THE TREATMENT

AND

UTILISATION OF SEWAGE.

O

A DIGEST OF FACTS

RELATING TO

THE TREATMENT

AND

UTILISATION OF SEWAGE.

BY

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PREFACE.

THE first edition was, as stated on the Title-page and in the Preface, prepared for the British Association Committee, appointed at Exeter in 1869 to report on the "Treatment and Utilization of Sewage;" it was published after the Report of that Committee had been read at Liverpool, and it was in no sense their Report, nor were they in any way responsible for its contents or bound by the conclusions arrived at; for whilst the facts brought forward rested on the authority of the documents quoted, the writer distinctly claimed for himself the sole responsibility "for the conclusions drawn, and for the opinions expressed."

It was, nevertheless, thought by some members of the Committee appointed at Liverpool in September 1870, that if the second edition were published under the auspices of the Committee they might be considered to be bound by the opinions and conclusions therein contained, or at any rate to have sanctioned them.

Under these circumstances the Author has thought it advisable to publish this edition entirely on his own responsibility, and so prevent any misunderstanding about the matter.

He has revised and corrected the entire work, and made important additions at various places, notably at pages 64, 65, 68, 98, 123, 128, 146, 166, 219, 221, 240, 248, 249, 260, and 282.

An abridged account of the more recently published researches on the subject will be found in the two Appendices, while the Summary contains a concise statement of the views which the Author himself has been led to adopt: references have been inserted throughout to show from what sources the numerous quotations have been derived, and to enable the reader to consult the originals for further information; and lastly, an Index has been added.

The Author is indebted to several friends for valuable hints and emendations, and hopes that with their assistance a faithful account has been rendered of the state of our knowledge on this subject at the present time; the importance of the matter comprised in the Appendices must be his excuse for having so long delayed the publication of this edition.

CONTENTS.

CHAPTER I.

EARLY SYSTEMS: MIDDEN-HEAPS AND CESSPOOLS.

CHAPTER II.

FILTH AND DISEASE—CAUSE AND EFFECT.

CHAPTER III.

IMPROVED MIDDEN-PITS AND CESSPOOLS; MIDDEN CLOSETS, PAIL CLOSETS, &c.

CHAPTER III.—*continued.*

CHAPTER IV.

THE DRY CLOSET SYSTEMS.

CHAPTER IV.—*continued.*

CHAPTER V.

WATER-CLOSETS.

CHAPTER VI.

SEWERAGE.

CHAPTER VI.—*continued.*

CHAPTER VII.

SANITARY ASPECTS OF THE WATER-CARRIAGE SYSTEM.

CHAPTER VII.—*continued.*

CHAPTER VIII.

VALUE OF SEWAGE.—INJURY TO RIVERS.

CHAPTER VIII.—*continued.*

CHAPTER IX.

TOWN SEWAGE.—ATTEMPTS AT UTILISATION.

CHAPTER IX.—*continued.*

CHAPTER X.

FILTRATION AND IRRIGATION.

CHAPTER X.—*continued.*

CHAPTER X.—*continued.*

CHAPTER X.—*continued.*

CHAPTER X.—*continued.*

CHAPTER XI.

INFLUENCE OF SEWAGE-FARMING ON THE PUBLIC HEALTH.

CHAPTER XI.—*continued.*

APPENDIX.

ADDITIONAL APPENDIX.

SUMMARY.

THE TREATMENT

AND

UTILISATION OF SEWAGE.

Μηδέ πυτ' ἐν προχοῇ ποταμᾶν ἅλαδε προρεόντων,
Μηδ' ἐπὶ κρηνάων οὐρεῖν, μάλα δ' ἐξαλέασθαι,
Μηδ' ἐναποψύχειν· τὸ γὰρ οὔτοι λώϊόν ἐστιν.

HESIOD, *Works and Days.*

THE

TREATMENT AND UTILISATION OF SEWAGE.

CHAPTER I.

EARLY SYSTEMS: MIDDEN HEAPS AND CESSPOOLS.

Our subject-matter falls conveniently under two heads: we have to consider, in the first place, the *Treatment* of Sewage, which resolves itself into various methods for *removal* of it from the neighbourhood, either in its native state or mixed with some substance which may facilitate its removal, as water; or may render it less disagreeable, as dry earth, ashes, salts of carbolic acid, salts of iron, &c. &c.; this removal being necessitated by the extremely *offensive* nature of excrement when allowed to remain for any length of time in or near houses, of which no one will require proof (although plenty will be incidentally given in these pages), and also by the great *injury to health* which results in various ways from the same cause, and of the reality of which we have now ample evidence. Divisions of subject. Removal.

And, in the second place, we have to consider the *Utilisation* of Sewage. We have to examine the evidence that has been brought forward to show that Utilisation.

the various refuse matters from human habitations may be applied as manure, with advantage to the crops and profit to the community, and at the same time without nuisance or injury to the neighbourhood: we have to see which of the various methods proposed offers the greatest chance of success in a sanitary, an agricultural, and a pecuniary point of view.

Definition of term "Sewage." The term "Sewage" will for convenience be applied generally to refuse matter (especially excretal) without reference to any method of removal; and this it is necessary to bear in mind, as no scheme which does not remove ALL refuse matter, in as inoffensive a manner as possible, and utilise it so as to "make it pay," can be accepted as anything like a final solution of the question that we have to study, nor can such a scheme be recommended to towns as a feasible plan for the removal of their difficulties.

Under our first head, then, we include the *collection* and *removal* of refuse matters, and more especially of human excreta, from habitations generally, and more particularly from collections, large collections, of habitations.

We begin with the deposition of excreta, and the places in which they are deposited.

No system. In the primitive condition of society no consideration was given to these matters, and no special places allotted at all for such purposes, and of course the result was, that excrement was deposited in any convenient or inconvenient locality: and we have to allude to such a primitive condition of things because it is not confined to some distant period, or to what we are pleased to call barbarian countries, but exists to-day in many of our own towns. In the Fourth Report of the Medical Officer of the Privy Council, dated 1861, we find, with regard to one place, that "in the great majority of cases, even *in the centre* of the town, no accommodation of any kind is provided, and hence the adult male population defecate habitually in the gardens or in the road, &c.;" in another town "children's excrement and other refuse are frequently allowed to remain dotting the space before and behind houses." In the Seventh Report (1864) we find that at Seacroft "it is the practice to throw everything in the shape of sewage, garbage, refuse, and even solid excrement, into the highway, on to the green or the adjacent midden heaps, or into a ditch if such be handy." In the colliery settlements at Gilesgate Moor the roadway is described as a succession of dust-heaps used "for all purposes of personal easement." From the Ninth Report it appears that until comparatively lately (1854), houses under £10 rental were not provided with privies or cesspools, the inhabitants using the open streets instead; and even in 1864 "many houses and courts are unprovided with any accommodation, and stools are seen about yards and entries;" while at Penzance the filth from the upper stories of the houses was commonly discharged into the court or passage below.

Want of privies

In the "Health of Towns" Report of 1844 (vol. i. p. 128) Dr. Duncan states that the whole of the cellar population of Liverpool, amounting to more than 20,000 persons, "are absolutely without any place of deposit for their refuse matter," while "of the front houses inhabited by the working classes, a large proportion are in a similar predicament."

As a slight improvement to this loathsome state of

A place set apart for refuse matter.

things, we come to the setting aside of a special locality where the refuse matter of one house, or often of many houses, may be deposited—in other words, a "midden heap;" and "occasionally a wooden erection may be seen, having the external aspect of a privy, and used as such, but with only a cross bar or plank for a seat, and *no cesspool whatever*, the excrement being allowed to accumulate there and diffuse itself thence for an unlimited time, or until it is required for manure." (*Fourth Report of Medical Officer of Privy Council. Appendix*, p. 38.)

Open midden pits and cesspools.

More frequently, however, some sort of a pit is dug in the ground and serves as the receptacle of filth generally; this is open to the air and without any pretence of drainage, and is known as a "midden" or "ash-pit," or, if used for excrement alone, as a "cesspool:" such pits are in gardens, yards, or courts, surrounded on all sides by houses, and are used by many houses, there being one or two "necessaries" for the use of many families. Thus "in each of the larger courts[1] there are usually two privies, with an ash-pit between them, situated within three or four feet of the doors and windows of the houses at the upper end, and *which are the common property of all the houses in the court.* These offices are often in such an abominably filthy and ruinous condition, as to make it a matter of wonder how they can possibly be used; the ash-pits are entirely uncovered, and the door of the privy is sometimes absent, having been broken or become dilapidated from age. In many instances the inhabitants of the front houses and cellars make use of the conveniences in the courts, so that the ash-pits generally

[1] Containing sixteen houses and a population averaging 80 persons.

become full to overflowing long before the nightmen make their appearance to empty them." (*Dr. Duncan's Report on Liverpool in First Report of Health of Towns Commission*, 1844, vol. i. p. 128.)

Dr. Trench, too, says: "Not only was space economized at all risks, and the built-up area dreadfully overcrowded, but privies and cesspools were placed inside houses and in other improper situations; while courts, terraces, and blocks of back-to-back houses, occupied by numerous families, were insufficiently supplied by a common latrine, with a deep, wide, open, and undrained cesspool." (*First Report of the Rivers' Pollution Commission*, 1868, vol. ii. p. 302.)

One privy for many houses.

The extent to which this want of convenience may be carried may be judged of from the state of some parts of Manchester in 1845, when it was reported by the superintendent of the nuisance inspectors that "there were 645 houses in the neighbourhood of Oldham Road and St. George's Road, with families of eleven persons on an average, making an aggregate of 7,095 persons, having only thirty-three petties (necessaries) for their convenience, which, as might be supposed, are generally in a most disgusting and filthy state;" while in another district "there are very few privies throughout the neighbourhood, three or four streets having no accommodation of that kind whatever." (*Second Report H. of T. C.* vol. i. p. 370.)

Under this head must be included stagnant ditches, which are used as open cesspools, as at Steyning, where Dr. Whitley reported that the drainage was into two open ditches, and that privies with open cesspools were general, there being sometimes six families to one privy; in one case, that of a very old cottage, the privy was against the outer wall adjoining the fire-place of the only sitting room and the end of the pantry.

In Leicester, in 1849, "the number of uncovered soil-pits receiving the soil, dust, and ashes, amounts to 2,900, and the aggregate surface of the said soil-pits exposed amounts to 1¼ acres." (*M.O.P.C.*, 1866.)

Open cesspools at various towns. At Penzance and other places the open cesspools were often flooded by showers, so as to overflow into the gutters of the courts; while at Warwick the practice used to be to dig a pit in the sandstone rock beneath the court-yard of the house, and throw all refuse into it; thence the liquid parts sank into the surrounding soil. It seems that there were in this town 1,516 cesspools, exposing an open surface of "37,000 square feet of fæcal matter to sun, wind, and rain."

At Rugby the open cesspools, which were from five to ten feet long, from three to eight feet broad, and from four to five feet deep, were lined with brick below the surface: into them all the refuse was thrown, the privy being placed at one end; where much ashes were thrown in they were rendered less offensive; but where little ashes could be got, as in the tenements of the poor, the "stench was intolerable and loudly complained of." While at Pill, near Bristol, Dr. Buchanan reported in 1866 that either the privy seats jutted over the edge of the river, "or that there was an open privy pit, great ponds of seething filth lying behind the privy."

As an extreme example of want of removal of refuse matters we may refer to a case described in the Second Report of the Health of Towns Commissioners (1845): "In consequence of the confined space the privy and ash heaps were accumulated in the cellars. Commonly the excuse for closed doors and windows was, the bad smell of the court; but here I found a special contrivance for keeping open the outer door, without which the tenant said 'she could not bide in the house'; 'the stench at night was sometimes past bearing, especially in rainy weather.' But the *rent was low*, 1*s*. 9*d*. per week for three rooms, *on account of the nuisance*."

Midden heaps in cellars.

"The cellar accumulation often overflowed, for 'it was such an awkward place: the farmers did not like the trouble of fetching it out,' and the landlady had sometimes been induced by the tenant's complaint to pay for its removal." (Vol. ii. p. 84.)

State of courts, &c.

The report just quoted abounds in examples of a similar state of things taken from various towns: "narrow and enclosed courts, with tunnel entries, most of them with the midden and privy heaps in a most pestilential condition;" "the upper end of the yard I found to be a receptacle for every kind of filth, and it was used as a privy by the inhabitants," &c. &c.

Of the state of the courts in Whitechapel in 1844 we find the following statement made: "Usually in the courts there is only one cesspool; they are badly cleansed; often overflowing. The effluvium is most offensive and noxious. In many of the houses the privy is in the cellar. In one of the courts in Essex Street, now pulled down, the privy was within three yards of the door of one of the houses, and the soil was lying outside of the privy door." (*First Report H. of T. C.* vol. i. p. 107.)

COVERED CESSPOOLS.

After the open midden heaps, ash-pits, and cesspools, we have the ordinary form of covered cesspool, a pit lined with brick or stone work, or merely dug in the ground and roofed over in some way. These receptacles, often of very large size, are placed under gardens, yards, courts, streets, and even houses, and usually, even when lined with masonry, allow the liquid part of their contents to percolate into the surrounding soil; indeed in many cases they are so built as to assist this escape in order that the solid contents may remain in a drier and comparatively less noxious state. Thus it is not to be wondered at that "the fluid contents of the overcharged ash-pits too frequently find their way through the mouldering walls which confine them, and spread a layer of abomination over the entire surface of the court;" while "in some instances it even oozes through into the neighbouring cellars, filling them with its pestilential vapours and rendering it necessary *to dig wells to receive it* in order to prevent the inhabitants being inundated;" it being added that "one of these wells, four feet deep, filled with this stinking fluid, was found in one cellar under the bed where the family slept." (*First Report H. of T. C.*, 1844, vol. i. p. 128.)

Percolation from cesspools.

In Bedford, in 1860, it was reported that cesspools were "almost universal," there being more than 3,000 of them, and as they were not allowed to drain into the sewers (!) the liquid matters soaked away from them as fast as possible into the surrounding soil. At King's Langley, Dr. Ord had four large cesspools opened, each being three feet square and four feet deep; they were placed under the pathway, and supposed to be for surface water. Two of them were found to contain dirty water, with some inches of black mud; one only black mud 20 inches deep; and the fourth was

Contents of them.

"filled with sewage, soft, solid, and of a most offensive character, the drains of five or six houses being led into it." At Seacroft, Dr. Stevens tells us that "on lifting one of the flags in the sitting-room (of a cottage) two buckets of sewage were found under the floor." At Alnwick we learn that in 1849 there were "large middens, foul privies, and cesspools crowded among houses originally built much too close, privies and cesspools within dwelling houses and under the floors of sleeping rooms;" and again, "in all sorts of corners and confined spaces in contact with the walls of dwelling-houses, and in some instances above the level of their floors." In another town we find that the privies attached to the cottages of the labouring classes, with their attendant cesspools, are situated just under the back windows, while "surface drains are not unfrequently used to carry away the sulliage from the overflowing cesspools." **Bad positions of.**

And to show that cesspools were not at all confined to the lower classes of houses, and that they were sometimes as badly placed in fashionable quarters, we may state that in Dover they existed "under many of the best houses." (*Fourth, Seventh, & Ninth Reports M. O. P. C.*)

But it is not at all a thing of the remote past, this covered, undrained cesspool. Dr. Trench, in his report on the *tunnel middens* of Liverpool, in 1863, thus describes the locality known as Kent Terrace, of which he remarks, that "although far from being the worst of the kind, it presents a tolerably average picture of the contrivances adopted in these terraced houses." (*First Report R. P. C.*, 1868, vol. ii. p. 302.) **Tunnel middens at Liverpool.**

It "is bounded and enclosed on the west by the front houses of the street; on the north and east by a high wall; on the south by oil-mills. The entrance is a passage 15 feet in width; thus, though not ranked as a close court, it is without any thorough ventilation. Here ingenuity has accumulated seventy-six houses, containing, at the period of inspection, families consisting of 529 souls, on a superficial area of 2,346 yards. Beneath these houses are tunnels of the following dimensions: viz. one under the south side, 160 feet in length by 6 feet 4 inches in height and 3 feet in width; one under the north side, 145 feet in length by 6 feet 4 inches in height and 3 feet in width; one under two ranges of houses in the centre terrace, 135 feet in length by 6 feet 4 inches in height and 3 feet in width. The total area thus occupied by middens is 192 superficial yards; their cubical contents 384 yards. In other words, the area of the middens is to the whole area of the ground occupied as 1 to 12·2; the area of tunnel and middens is to the area occupied by buildings as 1 to 9·25. A rough estimate given by a competent authority of the contents of these middens before thought full enough for emptying, is 225 tons. The only exit for the gases of this vast accumulated sewage is through privies, which in the centre terrace are so placed between two lines of double terraced houses that effluvium constantly and necessarily pervades every room of the building; and in the side terraces on ledges abutting on sleeping and inhabited apartments, where the like noxious effect is unavoidably obtained. The rain, as well as all the water escaping from taps or used for household purposes, find their way into the tunnels, so that at every period of the

Escape of foul air from.

day there is disturbance of contents, which stimulates the escape of the gases. No breath of air can reach the unhappy residents which is not fraught with offensive and deleterious compounds; no fire can be lighted in any household without attracting the influx of pestiferous miasma."

The thoroughness of this description must be our excuse for quoting it *in extenso;* the sanitary evils of such a state of things we shall have to treat of in another place.

In other towns. In several towns, as at Preston, Leeds, and Birmingham, such huge midden-pits still remain in an almost unimproved condition; they are sometimes covered and sometimes provided with drains, but are usually foul and stinking to the last degree; the liquid soaks out of them to a considerable extent, and pollutes the surrounding soil; in the last-mentioned town they are frequently under workshops, and in all they are emptied very irregularly.

At Halifax there are rows of privies in passages between parallel streets, with a long ash-pit under each row; many of them simply drain into the porous millstone grit. There is a charge of 1*s.* 4*d.* to 2*s.* a cubic yard made by the authorities for emptying them, so that it is usual to make them large and leave them a long while too full.

PERCOLATION INTO SURROUNDING SOIL.

The soakage from all these forms of open and closed cesspools, &c., into the surrounding soil has been referred to. Sometimes, as at Guildford, where they are sunk into chalk, this takes place to such an extent that they are actually stated to be "dry and inoffensive," and the frequency with which they need to be emptied of their contents depends of course upon their size and upon the rate at which the liquid parts soak out of them. Thus in Bridport they were sometimes not emptied "for a dozen years or more," at other places "once in two or three years," "at uncertain intervals," "at intervals of several years;" at Rugby "the solid parts accumulate for many years;" in Penrith "some cesspools have not been emptied for twenty years," even now (1866) the midden system is in favour there, and "in practice, middens are kept till they are full or till it is worth a farmer's while to buy their contents." While, as a crowning success to the percolation system, at Northampton the cesspools were pits dug in spongy sandstone, and were "made and closed for ever;" they were said to be hardly ever cleaned out, and always nearly empty! "It is a principle with the Northampton builders that a cesspool needs no drain, so absorbent is the sandy stratum." (*Seventh and Ninth Reports M. O. P. C.*)

Not emptied for long periods.

Northampton plan.

In one report we find it stated that the mischief which arose from the privy and cesspool system is due to the moisture of the contents, that the privy, if dry, is "unobjectionable," and that the dryness may be secured by mixing the ashes with the ordure and by adding an occasional spadeful or so of dry earth; and this naturally brings us to consider what becomes of the liquid part of the refuse in all the foregoing arrangements, in which no attempt is made to retain it, and in some of which, as we have seen, its escape is facilitated as much as possible. It plainly soaks into the surrounding soil; and when we consider how close to houses wells are often placed, we shall not be

Escape of liquid refuse.

surprised to find that they not uncommonly drain the cesspools: thus, at Harpenden, Dr. Hunter reported in 1864 that the wells were near to the cesspools and *at a lower level,* and that the water was so execrable that it was actually abandoned by the people themselves. At Bridport, where the cesspools were often "mere excavations in the soil," and where ashes and vegetable refuse were kept in uncovered pits, the well-water became turbid after rain, and it has been known to smell offensively, "looking yellow, tasting strongly, with a nice good drainy smell!" (*Seventh Report M. O. P. C.* p. 523.)

Wells drain cesspools.

In the reports of the Medical Officer of the Privy Council, we continually find such statements as that pumps and wells are "foul and unfit for use by infiltration from cesspools;" that the contents of wells are very foul, it being sometimes necessary to add chloride of lime to the water to destroy the offensive odour, and "yet the *dilute sewage* which they contained was largely used for drinking;" "the wells and cesspools appeared to exchange their contents with great facility." At Rugby, where the condition of the cesspools has already been described, the wells are dug in the same gravel as, and generally within five to ten feet of, the cesspools. It is "physically demonstrable that the cesspools do feed the wells," and in many cases it cannot but be that "the fluid thrown into the cesspool in the morning is pumped from the well at night," yet the water is by no means generally tainted, or at least the taint appears only at intervals, or if the water be kept. This contamination sometimes takes place so quickly, from the marvellous (it would almost seem purposely intended) perfection of the

State of drinking-water.

communication between these two necessaries, that Dr. Buchanan states, that at Pill one of the pumps instantly furnished chlorinated water upon chloride of lime being thrown on a neighbouring muck-heap.

Cesspools dug down to springs

This source of pollution of well-water was pointed out in 1844 by the Health of Towns Commissioners: "As houses are built and neighbourhoods become more crowded, the pollution of springs by the permeation of matter from cesspools becomes greater." "They have now got into a mode of deepening the cesspools until they come to the first stratum of sand, six, eight, or ten feet. This cutting generally carries the cesspool into a spring, and relieves the cesspool of the liquid portion of the refuse, which is carried away by the spring into any lower level:" a very pretty picture! And a few pages further on we find that certain houses at Battersea "were supplied with water from springs sunk to the same level as the cesspools. As the springs were lowered by the consumption of the water, it was found, to the surprise of the inhabitants (!), instead of coming up clearer, it was more discoloured—by the equalization of the water levels; . . . People have imagined that it is the gas which has polluted the water, but it is the cesspools that are now being *sunk so much lower* than formerly, partly that the water in the cesspool may not be higher than the level of the springs, and partly for the economy of cleansing." (*Mr. Joseph Quick's evidence. First Report*, vol. ii. pp. 117, 123.)

"We find the earth around it (the cesspool) usually saturated, and springs near are poisoned with the soakage from the cesspool; in some places it rots the floors. In taking up old foundations, the soakage 'is often found to be very offensive.'"

At Leicester, the following state of things existed before the sanitary improvements:—

"Many of the bog-hole wells in the central parts of the borough have been dug down to the water-seam, to avoid the expense of emptying—a practice which the principal well-digger of the town says he has followed for thirty years and upwards; and in support of the fact, numerous instances are given of the water being infected from the soil-pits, whose depth varies from five to twenty-five feet." (*Ninth Report, Med Officer of Privy Council*, p. 73.)

In the Second Report of the Health of Towns Commissioners much stress is laid on this source of pollution of drinking water: "It was only fit for slopping, not for use." Another witness says: "Complaints were made of the quality of the water, which, lying close to the surface, I have no doubt was affected by the percolation of the filth from the alley;" and the excessive hardness of the well-water of towns is continually referred to, great complaints being made of the inordinate waste of soap thereby occasioned, which often induced the inhabitants to go to some distance to fetch softer water.

Hardness of polluted water.

In the First Report of the Rivers' Pollution Commissioners (1868), Dr. Frankland has given some analyses of such well-water. In one case, that of the Bevington Bush Well at Liverpool, in 100,000 parts there were 86·7 of total solid impurity, containing 35·51 parts "of carbonate of lime, or their equivalent of other hardening ingredients (total hardness)" 12·61 parts of chlorine, and no less than 8·721 parts of combined nitrogen, of which 8·678 parts were in the form of nitrates and nitrites, which Dr. Frankland regards as evidence of "previous sewage contamination;" the organic nitrogen was present to a not very high

Analysis of it.

amount, while of the 35·51 parts representing the total hardness, only 11·52 parts were removed by boiling, leaving 23·99 parts still in solution, so that the "permanent hardness," which is the most undesirable and the most difficult to deal with, was very high indeed.

