably be to have the centre made of the best terrace work covered with cement, the margin, about two feet wide all round, being made of encaustic tiles pointed with hard cement. By such an arrangement the carpet, or other covering of the floor, need not cover the entire room, so that greater cleanliness and security from the ravages of insects are secured. Whatever flooring be adopted for the ground storey it should be air and water-tight. This is of *supreme importance* in this country.†

Upper floors are often made of wood.‡ When this is the

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stances which would doubtless do instead. Of course, no paper containing arsenic in the colouring matter should ever be used, as such a practice is very liable to cause chronic ill-health from arsenical poisoning in some individuals.

* Only good mortar must be used and the beating must be very carefully done. The surface layer of lime or cement must not be too thin, as is frequently the case, or it will certainly crack and permit the passage of moisture, dust and insects.

† There is little doubt that with pure drinking water, suitable clothing and a house with impermeable floors and walls, good health can be maintained by any one for a long period in a malarious place, whilst others, under less favourable conditions, suffer from repeated attacks of malaria. *v.* chap. III, p. 128.

‡ Various devices for rendering a wooden floor impermeable and non-absorptive of dirt and moisture have been invented. One of the simplest

case the joists and planks of the floor should form the ceiling of the room below so that neither dirt nor vermin can remain concealed. In England the space between the plastered ceiling and the floor above is usually filled with 'pugging' to deaden sound; it is not a good practice at any time, but is absolutely inadmissible in this country.

It is essential that precautions be taken during the construction of a house or other building to protect it from the ravages of white ants. For this purpose yellow arsenic or orpiment (*hartál*) is most generally used, but great care is required if this is done. Having ascertained that the foundation area is free from white ant burrows,* arsenic is mixed with the concrete, mortar and plaster used in the foundation, floors and walls to a height of four feet, but *never in any surface coat* so as to be exposed to attrition or rubbing. The mixing and application should be done under competent supervision.

Roofs.—The roofs of Indian houses are divisible into two classes, flat or *terraced* roofs and sloping or *pent* roofs.

Terrace roofs should have just slope enough (not less than 1″ in 10′) to allow rain water to flow off their surface. They are often very badly made and after a little time begin to crack and even gape. In many native houses they are much used as a place of resort in the evening and thus subjected to extra wear and tear. The consequence is that they leak† during rainy weather and render the house and its contents, such as beds, clothes, almirahs, etc., damp. Their construction being much the same as ter-

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and best plans consists in melting solid paraffin (*paraffinum durum*, B. P.), pouring it on the floor and ironing it in with a box-iron. The excess of paraffin is scraped off and the floor brushed with a hard brush: a little paraffin in turpentine is then put on, and the flooring is good for years. Longstaff, quoted by Parkes-Notter, p. 226. This would probably do excellently for teakwood floors. Other plans, suitable chiefly for softer woods, are given in S. and M., p. 777, *v.* also San. Record for 1893.

* *v.* note, p. 231.

† For compositions used to fill the cracks. *v.* Jones, *op. cit.*, p. 144. When an old roof is repaired by covering with asphalte it should be painted white, for coolness. *v. post.* p. 259.

raced floors,* the same care in laying the courses is necessary, and only well-seasoned timber should be used for the roofing.†

Pent roofs have very various coverings, such as terrace work, tiles, slates, thatch, corrugated iron, etc. Tiled roofs are coming more and more into fashion owing to improvements made on the common pot tile of native brick works. By far the best are the Mangalore and Allahabad tiles which are made of first class material and accurately to size. The details of construction of these tiled roofs are too elaborate to be described in this work.‡ In the Punjâb and some hill stations slates or stone flags are used and if the slates are of equal dimensions and not laid too sparsely they make a good roof. On the hills, wood planking, tarred over, and shingles, *i.e.*, square pieces of split wood, are also used for roofing. They are cool enough, but such roofs are certain to leak ultimately, besides remaining damp for a long time during wet weather.

Thatched roofs, consisting of long wiry grass laid in bundles on a bamboo frame work, and from six to twelve inches in depth, are very cool and wonderfully dry. They are largely used for bungalows in certain parts of India where the heat is very intense. Their chief disadvantages are the liability to take fire and the number of squirrels, rats and other animals which they harbour. It is a quite unsuitable material for most buildings, especially hospitals, other than very temporary ones. Corrugated or galvanised iron, zinc and lead sheeting, are all used as roof coverings, but especially the former. For houses in the Indian hill stations the favourite form of roof for excluding the frequent

* In the same way as for floors, instead of a lower foundation of bricks, tiles or stone flags may be used. "Three layers of tiles laid to break joint, the upper layer being covered with a thin coat of plaster, well polished and oiled, forms a very durable flat roof, and possesses the advantage of being lighter than a terraced roof, and in any case it is the upper surface that the water-tightness of the roof depends upon."—Roorkhee Treatise.