The amount of pollution of this water may be judged of from the statement that "after its descent to the earth as rain, 100,000lbs. of the water had been contaminated with refuse animal matter equivalent to that contained in 86,510lbs. of average London sewage." (*First Report*, vol. i. p. 118.)

Depth of well no safeguard.

The depth of a well does not prevent its being contaminated in this way, as the above is an example of a very deep well (now closed); it does, however, afford a greater chance that the organic matters may be more completely oxidized, and comparatively harmless products formed (especially nitrates and nitrites). The general conclusion about deep well water is that "when the well is at a distance from thickly-inhabited places, the quality of the water is generally excellent, but as the population around it increases, the water gradually becomes mixed with a larger and increasing proportion of excremental soakage." (*Loc. cit.* p. 129.)

Although the mere presence of nitrates and nitrites in a drinking water cannot be looked upon as affording conclusive proof of "previous sewage contamination," it should always be regarded as a suspicious circumstance, and should lead to a search for possible sources of contamination.

CHAPTER II.

FILTH AND DISEASE.—CAUSE AND EFFECT.

IT would seem scarcely necessary for us to show that the existence of the state of things which we have described in the preceding chapter is in all cases detrimental to the health of the inhabitants of the towns in which it exists, and that it must of necessity favour to an alarming extent the spread of many epidemic diseases. It will be well, however, to produce some evidence to show that such is the case, and that the opinion that the pollution of drinking-water by excreta, and of the air by emanations from cesspools and so forth, on the one hand, and on the other the amount of general sickness, and, in many cases, of special epidemics, stand in the relation of cause and effect, is a true one. With regard to the state of the city of York at the time of the plague in 1604, Dr. Laycock finds from the city archives that "there were wide stagnant moats, no drainage, narrow streets, and filthy open channels, the tide flowing above the city, and at ebb leaving sludge and mud on the deep banks of the river, and exposing the mouths of the sewers."[1] He reports also that the plague, in each of its visitations,

The plague at York.

[1] First Report, Health of Towns Commission, vol. i. p. 254.

broke out first in an abominably filthy place called "Hagworm's Nest," and that, curiously enough, the cholera of 1832 broke out first in the same place, and that each of these diseases progressed in much the same manner through the city, "marking the badly-drained districts by its course." From the time of the plague until the present century, it would appear, from an essay by Dr. Winteringham, that "York suffered constantly either from one epidemic or another. . . . Cholera, dysentery, or intestinal inflammation usually prevailed in July, August, and September." It is remarkable that the deaths, during the plague of 1664, were in the proportion of one death to three persons living, while from the cholera in 1832 they were in the proportion of one death to 142 persons living, a difference which probably had something to do with the improved sewerage and drainage of the city. In the reports of the Health of Towns Commissioners (1844) the instances are very numerous of production of fever, especially typhoid, under the conditions of polluted air and drinking water. In Bethnal Green, at Punderson's Gardens, of the state of which we have already spoken, it is stated that "fever constantly breaks out in it, and extends from house to house." Of Lamb's Fields it is said (*First Report*, vol. i. p. 30): "There is always a quantity of putrefying animal and vegetable matter, the odour of which, at the present moment, is most offensive. An open filthy ditch encircles this place, which at the western extremity is from eight to ten feet wide. Into this part of the ditch the privies of all the houses of a street called North Street open. These privies are completely uncovered, and the soil from them is allowed to accu-

Typhoid fever.

mulate in the open ditch. Nothing can be conceived more disgusting than the appearance of this ditch for an extent of from three to four hundred feet; the odour of the effluvia from it is at this moment most offensive. Lamb's Fields is the fruitful source of fever to the houses which immediately surround it, and to the small streets which branch from it. Particular houses were pointed out to me from which entire families have been swept away, and from several of the streets fever is never absent." Most of the witnesses examined were of opinion that "drainage, supplies of water, and ventilation, would extensively diminish existing mortality," and that where even partial improvement in these particulars, and especially more frequent removal of excreta, had been effected, considerable improvement in the health of the inhabitants had already taken place. Thus, of one court which was flagged, supplied with water, and cleaned regularly, John Liddell, Esq., says (p. 110): "In the seven months ending March 1843" (before these improvements took place), "I attended forty-one new cases of sickness in that court; in the last four or five months I have had but two cases." Dr. Aldis, in describing the offensive condition of the courts and streets in Whitechapel, says that one street "is very offensive in warm weather in consequence of the exhalations from stagnant water. I am called upon to visit more cases of fever there than in any other part of the district. . . Generally we find the most severe attacks of disease in the worst conditioned places" (pp. 112, 114). Of Liverpool, the condition of the cellars of which town we have already described, Dr. Duncan says (*loc. cit.* pp. 124, 133), "judging from the annual proportion

Fever dens.

Effect of even partial improvements.

Causes of high death rate in Liverpool in 1840.

of deaths to the population, Liverpool is the most unhealthy town in England" (that is to say, was in the years 1838, 1839, and 1840); and he contends that the causes of this are to be found in "vicious construction of the dwellings, the insufficient supply of out-offices and of receptacles for refuse and excrementitious matter, the absence of drains, the deficient sewerage, and the overcrowding of the population," and that these causes work in two ways, "partly by inducing a specific disease, and partly by deteriorating the general health of the inhabitants in such a way as to render them more prone to the attacks of nearly all diseases." In Mr. Chadwick's Report on the Sanitary Condition of the Labouring Classes in Great Britain, it is stated that in a block of dwellings for the workpeople attached to one of the factories in Glasgow, which were badly ventilated, over-crowded, and exceedingly filthy, fever was almost invariably present; "there were sometimes as many as seven cases in one day, and, in the last two months of 1831, there were fifty-seven cases in the building." After the rooms had been ventilated by tubes connected with the chimney of the factory furnace, we find "that during the ensuing eight years fever was scarcely known in the place." (*Loc. cit.* p. 135.)

Glasgow factories.

Infant mortality at St. Kilda.

A striking example of the danger arising from the emanations from decomposing excreta is to be found in the case of St. Kilda, in 1838. The diminution of the population was here shown by Mr. Maclean to be "partly owing to the prevalence of epidemics, but chiefly to the excessive mortality which is at all times going on in infancy." "Eight out of every ten children," he says, "died between the eighth and twelfth days of their existence !" and he adds that " the air of the island is good, and the water excellent," so that " there is no visible defect on the part of Nature," and that, on the contrary, " the great, if not the only cause, is the filth amidst which they live, and the noxious effluvia which pervades their houses;" the proof of this being that the clergyman's family, with four children, although living in precisely the same manner as the people around, with the exception of the state of their houses, "are well and healthy" (p. 140). In this valuable report Dr. Duncan points out that the Ward "where the largest proportion (more than one-half) of the population reside in courts or cellars, is also the Ward in which fever is most prevalent, one in twenty-seven of the inhabitants having been annually attended by the dispensaries alone;" and he remarks that "people do not die merely because they inhabit places called courts or cellars, but because their dwellings are so constructed as to prevent proper ventilation, and because *they are surrounded with filth*, and because they are crowded together in such numbers as to poison the air which they breathe" (p. 149). In cases where middens have been placed against the walls of houses so that their fluid contents have soaked through them, and the walls been continually wet with fœtid fluid, the families are stated " never to be free from sickness." In the courts in Liverpool (p. 274) there is one ash-pit destined to hold the offal from all the houses, which, being speedily filled, allows the filthy water to ooze through the sides into the nearest cellars, and from there being no underground drainage, and no thorough ventilation, the stench is horrible. "Thousands of our poorer classes are living, or pre-

Cellar population most unhealthy.

maturely dying, in these *fever-succession houses*." In the evidence given by Mr. Kelsey, on the drainage of London, when asked, "Does the state of filth and the effluvia caused by defective sewerage, by cesspools or privies, and decomposing refuse kept in dust-bins, powerfully affect the health of the population?" says, "Yes, it does; it always occasions a state of depression that renders persons more liable to be acted upon by other poisons, even if

Cholera.

it be not the actual cause of it. *The line of habitations badly cleansed and in this condition almost formed the line of cholera cases.*" Then naming a series of localities, he adds: "All these places are distinguished by filth and want of drainage and proper washing; nine-tenths of the diseases come from these filthy places."[1]

In the reports of the medical officer of the Privy Council we find innumerable instances of high death-rate, especially from typhoid fever, being caused by the means we have above described, and being, as we shall hereafter see, very considerably lowered on the

Pollution of water.

removal of these causes. In the Third Report it is shown that the water of Bedford (a town of cesspools) "was largely contaminated by decaying animal matter" (Professor Miller), and that every year there occurred there, "on an average, about thirty deaths from fever and diarrhœal diseases, to account for which number of deaths there must have been attacked every year by the same diseases, more or less severely, some hun-

The cause of typhoid

dreds of persons." In all the other towns into which the causes of epidemics of typhoid fever were inquired into similar conditions were found. At Bathwick there was operating in a high degree the influence of

[1] First Report, Health of Towns Commission, vol. ii. p. 216.

fæcal putrefaction in the air and drinking-water. At Kingston Deverill the water supply was good, and the privies far removed from the houses, so that the air was not much polluted. Typhoid fever, on being introduced, spread so as to affect a sixth part of the population, the reason probably being "that no precautions were taken in dealing with the evacuations of the sick; that these dangerous morbid products were extensively cast on to the common dust-heaps (as doubtless also into the common privies) of groups of houses wherein fever cases had arisen." At Dronfield (in Derbyshire), where too there was an epidemic which had been prevailing for about six months, the urgent evil was "accumulation of animal filth," the diarrhœal excrement of typhoid fever cases being apparently thrown about anywhere and allowed to run down the open drains in the streets. In the 4th and 7th Reports the epidemics of typhoid at various places, of which we have already described the sanitary condition as regards neglected privies, midden heaps, cesspools, and so forth, are shown to have always taken place in connection with accumulations of decomposing filth. Thus at Steyning, a town naturally very favourably situated, there have been continual "epidemics of cholera, small-pox, scarlatina, and diphtheria;" and with regard to typhoid fever it is stated that the cottage in which it was most fatal "was that in which fæcal impurity had been the greatest." (We have already described the condition of this cottage.) In the colliery settlements of Gilesgate Moor, which were in a most offensive condition, and where the inhabitants actually wantonly destroyed some privies which were provided for them, it is stated "that disease was very

Typhoid excreta.

Most disease where most filth.

common, and that minor ailments, nausea, vomiting, and diarrhœa are very constantly present." In one house in Seacroft there were five cases of typhoid and one of small-pox at the same time. Dr. Stevens reported that there was no drainage there, and that the wells were close to filthy pigsties and midden heaps. The water was foul.

Fever death-rate of Bridport.

With regard to the sanitary state of Bridport, a town which "enjoys, by its position, elevation, and soil, every natural sanitary advantage," Dr. Buchanan reports that the death-rate from fevers in persons of all ages has been 114, and that in one of the parishes it has been actually 136. Of this town he says: "Scarcely one London district really reaches the fever death-rate of Bridport, for those which appear to exceed it are chiefly those in which the great metropolitan hospitals receiving fever are situated. With London City, with Clerkenwell, with Marylebone, and St. Pancras, Bridport will not bear a moment's comparison as to its fever mortality; no, nor even with Holborn, or Bethnal Green, or St. Giles's."[1] (We have already described the condition of the cesspools and ash-pits of this town.) At Ashby-de-la-Zouch, after an absence of typhoid fever for two or three years (since the sanitary improvements), it reappeared owing to the filtration into a spring from an adjoining cesspool. It was shown that persons inhabiting more filthy houses than the one in which the fever appeared, and close by, but who got water from a neighbouring tap, were never attacked.

Spread of cholera.

At Pill, near Bristol, the cholera having been introduced into a public-house in a low-lying part of the town, at once spread with fearful ra-

[1] Seventh Report, Med. Off. Privy Council, Appendix, p. 524.

pidity, especially along the filthy creek which has been already described as an open sewer. At Carnarvon, too, the great spread of cholera was traced to the especially bad hygienic conditions. The researches of Dr. Snow and John Marshall, Esq., F.R.S., have proved that cholera is spread by contaminated drinking-water. At Terling and many other places typhoid fever has been traced to the contamination of the wells from the foul cesspools. In fact, all the evidence that we can collect leads us to the conclusion that "there cannot be a healthy population living over or amidst the emanations from cesspools." But this conclusion was come to long ago. We find from Dr. Laycock's evidence, before quoted (*see* page 17), that Caius (or Kaye), in his "Boke, or Counseill against the Disease commonly called the Sweate or Sweatyng Sicknesse," gives the following wholesome advice:—"Take away the causes we maye, in damnying diches, auoidynge cariôs, lettyng in open aire, shunning suche euil mistes as before spake of, not openynge or sturrynge euil brethynge places, landynge muddy and rottē groundes, burieng dede bodyes, kepyng canelles cleane, sinkes and easyng places sweat, remouynge dongehilles, boxe and euil sauouryng thynges, enhabitynge high and open places, close towarde the sowthe, shutte toward the winde, as reason will and the experience of M. Varro in the pestilēce at Corcyra confirmethe."

Kaye's advice.

It is continually pointed out that sickness is the chief cause of the non-payment of rent. One witness says: "Three out of five of the losses of rent that I now have are losses from the sickness of the tenants, who are working men. . . . . Rent is the best got from healthy houses." Another says: "Sickness at all times forms

Sickness causes non-payment of rent.

an excuse for the poorer part not paying their rent, and a reasonable excuse." (*First Report H. of T. C.* vol. ii. pp. 303, 312.)

So that filth causes sickness, sickness inability to work, inability to work poverty and non-payment of rent, to say nothing of starvation.

Legislative interference.

With regard to the interference of the Legislature to prevent a man doing as he likes in his own house, we may quote again the remarks made by Mr. Home on the former state of Liverpool:—"The man who, in a crowded street, is living in filth and breathing a putrid atmosphere, or who makes that street a receptacle for the offal which he casts from his dwelling, becomes the instrument of danger to his neighbour by spreading infection, and he not only hazards his own life, but endangers that of others. The man who erects a flimsy edifice in a crowded thoroughfare, which by its falling may destroy life, should be prevented doing so, and he who constructs a house to let for profit and pays no attention to those matters which are essential to comfort, but, on the contrary, so constructs it as to engender fever and endanger the lives of his tenants—all these are cases where, with propriety and in justice, the Legislature ought to interfere and to insist upon such a mode of construction as will not endanger human life."[1]

A man's right to injure himself or his own property,

In Vol. i. of the Brussels Public Hygiene Reports the conditions for the interference or non-interference of the Legislature are stated very exactly:— "Whenever an abuse in the exercise of the right of proprietor can only injure him who commits the abuse, the public authority is incompetent to interfere, and in this case

[1] First Report, Health of Towns Commn. 1844, vol. i. p. 282.

a citizen has the right to use and abuse his own person and effects. Whenever, on the contrary, the possible consequence of this abuse may be to cause the breaking out of epidemics or public calamities, the authority can, and even ought to interfere by prescribing regulations which forbid this abuse." As a forcible illustration the following is given:—"Because each farmer has the right to poison his own cattle, if he is such an enemy to his own interests as to commit this mad act, it does not follow that he has a right to sow a field with poisonous plants, the emanations from which might injure the health of the cattle of the neighbourhood;" and the conclusion is, that "each administration can order, and even ought, in the performance of its duty, to order, in the construction of habitations, everything which is essentially necessary to ward off epidemics, and to guarantee to the neighbours a healthy state of the atmosphere." (*Rapports du Conseil Supérieur d'Hygiène Publique,* 1er *Vol.* pp. 5, 6: Bruxelles, 1856.)

but not the community at large, nor public property.

Example.

Duty of the public authority.

CHAPTER III.

IMPROVED MIDDEN-PITS AND CESSPOOLS.—MIDDEN CLOSETS, PAIL CLOSETS, ETC.

THE simplest form of midden heap as it exists in all uncivilized places having been already described, it remains for us to allude to several improved forms of middens which have been fully described in a Report by Dr. Buchanan and Mr. J. N. Radcliffe, of which Dr. Buchanan courteously lent us the proof-sheets.[1]

Improved midden-pits, lined with cement.

The first improvement on the old midden-pits is to make them impervious by lining them with cement, and rounding off the angles so as to make them concave at the bottom. Thus, at Nottingham this is done, and the ashes are thrown in by a door at the side: here the pits are not drained, but are roofed over. The closets are not allowed to be less than 4 feet 6 inches long by 3 feet broad and 7 feet 6 inches high; their roof must be louvered for ventilation, and their floor sloping, that it may be easily washed. The single midden-pit contains 80 cubic feet up to the level of the ash-door sill, and one lengthened pit may be continued under a row of closets on the "block system," as it is called; it must be at least 15 feet from the house. A single closet costs from £9 to

[1] This Report has since been published in the Appendix to the 12th Report of the Medical Officer of the Privy Council.

£10, and several in blocks from £5 10*s*. to £6 10*s*. each. The closets are limewashed twice, and the pits emptied regularly four times a year. Dr. Buchanan found them clean, not wet, and productive of no great nuisance; but there was a smell, especially in the larger ones, when the ash-pit door was opened. Slops must not be thrown into these pits, or they invariably become offensive. At Stamford, the corporation have approved of a somewhat similar plan to the above, with the improvement of a shallower pit and a hinged seat, so that the ashes can be thrown directly on to the excrement: one of the doors into the midden is to be made large for the convenience of the scavengers. A "block" of four such privies will cost £35 9*s*. 0*d*.; of only two, £22.

Shallow pit: hinged seat.

In Manchester, as is well known, ash-pit middens are very much used. In his evidence given before the Royal Sanitary Commissioners in 1869, Sir Joseph Heron, the town clerk of Manchester, said: "The arrangement which we try to carry out is to deodorize to the extent practicable, by means of the ashes which necessarily are met with in every dwelling, and by an improved construction of ash-pits. There is a grid, as they call it, to allow the small ashes to pass into the ash-pit, and in that way also to have them cast on the fæcal matter; and it is generally said, and I certainly have been in privies and ash-pits which have been constructed upon a good principle, where there has not been anything like the smell which, I am sorry to say, I certainly often experience in water-closets in hotels in London." He however acknowledges that the plan is adopted merely "with a view to improving and getting rid as far as possible of the objections which

Manchester plan.

may perhaps be necessarily incidental more or less to that system," and that its object is to "keep out of the sewers as much as possible the fæcal matter which in itself renders them polluted," "until a mode of disposing of and dealing with sewage has been in some way satisfactorily determined."

Conditions required.

The specifications for the Manchester midden-pits require (1) that the pit "shall receive no moisture from the soil around, nor allow of any soaking of liquid filth out of it:" and this end is as far as possible secured by lining the pits with Rochdale flags embedded in mortar, and by giving the floor an inclination of not less than three inches to the outlet in connection with the drain; (2) "dryness, as far as practicable, of its contents:" this being secured by the inclined floor and by (3) "exact and efficient covering up of the deposited excrement by the ashes and house refuse;" an end attained by one of several methods:—(*a*) a grid, as described by Sir J. Heron, into which the ashes are thrown, and which sifts them, sending the fine ash by means of a shoot on to the excrement, and retaining the cinders to be used again as fuel; (*b*) a hinged privy seat, which can be lifted so that the ashes may be thrown on to the excrement: with this plan is sometimes combined a special urine catch-pan, so that the contents of the midden have a greater chance of being dry; or (*c*) the front board of the privy does not quite reach to the floor, and carries a narrow step, between which and the floor is the space through which the ashes are thrown: the seat is hinged at the back, so that seat, front-board, step, and all can be lifted up when the pit has to be emptied; and (4) "the dispersion, at some safe point, of any noxious gases

Ashes, how used.

evolved from the contents of the midden," which condition is secured by the construction of ventilating flues of not less than 81 square inches in area, which are carried up outside the wall of the house to three feet above the eaves. These middens (except of form *c*) are emptied through holes closed by ledged doors which lead into the passage running behind the row of houses, and the privies are covered with well-pointed slated or flagged roofs.

Ventilation.

These requisitions remind one of the regulations for the French *fosses permanentes*, except as regards the question of *dryness* of the contents, in which respect the midden-pits present a great advance on the foreign system. Their chief fault, as middens, is that they are too large, and so the accumulation becomes very great in them; they should also not be allowed to be close to houses, as one cannot be very sure that liquid does not, occasionally at any rate, escape from them.

At Salford, where midden-pits are almost universal, they are required to be three feet from the wall of the house, to have a drain into the sewer, and to be free from leakage; the closets must be outside the house, and have near the top an opening to the air of 12 square inches at least, and there must be one to every house. The slab is constructed so that the ashes are thrown under the "upright," as in the third Manchester plan: "Except where a closet was locked, and its use restricted to a single family, or at the most to two or three families, we found them in a most unsatisfactory state," the fact being that the people threw the ashes on the open ash-pits close by rather than under their own privy seats; thus showing that the lower classes

People don't use them properly.

of people cannot be allowed to have anything whatever to do with their own sanitary arrangements: everything must be managed for them.

A somewhat similar plan obtains at Saltaire, a village near Bradford, and although the slops go into the sewers, the midden-pits are offensive unless the ashes be very carefully thrown on to the excrement, a precaution which people, as a rule, cannot be expected to take; when well used, however, they give no offence.

The best form of midden closet is the one in use at Hull: it was tried because "the water-closet, *used in common by several families*," was, as might be expected, "everlastingly a nuisance." (The italics are ours.)

Smallest and best midden-pit.

In this plan there is no pit at all, but the *space underneath the seat*, between it and the floor, is the sole receptacle of the soil and ashes, which latter are thrown in with a scoop through the hole in the seat. The front board is movable, so that the scavenger may get at the contents with a spade. When these closets are used by decent people they are clean, and the contents dry and inoffensive, as plenty of ashes are thrown in, and the slops go into the drains; but when used by several families they were found to be overflowing from not having been emptied often enough; they then require to be emptied every day. "Many of the privies in poor quarters can only be reached through the house."

Scavenging.

The scavenging system is good. The town is divided into forty-six districts, of from 300 to 700 houses each. These districts are let out to separate contractors, one contractor being allowed to take two districts if he chooses, but not more. These contractors are paid by the value of the manure, and by an allowance which the Board makes them of 1*s*. to 1*s*. 6*d*. a year for each house, so that the proceeding costs the Board £2,000 a year, and is likely to cost them more, because the mixed soil and ashes do not sell well, and because increased supervision is necessary.

Best conditions. Where, then, the midden system is continued, the closet should be *away from the house*, and should be roofed in, floored with sloping flags, and well ventilated; the midden-pit should be very small, preferably only the space under the seat between it and the floor; it should be impervious on all sides, and should not on any account be against the wall of the house, or even near to it; it should not be drained, for if the ashes do not keep the contents dry, or nearly so, the system is a failure.

There can be no doubt, however, about the fact that any form of this plan is unadvisable, from the great expense of scavenging, and the inconvenience caused by the frequent visitations of the scavengers or "nightmen," especially as they have to dig out the contents of the pits. **Objections.** People do not like these frequent visitations, and this objection will be found to apply to many other systems which are now on their trial. Any plan which will make such visits as *infrequent* and as *short* as possible will be preferred by ninety-nine persons out of a hundred.

IMPROVED CESSPOOLS.

To obviate the evils of soakage, &c., "we line the cesspool with cement, and provide an overflow drain from it into the common sewer or the nearest outlet;" in other words, the improved cesspool is a

Cesspool lined with cement, and drained.

sort of *cul-de-sac* from the house drain, which catches the more solid matters, and keeps them for an indefinite time underneath the house or in close proximity to it, allowing the more liquid part to run away into the nearest sewer; the advantage of the plan being, it is presumed, the value of the manure so preserved. As to the relative value of what is lost in this way to what is kept, we must refer the reader to the head of "Utilisation." It must not be supposed that this care to prevent pollution of the neighbouring wells was always taken, for generally the surface drains were left to "carry off the sullage from *overflowing cesspools*," as at Ely and Chelmsford; and where the pits are drained, as at Stratford-on-Avon, they are often a nuisance through the choking of the drains; the actual disadvantage in some respects of draining them is seen from the fact that here they are only "*supposed* to be emptied about *once a year*." If a nuisance, and *if complained of*, the inspector removes them. No wonder that improvement is so slow! (*Ninth Report M.O. P. C.* pp. 155, 179.)

Overflow when not drained.

At Worthing the cesspools were "constructed so as to retain liquid as well as solid contents" (of course as far as practicable); "the overflow of them commonly passing into the trough system of public drains; and instance after instance is given of cesspools *requiring to be baled out*, or overflowing through inefficiency of drains from them." (*Loc. cit.* p. 194.)

At Liverpool, the Health Committee, in 1846, ordered all cesspools, middens, and water-closets to be drained into the sewers. "The perfect drainage of middens and cesspools was a great sanitary improvement. It lessened materially, though it did not entirely remove, the evils of the existing system." (*Report by Dr. Trench, First Report, R.P.C.* 1868; vol. ii. p. 303.

But it must be observed that the whole principle of cesspools is given up by draining them into the sewers, and it becomes difficult to see the object of their existence at all, especially as it is probable that, in the words of the last-mentioned authority, they "do, by their drainage, pollute the sewers to an equal, if not to a greater, extent than water-closets." (*Loc. cit.*)

Principle of cesspools given up, if drains are provided.

The closets, or rather privies, are of course of the simplest construction, as a general rule, and require no special description.

Where the cesspool system has been strictly adhered to, as in many continental towns, the huge pits, which are generally placed under the court-yards of the houses, are lined with cement, so as to be as impervious as possible; and in Paris and some other towns they must be provided with a ventilating shaft reaching up some feet above the roofs of the houses. The general rule is, that they shall be so large that they only require to be emptied once in three or four months: and this is usually done by pumping the contents through hose into large cask-shaped carts (*tonneaux*), which are sent for the purpose at night when required; or by air-tight carts, in which a partial vacuum is first created, so that the sewage is forced up into them through the hose by the pressure of the air, and pumping is not required.

Paris, &c., "fosses permanentes."

Thus, at Brussels, the specifications for the "*fosses permanentes*" require that "the pits (*fosses*) should be constructed according to the rules of the craft, with a *concave* floor (*pavement*) and rounded corners, and covered with a layer of cement or *trass*, which

Brussels.

does not leave any interstice by which the liquids and the (fæcal) matters could infiltrate themselves into the masonry and into the surrounding soil. When (fæcal) matters are allowed to remain in the pits, these must be provided with a ventilating pipe directed aloft, so as to carry away the emanations far from inhabited places." And with regard to the emptying of these pits, it "ought to be conducted with the greatest care. All precautions should be employed which may be necessary in order that the removal of the (fæcal) matters shall not infect inhabited places; to this end, recourse must be had as much as possible to pumps, which remove from this proceeding its inconveniences and its dangers." (*Conseil supérieur d'Hygiène Publique: Rapports adressés à M. le Ministre de l'Intérieur*, 2e vol. pp. 242–3. Bruxelles, 1860.)

Precautions.

Despite all such precautions, the "*fosses permanentes*" are not water-proof, but allow percolation into the surrounding soil to a great extent; and the operation of emptying them is *necessarily* a most offensive one, as every one knows who has passed along streets while it was going on, although (at any rate in Paris and Lyons) a sufficient amount of disinfectant fluid is supposed to be thrown down one of the pipes into the cesspool before the pumping commences.

Emptying.

"Séparateurs."

At Paris these cesspools are often provided with a separator to keep the solids and liquids apart: this is simply done by having two or more reservoirs, communicating one with another by means of small holes through which the liquid parts pass; each of these chambers is provided with a ventilating chimney. This separation materially retards decomposition. The Council of Salubrity found, "with a separator and good ventilation, absence of odour, and completely healthy conditions (*assainissement*); when ventilation is not provided for, or is badly understood, the separator only gives what result it can, and does not prevent the production of a bad odour." (*Tardieu, Dictionnaire d'Hygiène Publique*, art. "*Fosses d'Aisances.*")

The object of the precautions taken with regard to the pits and closets is to ensure as far as possible—

"(1) Absence of noxious or disagreeable miasms and odours. **Conditions required.**

"(2) Solidity, simplicity, and economy of the apparatus.

"(3) Preservation of the contents in their natural condition, and their removal as promptly as possible by methods calculated to obviate all inconvenience and all danger."

With regard to the closets for public buildings (hospitals, schools, prisons, barracks, &c.), it is ordered that "the soil-pan must be in porcelain (*faïence*), or in solid glazed stoneware. It is provided with a groove, to be filled with water or wet sand. The lid, to close it hermetically, must to this end be fitted with a ridge which enters the groove so as to prevent the issue of gases. This method has been applied with success in the cells of prisons recently constructed, where there is in each cell a completely inodorous privy-seat (*siége d'aisances.*)

"The pipe connecting the seat with the cesspool must communicate as directly as possible with the cesspool; its internal surface must be quite smooth, and it must be made of a material which will not be corroded by the action of the liquids or gases which may be in contact with it: to this end it must be **"Tuyau de chute."**

of lead, or preferably, in large establishments, of stoneware glazed on the inside; the various pieces of it must be firmly fixed with well-closed and luted joints. This pipe should have an apparatus for intercepting the air (valve or syphon), which may be washed by throwing water down or allowing some to run through it. There should be two such valves or syphons, the one directly under the soil-pan, the other at the lower extremity of the pipe: this lower syphon is not to plunge into the contents of the cesspool or sewer, its contents must *pour themselves* into that receptacle.

Trapped.

"At Brussels it is customary to place at the foot of the descent-pipe an iron reservoir which fulfils the part of a syphon. This apparatus allows of the cesspool being placed at a convenient distance, a communicating sewer being made. When the closets are indoors it is advantageous to arrange a sufficient and well-aërated space between the rooms of the house and the closet,[1] and to establish in this latter, besides the window or opening which lights it, a ventilation-pipe.

Ventilation of closets.

"Each closet is to have only one window, and the doors must be arranged so that the lower part of the legs and the upper part of the body can be seen." (For reference see p 36.)

Closets abroad.

At this point a few words must be said on the ordinary closet arrangements of continental towns as a general rule. We have observed closets of three kinds: (*a*) those in which the seat is made of wood, and which answer their purpose tolerably well in private houses, but which invariably become excessively filthy

Seats.

[1] This M. Tardieu terms a "surcroît de précautions!"

in all public places from the prevalent abominable custom of standing upon the seat; (*b*) those which have a stone seat, if a construction can be so called which could never have been intended for any one to sit upon: these are infinitely preferable to the former ones, wherever the above-mentioned habit is usual, as the stone slabs do not become sodden like wooden planks do, and can be washed more easily and more effectually; and (*c*) those without any pretence at a seat at all, and in which the convenience (?) consists of a zinc floor inclining to a hole, immediately beneath which is sometimes a swinging trap which closes the mouth of the pipe or drain, but which gives way with a slight weight, returning into position immediately afterwards. Of the three forms the last is undoubtedly the best fitted for all public places in countries where seats in closets are obviously an unnecessary luxury, and soon become an unmitigated nuisance.

No seat.

In all these cases the pipe descends directly from the soil-pan, when there is one, from the floor when there is not, to the cesspool under the house, and the flushing, such as it is, takes place when the slops are thrown down. There is often no sort of trap at either extremity of the pipe, so that the putrid gases formed in the cesspool rise up into the rooms of the house; when, however, one of the above-mentioned simple traps, invented by MM. Rogier and Mothes, is placed at either end, or one of these at the one end and a syphon at the other, there is much less danger of this.

Often no trap.

The ventilators of the cesspools are generally carried up along a stack of chimneys, so that the air in

Ventilators.

them is warmed and an upward current created. Although they rise above the chimneys, there must be a risk of the foul air being occasionally blown down the chimneys into the houses.

"Pneumatic" system.

A system called "Captain Liernur's System," is described at great length in a work recently published ("The Sewage Question:" F. C. Krepp). It is essentially a variety of the French "*fosse permanente*," the air-tight iron cesspool being placed under the street where two streets cross, instead of under houses, being connected with all the houses in several streets by iron pipes, and being emptied daily by "pneumatic pressure" into a closed, air-tight cart: no water is to be used in the closets, which are constructed on a special plan. We have little evidence of the practical working of such a plan, but we know what air-tight carts filled by "pneumatic pressure" are in continental towns, and have no desire to see their disgusting nocturnal processions in London, or anywhere else.[1] Every possible precaution is taken in Paris to secure as far as possible freedom from offence, and yet when the "*tonneaux*" are filled, and miles from the place where they get their load, they spread around them, as they go along towards La Villette, a most abominable stench.

Air-tight carts.

Cost of a cesspool,

As to the expense of a cesspool, it may be stated that such a one as is put to a labourer's house costs, for digging and lining with brick, from £1 10*s.* to £2, and that if lined with cement, without which there is no pretence at imperviousness, it would cost £1 more. If an overflow drain were provided, it would cost 1*s.* 6*d.* per foot, and be not less than thirty feet long (probably fifty feet); this, with the cement for a cesspool 3 feet 6 inches in diameter, "would not at the

[1] See Appendix.

London prices be less than £3 5*s*." "Making the whole expense of the cesspool so protected about £5, and involving an annual rent, at 10 per cent., of 10*s*. for the cesspool alone." (*First Report H. of T. C.* vol. ii. p. 318.)

The expense in Paris of making a cesspool varies from 160 to 200 francs (£6 8*s*. to £8) for one of eight cubic metres (282·4 cubic feet), provided with separators, ventilating shafts, &c.; such a reservoir "only becomes full at the end of a year in ordinary houses, that is to say houses inhabited by thirty persons." **in Paris.**

Expense of cleansing. The Health of Towns Reports inform us that the average expense of cleaning a cesspool in the metropolis was about £1 per annum. When this is tested by examining the evidence, it is found that in Southwark and Battersea the expense was "£1 *each time* for small tenements, and as much as £3 for large ones." Where percolation into the surrounding soil is favoured, the cost is of course lessened. "From four to eight-roomed houses do absolutely cost about 3*d*. per week for cleansing the cesspools." (*Loc. cit.* p. 122.) So that it is to the advantage of the owner of a cesspool in a large town to adopt the Northampton principle as much as possible, and assist the escape of liquid sewage into the surrounding soil, and therefore, as we have already seen, into the neighbours' wells, as much as he can. Surely it would be difficult to say anything more condemnatory of a system than this. No one maintains that it is an improvement to well water to be "diluted sewage;" whether it is a sanitary advantage or not, will be considered in another place. The total cost then, including the interest on the original outlay, would be "in the metropolis" from £1 to

£1 10*s*. per annum; or £1 2*s*. per annum, or from 4*d*. to 5*d*. per week, for common tenements; and this does not include the cost of the closet itself.

TEMPORARY CESSPOOLS.—"FOSSES MOBILES," PAILS, BOXES, TUBS, ETC.

Diminution of size. It is plain that in order to lessen as much as possible the chances of soakage from cesspools, just as from middens into which ashes, &c., are put, the best thing to do is to diminish their size as much as possible, so that they may be emptied frequently; this presenting an additional advantage in the more rapid removal of the refuse matters from the proximity of dwellings.

"Fosses mobiles." The most obvious example of this plan is to be found in the continental "*fosses mobiles.*" We extract from the Belgian report before quoted (page 36) the following account of the system as practised at Brussels especially in large public establishments:—

"The system of closets with '*fosses mobiles*' has for its object the collection of (excremental) matters in a state of purity, without mixture with water, in desirable conditions of cleanliness and absence of odour."

"Siége." "(1) *Seat.*—This consists simply of a soil-pan of stoneware or *faïence.*" There is no woodwork, and the soil-pan merely projects from the top of the descent-pipe. "Its border has a groove in it filled with water or sand, into which the raised rim of the lid fits.

"Tuyau manchon." "(2) *Connecting-pipe.*—This pipe, straight, *without syphon*, joins the descent-pipe at a very acute angle (22°), and is about 4 inches in diameter inside; it is, like the next, made of stoneware, glazed inside.

"Tuyau de chute." "(3) *Descent-pipe.*—This is from 6 to 8 inches in internal diameter; it is straight, vertical, and is composed of a series of pipes connected with each other by dry sand joints, without cement, fixed to the wall by iron bands; it rests, at the ground-floor level, on a strong flagstone. Its prolongation, through and below this stone, consists of a sliding pipe of wrought copper, capable of being lengthened or shortened, and solidly fixed to the stone by a cast-iron connecter. A sort of circular shallow dish (*écuelle*), which can be hung under this last part of the descent-pipe, serves at a given moment to shut its lower orifice.

"(4.) *Tub* (*tonneau*).—The excremental matters coming down the descent-pipe fall into a tub of from 2 to 3 hectolitres (44 to 66 gallons), into which dips, fitting tightly (into a hole in the top), the lower part of the pipe. A cover fitted with a spring serves to shut and lute, by means of a little hemp, the tub when it is full. Placed on a stand furnished with wheels, the tub is easily managed; when filled, it is immediately replaced by another similar contrivance. If the tub is underground, the rails (on which the stand moves) should be placed on an incline, so that the removal and replacement may be easily effected. The underground chamber must be isolated, and the entrance to it placed outside the building. The thorough tarring of the interior of the tub not only preserves the staves, but also partly neutralises the effect of the mephitic gases which the (excremental) matters disengage. "Tonneau," or "Tinette."

"(5.) *Ventilation-pipe.*—To prevent the smells and gases which are given off from the mouth of the tub, from spreading themselves (in the house) by means of the opening in the privy-seat, at the upper extremity of the descent-pipe is fixed a ventilation-pipe, which rises above the coping of the roof, and the action of "Tuyau d'évent."

which is increased by means of a vane, or any other contrivance producing the same effect."

The expenses of this apparatus are said to be "relatively small, and are besides amply compensated by the returns from the sale of the manure."

Earthenware urinals are placed in the boys' and men's departments, and are connected with the soil-pan or one of the descending pipes by means of a leaden pipe slightly bent in the form of a syphon.

"Siéges d'aisances mobiles."

With regard to the "*fosses mobiles*" for the sleeping-rooms and sick wards the following directions are given:—"These seats must be arranged so as to cause no smell. Wood is to be forbidden, as it is readily impregnated with fæces and urine; *faïence* stoneware, or pottery, as being too heavy and liable to be broken. Preference should be given to the utensil of galvanised iron or of counter-oxydised iron, used in prisons: closed by a lid of the same metal, which fits into a groove filled with water, this vessel is carried with one hand, by means of a handle fastened to two rings on it, without allowing gas to escape during its passage. It can be placed in an ordinary bed-chair when thought necessary."

Fault of ventilation.

In this system as applied to houses it will be seen that there is no trap, no syphon, nor indeed any contrivance to prevent the gases which accumulate from rising into the connecting-pipe and soil-pan; reliance is placed on the vane at the top of the "descent-pipe," which of course as a rule, if well arranged, causes a draught upwards, and upon the supposed air-tight lid. It is easy to see, however, that the draught can never be sufficient to draw the air very forcibly downwards when the lid is lifted, and so the light gases collected in the soil-pan (which is most conveniently placed to receive them) take this opportunity of escaping into the house. If by any chance the ventilation arrangements do not act as they should, there is nothing whatever to prevent the house being supplied with air through the privy-seat as soon as the lid is lifted.

Various devices are employed in Paris for the separation of the liquid from the solid contents in these tubs, and sometimes the liquid parts run away from them directly to the sewers, or into a cesspool.

The price of a single "*fosse mobile*" with a *séparateur* is from £2 to £2 10*s*.; for one having three divisions, and so serving for several descent-pipes, from £6 10*s*. to £7. The expense of emptying the solid matters alone for a house of thirty persons, and furnished with a "*séparateur mobile*," is: Removal of twelve boxes at 1fr. 50c. a year, 18fr.; hire of apparatus, 20fr.; *i.e.* 38fr., or about £1 10*s*. a year altogether. This, M. Tardieu remarks, is without doubt a high price; "an inconvenience which is inevitably attached to the system of '*fosses mobiles*,' but which is compensated for by the easy and prompt removal of the putrescible matters." (*Dictionnaire d'Hygiène Publique*, art. "*Fosses d'Aisances*.") **Cost.**

The establishment and management of these contrivances in Paris is strictly under the control of the authorities; they may not be fixed, moved, or emptied except by duly authorised persons, and since 1851 they must be supplied with a separating apparatus. **Authoritative supervision.**

The German system of moveable receptacles (*Abfuhrtonnen*) is much the same as the above, but the simpler form of a mere bucket under the privy-seat is in use in many towns (Berlin, Leipsic, &c.).

Vanishing point of cesspool.

This is the vanishing point of the undrained cesspool. We have seen it reduced to a 20, 40, or 60-gallon cask in the larger "*fosses mobiles;*" now we find it reduced to a mere box, pail, or bucket, just as we saw the midden reduced to a mere space under the seat, between it and the flagged floor; in each case the underground pit is entirely abolished.

From Dr. Buchanan and Mr. Radcliffe's report we find that this system is in practice at Leeds and at Nottingham; at which latter place, however, a little earth or ash is put into the bottom of the box, to prevent the contents from adhering to it. There are, besides, separate bins for the ashes and house refuse. These boxes are removed daily, or two or three times a week, being either emptied into the carts or carried off altogether and replaced by fresh ones; the scavenging is all done in the night, and the refuse is taken away from the town by canal barges and sold for manure.

Moveable tubs.

At Rochdale, too, moveable tubs under the privy-seat are in vogue. A little fine ash and common salt is sprinkled over the bottom of the tub for the same purpose as at Nottingham, and also perhaps with the view of retarding decomposition; the ashes and house refuse are thrown into a separate tub; the pails are made from disused paraffin casks, each cask being cut in two; they are fitted with iron handles and with tightly fitting lids, and cost 3*s.* 4*d.* each; they are changed twice or three times a week, and cause very little nuisance either in the houses or in the streets.

The cost of changing a midden closet into a pail closet is 30*s.*, or £10 for seven.

At Edinburgh the system of simply placing pails full of excrement, urine, and general refuse outside the houses for the scavenger to take away, has been long practised, as there has been literally no accommodation of any sort in the large tenements. The pail closet system has now been established there on a regular footing. The closets, which are roofed in, are placed in two rows, with a passage for the scavenger between them; the seats and divisions between the recesses are made of smooth slate; under the aperture is a short earthenware funnel, and below it is placed a moveable metal pail; this is removed daily by the scavenger and the privy cleansed, a reservoir of water being provided for this purpose. At Glasgow, too, the same system is at work "in various public and semi-public closets." Pails in Edinburgh.

The pails or boxes should be round and straight; square ones are not so strong nor so easily cleaned; they may be of wood, well pitched inside, or of galvanised iron. The closets should be made of impervious materials as much as possible, as then they are less liable to get fouled, and are also more easily washed; the ash-tub should be under a roof of some sort, or its contents will get wet and become a nuisance. The pails should be changed daily. Conditions necessary.

Dr. Trench, the medical officer of health for Liverpool, has made some practical observations on the difficulties of applying this system to large towns. He has calculated that the space that would be required for the spare receptacles for the borough of Liverpool, allowing that they were packed as close as possible, would be 11 acres, 2 roods, and 32½ perches; and that if they "were put on a railway, four abreast, they would extend to Ormskirk, a distance of twelve Difficulty, from number of pails.

miles." He adds: "I can form no guess as to what would be the extent of land required for the reception, emptying, washing, and deodorising of the receptacles directly on removal from the various houses; nor can I conceive where, within the area of our overcrowded borough, such spaces could be found; nor where, outside and beyond the precincts of the town, the Health Board of any suburban locality would allow their parishioners to be poisoned for the convenience of Liverpool."

Necessity of two sets of pails. He points out that it would be absolutely necessary to have "two receptacles for each house, one to use and one to clean." "But it may be said that there is no necessity to return always the same utensil. Then my answer is, that the disgust, the fear, the panic during epidemics of small-pox, of scarlatina, or of Asiatic cholera, that infection would be brought to one's home by these means, would soon control all municipal authority, and upset the whole scheme."[1]

Dr. Trench here assumes that the pails are carried away, contents and all, by the scavengers; a perfectly just assumption, as the plan of emptying them into the scavenger's cart, cleansing and replacing them on the spot, would create such a nuisance that it would not be endured. But his objections do not apply so forcibly to the ash or earth closet systems, as a like proceeding in these cases is not, i.e. *ought not to be*, attended with nuisance, and so the receptacles, not being carried away, cannot get changed.

Nuisance Mr. Menzies says of the pail system, that "it can never be adopted near dwellings of the better classes, for the sight and smell are so exceedingly nauseous that they could not be endured. The removal of the

[1] First Report, Rivers' Pollution Commission, 1868, vol. ii. p. 306.

matter is indeed at all times a filthy operation, and the iron pans when empty smell even worse than when they are full, as there is then a greater surface exposed."[1]

Trough latrines,

The trough latrines of Glasgow and Edinburgh may be conveniently considered here: they are in effect the pail system adapted to large collections of people. A long fixed iron trough, slightly inclined towards one end, runs along under the seats of a row of closets; it is provided with a little water, just enough to make the contents run easily, and it receives the total urine and excrement of the persons using it. In the Glasgow factories there is one on each of the four stories, and it is used by 180 to 200 persons; the contents are emptied once or twice a day down a vertical pipe into a large closed tank placed close to the ground, and holding 80 gallons, or about a day's produce; this is emptied by means of a 12-gallon two-handled pail into a closed cart, and the contents "carried away without very much offence."

not trough water-closets.

These must not be confounded with trough water-closets, which will be described in their proper place. They differ from them in this fundamental and essential point, that they are not connected with the sewers, and therefore require special scavenging arrangements.

Iron trough-closets of the above description, including ash-bins, cost "for two persons £23, for three persons £32, for four persons £41."

THE EUREKA SYSTEM.

Plan at Hyde.

In the *Journal of the Chemical Society* (March 1866) Messrs. Lawes and Gilbert have described this system as it was carried out at Hyde, near Manchester. A

[1] Management and Utilisation of Sewage, p. 6.

box containing "some disinfectant or deodorising mixture" was placed under the privy-seat, with instructions that no slops were to be put into it, left for a few days, then covered by a tightly fitting lid and carried off, and a fresh one put in its place. These covered boxes were placed in a close cart, and carried away to a manure manufactory near to the town, where their contents were treated with more disinfecting fluid, concentrated by distillation, and ashes added, the whole making a not very valuable manure (containing only between 1 and 2 per cent. of ammonia), one that would certainly not bear the cost of carriage "beyond the distance of a very few miles." The inhabitants considered the works a nuisance. Dr. Trench, in 1864, visited Hyde to inspect this process, and says that it was, in his opinion, in all its details, "a shocking and unmitigated nuisance." Dr. Beecroft, of Hyde, after having mentioned his own belief that the system had been the means of spreading infectious disease, and would be highly dangerous during an epidemic of Asiatic cholera, thus concludes: "If the Eureka Works were removed so as to do away with the excessive stink which we receive from them when they are in full work; if the boxes were numbered so that each house could always have its own returned; if the boxes were made or lined with a non-absorbent material in the place of the porous wood, as is the case at present; and if the boxes were emptied more frequently (daily when infectious disease existed), the system would be superior to the old ash-pits, though not to be compared with water-closets." (*First Report R. P. C.* 1868, vol. ii. p. 306.) We find, from the Report just quoted (vol. i. p. 51) that "the plan has at length

Poor manure.