† Used here in its technical sense, *viz.*, the joists, rafters, etc., upon which the roof covering is laid.

‡ *v.* For description of the former, Jones' Manual, for the latter, the Roorkhee Manual.

and heavy rainfall is a roofing or framework of wood covered with corrugated iron, the latter in its turn having a covering of Mangalore or other tiles. Without the tile covering, the iron roof is noisy during rain and hot.

Ceilings.—In a flat-roofed house of one storey only, the roof timbers are generally left uncovered internally except for a coat of paint, or stain and varnish, so that any injury done by insects can be at once detected. On the hills the same thing can be done with the pitched roofs of corrugated iron, but if these latter are used on the plains it is necessary for coolness' sake to lay a wooden ceiling underneath. In houses of more than one storey the ceilings of the ground-floor rooms are best made by simply leaving the joists and flooring of the room above exposed and painted any desired colour. There should be free ventilation and means of inspection round the ends of all wooden beams,* but the openings must be carefully closed with metal gauze to prevent the passage of birds and rats.

In former days a very favourite form of ceiling for a pent roof was that made by coarse canvas (ceiling-cloth) stretched flat on a frame beneath the roof and timbers and painted white. It looks well when new and bears a distant resemblance to an ordinary plastered ceiling, as used in England, but it has many disadvantages and is generally a quite unessential addition.

Rain pipes.—It is very important that a house should be provided with efficient means of getting rid of rain water as soon as it falls, and by getting rid of it is meant its complete removal to a distance. This is easily managed either with a flat or pent roof by having proper rain pipes fixed and *kept in repair*. With a pent roof there should be gutters placed all round the lower edge of the roof and verandahs to catch the rain, with openings into down-take pipes at intervals, these latter being bent outwards at the

* On account of the initial expense and liability to destruction of wood, Iron girders, trusses, etc., are coming more and more into use in Indian buildings.

foot and discharging into the surface drains running round the house.* Where the roof is flat the best plan is to have the water discharged through short spouts carried well out from the wall, the area on which the water falls being cemented and grooved so that the water flows away into the surface drains. It should be an axiom that *no water of any kind, clean or dirty, should be permitted to fall on and soak into the ground immediately surrounding the foundations of a house.*

Out houses and Compound.—Another point in which most Indian houses fall far short of sanitary requirements is the situation and condition of the out houses and stables, and the state of the compound. As a general rule, the kitchen, servants' godowns, stables and coach house, with other buildings often in addition, are all crowded together in admired disorder. In nearly all the older bungalows these 'offices' are in a semi-ruinous state and unspeakably filthy, the neighbouring subsoil being saturated with the organic pollution of years. Add to that a dirty hole or tank, sometimes full, sometimes empty, *always* used for purposes of ablution, bodily and otherwise, by the servants, a tumble down and dirty servants latrine or a tangled mass of undergrowth which serves this latter purpose, and one has a picture, by no means overdrawn, of fifteen out of twenty compounds.† Hence arise those seemingly mysterious cases of sudden disease,—cholera, typhoid fever, etc.—

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* The down-take pipe should be kept well away from the wall by supports, and both this and the gutters and spouts examined and cleaned periodically.

† As stated before (*v.* note, p. 225) the responsibility for such a state of things must generally be divided between the landlord and tenant. The former, however, has undoubtedly the advantage in most large towns and has kept on raising the rent to suit each fresh valuation or taxation by the municipality, while the tenant, powerless to pick and choose his residence, owing to the paucity of houses, has perforce to pay an enormous rent out of a salary worth just half its nominal value. There is no doubt, from information received from thoroughly trustworthy sources, that in former days when officials were more settled and received suitable remuneration, the ordinary bungalow compounds were much better kept in every way. In some *mofussil* stations, originally the sites of cantonments, the above conditions are reversed and it is the tenant's fault if the compound remains in a filthy condition.

which attack and carry off child or parent and are put down to the unhealthy climate!

In a new house, then, the kitchen, godowns and stables should be kept separate, and the godowns limited in number as much as possible. Tanks are quite unnecessary when there is a pipe water supply: if wells are made they should be carefully constructed* and their use ordinarily confined to garden purposes. Water should be laid on to all the buildings, and properly cemented places, leading to the surface drains, constructed for the washing of servants, carriages, etc. There should be a dry earth latrine for the use of the servants and the master of the house should feel it to be his *duty* to inspect the same periodically or else, if he feels unequal to the task, to depute the same to responsible authority.

Kitchens.—Indian kitchens, as being the place where the food which we eat is prepared, deserve careful notice. Yet what good is it possible to say of them? The following extracts from the pen of a well-known reformer† in this matter may serve to bring the picture more vividly than otherwise possible before the thoughtful reader. "Remembering as we all can so well the cheerful aspect of the English kitchen, its trimness, its comfort, and its cleanliness, how comes it to pass that in India we continue year after year to be fully aware that the chamber set apart for the preparation of our food is, in ninety-nine cases out of a hundred, the foulest in our premises—and are not ashamed? * * * Why, in short, in the one country are we scrupulously careful that our food shall be clean, and in the other at all times willing, apparently, to eat dirt?"

"Over and over again have revolting facts been discovered in connection with the habits and customs of the cook room. But instead of striking at the root of the evil,

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* *v.* pp. 54-5.

† Culinary Jottings for Madras, Wyvern, 5th ed., p. 496, *et seq.*, where the original article should be read by all interested.

and taking vigorous action to inaugurate reform, we are callous enough not only to tolerate barbarisms, but even to speak of the most abominable practice as jests! Though cognizant, that is to say, of the ingenious nastiness of our cooks, we shrug our shoulders, close our eyes, and ask no questions, accepting with resignation a state of things which we consider to be as inevitable as it is disgusting."

"But is it inevitable? Think first of all of the distances which as a rule separate our kitchens from our houses, and the fact that the room is part and parcel of a block of godowns—not unfrequently within easy access of the stables. Setting aside other considerations for a moment, do we not at once perceive here two grave evils: in the first place that proper supervision of the kitchen is almost out of the question; and, in the second, that promiscuous gatherings of outsiders,—the friends, relations and *children* (a fruitful source of dirtiness) of our servants—can take place in it undetected? Again, the room is generally constructed with as little ventilation and light as possible, its position with regard to the sun is never thought of, and arrangements for its proper drainage are rare. As there is no scullery, or place for washing up, etc., the ground in the immediate vicinity of the kitchen receives the foul liquid (as well as all refuse matter) which is carelessly thrown out upon it. The consequence is that hard by many a cook room, there is a noisome cesspool containing an inky looking fluid, the exhalations from which can scarcely improve the more delicate articles of food which are sent from the house for preparation."* The writer then passes on to describe the condition of the interior of the kitchen and the miserable fittings in connection therewith, and shows that it is impossible to expect the cook, amidst such degrading surroundings, to be clean in his habits or person. Most reasonable suggestions are made as to the situation, fitting up and general arrangement of the kitchen as it should be, and attention drawn to the fact that though

* There are much more *serious* objections to such a practice than this.

considerable opposition may be met with in the first case, a *good* cook will speedily appreciate light, airy and clean quarters, and that reform from without will sooner or later be followed by reform from within.

HOUSES OF THE POORER CLASSES.

That this is a subject of vast importance, no one who has an intimate knowledge of the conditions under which the millions of Indian poor live, will attempt to deny. That these conditions are not in themselves so absolutely degrading, so completely brutalising as those to which the poor of London, Paris and other great European cities are subject, is more or less certain, for even the poorest classes, the pariah and the ryot, are merely ignorant and uncivilised and have not had grafted upon them the unspeakable vices and misery which result from a long process of *decivilisation*. In addition, there are certain things in favour of the Indian poor, *e.g.*, the regular family life—as opposed to the swinish herding of the sexes in the East end of London—and the tropical climate, which is not so directly inimical to life as an English winter.* But even so, the fact remains that the dwellings of the poorer classes are of the rudest and most imperfect description and their surroundings worse.

In towns the buildings are of better construction, but any advantage derived in this way is more than negatived by

* In connection with this subject, the writer, in a course of lectures on the Principles of Hygiene delivered in Madras at the request of the Council of the Victoria Technical Institute, said,—"To the rich, who are able to live comfortably in special quarters and to leave them when they like, the great city seems a delightful place and they would not change for anything. But to the poor man, who has to pass one half of his life amidst the smoke and dust of furnaces, the roar and rattle of machinery, and the other half amidst that appallingly depressing scene, row upon row of small streets and slums; whilst the seasons come and go unheeded, save that it is summer, for it rains, and winter, for it is bitterly cold; to the poor man, I say, the city appears in all its hideous reality, and he curses the fate that placed him there."