Nuisance.

Has been abandoned.

een abandoned for both of the reasons referred to by Messrs. Lawes and Gilbert," viz. the alleged nuisance and the worthlessness of the manure.

THE GOUX SYSTEM.

This system, called also the "Patent Absorbent Closet System," consists in a modification of the ordinary pail closet by the lining of the tubs with some kind of absorbent material. The prospectus of the patentees states that "all kinds of vegetable and animal fibrous matters, useless for other purposes, are used as absorbents," and these are "to be mixed in such proportions as may be most convenient, together with a small percentage of sulphate of iron or sulphate of lime." These matters are pressed closely to the bottom and sides of the tub by means of a cylindrical mould, which is afterwards withdrawn, leaving, of course, a cavity in the centre of the materials. Ordinary midden closets can be easily converted into those suitable for this system by cleaning out the ash-pits, filling them up with engine ashes or other dry refuse, paving the floor under the seats, and covering them with slated roofs; in fact, by the alterations required for the ordinary pail closet. A separate tub is required for ashes and dry rubbish, but chamber utensils and so forth may be emptied into the tub under the privy-seat. The pails require to be removed weekly, or twice a week, and this is easily done by making the privy-seats moveable. The patentees state that "for the interior of mansions, dwelling-houses, schools, unions, hospitals, and factories, an adaptation of the system has been designed which provides for the removal of the collected

Absorbent materials. **Conversion of ordinary midden closets.** **Removal of tubs.**

matters without the trouble and inconvenience of carrying them down-stairs. This plan will cost less than the ordinary water-closet, and can be applied wherever such closets can be fixed." They also state that "a closet on the Goux system cannot be made uncleanly except by the most positive wilfulness." This would not, however, seem to be the conclusion to which Dr. Buchanan came in his inspection of the working of this system at Salford. He found that the absorptive materials appeared to be of very little use, and that, in fact, whenever the pails had been in use for more than two or three days, the absorptive capacity was invariably exceeded; that wherever they had been in use four or five days, or for a week, the pails were two-thirds or more filled "with liquid dejections, in which the solid excrement was floating," and that this was not always from the chamber utensils being emptied into them, although it must be remarked that this procedure is sanctioned by the promoters of the system. There is no doubt, however, that although the Goux system cannot be accounted among the "dry" methods of treating sewage, yet it is much superior to any form of midden system. When the closets are well managed they are generally clean, and afford no offensive smell, and they entirely prevent any pollution of the soil near houses. The Goux plan has also been applied to public urinals, but in this case the absorbent materials are only professedly "a filter through which the liquid urine passes into the receptacle below." This receptacle contains a small quantity of sulphate of iron, with the object of preventing fermentation, and the urine collected in it is subsequently used in the manufac-

Absorptive materials of very little use.

Urinals.

ture of the manure in connection with the contents of the pails. (See *Twelfth Report M. O. P. C.*, p. 116.)

The alteration of a midden closet into such a one as has been above described costs 35*s.*, and a set of tubs 10*s.*; each tub on an average contains 84lbs. of dejections, being calculated to hold 120lbs. Two men and a horse can remove 600 tubs in a week, or 22½ tons of contents, the cost being £1 a week for each man, and £1 a week for the horse; say 2*s.* 9*d.* a ton for the cost of removal. For this crude material from 5*s.* to 6*s.* a ton is given by the farmers, but when a manure is prepared from it by the plan originated by Mons. Goux, it sells for £2 a ton, and is "considered cheap at the price." The method of preparing the manure from the stuff collected is to spread it on a floor and sprinkle it with a little sulphuric acid, when, "after a certain amount of fermentation and consequent destruction of the fibrous matter, the whole becomes a homogeneous, inoffensive, but feeble manure, which may be very fairly described in the words used by Messrs. Lawes and Gilbert about the Eureka failure." (*First Report R. P. C.* 1868, vol. i. p. 51.)

Expenses.

Feeble manure.

Of this and all similar systems it has been well said, "not only that it is but a part of the excrementitious matter which is dealt with, but that even as regards that portion of the excrement which they do remove, they so entirely depend upon efficient cleanly superintendence and direction, that wherever they have merely had the average man to work them, they have failed. Moreover, this very frequent collection of filth by hand from houses, and its removal, sometimes through the cottages themselves, almost necessarily under the eye

Too much supervision required.

Offensive methods.

and nose of the household, whatever may be the importance of the economic object aimed at, is universally condemned by our domestic habits as nasty and offensive. They can never be an entire success, and, in competition with the water-closet, a jury of average householders will certainly condemn them for lack of cleanliness and comfort." (See the last reference.)

UTILISATION.

It has been shown by Messrs. Lawes and Gilbert from their own calculations, and also from the results obtained by Messrs. Hofmann and Witt, and by Dr. Thudichum, that the average amount of ammonia voided annually by an individual of a mixed population of both sexes and all ages, is, in urine 11·32, in fæces 1·64, total 12·96lbs.;[1] and that the estimated money value of the total constituents is, in urine 7*s.* 3*d.*, in fæces 1*s.* 2¾*d.*—total 8*s.* 5¾*d.* We note at once the comparative worthlessness of the fæces in an agricultural point of view, and are thus prepared to see any plan fail, economically speaking, which does not make it its especial business to utilise the ammonia and other valuable manurial constituents of the urine.

Value of excreta.

(A.) MIDDEN SYSTEM.—FRENCH "FOSSES."

Sold to farmers.

In country places the filth of the ash-pits, &c., is usually sold to farmers, who come and fetch it away, and sometimes it seems to sell well. Thus, at Stratford-on-Avon the manure is said to be "readily disposed of." It is, however, allowed to accumulate

[1] This quantity is considered by Messrs. L. & G. to be too high when applied as a means of calculating the value of sewage: they are of opinion that in that case 10lbs. of ammonia per head per annum, with a value of 6*s.* 8*d.*, would be a more accurate estimate.

until it suits the convenience of the farmers to fetch it away, and in many places they refuse to take it at all. This takes place in like manner in the lower neighbourhoods of towns, where "the refuse of the courts and alleys is reserved in the necessary pits till the accumulation is very considerable; the inhabitants then sell it for a few shillings per load, and divide the amount so obtained amongst themselves."

Not a good manure.

Although many of the disadvantages of the midden system may be obviated by improvements in the construction of the pits, &c. it can only answer in exceptional cases, as most of the urine is lost and the manure obtained is only well suited for heavy clay soils; for most soils the admixture with ashes renders it comparatively worthless.

Does not pay.

And in a town in which it has been most perseveringly employed—Manchester—it has failed in an economical point of view; on this head Sir Joseph Heron, the town clerk, says, in his evidence before the Rivers' Pollution Commissioners: "It is true in Manchester, as well as in Liverpool and in other places, that the expense we incur in removing the night soil is by no means returned to us by anything that we obtain for it, and we often have to carry it at a very considerable loss. *In no case is it found that it is paying.*" (See page 257.)

French "voiries."

In France the contents of the "*fosses permanentes*" and "*fosses mobiles*" are not usually utilized without preparation, but are carried away in the "*tonneaux*" to some distance from the town, where they are emptied into the highest of a series of basins ranged one above another; here they are exposed to the air for some time, and while the liquid parts run away into the lower basins, the undissolved solids subside in the higher ones. The liquids are reduced in quantity by spontaneous evaporation, but they have for the most part to be pumped away, generally into the nearest watercourse; sometimes, however, they are evaporated, mixed with sulphuric acid, and sulphate of ammonia thus prepared. The establishments in which this latter process is carried on have been placed in the first class of "établissements dangereux ou insalubres," the reason being that they cause an "odeur désagréable et portée au loin." The solid part which subsides is dug out of the pits, further dried by being spread out on a large surface of ground and stirred about continually, piled up when nearly dry in immense heaps, and left for a year at least, often for several years; it is then sold under the name of *poudrette*. "It has then the aspect of a greyish-black earth, light, oily to the touch, very friable, and spreading a peculiar odour, disagreeable and nauseous, which is not that which the matters which compose it exhale in their native state, or even before their perfect desiccation." (*Parent Duchatelet.*)

Liquid part mostly lost.

"Poudrette."

The *poudrette* prepared from the deposit in the lower pits is especially sought after by the farmers, as it contains the finer particles which have escaped precipitation in the higher pits, and at the same time less useless material.

In Paris the business of removal and preparation of the manure is let out to a contractor, and the city would appear to make a gain out of the transaction, *i.e.* the public funds are benefited by it; but not so the ratepayers! They pay a considerable sum for the emptying of their cesspools, 8fr. a cubic metre, 15fr.

Loss to the public.

for a "*fosse mobile*" (Tardieu); and Mr. Krepp calculates that the "*poudrette*," which sells only at 47fr. 50c. a cubic metre, really costs the city 146fr.

(B.) PAIL SYSTEM.

In this system we have the fæces and urine pure, without any admixture of earth, ash, or water, except in some cases to a trifling extent. The evidence generally shows that this plan can be made to pay, and indeed generally does pay its cost at any rate.

Can be made to pay.

"In the town of Gröningen the yearly profit amounts to about £1,600; in Antwerp it is £2,700, at Ostend £700. In Strasbourg the cost of removal is only just covered by the sale of the manure. The sale of the refuse from the barracks at Carlsruhe, where 2,800 men were quartered, has realised a profit of £300 a year, and the attendant expenses amounted to about £40 a year." Sometimes, however, the expenses exceed the income derived from the sale of the manure: "thus, in Stockholm, with a population of about 150,000, the expenditure amounts to £35,000 a year, and the income derived from the sale of the refuse as manure is £33,000 a year."[1]

Various examples.

In Nottingham the contents of the boxes are sold at from 3*s*. to 4*s*. a ton; this brings in £4,000 a year, while the cost of scavenging is £6,000. At Rochdale the plan scarcely pays its expenses at present, as there are only 580 pail closets, and so the expenses are relatively high. If, however, all the 4,000 midden closets of the town were changed into pail closets, Mr. Alderman Taylor calculates that the profit to the town, on the sale of the manure

[1] First Report of British Association Sewage Committee, 1869.

at the present rate (15*s*. a ton), would be £9 a week, or £468 a year. He however anticipates a higher value for the manure.

Cost of scavenging.

In Glasgow the estimated value of the contents of the pails, troughs, &c., plus the ashes and street sweepings, is £18,000 a year, while the cost of cleansing the city is £27,000; from which we see at once that the cost of removing the excrement of a large city by cartage is enormous.

The advantage in a commercial point of view of the pail or tub system over the midden system is, that it produces a valuable manure, which can be made, as at Salford, to pay more than the cost of collecting it. It is the system which has answered so well in China and Japan for so many centuries, and which has prevented those countries from being now barren wastes. But it is one which accords in no way with modern ideas of cleanliness, and which could never be introduced into the better quarters of any town; for the lower classes of habitations it is a great improvement on the old midden heaps, cesspools, &c., as it necessitates the daily or even more frequent (as at Edinburgh) removal of excremental matters, which can be easily disinfected if necessary.

Has succeeded in the East.

It must, however, be considered to be the only plan that we have yet examined that can be made even to pay its expense as a general rule.

SANITARY OBSERVATIONS ON THE IMPROVED MIDDEN AND CESSPOOL SYSTEMS.

It having been already shown that accumulations of excretal and other filth afford a nidus for various diseases, it need only be pointed out here that the sanitary advantage possessed by these systems varies precisely with the frequency with which they provide for the removal of the refuse matters, and with the perfection of the means taken to prevent their decomposition.

Frequent removal.

Wherever one of these plans has been introduced, a step in the right direction has been made, and the necessity of the speedy removal of excrement has been acknowledged, except indeed in the case of the large cemented cesspools, "*fosses permanentes*," in which, however, every precaution is taken, abroad at any rate, to prevent the contamination of water or air; with what result we shall soon see.

Any state of things is better than the one described in our first chapter, and the frequent removal by hand and cart, although annoying, affords less nuisance and much less positive danger than the stinking heap of putrid filth in the ordinary midden heap or cesspool.

Pail system best, but nasty.

The simple pail or tub placed under the privy-seat, and removed daily, or even twice a day, is the most thoroughgoing of these methods, but, to say the least of it, a very nasty one, and a very troublesome one too. The French "*fosse mobile*," with its "*séparateur*," is by far the best plan for keeping excremental matters intact for a few days, and is much superior to any pails or buckets lined with absorbent materials or provided with disinfectant matters. But this, though a vast improvement, as pointed out by Parent Duchatelet, on the "*fosse permanente*," is, with most of the systems now under consideration, a mere makeshift to obviate the nuisance and expense of too frequent removal, while at the same time effectually preventing long storing.

"Fosse mobile."

The question in fact to be solved would appear to be, with all the methods which require hand and cart labour, how can the refuse matters be kept as long as possible without being positively dangerous to health? Instead of, as it should be, how can they be got rid of as fast as possible?

Wrong principle.

This consideration at once stamps all methods of removal by scavenging, and must of itself bind them to a false principle, and lead to their condemnation; indeed, they are only commended by the fact that they do not utterly waste the valuable manure with which they have to deal.

Midden-pits.

The midden-pits are improved, from a sanitary point of view, as they depart farther and farther from the old conventional ash-pit: it is found practically, however, that they cannot usually be kept dry, and so they have to be drained into the sewers.

Gases in cesspools.

The large cesspools become filled with fœtid gases, containing a large proportion of sulphuretted hydrogen, and many were the cases of asphyxia caused by it during the emptying of the "*fosses permanentes*" by hand and bucket; this asphyxia, which the workmen call "*le plomb*" (probably from the sense of extreme oppression of the chest), and which occurs also to the workers in sewers, is, according to Parent Duchatelet, not so common as it has been stated to be.

Influence on diseases.

People exposed habitually to such an atmosphere (*vidangeurs, égoutiers, gadouards*) suffer also from headaches, and from ophthalmia ("*la mitte*"); their term of life does not, however, appear to be shortened, probably because those who are not of very strong constitutions give up the work at once. Parasitic diseases and most skin diseases are very uncommon among them, and they are said by the above authority to be remarkably free from intermittent fever and from cholera. He gives also an instance of three young women who had been pronounced consumptive by several physicians, and who were perfectly cured by working at the *poudrette*. Query, would they not have been as much improved in health by any *out-of-door* work? Venereal diseases are, however, undoubtedly, according to the testimony of Hallé and of the last-named observer, aggravated to a remarkable degree by this foul atmosphere, and "those who, having one of these diseases, persist in working, perish inevitably."

With regard to the symptoms of the asphyxia, they vary according as it is caused by want of oxygen or by the presence of a notable quantity of sulphuretted hydrogen. In the first case there is a difficulty of breathing, which gets worse and worse—it is a true suffocation; in the second, "the individual is seized suddenly, and dies instantly; or, if the quantity of deleterious gas is too little to bring instant death, the asphyxiated person, suddenly losing consciousness, is taken with convulsive movements or other very grave nervous disturbances, and it is only after several days that he recovers a perfect state of health." (*Parent Duchatelet: Hygiène Publique*, vol. i. p. 268.) Forms of asphyxia.

Sufficient evidence has already been adduced to show that an atmosphere tainted with the offensive gases given off by decomposing refuse is, even when much diluted, deleterious to health; but we may here quote a passage from the Health of Towns Reports (1844) which forcibly illustrates this point:—"It is not a great many years since four men fell victims to the poison whilst engaged in clearing out a privy near Cases in England.

Brompton, and still more recently an accident of a similar nature happened at Clapham. Twenty-three children belonging to a boarding-school at that place were simultaneously attacked with violent irritation of the stomach and bowels, convulsive twitchings of the muscles, and excessive prostration of strength; and two of them died in about twenty-four hours. The symptoms were ascribed by the medical attendants to the inhalation of sulphuretted hydrogen from the contents of a foul cesspit which had been scattered over a garden adjoining the children's playground. Although these effluvia are breathed by the inhabitants of our courts and back streets, in a state, of course, of extreme dilution, we cannot suppose that they are on that account entirely harmless. What in a concentrated form is so very deadly, must, in a diluted state, be injurious to health." (*Loc. cit. First Report*, vol. i. p. 139.)

Effect of foul gases on children.

Disease caused by poudrette.

The French *poudrette* itself, though inoffensive in a dry state, undergoes a kind of fermentation when moistened; and one of Parent Duchatelet's most remarkable memoirs contains an account of a disease that broke out on board the *Arthur* (a boat which had been loaded with *poudrette* on a rainy day), "of which half the equipage perished, the rest arriving at their destination in a deplorable state of health." The workmen who removed the stuff from the vessel were also seized by the disease, which, from a most accurate description given of the symptoms on a similar occasion by the same author, would appear to have been typhoid fever; he says it had "all the symptoms of one of those grave diseases known under the name of adynamic fever." (*Hygiène Publique*, vol. ii. p. 257, &c.)

These cases should be kept in mind during the transportation of any manure that requires to be kept dry.

The sanitary results of the midden closet system are not, moreover, what were contemplated by its supporters. The average death-rate of Manchester, where it has been carried out with great attention to detail "for fifteen years, as reported by Dr. A. Ransome and Mr. W. Royston, was 32 per 1,000, or, excluding certain healthy suburban districts, 34 per 1,000; while in 1865, an exceptionally bad year for epidemics of small-pox, scarlatina, &c., it was 39 per 1,000. It is also stated that the infant mortality of Manchester is higher than that of any other place in the kingdom, this fact being regarded as an invariable sign of sanitary neglect."

Manchester mortality.

"It is believed that much of the unhealthiness and mortality in Manchester, especially among children, may be ascribed to the atmospheric pollution caused by the present privy and ash-pit systems." (*British Medical Journal*, June 18th, 1870.)

CONCLUSIONS.

We have now dealt with the treatment of liquid manure, as such, in the various forms of cesspools, pails, tubs, and so forth, without the addition of any notable quantity of extraneous matters, whether with a view to the dryness or the disinfection of the contents; and also, on the other hand, with its treatment by admixture with a sufficient quantity of ashes and other refuse (as in the various forms of midden-pits and closets) to render the whole a more or less solid dry mass. We have seen that the former of these systems is as a general rule connected with a considerable amount

Nuisance.

of nuisance, either in the collection or removal of the excremental matters, or in both of these particulars, and that, although one modification of this system has practically succeeded in an economic point of view in certain countries, and even in a few of our own towns, it can never be looked upon as a solution of the question of the removal of excrement which can be adopted generally by the community as a final one, or even as a suitable one.

"The pail system presents several advantages for poor town districts. It may safely be employed for excrement-removal if moveable pails of defined construction be used, and be changed every day for fresh pails. Such a system, involving similar construction or constructive alterations as are required for the toleration of a midden system, offers advantages over the latter in regard of facility for frequent removal of excrement, in regard of safety from nuisance, and probably in regard of profit in disposing of excrement as manure." (*Twelfth Report M.O.P.C.* p. 140.)

Frequent removal.

With regard to the second of these systems, we have seen that it is almost invariably connected with great nuisance, both in the storing and in the removal of the contents of the pits or closets, and that it possesses the additional disadvantage of the necessity of disturbing these contents in order to remove them.

"The midden system may be modified so as greatly to reduce nuisance and danger from it. We have described the form of midden-closet which we think presents fewest objections. We cannot speak of satisfactory safety in the use of even this form of midden-closet, partly because we hardly expect to see it carried out with daily emptying, and partly because the materials of the midden would probably be retentive of some excremental matters; but if under certain circumstances middens, constructed as above, should be tolerated, it would, we think, be scarcely less than essential, first, that they should, if in a densely populated neighbourhood, be emptied daily, or under other circumstances at least once a week, and secondly, that the arrangements for excrement removal should be wholly in the hands of efficient persons appointed by the sanitary authority." (*Twelfth Report M.O.P.C.* p. 140.)

The improvements have in each case chiefly consisted in the diminution of the size of the receptacles, and the consequent more frequent removal of their contents, this being accompanied by one or both of two sorts of nuisances—that arising from the offensive smell of the contents, which can only be partially prevented from escaping (by such contrivances as air-tight lids and so forth), and that caused by the too frequent visits of the scavengers—a nuisance thoroughly detested by every householder, whatever be his station in life. In neither of these systems is there any provision made for the removal of the liquid house refuse from slops, washing, cooking, and so forth, so that all these, and generally the chamber slops as well, have to be thrown down the sink and pass away into the sewers, thus necessitating the purification of the sewage in some way, and so leaving the great question unsettled. Indeed, the amount of purification which would accrue to the sewage from such a proportion of excremental matters and nothing else being kept out of it, is not nearly so great as is generally supposed, the other refuse matter that the sewers necessarily carry away from all towns being so great in amount that it is certain that, even if all the excremental matters could be kept away from the sewage, it would not be sufficiently pure to be allowed to empty itself into a river, and the necessity of purifying it would arise as much as ever. (*See* pp. 127—130.)

Nocturnal visits.

Slops go into sewers.

Sewage must be purified.

CHAPTER IV.

THE DRY-CLOSET SYSTEMS.

Introductory.

We have now to consider the two methods which have arisen more or less directly out of the incompleteness of the two foregoing ones, and which are the only ones that we can look upon as in any way affording something approaching to a solution of the question of excremental removal. The first of these, the so-called *dry-closet system*, has for its object the separation of the excremental matters *in toto* from the sewage, and the removal of a great part of them at any rate in a dry and inoffensive condition. The best form of this system, according to its originator, professes also in an indirect sort of manner to treat the other house refuse, liquid and solid; how far it is possible that it should *practically* achieve these results we shall presently see. The other is the *water-closet system*, by which the whole of the excremental matters, solid and liquid, together with all the liquid house refuse, is washed into the sewers, carried at once away from the vicinity of houses by the unaided force of gravity, and either, as has been hitherto the case allowed to fall into a watercourse or into the sea, or utilised as manure by one of the processes that we shall hereafter describe.

ASH CLOSET.

The dry closet which approaches nearest to the best form of midden closet is the one in which ash is used as the deodoriser. This is described in a paper read before the Manchester and Salford Sanitary Association by Mr. Morrell, of which an extract is given by the Rivers' Pollution Commissioners, 1868. (*First Report*, vol. ii. p. 309.) Each closet is provided with an ash-sifter, which is brought into motion by the opening of the door, the fine ash falling through into a storing measurer, fixed in the back wall. The seat of the closet is covered by a lid, which, when opened or shut, measures out into the excrement receptacle (an easily moveable water-tight vessel) a quantity of ash sufficient to deodorise its contents. The cinders which do not pass through the sifter are of course used again as fuel. It is stated that whenever there is not sufficient ash-dust to be had, as perhaps may sometimes be the case in summer, "it is easy to supplement it by throwing on to the screener some fine street sweepings." For stories above the ground floor it is proposed to have a wide tube brought down to or below the ground floor, and opening into a receptacle placed there, which might be removed when full, or as occasion required. "A circular vessel, two feet deep and one foot nine inches in diameter, will contain the ash and excrement refuse from one house with five occupants for twenty days. Removal once a week, or once each fortnight, for such a house, will therefore be sufficiently frequent." Mr.

Mechanism.

Street sweepings utilised.

Plan for stories above ground floor.

Separation of urine.

Taylor has patented a dry closet of much the same kind as the above, but in which the urine is not allowed to remain with the soil and ashes, but escapes from the soil-pan into a special receptacle at once, before the ashes are thrown upon the soil by the shutting of the lid of the closet. The advantages claimed for this method are, that the material required, ashes, is always on the premises, and would have to be removed in any case; that the apparatus is strong and not complicated, and its working easy; that the excremental matters are completely deodorised and rendered inoffensive; and that the mixture produced is very valuable as an agricultural manure, "selling readily for £8 a ton." A very simple and effective form of dry closet is the Carbon Disinfecting and Deodorising Closet, of Messrs. Weare and Co., which is in use in some parts of Liverpool. Immediately under the seat is a perforated earthenware pan, and below this a moveable box containing a perforated iron bucket, the space around the pan and bucket being packed with ashes and fine wood charcoal; in the lid is placed a box containing some disinfecting powder, which is dusted on to the excrement by the shutting of the lid; the excess of water passes by a pipe into the drain.

Ashes always at hand.

Weare's Carbon Closet.

These plans are open to nearly the same objections as the dry-earth system (see p. 85, &c.), but have the advantage that ashes are always at hand.

THE DRY-EARTH SYSTEM.

The principle of this system is, that earth is the natural deodoriser of excremental matters, and the plan by which it is proposed to make earth available for this purpose is precisely the reverse of the one upon which all the other systems depend. It proposes to bring a certain quantity of earth to the manure, while all the others take the manure in some form or another to be placed upon the earth; in other words, a sufficient quantity of dry earth is to be brought into every community where this system is at work, completely to deodorise and render inoffensive all the excremental matters of population. In the prospectus of Moule's Patent Earth Closet Company it is stated that this system "is founded on the fact of the deodorising power of earth, a *given quantity* of *dry* earth destroying all smell, and entirely preventing noxious vapours and other discomforts. The practical application of this power consists in a reservoir for containing *dry earth*, and in an apparatus for measuring and delivering the requisite quantity, so as to deal with every operation *in detail*. This apparatus can be applied to most existing closets." The first essential, then, in the working of this system is that the earth should be *dry*, and the second that it should be applied *in detail*, that is to say, that each particular stool must be covered at once with the requisite quantity of this dry earth. It is found in practice that a pound and a half of dry earth (two pounds and a half would appear to be required in India) is sufficient to remove all smell from the stool when thrown over it, and the mass remains inoffensive for two or three months, or even more. It appears that a certain disintegration of the fæcal matters and a combination between earth and the organic matters contained in the excrement takes place. After a time no excremental matter whatever can be detected in the mixture; everything disappears, even

Earth brought to the excreta.

Essential conditions.

Action of earth.

May be used several times. paper. After keeping and drying it may be used again many times with the same result, but it is not found that this repeated use is advantageous in an economical point of view. Less earth than the amount above specified is insufficient, more is useless. In a pamphlet by Messrs. Girdlestone, the engineers of the Earth Closet Company, it is stated :—

Kind of earth required. "1. That any surface-earth and almost any clay will deodorise excrementitious matter, but that sand and chalk will not.

"2. That such earth, if dried and sifted, has such power of absorption that it is capable of receiving both liquid and solid excreta, and of rendering their removal practicable without offence, and also without any loss in the value of the manure.

"3. That a very small quantity of earth is required, and that the same portion of earth may be repeatedly used with the same effect.

Prevention of fermentation. "4. That the action of the earth on the excreta is immediate, all fermentation being prevented, the obnoxious agent being dealt with at once and in detail.

"5. That while the earth absorbs the excreta, they in their turn possess a decomposing power, such that any extraneous matter deposited with them disappears in a short time.

"6. That the absorption and deodorisation of the excreta result in preventing infection." (*The Dry-Earth System*, p. 4.)

Best kinds of earth. In Dr. Buchanan's report (Twelfth Report of the Medical Officer of the Privy Council) on the working and applicability of this system, he states that dry clay or loamy surface-earth, but especially the brick earth of the drift formation, are the kinds best suited for the purpose, and that after a month or so the mixed mass of excrement and earth may be wetted and moderately heated without producing any smell. The closet. With regard to the particular closet or commode, it is of much the same kind as the one that has been described as the patent ash closet. A receptacle for the dried earth is placed at the back, and either by a handle (the "pull-up") or by the action of the seat itself (the "self-acting") the requisite amount of earth is allowed to fall from the hopper into the pit or vault so as to cover the excrement. It is plain that the earth-receiver may generally, at any rate in fixed closets, be carried up to a considerable height in the wall so as not to require replenishing for a long space of time. For upstairs closets it is proposed to construct a shaft inside or outside the house, down which the contents of the pail may be emptied, or the pail itself may be fixed and connected with an earthenware pipe which descends vertically into a vault beneath. The prices for commodes vary from £2, that of the single moveable nursery commode (for children), to £7 5*s*., that of a more finished kind, on castors, with self-acting apparatus and fixed seat. If larger earth reservoirs are required, the cost is somewhat more. The tanks for the closets cost from 7*s*. 6*d*. to £1 5*s*. each, and the apparatus for placing in closets costs £1 15*s*. for the pull-up, and £2 for the self-acting (without the pails or tanks), while the apparatus for upstairs use, including the pail and pull-up mechanism, comes to £4.

Shaft for upstairs closets.

Cost of apparatus.

The commodes are made so that they can be easily moved and placed in any convenient situation in-doors or out-of-doors: they are especially intended for use in bedrooms, hospital wards, and so forth, and it is claimed for them that they—like the closets—entirely prevent all disagreeable odour when properly supplied with dry earth. It is stated that it is necessary "to cast one service of earth into the pail when first placed in the commode." It is essential that the earth be both dried and sifted. For large communities

Commodes.

Drying and sifting of earth.

it would be advisable that these operations should be carried on at one spot and on an extensive scale; but for country houses, where each household would probably prepare its own earth, a small portable dryer may be obtained for from £1 10*s*. to £2, and a dustless sifter for earth and cinders for £1. As a general rule it would be found that the sifting might be performed by means of an ordinary riddle or sieve. It need hardly be stated that it is absolutely necessary for the proper working of these closets that no slops should be thrown into them. If even the contents of the bedroom utensils be poured down them it would be necessary to supply them with a considerably larger quantity of earth. In public places urinals can easily be constructed acting on this principle, and are certainly, when properly supplied with earth by hand labour, almost entirely devoid of any offence. The system is now at work in several large institutions, and it has undoubtedly been found, when properly managed, to work well. The Convict Lunatic Asylum at Broadmoor is entirely supplied with earth closets, the water-closets with which it was originally supplied having been done away with because it was found that they were "a constant source of expense and annoyance," this being caused by the fact that the water supply apparatus was not very good, and that the closets were not properly ventilated. Now a mixture of sifted peaty earth and ashes is used, and the earth and excrement fall into a galvanised iron pail provided with wheels. The slops are still passed through the drains originally laid down by Mr. Menzies, as also is the urine from the men's urinals, and this mixed liquid is used to irrigate "some grass lands in the

No slops to be thrown in.

Urinals.

Examples of the working of the system.

Slops and urine still go in drains.

adjacent valleys."[1] It is stated that the only fuel required for drying the earth in the most efficient manner is provided by the cinders which are sifted from the ashes of the establishment, the fine ash being mixed with the dry earth (which is dried in a kiln built for the purpose.) It is also stated that in this establishment there is a saving of nearly half the amount of the water originally used. It will be noticed that this asylum affords an instance of a place where the water-closet and irrigation system has been changed for the earth-closet system, plus the utilisation of liquid refuse by means of irrigation as before.

Saving of water.

Irrigation.

In the Dorset County School "the ordinary system previously employed had resulted in trouble and annoyance perpetually recurring." (Messrs. Girdlestone.) We find from Dr. Buchanan's report that the whole of the day urine is dealt with as well as the stools, but that the night urine goes with the slops, a sufficient proof of the impracticability of the plan which has been proposed for separating the urine from the other slops. At this school the system is carried out in the following manner:—There is a water-tight vault with two closets at each end of it, the urinals being placed between. The dry earth is stored in a shed close at hand, and with it the hoppers of the closets are filled as often as required, and the urinals are supplied four times a day. A ton a week is required, or four pounds a day to each boy. The contents of the vault are removed without any smell, except on an occasion when earth had been supplied in insufficient quantity. It is stated that the agricultural value of the earth which has been twice

Day urine dealt with.

Quantity of earth.

Value of the manure.

[1] "The Dry Earth System," p. 7. (Messrs. Girdlestone.)

through the closet is from £2 to £3 a ton, or 15*s.* a year for each boy. (We do not see how this is possible, the value of the total excreta being only 10*s.* a head at most.) The closets caused no offensive smell, and the diarrhœa, which had been epidemic in the school, has ceased since their construction. A "low fever" which existed in parts of the town around the school in 1866 and 1867 did not show itself in this establishment at all. The whole cost of the repairs of these closets in four years is stated to be less than 10*s.*, while that of the water-closets was more than £3 a year. From the same report we find that at the Dorset County Gaol these closets have been used for three years for the whole dejecta, both night and day. About 3lbs. of earth a head are used daily; this is not enough. The manure is kept in a heap in the shed; when turned over for drying it is found to cause a bad smell. It fetches about £1 a ton, or 10*s.* a year for each prisoner. A saving to the extent of £15 a year in plumbers' bills is said to have taken place. The health of the prisoners has not been affected, having been good under both systems. At Lancaster Gaol the pail system was found always to be offensive, notwithstanding the provision of water-tight lids for the receptacles. Earth closets are now substituted for the pail closets, and are supplied with earth by hand, each prisoner throwing it into his closet with a scoop. Dr. Buchanan saw a heap of compost in the shed in the yard, and found no smell in the shed, but a handful of the mixture had a urinous odour. The slop water and the contents of the pails that are left are thrown into the sewers. At the Grammar School in Lancaster these closets answer very well, as also at

Sanitary result good.

Results at Dorset Gaol.

Pail system offensive.

Compost inoffensive.

the national schools: the only one found in an offensive condition was one of the girls' closets, into which some large stones had been thrown by some workmen, and to which earth was not supplied pending the removal of the stones. It was stated here that the trough water-closet was found to be very offensive. At St. Mary's College, Oscott, near Birmingham; at the Manx Lunatic Asylum, Isle of Man; at Reading Union Workhouse, and at other workhouses and factories, the system has been successfully applied.

Failure of trough water-closet.

At Wimbledon Camp, since 1868, this system has been annually in operation. In 1866 and 1867 the excrement was removed by water through drains into a brook, causing of course "serious nuisance in the neighbourhood." In 1867 earth closets were tried on a small scale, and they were found to succeed so well, that in 1868 they were established throughout the camp.

Wimbledon camp.

The plan adopted at Wimbledon is a very simple one. Rows of closets made of deal boards are placed back to back, with a passage between the rows, to which access is only attainable by the attendant. Under each row a long pit is dug in the ground ($4\frac{1}{2}$ feet deep by 5 feet wide), into which the excrement falls. Each closet has an apparatus which is worked by the weight of the person on the seat, and which causes one and a half pounds of dry earth to fall from the receptacle on to the excrement. The urinals are also placed over the pits, and are supplied with dry earth by hand labour. Each urinal requires about 180lbs. of earth in a day. Before the meeting 120 tons of earth were dried and stored, and it was found that 140 were required. The hoppers of the closets are filled every morning, and refilled as often as required

Arrangement.

Quantity of earth.

by an attendant. It is estimated that the public closets were used once a day by 3,000 persons, and the public urinals more than 10,000 times in the day: five ounces being the average weight of a stool, and six fluid ounces the average quantity of urine at each micturition, it follows that "a total of nearly 1,000lbs. of solid and over 3,000 pints of fluid excrement" were thus disposed of daily. (*Twelfth Report, M.O.P.C.* p. 90.)

Amount of excreta disposed of.

Superiority over other systems.

In the *Times* for July 24th of that year, it was stated that "hitherto chloride of lime, flushing, and various other expedients have been resorted to, and have worked more or less successfully, but always with drawbacks of a too obvious character," but that, notwithstanding the increased numbers in the camp, and the excessive heat, the earth closet had succeeded so perfectly, that there was "absolutely no annoyance of any kind."

The *Lancet* also bears testimony to the great success of these closets at Wimbledon, and points out that it "follows, as a matter of course, that they must be in every way suitable for the exigencies of rural districts."

The number of closets in the camp is stated to have been 108, and of urinals 46; the number of volunteers was 2,300, and the number of visitors 34,792. It is plain that the system was here subjected to a very severe test, especially when the excessive heat of the weather is taken into account.

Unfavourable opinions.

It must, however, be observed that the opinion that the earth closets at Wimbledon in the year 1868 were in every way a success, although maintained by Captain Drake and Surgeon-Major Wyatt, was not shared by every one who saw their working throughout the meeting. Dr. George Johnson pointed out that there was probably some close relationship between the earth closet system and the great prevalence of diarrhœa in the camp; and though the cause of this diarrhœa has been to a certain extent explained by the excessive heat of the weather (diarrhœa having also been very prevalent in London at the same time) and the too great use of imprudent drinks by the men, yet Dr. Reed maintains that the earth closets had a good deal to do with it. He says: "The trial of the dry earth closets in 1867 proves that when they are used by *a few persons only* they act very well, and will answer in isolated houses where earth can be procured *in such quantities as actually to smother the excreta;* but the trial in 1868 proves that in camps, and if not in large towns, they (in my opinion) are useless and highly dangerous to health." In the letter just quoted, which appeared in the *Lancet* of April 17th, 1869, Dr. Reed states, with regard to the earth pits, that "by the time the camp was nearly over these cess-pits became cesspools full of nothing but excreta, urine, and mud. . . . Any one who had to visit these places at Wimbledon in 1868 can testify to the fact whether even 'deodorisation' was perfect or not. . . . The excreta and so forth were not 'deodorised' or 'disinfected' and 'rendered innocuous' in the Wimbledon camp of 1868." He agrees with Dr. Johnson that the prevalence of diarrhœa in the camp was due to the "stench" given out by the closets: adding that the supply of earth was too limited. "Frequently by ten o'clock A.M. many boxes were empty, and were never refilled all day. The working of the apparatus was uncertain, for frequently the earth would not pass through, either because it was too damp or the place

Dangerous in towns.

Imperfect deodorisation.

Earth not well supplied.

was choked up." On Captain Drake's denying these charges, and stating that the earth system was gradually introduced and worked on the whole successfully, acknowledging at the same time that there were some "offensive closets," and that the "self-acting apparatus in the urinals was unsatisfactory and was purposely put out of gear," and in answer to a letter from Messrs. Girdlestone, the engineers of the Earth Closet Company, quoting the opinion of Surgeon-Major Wyatt, who expressed his "cordial approval of Moule's system of earth closets, the merits of which have been severely tested," Dr. Reed pointed out that Captain Drake admitted the truth of the bulk of his accusations, and maintained that the reason why some latrines had to be emptied during the meeting was, as he had stated, that they became filled with urine, excreta, and mud.

Charges partly acknowledged.

In fact, in an article in the *Lancet* of July 3rd, 1869, Surgeon-Major Wyatt, while pointing out the difficulties of attempting to work any other system than this successfully at Wimbledon, acknowledges that in 1868 the arrangements for carrying out the earth closet system "were not quite so perfect occasionally as could be wished," and that the closets were not always deprived by the earth of their odour on account of the excessive use of them, advising that we should "try again under more favourable circumstances and better surveillance." He also suggests that the earth should be mixed with about one-fourth of its weight of freshly burned lime, and that Macdougall's powder should be employed for the use of the urinals.

Improvements suggested.

Success in 1869.

With regard to the meeting of 1869, Surgeon-Major Wyatt says (*Lancet*, July 24): "During this meeting, a better surveillance of the closets has been insisted on, and they have been used to an enormous extent by the vast concourse of people assembled, but I have heard of no complaint of any want of deodorisation;" and Capt. Drake describes a few points to which attention should be directed in introducing the system into barracks or permanent camps, especially insisting on the quality of the earth, which "should be a clayey loam, friable and thoroughly dried. No soil must be used which contains vegetable matter;" and observing that the urinals should be separated from the latrines, and supplied with earth by hand twice a day, "no self-acting apparatus being found to answer."

Supply of earth.

The pits filled during the meeting of 1868 were emptied in the summer of 1869, and a bad smell was produced during the operation. This is stated to have been caused by the fact that the earth was not of a good kind, and that the quantity was too small. In 1869 the pits were emptied directly after the meeting, and very little smell was noticed; the quantity of manure produced was 117 cubic yards. This year (1870) the closets undoubtedly acted well on the whole, and diarrhœa was prevalent to no great extent. On one occasion, however, we remarked that the closets were very offensive, exceedingly so, probably from not having been properly supplied with earth; and we find from the *British Medical Journal* of August 6th, that "throughout the meeting there were occasional evidences of Moule's earth system breaking down; but these were, we believe, due in a great measure to the defective earth supplied for use."

Bad smell on emptying the pits.

Occasional failures this year.

On the whole, then, we may conclude that this system has at Wimbledon worked well whenever the

Conclusions from Wimbledon experience.

requisite care and attention have been given to it, but that, whether from mistakes made "as to the detail of the number of latrines in different places causing some closets to be overcrowded," as Captain Drake will have it, or from the supply of earth being insufficient or insufficiently dried, we may take it as certain, that in 1868, as in the present year, it was not always found practicable to keep the closets in perfect working order.

THE EARTH CLOSET SYSTEM IN INDIA.

Success in Bengal.

The general conclusion of the reports of the Sanitary Commission for the Bengal Presidency, and of the Governments of Fort St. George and Bombay, are to the effect that the dry earth system is a great improvement on the former state of things, and that it has been found to be a "public benefit of very great value."

Dr. Mouat, the Inspector-General of Jails, writes:—

"It is, in my humble judgment, impossible to over-estimate the benefits that will result from the labours of the Rev. Mr. Moule in this important branch of hygiene. It has already, in the infancy of its introduction in Bengal, worked wonders, and I have little doubt that its economic advantage will hereafter be as great as its immediate influence in promoting the comfort and improving the health of all public institutions in which it is properly used." (See *Report* No. 126, dated 18th April, 1867.)

Suitable for jails.

The system is at work in the jails of the Punjaub, of Oude, of the Mysore and Coorg provinces, &c., and the Commissioners all report most favourably of it.

From the proceedings of the Government of Bombay it would appear that the introduction of the earth closets into hospitals and jails has been often attended with success, especially "in some hitherto notoriously unhealthy jails;" but we find a great many reports of failure from various causes: "Earth could not be got except from a great distance;" "carbolic acid powder is used, and is preferred;" "failed during the monsoon;" "tried for two months, but discontinued, as the men could not be prevented from using water." Nevertheless, there is no doubt that the great majority of the reports are very favourable to it.

Some causes of failure.

It would appear that the dry earth principle has been for a considerable number of years in use in India, it having been "employed in the Punjaub, introduced by Sir Henry Lawrence many years before it was perfected as a system by Mr. Moule." "Although it had been used as far back as 1854 in the Poona jail, Dr. Ogilvie was the first in this Presidency to employ it systematically, but not by any means in so complete a form as it is now used under Mr. Moule's system." (No. 1,594: dated 26th April, 1867.)

First introduced by Sir Henry Lawrence.

Sir Henry Lawrence's plan was a very simple and effective one: the privy was merely the space between two low walls; dry earth and cook-room ashes to the depth of four or five inches were spread in it, and also in front of it to absorb urine; while a heap of earth with a wooden trowel was provided opposite each seat, and every prisoner was required, under pain of severe punishment for neglect of this duty, to throw some of the earth into the privy immediately after using it; the trenches were to be cleaned out "twice, thrice, or oftener in the day," and fresh earth supplied; while during the rains, matting coverings were to be provided.

Simple plan.

Madras Reports.

The Madras Reports have not been so favourable to the system on the whole; they are very important, as they enter in the minutest manner into practical details. In examining carefully these Madras Reports (1867-8-9), we are at once struck with the great practical difficulty that there appears to have been in carrying out this system, even where so much hand labour can be got cheaply, and with the conviction of every one who has had anything to do with it, that the system inevitably fails where the most efficient supervision is not continually given to it. We find such statements as the following:—

How far successful.

"That wherever large numbers of persons *under control* are congregated, Mr. Moule's system of conservancy has been entirely successful, and that it is, so far, a great public benefit."

"As in many stations in India a good system of drainage and water supply are both deficient, Mr. Moule's system of dry earth sewage is the best means available for our barracks, hospitals, jails, and other public institutions." (*No.* 125, 22*nd May* 1867, par. 9, 12.)

"Great care and constant attention are required in adapting all the parts of the process to each other: mechanical difficulties have been experienced in the use of hoppers for throwing in the earth; scoops for throwing in the earth after using the latrine are imperfectly applied; native servants have had to be appointed to this duty." (*Report on Sanitary Improvements in India*, 1869, p. 209.)

Weight of earth necessary.

It is insisted in these Reports that 2½lbs. of dry earth is the least quantity that can be accepted "as the weight of earth necessary to deodorise and maintain in a state of inoffensiveness the solid and fluid dejecta of a healthy adult, as ordinarily passed into a privy-pan or tub of moderate sectional area;" but this, it must be observed, does not include any urine other than such as is passed during the use of the closet. From Surgeon-Major Ross's experiments it appears that $2\frac{1}{4}$lbs. of earth are required for each use of the urinal, and that provision must be allowed for three such uses during the twenty-four hours. The aggregate amount of urine passed being thirty fluid ounces, or $1\frac{1}{2}$lbs. (pounds and pints of urine are, practically speaking, convertible terms), it follows that 36lbs. of earth are required for each gallon of urine, and this is certainly the least estimate. From this it appears, that to deodorise the urine of 1,000 men no less than 1,099 tons of earth would be required per annum. It is scarcely wonderful that "in the urinals the Commission think that the difficulty, owing to the enormous quantity of earth to be brought and removed, 'is practically insuperable;'" and that in their suggestions they state that "pans designed to separate the solid and fluid feculence should be adopted if possible;" Dr. Ross estimates the total quantity of earth required to deodorise the whole excreta of an adult at $9\frac{3}{4}$ lbs., of which 3 lbs. will be required in the latrines, and $6\frac{3}{4}$ lbs. in the urinals. "This raises the amount required to be supplied for 1,000 men to something like 1,588 tons per annum, while the mixed earth and ordure to be removed will amount to 1,995, or say 2,000 tons! This is undoubtedly an enormous mass of soiled earth to transport to the place of deposit." (*Proc. of San. Commissioner for Madras*, 1868.)

Amount of urine.

Impracticable for urinals.

Enormous amount of earth.

After pointing out the necessity of dryness, pulverisation, and immediate application of the earth, and insisting that it is also necessary that no water be used in or about the latrines, and that "any incidental dripping of fluids must be covered and absorbed by dry earth," the qualities of various kinds of earth are also discussed. Dr. Blakelock has shown that "7lbs.

of clay have the same deodorising power as 17lbs. of the ordinary sandy loam procuralbe at Madras." The order of eligibility of various soils is stated to be the following:—1, rich garden mould; 2, peaty soils; 3, black cotton soils; 4, clays; 5, stiff clayey loams; 6, red ferruginous loams; 7, sandy loams; 8, sands.

Value of different sorts of earth.

Pug-mills.

Contrivances called "pug-mills" have been established for mixing thoroughly the earth and excrement. Opinions seem to differ very greatly as to the efficiency of the working of these mills, but Dr. Ranking concludes that "efficient supervision, in fact, ensures all that is contemplated by the use of the mill, while neglect entails failure and needless expenditure." (Par. 61.)

Macdougall's powder for the urine.

A considerable amount of evidence was brought forward to show that Macdougall's disinfecting powder, which costs £10 a ton, may be used with advantage for the deodorisation of the urine, the dry earth being only supplied to the latrines. "Dr. Stewart Clarke states that six per cent. is sufficient to deodorise and maintain in a state of freedom from ill odour the solid and fluid excreta of latrines and urinals;" and he shows, with regard to urine alone, the total annual quantity for 1,000 men, plus six per cent. for disinfecting fluid, comes to 580,350lbs.; whereas in the earth process the amount to be removed would be "no less than 3,011,250lbs., or 1,344 tons!" (*Loc. cit.* par. 69.)