"The average ryot in this country cannot be said to lead too pleasant an existence, but at least he does not know much better, and the hardships he undergoes, short of actual starvation in famine years, are in every way lighter than those of his fellow man in the slums of London, Liverpool or Glasgow."

the increased want of free ventilation and pure air. The ordinary poor live in small houses with brick walls and thatched, tiled, or terraced roofs. The foundations are shallow, the walls made of miserable bricks laid in mud or the poorest mortar, whilst the floor is simply made of mud plastered with cowdung. As a rule, there is a plinth, but owing to the method of construction of the lower part of the building, this is of little use so far as impermeability to ground air and moisture is concerned. The precautions to be observed with reference to selection of site, the allowing for free external and internal ventilation and provision for the removal of waste matter, are practically unknown; hence it is extremely common to meet with houses which violate directly every single condition of healthiness. Not only so, but care is taken to make matters worse by turning the walled-in space at the side or back of the house and the front verandah into stables or cowsheds. The windows, if such exist, are very small and are always barred, frequently shut.

The following extracts* from a description of the smaller native houses refer to some of these defects:—"The only ventilated openings in these habitations are small sized windows and doors, which too often admit only stagnant air loaded with all sorts of impurities, and never drive it out. In country places houses possess yards bounded by a brick or mud wall, which keeps the inside air very foul. A large number of houses in these places are very old and ricketty. Over a large part of the country there are no tiled and sloping roofs, but a flat layer of earth overtops the house and presses it down. Openings in the way of sky-lights in the roof to allow the foul air and smoke to pass out are seldom seen. In the Konkan and near the Ghauts, at the front or back of the houses there are generally to be found dense masses of vegetation—the delight of the owner. * * * Where open

* K. V. Dhurandhur, L. M. & S. Trans. VIIth Internat. San. Sci. Cong., Vol. XI, p. 138.

spaces exist round about a house, they are very often surrounded by a fence of prickly pear or wild cane growing in luxuriance, and inviting or concealing filth of every kind. * * * In many cities the privies are found near the entrance of the house, and are ranged on both sides of the streets. In many big towns in Gujerat and the Deccan, a latrine can very often be seen in front of houses with a cook-room by its side, and a bed-room over it. * * * There is always a place reserved somewhere close to the hut of the poor or to the dwelling of the well-to-do, which serves as a pit in which all cattle dung, ashes and home rubbish are collected for one whole year, to be removed to the fields for purposes of manuring."

The poorest classes, including ryots and coolies of all sorts, live in still worse houses or huts made with mud walls, or wattle and mud, the floor and walls plastered with cowdung, the roof thatched with grass laid on a framework of bamboo. These houses are hot in hot weather, damp in wet weather and cold in cold weather; their site is generally the worst possible; windows are unknown and at night, if it is at all cold, every hole, including the door, is carefully closed.

But there is no need to dwell further on their deficiencies: it is more important to consider whether it is possible to improve them in any way. This is a matter of extreme difficulty, primarily, because the people are so poor, and secondarily, because they are so apathetic. Looking upon disease, as nearly all of them do, as sent by offended or evil deities, they are the last to be induced to believe that semi-ruinous dwellings saturated with moisture and filth can be the predisposing cause of numbers of the diseases which attack them. Any remedies that may be suggested or tried must be purely local in their effects and their exact nature must largely depend on the circumstances of the place with reference to situation, climate, customs, etc. Strict rules and regulations regarding the construction of any buildings used as dwellings by human beings are necessary, but what is infinitely more important is that these rules should be faithfully adhered to, and that *any building erected in violation thereof should be peremptorily pulled down or its construction stopped till the needful changes have been made.** Individual poverty is no excuse for a permanent policy of do-nothing; for this matter—the better housing of the poor—is a national one and of pressing importance, if the death-rate is ever to be effectually and permanently lowered.