Sanitary benefits from earth closets

Dr. Ranking, towards the end of his Report, states that "there is abundant evidence to prove that the introduction of the dry earth system has effected a marked change in the sanitary condition of barrack and hospital privies and urinaries, and that it has exerted a most beneficial influence upon the health of the troops." When we put by the side of this sentence the following statement by the Inspector-General of Prisons in the Bombay Presidency—"this simple and inoffensive system has entirely superseded that of noxious drains and cesspits formerly in vogue"— we are able to understand at once that the earth closet system carefully carried out has been an undoubted improvement upon the former state of things. Even in these earlier reports it is pointed out that "the objection to the system is the great cost of furnishing earth for daily use, and of its removal. In these respects water conservancy, by which human excreta can be removed in suspension by public sewers, will, wherever water supply is available, be found more economical." And again: "As regards the ultimate use of human excreta as manure, it is probable that when thus diluted and applied to the soil, this form of manure has more fertilising properties than the excreta mixed with dry earth and known as *poudrette*." But from a memorandum by the Army Sanitary Commission (No. 8) in the Report on Sanitary Improvements (1869), we find that the practical difficulties in the working of the system, instead of decreasing with experience, have, on the contrary, increased to such an extent as to oblige the authorities to look for some other method for the disposal of their refuse. The Commission point out that it is insufficient "to remove only one class or cause of impurities and to leave the others; and no sanitary proceeding which does not deal effectually with all of them, can be considered as sufficient for health." (*Loc. cit.* p. 208).

Former system.

Water carriage most economical.

Liquid manure better than solid.

Difficulties increase.

"The following sources of impurity require to be continuously removed from inhabited buildings in India, as elsewhere: (*a*), solid

Total refuse.

kitchen refuse, including *débris* of food; (*b*), rain water, which would, if left in the subsoil, tend to generate malaria; (*c*), all the water brought into the station, except that which accidentally evaporates. This water is used for drinking, cooking, washing, baths, and lavatories. The amount cannot be taken at less than 12 gallons per head for every healthy man, woman, and child, including servants; from 30 to 35 gallons per head for every sick man per day, exclusive of water for horses . . . . Practically this water in all climates, but especially in India, becomes, if not safely disposed of, an inevitable source of disease and ill health. It contains a large amount of putrescible matter, and, if urine were mixed with it, it would become so noxious that it would matter very little whether or not the contents of latrines were added to this other sewage; (*d*), the matter from latrines, including solid and fluid excreta, at about one pound per man per day, or, in round numbers, half a ton per day per thousand men."

Foul water.

Excreta.

They state that the solid *débris* being removed by hand or cart labour, the refuse water must "either be passed into cess-pits, or it must be carried away, or it must be allowed to find an outlet where it can by surface drains—probably into the subsoil." That the rainfall must be removed in India "by improving the surface, and by impervious surface-drains," while the subsoil must be freed from excess of water by subsoil drains. The latrine matter, with which alone the dry earth system proposes to deal, "is to the fluid refuse of barracks, hospitals, cook-houses, and so forth, as 1 to 190; that is, for every pound of human excreta removed under the dry earth system, there are in every well-regulated establishment about 190 of fluid refuse which must be otherwise disposed of." The earth system, then, "deals only with one part out of 191 of the total injurious barrack and hospital refuse, while it makes no provision for the removal of surface or subsoil water." After pointing out the various practical difficulties which have already been

Earth closet disposes of only one part in 191 of the total refuse.

noticed, and alluding to Dr. Ranking's suggestion to deal with the urine separately by Macdougall's disinfecting powder, they remark on the practice of burying the mixture of earth and excrement, stating that it "must result in fouling large areas of ground;" for that, "even after careful mixture of excreta with earth, the mass when buried gives out offensive vapours in rainy or damp weather." (Par. 4—15.)

The compost becomes foul when damp.

"It further appears that when a small quantity of the deodorised and buried excreta is taken up and diffused in water, the resulting fluid is found under the microscope to teem with vibriones and other forms of organic life, the very forms which some writers have included among the causes of Asiatic cholera. Without laying undue stress on this fact, it still may be taken as showing that, in India, the earth process and subsequent burial are inadequate for the requirements of health, at least in the case of large fixed populations, and that if this process is to be continued for such populations, it may be modified and brought more in accordance with natural laws." (Par. 16, 17.)

Develops vibriones in water.

Here we may remark that the burial of this manure in pits is no part of the earth closet system, and that sanitary evils resulting from this practice are not to be put down to the blame of that system, except inasmuch as it has been found impracticable to sell the manure at a price which would pay for its carriage to a sufficient distance.

Burial of it in pits a mistake.

The suggestion with regard to cholera reminds us of Pettenkofer's views, and, coming as it does independently of them, must be taken for what it is worth when viewed in the light of his objections to the dry earth system. The application of deodorised matters as manures is referred to in these terms:—

"If the deodorised latrine matter were used for agricultural purposes, it must be borne in mind that all manure must be in

Manure must be in solution.

solution before it can be taken up by plants, and if it must be in solution it may as well be conveyed in water. Now, conveyance by water in England costs only a tenth part of conveyance by cart. Foul water already containing manure in solution exists at the stations and is not removed by the dry earth system, but it is absolutely necessary that this foul water, derived from the water supply carried into stations, should be removed from them. By far the cheapest way of doing this is by drains, and, if there be drains for foul water, there is no reason why the latrine refuse should not be carried away in the same drains . . . . The first cost of trough latrines or soil-pans may be taken at £1 sterling for every ten men . . . . There must be foul-water drains unless the foul water is carted out of the station. To have two systems of cleansing stations, a foul-water system and a dry-earth system, would simply be paying double where one payment would answer; or if all the excreta, solid and liquid, are to be carted away, this must be done at a cost ten times greater than that which would be necessary if all the excreta were removed by drains." "The removal of latrine matter is simply an incident in the drainage of a station, and in draining a station we have only to consider the population and the amount of water supply brought into the station and fouled by domestic use. The real question is how this foul water can be most easily and cheaply removed. It is necessary to enunciate this principle broadly, because the amount of nuisance from imperfect latrines in such a climate as India has naturally drawn the attention of medical and other officers to the necessity for abating this nuisance, to the possible underrating of sources of disease from the foul water of stations of equal if not of greater importance." (*Loc. cit.* par. 22, 23, 24, 26.)

Drains necessary.

Why two systems?

Removal of foul water the chief question.

It therefore follows that the foul water must either be carried away in drains, or be carted away at stated periods (becoming putrid in the interval), at ten times the cost. The water latrines could be emptied into the drains, a proceeding involving no additional expense, but doing away with the whole cost of the earth closet system.

Too expensive to cart it.

"Whether the dry earth system be used or not for latrines and urinals, the health of stations will be only partially improved, unless provision be made for removing away from stations all the foul refuse water as well as the malaria-producing subsoil water of the station." (Par. 25.) Subsoil water.

The Commissioners then discuss some of the results that have been attained by the irrigation system, and "suggest whether some one Indian station might not be improved on similar principles, and the sewage rendered available for supplying troops and horses with farm produce" (par. 50), and they conclude their report as follows (par. 52):— Irrigation proposed.

"It will be seen that the fundamental point in the question is the removal out of the station of all water brought into it for domestic use. The cheapest way of doing this is by drains laid to an outlet; and if drains be provided, there is no reason why the latrines should not be connected with them. But if from local circumstances it be impracticable to remove refuse water by drains, then the other alternative of collecting it carefully and carrying it away will have to be adopted, and in this case the latrine matter might be separately dealt with for agriculture." Latrines to communicate with drains.

It should be added that "there is, however, scarcely a plan which has come before the Committee showing a fall in the ground which would render natural drainage impossible." It is difficult to suppose that a system that has been attended with such practical disadvantages (even under the advantageous conditions presented by the systematic management of barracks and prisons) that the question of abandoning it is already being considered, is ever likely to be turned to any account for the removal of the solid excretal matters of the populations of large towns. Drainage by gravitation almost always practicable. Difficulties much greater with towns.

THE EARTH CLOSET IN VILLAGES AND TOWNS.

With regard to the applicability of this system to villages, it is stated in a published letter, that "in the villages of Halton, Buckland, Western Turville, and Ashton-on-Clinton, on Baron Rothschild's estate in Buckinghamshire, with a population of about 800 persons, the system has been in use for eighteen months. The overflowing and fever-breeding cess-pools, ditches, and privies, have been cleared, and not a foul smell can anywhere now be found." Its working at Halton is described in Dr. Buchanan's Report, which we have so often quoted: it has been there in use for three and a half years, the thirty-three houses of Halton being all supplied with earth closets, which are detached from the house in all but two cases. The earth used is a loamy garden mould, well dried; it is used twice. There is an opening at the back of the closets for the supply of earth and for the removal of the manure from the pit. A self-acting apparatus is supplied which acts by the weight of the sitter. One hundredweight of earth a week, on the average, is required for each closet. A very slight smell is said to be caused during the drying process, but it is so trifling that it offends no one.

Improvements at Halton.

Arrangements.

Ashton-on-Clinton, a village two miles off and with twenty-two closets, is managed by the same scavenger as Halton, with one horse and cart, and the occasional services of a boy. It is estimated that 600 people *together* could be managed with the same staff and at the same cost as the 300 in these two villages. The cost was as follows:—The drying-sheds and kiln cost £150; the weekly cost was 25*s.*, namely, 15*s.* for the

Cost.

man's wages and 10*s*. for firing, occasional cost of horse and boy, and all other incidental expenses. The earth passed *once* through the closets, was stated to have a minimum value of £3 a ton; but, on the supposition that earth passed *three times* through them has this value, the gross annual return would be £130, or under 10*s*. a head. (*N.B.* This is above the possible value unless all the urine is retained.) A half of this would meet the current expenses, and the other half would remain for repairs, for repaying the original outlay, and for profit. **Value.**

In the instance in which the closets are under the same roof with the house, "the occupiers, not liking them so placed, had only used them occasionally when there was sickness in the house; for ordinary use they had a garden privy with cesspool, the only one left in the village; it was a typical, old-fashioned privy, and gave the only decided stink met with throughout Halton." **Earth closets not liked in the house.**

These villages are both well supplied with water and sewerage arrangements, and each cottage has a piece of ground attached to it; fever and diarrhœa are wholly absent from them, but this was the case for years before the introduction of the earth closets.

In Lancaster, earth closets have been introduced by Mr. Garnett into some of the poorer houses—450 in number, and inhabited by about 2,250 persons, or one-seventh of the population of the town. The pits of the latrines are emptied once a month; the scavengers visit each latrine once a day, and put in earth for twenty-four hours' use, allowing about a pound for each use of the closet. No slops are allowed to be put in, and the urine is collected in large vessels and removed by men, as it is found to be less expensive **Closets visited once a day.**

Some of urine collected separately.

to remove it than to bring sufficient earth for it. Some closets are, however, used for the whole of the excrement and urine of the population. Fourteen tons of earth are required for the 450 houses. The ashes were first mixed with it, but this year nothing but earth is used. There was no odour *except where the orders about slops had been disobeyed.* They were altogether found to work better than the water-closets in similar parts of the town, which get choked up and become offensive. The soil from the closets is here not dried again for use, but carted away crude up to the top of a neighbouring hill, mixed with blood, offal, and straw—from the shambles—street sweepings, and so forth, and spread in long heaps, with a tramway along the top of each heap; the urine which has been collected from the houses is added, by means of water-carts which run along the tramways. In the summer it is at once absorbed, but in the winter the surface is wet, and the heap is found to smell offensively when dug into, this being chiefly due to the presence of matter from the shambles. A larger quantity of earth has lately been used with considerable advantage. The sale of the manure is said about to pay for its manufacture. It costs from 7*s.* 6*d.* to 10*s.* a cubic yard to make, and sells at 10*s.* a cubic yard. The analysis of a sample (1st Report of Rivers' Pollution Commissioners, 1868, vol. i. p. 50) shows that it contained only ·207 parts of total combined nitrogen, and ·326 of phosphoric acid, in 100 parts; and the remark is made that "these figures indicate a practical value certainly much below that at which we had been led to estimate it by mere inspection; and it is manifest, from the very small amount of total combined nitrogen,

Treatment of the soil.

Addition of urine.

About pays costs.

Feeble quality of the manure.

that much of the urine escapes preservation. . . . More than 93 per cent. of the finished manure consisted of nearly worthless mineral matters and water." At Lancaster the advantages are stated to be, that an earth closet is cheaper than a water-closet, and causes less offensive smell, that "few or none of the deaths from diarrhœa and typhoid have been in houses provided with earth closets," that "fever has almost wholly disappeared from parts of the town where it was formerly rife," and that the saving of water is a considerable gain; but we must especially draw attention to the fact that in Lancaster the refuse water, which is not, as we have before stated, treated satisfactorily by this system, can be got rid of by turning it into the sea; so that this is obviously an exceptional case.

Sanitary benefits.

Easy disposal of foul water.

Dr. Buchanan calculates that the original outlay of a town of 1,000 inhabitants, in changing from outside privies to the E.C. system, need not exceed £250, and the weekly expenditure £4 15*s*. If the earth were used once there would be an annual income of £365 against an expenditure of £260; if four times it would sell at £3 a ton, and produce an income of £600 with an expenditure of £244. But in the only town where it has actually been tried, with diminished expense from separate collection of urine, it only just pays its costs.

Estimation of profit and loss.

The Messrs. Girdlestone, in pointing out the duties of the scavenger in villages supplied with these closets, state that "the dry earth system and the water system could be made to work together in a village where a general adoption of the former could not be carried out;" and also admit that "in addition to the obnoxious refuse which the earth system treats, there are in all habitations the liquid refuse substances of the

Water system as well, in some villages.

kitchen, the washhouse, and the chamber, to be provided for." They suggest that *light and inexpensive sewers* should be made to carry them away, or that they "may be conveyed, by *sub-irrigating drains,* into the soil of the adjacent gardens, and there used as a valuable supplementary manure;" and that in the former case this liquid refuse should be partially purified before reaching the street sewer, by draining it through some available medium, such as a compost heap in which ashes would be a principal ingredient, and by the use of disinfectants where these might appear to be necessary. They point out that "the small system of drains required for the liquid refuse, if earth were applied to the extermination of the solids, would not require more than one-third of the cost bestowed on drains under the water system." That this would not be the case we shall show in due time (p. 96).

Necessity of sewers, and of irrigation.

Compost heap to purify the refuse water.

Captain Drake sees the difficulty of a separate drain system, and actually suggests in his letter to the *Lancet* (July 24th, 1869), that "the refuse water from kitchen sinks, &c., should be drained *into cesspools,* accessible to a cart in the same way as the latrines. It can then be pumped into a cart and removed."

Cesspools for the foul water.

This suggestion speaks too strongly for itself to need any additional remarks.

The Rev. Henry Moule, in his pamphlet on "The Science of Manure as the Food of Plants," states that the liquid refuse of his house was at first conveyed by drain-pipes into a tank in his garden, but that, especially in sultry weather, the contents of this tank fermented and became exceedingly offensive. He then interposed, between the house-pipes and the drains, tubs with holes in the bottom and nearly filled

Offensiveness of water tank.

with earth mixed with a small portion of coal ashes. This method sufficed to prevent the offensive smell from the tank "*so long as the earth was frequently changed:* but, if the earth continued to be so used more than forty-eight hours, ammonia was soon perceptible in the one tub, and from the other there arose a most fœtid smell." Such a method as this might answer very well with careful management in cottages and in detached country houses.

Filtration, how far successful.

He considers that "the removal of such refuse from houses, whether detached *or in villages and towns*, is perfectly feasible;" while in a letter addressed to the Editor of the *Hertfordshire Express*, he states that "in a town standing, for instance, as Epping does, the whole of both bath and slop and sink water may be disposed of *by sub-irrigation* on ten or twenty acres of land at each end of the town, and by it the land be made worth £20 per acre."

Refuse water utilised by irrigation.

From all these statements, made by the supporters of the system be it observed, it is evident that, as in all other systems which keep the excremental matters from the sewers, a special arrangement has to be made for the treatment of other refuse matter which is too valuable to be lost, not to say anything of its rendering the sewage unfit to be allowed to run into a watercourse. The plan proposed by Mr. Moule to meet this difficulty could obviously not be applied in towns, however well it may act when carefully conducted in country houses; although even under these favourable conditions it is questionable whether persons who have not a special predilection for the system would consent to have buckets of earth and ashes placed as filters for the slops, the contents of which buckets are

Plan of filtration not feasible in towns.

Obvious fatal objections. acknowledged to become offensive if they are not changed regularly every forty-eight hours: but the other suggestion, namely, that this liquid refuse might be disposed of by sub-irrigation of a few acres of land, is much more important, inasmuch as it acknowledges that, practically, the earth closet system has not solved the question of entire removal of refuse matters, but that, even with it, some irrigation system is required. The suggestion that the sewers might be made of much lighter construction and at a much smaller expense, if the earth closet system were in vogue, can hardly be accepted unless it be admitted that even under this system it would advisable to have sewers provided for the slops and liquid refuse generally *apart from the drains provided for the rainfall and the subsoil drainage*, otherwise the difference in the size and construction of the sewers and in their cost could amount to next to nothing; the great size that they have to be made when used, as is generally the case, both as drains and sewers, being necessary chiefly to provide for a sudden excessive fall of rain. We come then to this dilemma—either two systems of sewers must be supplied, or, the liquid refuse being received into the one system of drain-sewers and mixed with the whole of the drainage water, this quantity must be purified in some way at a great expense, although its value as manure would have been diminished by precisely the amount of fertilising ingredients that had been kept from the sewers by the dry closets.

Acknowledgment of failure to deal with liquid refuse.

No diminution in size of sewers.

Dilemma.

In fact, as far as the Utilisation question is concerned, there is a greater necessity for two sets of sewers with the earth closets than without them.

Two sets of sewers necessary.

The advantages claimed for this system are, that when properly managed it disposes of the excremental matters without any nuisance or injury to health, and produces a manure sufficiently valuable at least to pay the expenses of the management of the system; that in the poorer districts, where supervision is always necessary, the earth closet affords especial advantages over the water-closet, in being cheaper in cost, requiring less repair, not being injured by frost nor by improper substances thrown down it, and in greatly reducing the quantity of water required. Such of these points as have not already been considered will be referred to in the account of water-closets. It is maintained that a great advantage is to be found in the fact that all the manurial value of the excrement is retained in a form in which it can be easily carried about from place to place, and in which it is especially fitted for agricultural purposes.

Advantages in poorer districts.

(*See* "Water closets.")

Portability of the manure.

But in retaining all the manurial value of the excrement, the compost can only retain what is there, and we must remember that the fæces only contain one-seventh part of the total valuable constituents of the excreta. That it has been found to constitute a very suitable manure, and to give very good results, there is plenty of evidence to show; that unless much urine is collected with it, it cannot be really valuable, is also certain. We have seen that at Lancaster, where it is carefully watered with the urine collected from house to house, it is only a feeble manure, as shown clearly by its chemical composition; and the ready sale of any such compost (unless containing much urine) only shows how much false guano there must be in the market.

Valuable only if it contains much urine.

As to its especial fitness for agricultural purposes, Liquid manures better than solid ones.

there is no doubt that all solid manures are less suitable than liquid ones containing the same manurial constituents. (*See* the evidence from India).

The general conclusion come to by Dr. Buchanan and Mr. Radcliffe is, that "the earth system affords a second (see p. 123) way of safely disposing of excrement. It is . . . an essential element in this system also, as applied in poor neighbourhoods, that the entire management of it shall be conducted by the sanitary authority." (*Twelfth Report M.O.P.C.* p. 140.)

Dr. Buchanan, at the end of his valuable Report (*see* Twelfth Report M.O.P.C.) brings forward and discusses the objections that have been made to this system. They are as follows:—

Objection that earth closets are looked upon with aversion.

1. That for private houses water-closets are thought to be cleanly, earth closets to be dirty. This objection may appear to be trivial, but we are afraid that it will be found to be a very practical one, and that it is not made without good reason. We have already seen that even in Halton, where these closets were "under the same roof with the house," the occupiers actually refused to use them, and preferred their garden privy with its stinking cesspool. This must have been either because they had used them and found them, when so situated, to be a nuisance, or because there was to their minds a sentiment of uncleanliness in having the improved privy in such close proximity to their dwelling rooms. We expect it will be found that many other people will share this feeling with them, and that this objection will therefore be found a very potent one.

Here we may quote Dr. Parkes:—"Until there is greater evidence about the complete deodorisation and innocuousness of the mixed soil and earth when retained in houses (especially in the tropics), it would be desirable to have the earth closets always external to the houses, and if possible the soil should be removed daily." (*Hygiene*, 2nd ed., p. 332.)

2. That the earth closet gets out of order. This objection is answered by a reference to the schools and gaols in which the system is at work, and it is pointed out that with supervision these closets do not get out of order, while water-closets in the poor parts of all large towns may almost be said to be never in order. We must at once insist that it is not fair to compare closets over which a daily careful supervision is exercised with others which are supposed to work by themselves, and to require no supervision whatever, and so are left to the tender mercies of their employers. It should be pointed out, that were the earth closets to come into general use, it would be absolutely impossible to prevent bedroom slops and so forth being thrown down them, especially in the case of closets in the upper floors of houses in towns, in which case it is obvious that the pit into which the pipe from these upstairs closets is to descend directly would simply become a cesspool, with the additional disadvantage over the old-established cesspool, of not having any pretence at a mechanism for keeping noxious gases from getting into the house; in fact, wherever liquid refuse got thrown into the earth-closet, either upstairs or downstairs, the receptacle would become no better than a cesspool, without the advantages of a well-constructed one.

Must not compare things unfairly.

Earth pit would often become a cesspool.

3. That it is not applicable within houses, especially above the ground floor. There can be no doubt that

Invalid objection.

this is not a valid objection, except indirectly, for the reasons we have just mentioned.

4. The quantity of earth required in the case of towns would be too great. With regard to this point Dr. Trench states (*First Report, R. P. C.* 1868, vol. ii. p. 305) that Mr. Bateman has calculated "that for London the amount of soil required will be 2,000,000 cubic yards a year, which would necessitate the digging of 200 acres to the depth of six feet, or 400 acres three feet deep, every year. The amount required in Liverpool, calculated on the same ratio for population, would be 400,000 cubic yards, or the digging of forty acres to the depth of six feet, or eighty acres to the depth of three feet." If one of the objections to the pail system be found in the blocking of the streets by the scavengers' carts, this objection must hold with increased force where not only the excremental matters have to be removed, but so enormous a quantity of earth has to be brought into the town and taken out again. Mr. Moule indeed believes that this may be done "*without any increase of traffic in the streets,*" by some underground method. Whether it would be likely to cost less, or even as little, to make underground tunnels communicating with the lowest part of every house in a town, tunnels which to be of any use would have to be sufficiently large to allow the construction of a tramway in them, as to use the existing sewers for the removal of excrement, or even to construct a special set (as proposed by Mr. Menzies) of pipe-sewers for this purpose, and leave the large old sewers for drainage, we leave the reader to judge for himself.

Amount of earth which would be required for London.

Removal underground.

5. The objection of Professor von Pettenkofer,

brought forward by Dr. Rolleston in the *Lancet* of March 6th, 1869, that he fears the greatest danger from the earth system, especially as regards cholera. With regard to this objection, Dr. Buchanan points out that all the evidence from India, especially "in respect of cholera," is in the opposite direction. Dr. Rolleston thinks that because the soil is deodorised it is not therefore rendered innocuous. To this the supporters of the earth closet system reply, that the presumption is in favour of the contrary opinion, and that no facts have been brought forward against it. Dr. Rolleston, however, in defence of his position, has quoted Dr. De Renzy's statement in the Fourth Annual Report of the Sanitary Commissioner with the Government of India, 1867 (Calcutta, 1869), p. 211, par. 440 :—

Pettenkofer's objection.

Dr. Rolleston's opinion.