Two partial remedies are possible and have been applied to a small extent in Calcutta† and Bombay, *viz.*, the destruction of unsuitable buildings, *i.e.*, those which it is impossible to 'improve' in any way, and the erection, by means of private benevolence or municipal sanction, of model dwellings.‡ To these latter there is certain to be considerable opposition at first, as there was and is in England, but in process of time it would die away and the benefit to the community at large would be great. As a matter of fact there already exist such models in various 'lines' for police, commissariat coolies, Government peons, etc., but even these are by no means perfect nor hygieni-

* Such rules do exist under various local acts. *v. Post.* Part V, Sanitary Legislation. Elaborate rules are not necessary; what is wanted is the *authority* to carry out simple regulations, and *systematic* periodical inspection, by trained inspectors, of all old and new buildings. It is a disgrace that in towns like Madras and Calcutta, occupied for many years by so cleanly a nation as the British, filthy tumble-down parcherries or bustees, rivalling, if not surpassing, the villages of darkest Africa, should still abound. Poverty is undoubtedly a difficulty, but is not a sufficient excuse.

† Demolition or improvement of insanitary dwellings in one direction is of little use, if the erection of similar dwellings in other directions is not prohibited. "If these places, which hardly anything short of clearance will remedy, are not to grow worse, and if other localities like them are not to spring into existence, building regulations which will effectually prevent huts and houses being built irrespective of ventilation, drainage, air-space, and means of scavengering must be enforced. * * In Calcutta, though considerable sums are being spent in endeavouring to improve unhealthy localities, equally unhealthy areas are arising." *v.* Report by Dr. Simpson, M. O. H., Calcutta, I. M. G., January 1887, quoted by McNally, *op. cit.*, p. 128.

‡ A wealthy Indian philanthropist, of whom there are many such, could find no better way of doing good to his poverty-stricken fellow subjects than by devoting a large sum of money to the erection of model dwelling houses, under trustworthy direction and supervision, in several of the larger towns.

cally commensurate with the expense incurred in building them: in addition, they are not the sort of houses suitable as dwelling places for the ordinary civil population.*

The rules to be followed in planning and building such houses are roughly outlined in the requirements of a healthy dwelling as before given, due allowance being made for the absolute necessity of *cheapness*. Be it remembered, however, that demand creates supply and that cement, tiles, iron, etc., will all become cheaper as they are more commonly used in construction. Finally, it is essential to secure the warm co-operation and example of the more enlightened of the community, and in getting this there will be no great difficulty if the sanitary advisers and well-wishers are in earnest sympathy with those they seek to benefit.

For the repair and maintenance in a state of comparative cleanliness of the ordinary houses of the natives of this country, the following twelve simple rules should be adhered to. (1) The use of cowdung as a covering for the floor and walls should be given up; it is *a dirty habit and an unhealthy one*, for cowdung attracts excess of moisture and forms a *nidus* for microbes. (2) Mud floors should have *the surface dug up and removed every few months*, a layer of fresh mud, to replace the mud taken away being laid on and beaten in during dry weather. (3) Mud walls should be left in their *natural condition internally*, or *whitewashed* every four months. (4) Every room should have either *two windows about 2 ft. square opposite each other* or else *one window 3 ft. square opposite the door*. Windows *must open to the outer air*.† (5) In the cook room there should be some sort of vertical opening or chimney in the roof to allow of the *ready escape of smoke*. (6) Dirty water and food refuse should on no account be thrown away in the immediate vicinity of the house, but *carried to a drain or*

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* A reward might be offered, sufficient to tempt the most capable persons to compete in designing model dwellings of the various classes required.

† In the large native houses one window or the door would open naturally on the inner court, the other on the outside wall of the house.

dust-bin respectively and there deposited. (7) The earth round the dwelling should be *well beaten down* and a *small channel made leading to the ditch or drain at the side of the road*, for disposing quickly of the rain water as it pours off the roof. (8) The house should be *opened up as much as possible, morning and evening,* to allow of free perflation. (9) Its exterior should be *whitewashed* as often as necessary to keep it cool and clean. (10) The latrine must be *outside* the general building, with an *impermeable floor* of asphalte or cement, if possible,* *easily accessible from behind* for the sweeper, *cleaned daily,* and with a door and window large enough to allow of *plenty fresh air and light* gaining admittance. (11) Whilst a few plants and small trees in the neighbourhood of a house are pleasant, there should be *no interference with the free passage of fresh air and light to all parts of the dwelling,* and all animals such as cows, ponies, fowls, etc., should be *separately housed outside the house and its enclosure.* (12) The occupants of the house should be *limited to the proper number,* and the unhealthy and objectionable practice of letting rooms to various families prohibited.†

ENCAMPMENTS OF THE NOMADIC CASTES—GIPSIES, PILGRIMS, ROAD COOLIES, ETC.