"Dr. Mouat states that 'although adynamic fevers may occur occasionally in an endemic form, they will never become contagious so long as the present conservancy arrangements be obtained.' Actual experience has, unfortunately, already falsified this prediction. In 1866 the fever appeared with all its former virulence in the Umballa jail, and caused 48 deaths out of a strength of 698 convicts, and last year it appeared in the Peshawur and Rawul Pindee jail. Nowhere, I venture to say, is the dry earth system carried out to greater perfection than in the Punjaub jails, *but the fact remains that in spite of the most thorough deodorisation of excreta, the contagiousness of jail fever remains unchanged.*"

Facts with regard to fever in jails.

He also quotes the report of the Sanitary Commission for Madras, which states that—

"The expense attending anything like a system of conservancy upon the dry method is enormous, and even in carrying it out to the extent that is now done, the greatest difficulty is experienced in disposing of the refuse. It was formerly deposited upon waste land in several localities, but

Expense and difficulty.

Nuisance caused in Madras Presidency.

these became such intolerable nuisances that it was necessary to adopt other means."

It has been seriously proposed to burn the refuse matters, but now the question of employing them by irrigation is being considered.

Danger of moisture.

Dr. Mouat's own evidence states that "when the admixture with earth is carelessly performed, or where the earth used contains a large amount of moisture, the fermentation of excrementitious matter will take place, and disease will be the certain and sure result."

This objection, then, can hardly be considered to have all the facts against it; in fact, in a variety of different ways the "*cabinet inodore*" would become a stinking cesspool, and an especially dangerous one.

Risks to health from defective working.

The great practical objection which must entirely condemn the system, viz. that it only removes a small part of the refuse matter, has been discussed at length already (*see* pp. 85 to 89). We are quite content to accept the opinion of Colonel Ewart, quoted as follows by the Messrs. Girdlestone when contrasting the Milan and Paris methods of water-tight carts with the dry earth system: "That no scheme of town drainage can be recommended which is dependent on mechanical arrangements of great complexity, and in which *serious risks to health would be incurred if any fracture or defect were to arise in the machinery used, or any of those failures were to happen which are necessarily incidental in practice to such a scheme*" (*The Dry Earth System*, p. 29); and we beg to submit that the words we have italicised are at least as applicable to the dry earth closets as to the improved Paris cesspools, which latter do not at any rate depend, as the former do *entirely*, upon the continuous and sufficient supply of an extraneous material of a particular quality and in a particular condition.

Let us finish the description of this system with two quotations—one from the paper of Messrs. Lawes and Gilbert, already referred to (see p. 49):—

Obvious objections.

"Very obvious objections to such a system are the difficulties of the supply and preparation of the soil in the case of towns, or even in the country in wet seasons; the fact that but little of the urine (containing as it does so large a proportion of the valuable manurial constituents of human excretal matters) would reach the compost so prepared; and that, in the manure produced, the more valuable matters would be diluted with so large a proportion of comparatively useless material, that beyond a very short distance the cost of carriage would be all that the manure was worth. On the other hand, that the adoption of such a system would be a great improvement in a sanitary point of view, in the cases of sick rooms, detached houses, or even villages where the water system is not available, and that it might be even economical, where the earth for preparation and absorption, and the land for utilisation, are in close proximity, may perhaps be readily granted; but we are certainly not so sanguine as the Rev. Mr. Moule, who seems to think that, with the aid of earth closet companies, his plan is as practicable for large towns as is the supply of water, gas, and coal at present, and much more so than the removal and utilisation of dilute town sewage."

A sanitary improvement, and economical in some places.

Opinion of the Rivers' Pollution Commissioners.

And the other from the First Report (vol. i. p. 50) of the Rivers' Pollution Commissioners, 1868, who, having remarked on the special service and attention which these closets require, thus conclude:—

"Add to these circumstances the enormous aggravation of all the difficulties of the plan, when not 50 but 50,000 households have to be provided with the necessary appliances and induced to work them properly, and we can have no hesitation in pronouncing the dry earth system, however suitable for institutions, villages, and camps, where personal or official regulations can be enforced, entirely unfitted to the circumstances of large towns."

CHAPTER V.

WATER-CLOSETS.

WE have seen that in many towns it has been found advisable to connect the cesspools with the already existing drains. It is hardly necessary to point out that drains exist, or ought to exist, in every town or village for the carrying away of the surface and subsoil water and refuse of various kinds.

Drains necessary.

We have also said that by this connection of the cesspools with the drains the principle of a cesspool is entirely abolished and its use not easily seen. In fact, if any part of the decomposing materials from excrement be allowed to pass into the drains of a town, it is difficult to see why the whole of it should not be allowed to do so. By interposing a cesspool between the privy and the drain, we form a collection of putrefying matter in the close vicinity of the house, and with this system the inhabitants of towns may be well said to be "living on a dungheap." On the other hand, by connecting the privy directly with the drain, the refuse matters pass immediately away from the house, and so from the town.

Why retain cesspools?

It has, however, been found necessary, in order to ensure this passage being as quick and perfect as possible, that water should be thrown down the privy, in order that the refuse matter may be washed away at once, and so water-closets of various forms have come to be established in most towns.

Water necessary to ensure speedy removal of excreta.

In the First Report of the Health of Towns Commission (1844) special attention is given to the question of the desirableness of the change of middens and cesspools into water-closets. Such opinions as the following are continually expressed by the witnesses examined by these Commissioners:—

"Water-closets should be substituted, for necessaries, and no accumulation of excrement allowed." "It is evident that the only complete remedy is to prevent the accumulation of manure in such large quantity in the immediate neighbourhood of dwellings, by washing it away into the sewers, that is by the erection of water-closets in all cases where houses are built closely together; where great economy is important, a very simple form of water-closet would suffice." (*First Report*, vol. i. p. 212.)

Prevention of accumulation of refuse desirable.

Again:—

"The general adoption of apparatus of the nature of a water-closet would be an immense stride to general cleanliness, and would unquestionably diminish by three-fourths the pernicious exhalations that emanate from all the courts, alleys, and back-yards of the town. It would also abolish the obnoxious employment of night-soil collecting, which is not only injurious to the health of the persons engaged in the trade, but is likewise detrimental to the community at large." (*First Report*, vol. i. p. 306.)

Obvious advantages of speedy self-acting removal.

At Liverpool, where there was a clause in the Sewerage Act against the connection of soil-pipes from water-closets with the public sewers, it was found to be constantly evaded, thus showing the importance to the inhabitants of that communication. The reason given for this prohibition was that it was a question—

Evasion of a bad regulation.

"Whether the filth and soil from water-closets being allowed to go into the sewers and thus pass through a great portion of

Why it existed.

the town, emitting noxious smells to escape from the eyes of the sewers, is not more detrimental to the general health of the inhabitants than when it runs into cesspools upon the premises of the occupants, and emptied only when necessary, because the cesspools can be so constructed as to be perfectly air-tight, and prevent any escape unless when emptied." (*Second Report*, vol. i. p. 146.)

Cesspools not impervious: often not intended to be so.

We have already seen that cesspools practically are never so constructed, and that their contents always to a certain extent escape from them into the surrounding soil and are carried away by the drains, and that in fact in many cases they are specially so constructed that their contents shall escape as freely as possible. We shall hereafter show that the sewage of a town supplied with middens and cesspools is to all intents and purposes as offensive and as noxious as that from a town entirely supplied with water-closets; it may, indeed, be more so.

Real meaning of above argument.

But beside this, if the reason given above means anything, it means that it is more dangerous for foul water to pass through and away from a town, with some chance at any rate of no great an amount of decomposition taking place, than for it to remain for some time in cesspools under yards and houses, decomposing, and emitting nauseous effluvia continually—a manifest absurdity.

At Bristol the outside privies are connected with the sewers, but they are not supplied with water. "They are made, not with the earthenware pan and trap, in the rough use of which by careless folks so much difficulty is experienced in other towns, but with a stone shoot and 'eject' communicating with a 9-inch pipe, and the whole well set, under rules printed by the Local Board, and acted on in practice.

Certainly the stone traps or ejects often get blocked, but not more frequently (if so often) as under the customary arrangement of pan, trap, and wretched water supply of the poor quarters of most towns; while the construction allows of articles that are improperly thrown into the privy being easily pulled out or flushed away." (*Ninth Report M. O. P. C.* pp. 63, 64.)

This shows that it will not do merely to connect privies with the sewers; there must be some ready means of flushing them from time to time.

Ordinary water-closet. The prevalent form of water-closet need hardly be described. It is essential that the descent-pipe from the soil-pan should be syphon-shaped immediately under the pan, so as to prevent the passage of gas from the pipe into the house, and it is advisable that this should be still further secured by the trap of the pan retaining water upon it continually.

The earthenware soil-pan should not be conical, as it is usually made, but the back of it should slope away so that it may not be soiled by the fæces above the level at which the "luting" water stands.

Flushing apparatus. As to the apparatus for flushing the pan, the ordinary "pull-up" plan answers capitally with careful people, as the valve in the cistern is not liable to get displaced; but a very common fault is, that the entrance of the water into the pan is badly directed, so that it does not whirl round the pan as it should do to clean it thoroughly.

Closets should always be ventilated as far as possible separately from the rest of the house. The plan of having them close to the entrance to the garden or yard, and with a door which shuts them off entirely from the hall, is an excellent one; and wherever two doors can be interposed between them and the rest of the house, it is advisable that they should be, and that the space between them should have a window left generally open; by this means air from outside enters easily, and should be allowed an exit by the closet window, or preferably by a

Ventilation.

ventilator in the roof. McKinnell's is an excellent one for this purpose, as it provides an easy exit for air as well as an entrance. It is not enough to have an opening by which air can go out; it is also necessary to see that it does go out by it, and that its exit is not, as is too often the case, from the closet into the staircase of the house.

In blocks of dwellings for the poor, "model lodging-houses," &c., the closets, sculleries, &c. should all be ventilated from the galleries, and should wherever practicable be entirely separated from the dwelling

Good plan.

rooms by an open gallery. An excellent arrangement, which should be more generally adopted, is to have a pipe running from the upper part of the descent-pipe, and carried up above the roof of the house; in this way any foul air that may be driven past the syphon at the lower end of the descent-pipe will not be able to force the upper syphon, an easy exit being provided for it through the open ventilation-pipe. It is, however, essential that this latter should not be used as the waste-pipe of the rain-water cistern, or during a heavy shower it will be blocked up, and, the drain-sewers being perhaps overcharged, sewer gases will be forced up into the water-closet, and the consequences may be disastrous, as indeed was the case at Croydon. (*See* p. 173.)

When artificial.

In hospitals, &c., which are warmed and ventilated by special artificial means, it is very easy to ensure perfectly separate ventilation for the closets just as for fever wards.

Urinals should be lined with slabs of smooth slate, or, if circular, with hard stoneware: they should not be placed in unsightly blocks at long distances apart, but should be in small clusters or singly at more frequent intervals. That they can be kept perpetually *perfectly* clean and inodorous is shown by those in Paris and other large French towns; but to this end it is necessary that water should trickle down them *continually*; no great amount of water is wasted in this way, and rain water could often be collected for the purpose. That urinals cannot possibly be kept clean without a small but *constant* flow of water is amply proved in London, where the state of the public urinals is most disgusting, and a disgrace to the authorities who have the care of them.

Urinals: constant flow of water.

SUPPLY OF WATER.

It must at once be premised that soil-pans and house-drains cannot be kept in an efficient state of cleanliness by merely throwing slops and waste water down them. Some sort of regular supply of water is absolutely necessary. This supply may come directly from the water mains, or may be given from a cistern in close proximity to the water-closet; and, again, the closet may be supplied mainly, if not entirely, from a rain-water cistern—a plan which has hitherto not received sufficient attention.

Regular supply necessary

In the East London Water Bills Report of 1867, Mr. James Simpson gave evidence that self-acting water-closets are very economical as to the water; the self-acting apparatus being connected either with

Self-acting apparatus.

the seat or, more preferably, with the door of the closet: in the one case it is the weight of the individual which moves the contrivance causing the water to rush into the pan when he rises, and in the other the opening and shutting of the door. It is plain that with the latter plan waste cannot be entirely prevented, because if people choose they can prop the door open continually. This, however, cannot be done from mere carelessness, and if the state of the closet be such as to require flushing for a considerable time, it can scarcely be said that the water is wasted.

Mr. Bateman was of opinion that the amount of water can be easily regulated by a "*waste preventer,*" a contrivance limiting the amount of water that can run through the closet supply-pipe. The opinion seems to be that waste is generally due to improper apparatus. Whenever the closet was supplied by a tap directly from the main, the waste was invariably enormous, from people leaving the tap open and the water running, from sheer carelessness; and also under this plan, when the water in the service main has to be drawn off for repairs, the result has been, in Liverpool, that "a vacuum has been created, and the soil has been sucked back through the supply-pipe into the service main, and so carried on, and has contaminated the water of a whole district." This happened in cases where the service-pipe from the main was connected *directly with the soil-pan* of the water-closet.

Improper methods cause waste.

Connection of water-pipe directly with closet pan.

Mr. Rawlinson considers that "waste preventers" are useless, and ultimately become a nuisance. He suggests that in the poor districts of towns, fifty or one hundred gallon cisterns should be constructed, a pipe passing from such a cistern to the inside of

Supply by large cisterns.

several houses, and each tenant being allowed to take as much as he wants.

The constant system of water supply is agreed on almost all hands to be infinitely superior to the intermittent, as the necessity for cisterns is thus entirely dispensed with. The waste alleged as a fault of that system is to a great extent, if not entirely, prevented by the taps being placed in the interior of houses instead of outside them, and the pipes which supply the water-closets may be provided with a small service-box into which water flows.

Service-box for water-closets.

But, after all, the great cause of waste is want of supervision. "A system of water supply, whether intermittent or constant, necessitates a constant and careful supervision."

Supervision.

Among the disadvantages of the constant system, it is stated that in Salisbury the supply sometimes runs short in the highest parts of the town while it is being wasted in the lower parts. But here in the poor tenements there is no self-closing apparatus, the water waste preventers having been tried, but abandoned, because it was found that they froze in the winter.

Supply may run short in higher parts of towns.

At Penrith, houses in the poorer parts of the towns had outside taps which were found to conduce yearly to waste. They have since for the most part been changed for inside ones.

Outside taps.

It is obvious that when taps are in the interior of houses the water cannot be left running without serious inconvenience to the inhabitants, and such carelessness is less likely to occur.

In the Reports of the Medical Officer of the Privy Council we find examples of the various methods of flushing water-closets. Thus at Banbury the out-door

Methods of flushing.

closets are not connected with the water mains, but merely cleansed by a bucket of water being thrown down them. These answer very well, and they are not choked up, even when misused by dirty people.

It is to be remarked, however, that they are out of doors. The others that are indoors are connected with the mains by means of cisterns, and nearly half of the supply is said to be wasted.

Service-boxes. At Dover the same is the case, but service-boxes are being gradually introduced.

At Penzance the supply is direct from the main, with a self-acting valve on the pipe. There is no great waste.

Waste. At Ely it was found that the constant system did not give a sufficient flushing power, so that a great amount of water was wasted, as it was left running continually.

At some places, as at Penrith, water-closets are forbidden to be constructed unless provided with cesspools. At Brynmawr there are water-closets in the poorest houses, and they communicate directly with the sewers. There is no cistern or service-box, and at first self-acting valves were provided, but they soon got out of order; now, common screw taps are used, and it is found that there is not much waste, placards being placed on the doors inculcating care. The flushing power is, however, not sufficient for the closets at the higher part of the town, and this is a fault very general with the constant system of water supply when cisterns are not provided for the closets.

Screw taps.

At Ashby-de-la-Zouch the water-closets are supplied by a service-box. These boxes are found to act well, even among dirty people, but frost injures them, and so has prevented their becoming universal. **Fault of service-box.**

Dr. Syson has proposed, at Salford, to apply the water of the river for the purposes of water-closets "by a mere scheme of storage-reservoirs higher up." We are of opinion that the rain-water falling on each house might be utilised in this way during the greater part of the year, being only supplemented by water from the mains when the rain-water storage-cistern, which might often be of considerable size, ran dry. **Use of river or rain water.**

The advantages, then, of a constant service at high pressure are—that the water is always fresh from the main, and that the pollution of it in cisterns is avoided—this last advantage being exceedingly great in the poorer classes of houses, where the cisterns are continually allowed to get into an exceedingly filthy state; that there is always a supply of water; and that the mains are charged in the case of fire. **Advantages of the constant system**

The disadvantages are—the leakage of the fittings and the weakness of the lead pipes (that is to say, of the lead pipes originally laid for the intermittent system); the fact that the increased consumption of water in the early part of the day requires an increased pumping power; and the points that have been already alluded to, namely, that the waste at low levels reduces the pressure in the mains to such an extent that the higher levels cease to be supplied, and that during the repair of the mains the whole district would have to be deprived of water. **Disadvantages.**

It is probable that, in most cases of constant supply, the water-closets, at any rate at the higher levels of the town, would have to be supplied by cisterns, as the flushing power from the mains in **Cisterns: where necessary.**

those parts would probably of itself not be sufficient.

On the intermittent system the water must be kept in cisterns, and, where cisterns are not supplied, as in many of the poor districts of towns, in tubs, butts, and so forth, in which it becomes foul and unfit to drink; and a special cistern has to be provided for the water-closet.

The Royal Commissioners on Water Supply (from whose Report this information is chiefly derived), found that the waste of water is much less under the constant system, although the actual use of it is greater.

Waste less with constant system.

But these are not the only advantages. The water is purer and fresher, and at a lower temperature in summer, and it is less subject to frost in winter; and as to the disadvantages, the inconvenience from interruption during repairs is never actually experienced, as the interruption need only be for a few hours in any case. On the other hand, the interruptions from neglect of turncocks, limitation of quantity, leaky taps and cisterns, and so forth, are absent in the constant system. The economy in pipes, &c., is obviously great. The pipes are smaller and are made much stronger, so that practically there is less bursting, while cisterns are not required at all. Where cisterns already exist, however, they have often been retained on the constant system.

Additional advantages.

Economy in pipes and cisterns.

From the Report on the East London Water Bills, we find that where the intermittent supply has been changed to the constant, there has been an enormous waste of water, chiefly from carelessness.

Precaution during frost.

It is recommended that in frosty weather the water should be turned off from the house by the turn-cock and that the water actually in the pipes should be run away from the lowest tap (water-pipes do not often freeze underground); and that the tap should be placed so that the water cannot run away to waste without producing inconvenience, and that for water-closets special arrangement must be made so that the water cannot run continually. Mr. Hawkesley says that "it is a question of the size of the pipes," and that when a constant supply is well managed the waste is less. Position of taps.

Inspection, however, is always necessary.

It is stated that at Norwich the consumption has descended from forty gallons a head to fifteen, since the fittings have been inspected. Result of inspection.

When the cisterns are not removed their waste-pipes must be cut off, or the water will frequently be allowed to run into them.

The water-closets may be supplied from the cistern by means of a double valve, so arranged that when one valve is open the other is necessarily shut. Double valve.

In Mr. Easton's evidence a contrivance is described which consists of an air-vessel into which the water runs directly from the main, and so compresses the air above it. When the handle of the closet is lifted up, the water in the vessel is thrown out by this compressed air. But the arrangement is such that no more can come from the main into the air-vessel until the handle is let down again, so that it cannot possibly be caused to run continually. It may be so managed that the vessel takes a considerable time to fill, so that even by pulling the handle up and down no great waste can be effected. Air-box.

The Commissioners are of opinion that "the use of

Contamination by cisterns.

cisterns for the purpose of storing water for consumption is probably a more fertile cause of impurity than any pollution of the river from which the water is drawn;" and Mr. Rawlinson remarks that "the water that the poor people get is contaminated so far as water can be contaminated." (*Loc. cit.* qu. 3,695.)

The Health of Towns Commissioners considered the question of a constant water supply very fully, and showed that if it were adopted—

Cost of constant supply.

"The use of water-butts and water-tanks may be entirely dispensed with, and water may be distributed into every room fresh from the general reservoir or filter, at an expense not exceeding 1½*d.* a week; that for the cesspool, a cleansing apparatus, or soil-pan with water, of the nature of a water-closet, and the requisite drains, may be substituted at an expense of not more than 1½*d.* a week, and all refuse be instantly removed in water through impermeable pipes; so that the foundation of the house need not be saturated with decomposing matter, and none need remain on the premises to give off effluvia." (*First Report,* vol. i. p. 109.)

It is there stated that the Trent Water Company has always maintained the supply constant by night and day—

Less expensive to company;

"Except during a period of one month, when for the purpose of experiment the water was shut off at ten in the evening, and turned on again at five in the morning. It was then ascertained that it would be less expensive to pump water than to maintain an extra establishment of servants and workmen to open, shut, and repair the valves, to draw the fire-plugs for the more frequent cleansing of the pipes, to attend to complaints of deficiency and inconvenience, and to make the inspections necessary to prevent advantage being taken of the absence of the water to attach communication pipes without the Company's consent or knowledge." (*First Report,* vol. i. p. 327.)

They also came to the conclusion, that by the arrangement of keeping the pipes constantly full, dispensing with the necessity of tanks, ballcocks, branch pipes, and so forth, more than half the tenant's expenses, and more than one-third of the total expense of introducing water into houses, were got rid of. To tenants.

CAUSES OF FAILURE OF WATER-CLOSETS.

It is plain that water-closets are no more likely to be free from nuisance than any of the other contrivances before described, if they are not properly taken care of. Their very principle requires that they should be supplied with sufficient water, at a sufficient flushing power; and it is universally acknowledged to be advisable that in closets frequented by great numbers of people, as in schools, railway stations, hospitals, and so forth, the method of supplying the water to the pan should be self-acting, and that in the poorer districts of the towns this should also universally be the case. Wherever water-closets have been found a nuisance, these conditions have invariably been flagrantly violated; thus, in Hull, it was found that water-closets, when used by several families, were objected to as being "everlastingly a nuisance." Conditions necessary.

In Nottingham the water-closet fails in the poor quarters, and, as we have already seen, pail-closets have been substituted for it; the reason of this is that, as in all other such cases, there has been a want of any sort of supervision, and moreover a wrong kind of closet. Violations of them.

At Edinburgh, where pail-closets are so much used, water-closets were tried in the lodging-houses, but were found to be much befouled. When limited to one, two, or three families, and kept locked, they worked satisfactorily.

The same effects were experienced at Glasgow.

In the poor parts of all towns, water-closets, especially when frequented by several families, will be found to fail unless they are, at any rate to a slight extent, under the control of an authoritative supervision. It is not fair to compare water-closets which have not been placed under any pretence of supervision with other forms of closet which have been minutely and constantly looked after by appointed persons.

Unfair comparisons.

In Dr. Buchanan's Report on the working of the earth closet system, it is stated that at Lancaster Grammar School the water-closets always got out of order, from things being put into them and from the apparatus being broken, showing that the apparatus itself was not of that simple and self-acting character which we have already insisted on as being necessary in all large establishments.[1]

Ordinary form unsuitable for careless people.

The ordinary water-closet is obviously quite unsuited for careless and wantonly mischievous people. The pans get broken, the traps choked up, the water is left running on continually from the tap, or the tap is broken and leaks wastefully; in frosty weather there is no water, and the consequence is that the closets become filthy and stinking, and are cleaned out only once in several days; while closets which are well cared for, even in the same quarters, and which are not frequented by too many families, are found in good condition without waste of water, and very rarely injured by frost.

Merely requires ordinary care.

1 The W.C.'s still left, "which have all their apparatus broken, are now cleaned by buckets, and are found free from smell." (*Twelfth Report M. O. P. C.* p. 83.)

In Carlisle, "water-closets are universal and kept in good order, Macfarlane's especially being found admirably suited to the wants of poor neighbourhoods." (*Ninth Report, M. O. P. C.* p. 108.)

SIMPLER FORMS OF WATER-CLOSET.—COSTS.