Nomadic Castes.—This is a matter that requires considerable attention being paid to it and receives but very little. There are, in India, numerous tribes or castes who lead a roving, nomadic life and settle down, in the course of their wanderings, for a longer or shorter time, on any piece of open ground they take a fancy to. The best

* Tarred chatties make the cheapest suitable form of receptacle. Two should be placed, one in front of the other, so as to receive and keep separate the liquid and solid excreta. Of course if the latrine communicates with a *pucka* open or closed drain, a sloping impermeable floor is all that is necessary. Cesspools, *khalcoovas*, *sundasses*, etc., are quite inadmissible.

† The extent to which this practice obtains in some places is almost unbelievable. Every available room and corner is 'let,' and the whole place being screened off with *tatties*, etc., at various angles, ventilation is impossible. In addition, each party does its own cooking in the one room or corner of the verandah belonging to it, whilst one filthy latrine does duty for the entire establishment.

known are probably the *brinjarries* or true gipsies and the *dhers* or *wadders*, the tank and well diggers of Southern India. Besides these, there are others, such as the tribes with large flocks of sheep and goats, etc., etc. The gipsies usually erect rough tents made of skins and cloths supported on a framework of sticks, whilst others build bell-shaped or dome-shaped hovels of mud, bamboo matting, palm leaves, etc. These people are a standing menace to the health of a community and have been repeatedly the means of spreading disease from one locality to another.* In the event also of cholera appearing in any town it is certain to find an especially congenial home in any place long-occupied as an encampment by one of these castes. The people themselves generally pass the greater portion of their lives out of doors, and those that survive the perils of infancy often live to a great age. Being, however, as they are, extremely filthy in their habits and surroundings, special attention should be devoted to them by the municipal authorities, and they should not be allowed to pick and choose the sites of their temporary habitations but be made to settle on selected pieces of ground and be subjected to regular inspection, under penalty of having to 'move on' to another district.

Pilgrims.—Somewhat allied to these in point of habits are the crowds of pilgrims that infest the great highways to celebrated shrines, such as Puri, Hurdwar, etc. They mostly move by night and settle down at sunrise like a swarm of locusts in the outskirts of a town or village, occupying the regular camping place without fear of molestation. The consequence of such a custom is that on these principle highways the best camping places are in a chronically filthy condition, the ground sodden with excrement and the water supplies contaminated, so that in the case of regiments or other bodies of men travelling by the same road, cholera, dysentery and other diseases suddenly make

* As small-pox has lately been spread in England and typhus fever in France by wandering tramps and mendicants.

their appearance and work dire havoc.* Such conditions prevail especially where the road passes through the territory of semi-independent rajahs, and the risk of encamping a body of four or five hundred men and several hundred women and children on such plague-spots is very serious. In former days, when regiments were constantly moved from one station to another by road instead of by rail, considerable care was exercised in the up-keep and sanitation of camping grounds, but since the construction of railways throughout the land the precautions taken have diminished whilst the evils remain. Consequently, those in medical charge of troops or other bodies of men marching by road must take great trouble to see that no place habitually used as an encampment by pilgrims, caravans, etc., is chosen, save under dire necessity, for occupation by those in their medical and sanitary charge. Similarly, the sanitation of the reserved camping ground near any town or village should be carefully looked to by the civil authorities, and a special piece set apart, with its own water supply, for those who may be expected to be reasonably clean in their habits.†

Construction coolies.—Still another very important branch of this subject is the selection of the site for and the erection of buildings meant to be occupied, from several months up to one or two years, by gangs of workmen and coolies employed in the construction of roads, railways or other public works. These buildings are often raised on most defective situations and constructed of most wretched material, so that the unfortunate occupants fall victims with the utmost certainty to any prevalent disease; and

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* *E.g.*, the road from Central India leading to Puri on the East coast, near Cuttack, was (1888) infested from end to end with bands of pilgrims, the consequence being that, in many cases, the only suitable encampment for the regiment with which the writer was marching, was quite unusable and had to be passed by for another in many ways defective, particularly as regards water supply.

† A great deal depends, of course, on the amount of interest in sanitation taken by the Commissioner or Collector of the district and his sanitary advisers. In one district the camping places will be models of cleanliness whilst in the next the reverse may obtain.

not only so, but owing to their poor clothing and diet, the rigour of the weather during the rainy or cold seasons, the absence of all proper ventilation in their lines at night, and last, but not least, the feeling of home sickness or nostalgia they suffer from so keenly, it is by no means uncommon for some disease such as epidemic pneumonia, scorbutus, typhus (?) or other fever to break out amongst them and help to swell the already large number of deaths. Before a single foundation is dug or a single cooly imported, the site, plan of the buildings, available articles of food and clothing and their price, and all other essential details should be the subject of careful and *responsible sanitary enquiry*.*

CAMP LIFE IN TENTS.

In choosing a site for a pitched camp, the same precautions are necessary as on other occasions, with regard to drainage, water supply, etc. On arrival, the first thing is to ascertain the nature and distribution of the water supply and to make arrangements by which the purest water will be reserved for drinking purposes alone. A small amount of purified water should always be carried,† so as to obviate the possibility of having to drink from a doubtful source. Tents are best pitched in a place not recently occupied by other persons, on gently-sloping ground free from brushwood, but well-shaded by large trees. Ventilation during

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* It is the old, old story of good sanitation being the truest economy in the end. In addition, the sacredness of human life needs to be constantly impressed on officials and it should be understood clearly, and *acted upon*, that the immediate head of the works or operations is *directly responsible for the lives of those under his charge*, from the greatest to the least, and that unless he can show by documentary and other evidence that he did his best to prevent loss of life from accident or disease, the consequences will be very serious for him. I have seen coolies and camp followers eating, sleeping and living perforce under conditions such as no man but a savage would allow the meanest beast of burden to exist for a day. That such a state of things is a disgrace and, in the end, infinitely more costly, admits of no argument. Neither the training of an engineer nor of a medical officer, pure and simple, will make an efficient sanitary officer, as is too often assumed. Special training and experience are absolutely necessary. On the other hand, the coolies themselves often object to any ventilation, etc., most strongly, and will come in a body and petition against any windows being made in their lines!

† *v.* p. 96.

the night should receive careful attention,* and in the day time, when empty, the tents should be opened up as much as possible to allow of free perflation.

If intended to be occupied for more than one or two days, the encampment should be carefully arranged so as to keep the dwelling tents to windward† and to have the kitchen, servants' quarters, latrine tents and animals quarters all separated by proper distances. Any servant, after due notice given, found committing a nuisance near the camping ground should be punished. After a few days occupation the tents should be struck and re-pitched on fresh ground, unless the greatest care has been exercised in regard to sanitation. Further details as to arrangement, drainage, cubic space, etc., will be found under military hygiene.‡

HOSPITALS.

For General and Special diseases.—These, in common with jails and barracks, are commonly built more carefully and of better materials than ordinary dwellings, and in addition they are more strictly looked after with respect to sanitation and repair. The form of building most suitable as a dwelling-place for a number of sick persons has received a very large amount of attention from architects, medical men, nurses and many others, and hospitals are to be found scattered through the great cities of the world of every conceivable form and structure.§

With regard to details of construction, the directions given for the building of an ordinary house apply in similar manner, but there are one or two additional points requiring mention. In designing any hospital the architect

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* A few years ago, two native *shikaris* on the Nilgiri Hills closed their small tent at night and kept a pan of hot charcoal beside them for warmth. Next day they were both found dead, having been poisoned by the carbon monoxide given off from the burning charcoal. *v.* p. 11.

† Except in the case of hot land winds or wind blowing from a malarial swamp.

‡ *v.* Part IV.

§ *v.* The magnificent work by Burdett, lately published, on the Hospitals and Asylums of the World.

requires to keep two things prominently before him, *viz.*, the necessity for *very free ventilation* coupled with *compactness of the building*, so that the staff for attendance on the sick may be no larger than absolutely necessary. But of all things, pure air is *the* most essential requisite for every hospital.

It is not only the fact that there are a great many people occupying one building that is so important, but that these are *sick* people; and this for a two-fold reason. In the first place, each person requires an additional amount of pure air to aid him in the process of recovery; in fact he should be bathed in pure air. In the second place, the air of a hospital becomes much more readily loaded with impurities from the persons of the sick, their bedding, clothes, dressings, wounds, utensils, excreta, etc., and these impurities may be and often are of a specific nature, so that if not speedily removed they may be the direct cause of spreading tuberculosis, pyæmia, erysipelas, hospital gangrene and many other diseases. Many diseases which formerly devastated hospitals and made them literal death-traps, have now, by ventilation and cleanliness, been almost entirely banished.*

Before, however, taking up the consideration of the most approved designs and arrangements in modern hospitals, reference must be made to some of the work done in past years in connection with the reform of Indian hospitals. Foremost among names associated with such work stands that of the noble-hearted Florence Nightingale who, at the request of the President of the Royal Commission on the Sanitary State of the Army in India, contributed a most valuable report on this subject.† After discussing the

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* The subject of the reform of hospitals generally cannot be further considered here. It is of absorbing interest and affords most conclusive testimony of the value of true hygiene. Those wishing further information may consult the articles in Parkes' Hygiene and Stevenson's and Murphy's Treatise and the references contained therein; also the comprehensive work of Burdett, before referred to.

† Entitled, "Observations on the Sanitary State of the Army in India." She also wrote another most valuable work, "Notes on Hospitals."

various weak points in the surroundings, accommodation, mode of life, etc., of British soldiers in India* she goes on to discuss the question of hospitals in that country. Some of the statements are almost unbelievable, but they are all taken from the actual reports sent in by medical, engineering and other officials on the spot.—"The 'sanitary state' is generally represented as 'good,' although at the same time we are told, as in certain cases, that the hospital is 'unfit for accommodation of European patients;' or that 'epidemic disease has appeared in it;' that 'sores become erysipelatous;' that, as at Bangalore, 'one of the flags [stones] in the floor being removed, the smell from the opening was so offensive that the surgeon was obliged to run;' that 'gangrene and phagedœna have appeared, when the hospital was crowded;' that 'the privy is a nuisance to one ward;' 'that the cesspools are always more or less offensive;' that the 'out-houses are in a very dirty and unwashed condition.' At Muttra the contents of the latrines are 'carted away every morning for combustion in one of the many brick kilns which surround the station, and help to poison the air.' At Madras, the sanitary state is called 'good,' and the Commander-in-chief himself adds, 'if the vile, stinking river Cooum were not under the very noses of the patients.'"† * * * "Bangalore gives a reason for the covered way to the latrines, which we should never have thought of: 'it is a covered place for exercise'" (!) * * * There is no instance, except at Wellington, where the hospital, if on one floor, as is usual, is raised from the ground with any current of air beneath. These hospitals are stated as at Bangalore, to be 'always damp in wet weather.' And often the floor is merely the ground bricked over. Rangoon and Tonghoo live like the beavers, and raise their barracks and hospitals on piles, with free passage for air underneath. The consequence is that in those jungly swamps, they are more

* *v. post.*, Part IV.

† The 'vile, stinking Cooum' is still under the noses of the patients in both the General and Station Hospitals, Madras; and is probably now more vile and stinking than ever it was.

healthy than at most other Indian stations where the men sleep close to the ground." * * * "The wards can never be said to be light or airy; 'as a general rule, hospitals are badly-lighted and gloomy;' doors are more common than windows. And these doors, when closed, leave the ward, if not absolutely dark, yet absolutely dismal and close. Indeed a dark ward must always be a close ward. Or 'light enters from a couple of panes in the doors near the top, and when closed, darkness is almost complete.' There is in Indian hospitals hardly a room light enough to perform a surgical operation. And operations, it is stated, have to be performed in the verandahs. The inner verandahs are generally used for sick whenever more room is wanted: the outer ones sometimes cut up for lavatories, destroying what ventilation there is. The superficial area *per* bed is almost invariably too small, and the wards almost as invariably too high; the result to the sick being that, with an apparently sufficient cubic space, the surface overcrowding is excessive. One of the worst examples of this is the recently constructed hospital at Trimulgherry (Secunderabad) which consists of three wards, two of which contain no fewer than 228 beds each; the wards are 42 feet high, and afford 1,001 cubic feet per bed, but the surface area per bed is only 24 square feet." * * * "All the defects of the barracks re-appear, and with worst consequences, in the hospitals: *viz.*, bad water supply, bad ventilation, no drainage (Ferozepore says 'drainage not necessary'), offensive latrines, so offensive indeed that the patients have sometimes to leave a particular ward, no means of bathing and hardly any of cleanliness." The food, cooking, clothing and attendance are all shown to be faulty.

Native hospitals are "generally nothing but a shed, perhaps a 'gun shed,' or a 'cattle shed' as at Kolapore, converted into a hospital, where the sick receive nothing but medicine. The patients cook their own diets, eating and drinking what they please." * * * "There are no conveniences; sometimes the sick go home to wash or bathe