The First Report, already referred to, of the Health of Towns Commission, has afforded us some very valuable evidence with regard to the possibility of constructing water-closets at a sufficiently cheap rate in poor neighbourhoods, and several simple forms of apparatus are described in this Report. **Cheap plans.**

"A pan with a perpendicular pipe leading into the drain, through which the waste water from the house and roof would flow, would be sufficient. The present necessaries might be converted into such water-closets at an expense of £5 or £6 each, and the tenants would very gladly pay a small additional rent to be free from the annoyance and injury the present arrangement produces; while the landlords would find it their interest to incur some expense to avoid the injury which their property now suffers from liquid filtering through to the foundations of the houses." (*First Report*, vol. i. p. 212.) **Increase of value of property.**

This would seem to be rather a high estimate, as the calculation for erecting a cheap water-closet in Ashton-under-Lyne gives it at £1 13*s.* 5*d.* for a closet on the ground floor, and an additional charge of 12*s.* for fitting up one on the chamber story. This includes a strong fire-clay water-closet basin, with a proper fitting socket joint; a strong fire-clay S-shaped soil-pipe, 4 yards of fire-clay water-pipe, all to be glazed and smooth inside; 5 yards of ½-inch patent lead service-pipe; one water tap, and all the necessary fittings. The remark is made that the "fire-clay pipes mentioned above are ¾in. in thickness, exceed- **Construction and cost.**

ingly strong in texture, and by no means brittle like earthenware." (*First Report*, vol. i. pp. 306-7.)

Materials. In the second volume of this Report there are some plates with descriptions of very simple forms of closets, consisting of a soil-pan and a syphon pipe or simple trap placed at the junction of this with the house-drain. The soil-pipe is made of cast-iron, the disadvantage of which is that it corrodes after a time, and the filth is then apt to adhere to it; or of earthenware, which answers the purpose better. The seat of the closet is slung on hinges to a wooden frame, so that it may be lifted and vessels emptied into the soil-pan without wetting or dirtying the seat. The expense of this apparatus is stated to be from 25*s*. to 30*s*., including the price of fixing. This is supposing that a great number were required. If a water-pipe and tap were added, it would perhaps cost about 15*s*. more. (*First Report*, vol. ii. pp. 315-16.)

Again: Mr. Thorp gave evidence that he had constructed water-closets for the Hull gaol, with an iron

Very cheap form. soil-pan of about 10 inches in diameter and a pipe of 5 inches, the pan and pipe being joined together by a bell-end, run in with lead, and the pipe being S-shaped. He says that "if numbers were made they might be made at low prices, less than £1 each," and that "this same kind of closet made of earthenware may be fixed at about 8*s*. each." He adds:—

> "It is quite sufficient to prevent any smell coming into the room from the drain, and it passes the soil and everything well, although there is no regular supply of water, and only such

Soil-pan used as sink.

> water is used as may be put in from time to time, the soil-pan being in fact used as a sink. But it would be a proper improvement to have regular supplies of water, and then the apparatus would work completely." (*First Report*, vol. ii. p. 333.)

Its cost adds $1\frac{1}{4}d.$ to the weekly rental, or $2\frac{1}{4}d.$ including cost of water (Nottingham): "less than half the existing charge of the present noxious system" (p. 319).

In the East London Water Bills Report it is stated that the cost of a pan and syphon tap was 38*s.* with 6*s.* or 7*s.* for fixing, but that if the pan already existed the cost was only 37*s.* altogether. The double valve cistern is stated to be the cheaper plan.

Other estimates.

In Liverpool every syphon water-closet ordered costs £3 10*s.* (*Twelfth Report, M.O.P.C.; Appendix*, p. 120.)

TROUGH AND TUMBLER WATER-CLOSETS.

The ordinary form of water-closet having as a general rule failed in the poorer neighbourhoods of large towns, from the too complicated character of the contrivances for flushing the pan, and their easy accidental and wilful destruction, and also on the other hand from the entire want of all authoritative supervision, several devices have been proposed by which the water-closet system can be successfully introduced into such neighbourhoods.

Plans for poor neighbourhoods.

To several of these contrivances we have already alluded in the simpler forms of the ordinary water-closet, but to some others which seem especially suited for large collections of persons in back streets, courts, and so forth, a special allusion must be made.

What are called trough water-closets have been erected in Liverpool, West Derby, Warrington (one as a trial), and perhaps other towns; they may be briefly described as follows (see *Twelfth Report, M. O. P. C.; Appendix*, p. 120):—

A long trough is placed below and behind the seats

Trough closets.

of a series of closets. At the one end is a communication with a drain leading into the sewer. This opening is closed by a plug connected with an iron rod, by which it can be raised or lowered into the drain mouth by the scavenger. Behind the back wall of the water-closet is a small chamber to which the scavenger only has access, and it is from this chamber alone that the plug can be interfered with. The scavenger comes daily, lifts up the plug, lets the contents of the inclined trough run into the sewer, washes out the trough with hose which is placed in the chamber for the purpose and which is connected with a hydrant, sweeps it clean, charges the trough with water, lets down the plug into the drain mouth, and leaves it for twenty-four hours. The closets themselves are cleaned by the users in rotation, and an inspector calls every two or three days to see that it is done. If it is not done properly the offenders are summoned, and some have been sent to prison for the offence. The ashes and other refuse are put into the street and carted away daily by the scavengers.

Scavenger's duty.

Penalty for not keeping closet clean.

The cost of these trough closets is £5 10*s*. for a single one, and £7 10*s*. for a double one.

Dr. Syson, the Medical Officer of Health for Salford, says, as his reason for having "a strong prejudice against trough water-closets":—"We had one at a school where I was, and I may say that it was a frightful place, and there is one at the workhouse now here. I have been in it, and it smells; it wants emptying frequently to keep it sweet." (*First Report R. P. C.* 1868, vol. ii. p. 189.)

Adverse opinion.

This one, although emptied every twenty-four hours, must have been badly managed in some way: at any rate we have sufficient evidence as to the great sanitary boon that these closets have been to the poor districts of Liverpool (*see* p. 175) to warrant us in considering this as an exceptional case; Dr. Buchanan and Mr. Radcliffe say:—"Nothing could be more admirable than the working of the Liverpool arrangement, and nothing could be more marked than the difference between them and what are called water-closets in the poor neighbourhoods of London and other large towns."[1] Favourable one.

Another contrivance of a similar sort, but entirely self-acting, known as the "Tumbler" closet, has been introduced into Leeds, Birkenhead, and Tranmere. In this there is also a trough running under the privy-seats and made of tile; the water trickles into a swinging basin at the upper end, which is so constructed that it capsizes when full and washes out the contents of the trough into the drain; it can be arranged so as to capsize at any interval that may be thought advisable. "For a tumbler closet one-and-a-half gallons, and for the ordinary syphon or pan closet two gallons a head per twenty-four hours," are required. These closets are found to keep very clean, "to require fewer repairs and less attention than the syphon or pan closets," and to be unaffected by frost.[2] Tumbler closet. Quantity of water.

By these simple contrivances it is found that the water-closet system may be managed so as to be "entirely applicable to the circumstances of the most ignorant and most careless population;" the only necessary addition being that, as in any other arrange- Conditions to ensure perfect success.

[1] See Twelfth Report M. O. P. C. Appendix, p. 139.
[2] First Report, R. P. C. 1868, vol. ii. p. 251.

ments, the management be entirely undertaken by the scavengers of the sanitary authority.

"Where these conditions are observed as thoroughly as they are observed in parts of Liverpool, we believe that water-closets are the best means of removing excremental matters from the poor neighbourhoods of a town."[1]

No carting necessary, except for ashes.

It will be at once observed that in each of these cases the scavenging arrangements need not be anything like so complicated as they must necessarily be with any of the other systems that we have already considered. There is no removal or carting away of the excremental matters in any form, the scavenger has merely to visit the place to see that all is going on right, and in the case of the trough closets to empty the contents of the trough down the drain. The ashes of course have to be collected separately, just as in all other parts of the town.

Water closet always adopted by clean people.

In the various Reports on this subject, one continually meets with the statement that in a certain town there are only a few water-closets, and these always in the best houses. From this we see that the persons who are best off, and who are, as a rule, cleanest in their habits, have invariably adopted the water-closet system in preference to any of the older ones. It is found, when properly managed, as every one very well knows, to be in no way a nuisance; on the contrary,

Reasons.

by it all the excremental matters, together with all the slops and liquid house refuse, are immediately carried away, out of and far from the house and the neighbourhood, and by a simple trap, or syphon, the entrance of foul gases from the drain into the house

[1] Twelfth Report, M. O. P. C. Appendix, p. 140.

is, to all intents and purposes, entirely prevented. If, then, the lower classes of people do not manage water-closets as they should be managed, it is plainly not the fault of the system, but the want of a due regard to cleanliness on the part of the users; and until they can be taught to manage them themselves, the only way to get out of the difficulty is to have them managed for them.

What we have wished to point out is, that instead of destroying the water-closet system, as introduced into the neighbourhoods to which we have just referred, it might undoubtedly be made to anwer perfectly every sanitary requisition by a tithe of the supervision and incomparably less scavenging work than is universally acknowledged to be absolutely necessary in all other forms of excremental removal.

Necessity of supervision, but of much less than with any other system.

In fact, we must agree with Dr. Syson, who said before the Rivers' Pollution Commissioners, "where a water-closet is mechanically perfect, I look upon it that it is perfect in theory; but I find from experience that water-closets, and the drains connected with them, are laid out so badly, that they themselves are apt to become a source of annoyance and discomfort." (*First Report R. P. C.* 1868, vol. ii. p. 189.)

True reasons of failure, when it occurs.

So that it is not the fact of their being water-closets, but the fact of their being badly constructed or not looked after, that makes them a nuisance wherever they are so.

The great improvement in the sanitary condition of towns into which the water-closet system has been introduced, will be described in another place.

CHAPTER VI.

SEWERAGE.

Original idea of a sewer.

THE original idea of a sewer was that it was a large drain to carry off the rain-fall and subsoil water of a town, and it was only secondary considerations that pointed out the convenience of making this drain a receptacle for liquid refuse matters also. That the Cloaca Maxima of Rome was built with the first-named intention, we see from the account of it given by Livy:[1] "Et infima urbis loca circum Forum, aliasque interjectas collibus convalles, quia ex planis locis haud facile evehebant aquas, cloacis e fastigio in Tiberim ductis siccat;" but that it was used for the secondary purpose which we have just mentioned, and with which we have especially and indeed almost exclusively to do, we see from the statement: "Cloacamque maximam receptaculum omnium purgamentorum urbis, sub terram agendam."[2] Smaller sewers were made which either opened directly into the Tiber or into the Cloaca Maxima itself, and which "ramified through all Rome."[3] Pliny calls these *cloacæ* "operum omnium dictu maximum."[4]

Secondary one.

[1] Livy, i. 38. [2] Livy, i. 56. [3] Smith's Ancient History, vol. ii. p. 193. [4] Pliny, Hist. Nat. xxxvi. c. 15, s. 24.

From the time when Tarquinius commenced this grand work down to the present day, it has been found necessary to provide sewers for towns, no matter in what way the actual excrementitious matters are dealt with, and as a general rule they have been built more or less on the Roman plan. This we do not wonder at, since the durability of these works is shown in the fact that the great prototype which we have above mentioned has lasted almost entirely unhurt for twenty-four centuries, and still continues to perform its original functions of *drain-sewer.* The city which at present exemplifies in the most complete manner an enlarged and improved form of this system is perhaps Paris, underneath the principal streets of which not merely sewers but subways are constructed, with the tributary mains named and the house-pipes numbered. The London main-sewers vary from 4 feet in diameter to 9 ft. 6 in. by 12 ft. in some cases; the three northern outfall sewers are each 9 ft. by 9 ft. (with vertical sides), the southern outfall sewer 11 ft. 6 in. in diameter. Such an enormous size as this is found requisite not for the actual amount of foul water which generally does pass down the sewers, but, as Parent Duchatelet points out, for that which it is *possible* that the sewer may be required to contain under certain circumstances, especially during heavy rains. Neither the existence of such sewers nor their size in any way depends upon the amount of excrementitious matter that is received into them. The sewers we have mentioned were all constructed for towns in which the solid part of the excrement and a certain proportion of the liquid were carefully kept away from them, that being considered to be the part most valuable as

Cloaca Maxima the type.

Immense size of drain-sewers.

Reason for it.

Excrement kept out of them;

manure. In Paris this is especially the case, as we have already pointed out, by the general prevalence of the system of "*fosses permanentes*" and "*fosses mobiles.*" In London, too, this was the case when the privy system was in vogue, and of other towns the same remark may be made.

"Up to about the year 1815, it was penal to discharge sewage or other offensive matters into the sewers: cesspools were regarded as the proper receptacles for house drainage, and sewers as the legitimate channels for carrying off the surface waters only. Afterwards it became permissive, and in the year 1847 the first Act was obtained making it compulsory to drain houses into sewers." (*Bazalgette, Main Drainage of London*, p. 5.)

In Rome, certainly, the greater part of the excrementitious matters were collected in enormous underground pits, which have been lately discovered by Mr. Parker, so that in no case were these sewers constructed for the removal of excrementitious matter. It does not by any means follow from this that the water they conveyed was to any notable extent less impure or less offensive than the contents of sewers into which the whole of the refuse matter of all sorts is received. This was perfectly well pointed out by Parent Duchatelet, in his remarkable memoir on the sewers of Paris, published in 1836. He there considers that the identity between the sewers and the "*fosses*" has been completely proved, and he rightly argues, that sewers, even under the conditions found in Paris, require to be constructed with the same precautions as the "*fosses*" themselves; in fact, any one who has examined the sewers of Paris, Lyons, or any other town where the cesspool system is as efficiently and thoroughly carried out as it can be, knows perfectly well that the sewage is just as

But contents still foul.

Same rules as for cesspools

foul, just as offensive in every way, as it is in the most thoroughly water-closeted town. But we have had lately some important evidence on this point, in the First Report of the Rivers' Pollution Commissioners. It is there shown, that there is "a remarkable similarity of composition between the sewage of midden towns and that of water-closet towns. 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. For agricultural purposes, ten tons of average water-closet sewage may, in round numbers, be taken to be equal to twelve tons of average privy sewage." It is also shown that more persons contribute to a given volume of sewage in midden towns than in water-closet towns, because it is found that the proportion of chlorine is greater in the sewage of the former towns than in that of the latter, and the cause of this difference "is obviously to be sought for in the somewhat increased quantity of water needed by and supplied to" the water-closet towns. (*First Report R. P. C.* 1868, vol. i. p. 29.)

Recent confirmation of this point.

Water-closet sewage v. privy sewage.

Latter so rich because less water with it.

We must remark, however, that although there can be no doubt as to the truth of the general fact above stated, yet it may be questioned whether the similarity between these two sorts of sewage is as great as is here indicated. It would not appear that the samples, of which the analyses above referred to were made, were really average samples, that is to say, procured by taking samples at frequent intervals during a period of twenty-four hours, and mixing them *in the proportion indicated by gauging at the time each sample was taken*, a source of error pointed out to us

Average samples.

by Mr. Thornhill Harrison. However, the exact results may be ascertained by future researches; what cannot be denied is "that the very large collection of feeble manure from the several towns . . . . does really very little to save the rivers. . . . . Bolton receives its river water virtually clean, and hands it on in an extremely foul and offensive condition. Rochdale fouls the Roch and Spodden, and Bury makes a most obvious addition to the filth of both the Roch and Irwell passing by it. Over Darwen adds most offensively to the pollution of its stream, and the Blakewater is entirely converted into sewage by the town of Blackburn. The Irwell and Irk and Medlock come down already very foul, but the quantity of filth they bring is enormously increased as they pass through Manchester and Salford" (p. 36); and from their researches these Commissioners were led to conclude that "retention of the solid excrement in middens is not therefore attended with any considerable diminution in the strength of the sewage, although the volume, even in manufacturing towns, is somewhat reduced; neither is the case substantially different where earth closets are substituted for the Lancashire midden, for the sewage from Broadmoor Lunatic Asylum, in which these closets are partially used, exhibits no exceptional degree of weakness. . . . . It seems hopeless therefore to anticipate any substantial reduction of sewage pollution by dealing with solid excrementitious matters only" (p. 30). Thus, then, we see that in every case the sewers not only act as drains, but remove an immense quantity of refuse matter, and that therefore Parent Duchatelet's conclusion, that they must be considered

Rivers fouled in any case.

Useless to deal with solid excreta alone.

Drains act as sewers under any system.

as elongated cesspools, was a correct one. We have seen how it is necessary to construct cesspools; that the one great condition is that they should be impervious, in order that their contents may not soak through into the surrounding soil, poisoning the wells and giving off foul emanations into the air. This, therefore, is a conclusion which has also been come to in the case of sewers: they must be made *imvervious*, and to this end, in Paris, following up the recommendations of the renowned hygienist whose name we have just mentioned, they are lined throughout with impervious cement; and even as a reçommendation for ordinary brick sewers, one witness before the Health of Towns Commission stated that when *properly constructed*, and with good stone-lime and river sand cement, they become water-tight after a time. But here we stumble upon a dilemma: we have pointed out that the original object of the sewers was to carry off the rain and subsoil waters, that is to say, to act as drains. Now drains, in order to be efficient, must be pervious, must allow the subsoil water to get into them as easily as possible. "A drain," says Mr. Bailey Denton, "is intended to draw out of the land through which it passes, the wetness that is in it, and to exhaust that wetness as far as capillary attraction and natural retentiveness will permit." (Letter to the *Times*, October 28th, 1869.) But now we find that, through the introduction into them of refuse matter of towns, in all cases it is decidedly advisable to have them impervious; in fact, we require to make them pervious and impervious at the same time,—an obvious impossibility. But it may be alleged that as a general rule there will be no risk of the

Must be impervious.

What a drain is.

"Reductio ad absurdum."

foul water percolating through the sewers into the surrounding soil. It is perfectly true that where the incline is sufficient and the sewers well constructed and without any chance of obstruction, there will certainly not be any great risk of this taking place; but where the ground is flat, so that sufficient incline cannot well be given to the sewers—as is the case in Paris for the most part—or where there is any chance of the backing up of the sewage from the outfall, either because this is—as at Cambridge, for instance—under water, or because the tide rises into it, as in many seaboard towns, it is certain that such percolation does take place to a very great extent. The well-water at Cambridge contains for the most part a good deal of fæcal impurity, which would appear to arise mainly from this percolation from the sewers.

Percolation out of sewer.

Thus we see that constructions which ought to be mainly regarded as drains have come to be *especially looked upon as sewers* (to express this double function we shall call them *drain-sewers*); and while the importance of their being impervious has been strongly pointed out, the necessity for their being capable of acting as drains has been to a great extent overlooked. The extreme importance of this latter point we shall have to consider in another place; suffice it here to say that it is certain that towns must be provided with *pervious drains*, and it is also, from the foregoing considerations, equally certain that they must be provided with *impervious sewers*.

Ultimate change of destination.

Drains and sewers both necessary.

DRAIN-SEWERS.

As these drain-sewers are, however, at present the usual ones employed in most towns, and as in their capacity of sewers they therefore come under our subject matter, we will consider briefly the practical points to which attention should be especially directed in their construction. With regard to their form, some important evidence was given by Butler Williams, Esq., C.E., before the Health of Towns Commission. It is plain that the best form to be adopted is the one which, with the greatest economy of work and materials, combines the greatest power of resistance to external pressure and the greatest facility for the freest flow of sewage contained in it. A very primitive rectangular form, with upright sides and a flag or slate bottom or top, need scarcely be considered, as it obviously does not fulfil these conditions; it combines in fact almost the maximum amount of friction and retarding of the materials passing down it with the minimum amount of strength, and has always been found to fail. The Romans knew very well that an arch was stronger than a flat roof, especially than one made of a single flagstone, and they constructed their great sewers with arched tops. In the form which has upright sides with an arched roof and a flat bottom the friction is as great as in the one above mentioned, and deposit very easily accumulates. When the bottom as well as the roof is arched, as in the Westminster sewers, the friction is very much reduced; while the elliptical sewers not only offer less resistance to the passage of sewage in them, but at the same time greater resistance in every direction to external pressure, while a still further improvement is the substitution of an egg-shaped section for the true elliptical one, the smaller end of the oval pointing downwards. The advantage of this is, "exclusive

Form.

Rectangular fails.

Arched roof.

Elliptical section.

Egg-shaped section.

of its superior strength and economy, that when the water is small in amount the narrowness of the lower part gives a greater hydraulic depth, and therefore produces increased velocity, and, when the body of water is increased, more capacity is obtained." But the question of economy must also be considered, and with regard to this we find, comparing egg-shaped sewers with those of the Westminster form of the same capacity, that while one mile of the former would only require 924,140 bricks, one mile of the latter would require 1,378,080; or "one mile of sewerage of the upright form would require upwards of[1] half a million of bricks more than one mile of the egg-shaped sewer; and the number of bricks that would complete one mile of the upright formed sewerage would suffice for one mile and a half of the egg-shaped sewer."[2] The difference would amount to 1,116 yards of brickwork, "which, valued at 20*s.* a cubic yard, would amount to £1,116." Besides this, it appears that the "width of the footings used in the upright-sided sewer causes great expense in the excavation," and, taking the average depth of the main line excavations at 20 feet, it is found that 5,865 cubic yards per mile is the amount of excess of excavation required in the case of the upright-sided sewer.

Economy in bricks.

Difference in cost;

in excavation.

This it is reckoned would carry the excess of expenditure to £1,660, or altogether "the difference in expense between the construction of upright-sided sewers with man-holes, and egg-shaped or arched sewers with flushing apparatus, would be about £1,800 per mile, or for 118 miles would be nearly a quarter

Total difference.

[1] (? Nearly.)
[2] First Report, Health of Towns Commission, vol. ii. p. 460, &c.

of a million." The distance of 118 miles is mentioned because it represents the length of main sewers built in London during the ten years preceding the Report. That is to say, that the upright-sided sewers, which offer the greatest resistance to a free flow, in which great accumulation of filth takes place—even to the extent of several feet in depth in some cases—and the sides of which often get pushed in by the pressure of the soil around, as exemplified by several instances cited in the Report above quoted, cost very considerably more than the egg-shaped variety with all its advantages of increased velocity of the current, diminished deposit, and superior strength. Where circular, elliptical, or egg-shaped sewers have been substituted for upright-sided ones, which had previously failed, they have been found to succeed well.

Worst form the most expensive.

It is better that sewers should be too large than too small. We have seen of what an enormous size they may be made, and are made in some cases; but the question is, what is the least size which will answer the purpose, so that the expense of construction may be diminished as much as possible? The general idea is that the mains should be sufficiently large for a man to creep through in order to remove the deposit which may accumulate in them. This is now usually considered unnecessary, as the sewers should be so constructed that occasional flushing will do this.

Should be large.

Common notion.

To take some instances of the sizes actually in use, which will perhaps be the most practical way of looking at it, we find that in the courts and alleys in London, the sizes are from 3ft. by 2ft. 2in. to 4ft. by 2ft. 4in. In streets they are from 4ft. 6in. by 2ft. 6in. to the size of the mains, which has been given pre-

Sizes in various towns.

viously: one of these, despite its enormous dimensions, has (even quite lately) been overcharged. In Dover the main valley sewer is 4½ft. by 3ft. In Salisbury the new sewers are about the same size, and the mains are so constructed that the subsoil water percolates into them freely. In Bristol the main outfall is 5ft. by 4½ft., and the mains vary from this size to 2ft. by 1½ft.; and it will be found practically that where the drain-sewer system is still carried on, the minimum size for the mains will be about 3ft. 6in. by 2ft. This size would allow a man to creep through the sewer easily if necessary.

Calculated size.

It is calculated that a main drain-sewer intended to receive all the sewage of a thickly populated square quarter of a mile, with a water supply of twenty gallons a head, and also the rainfall of the same surface, would only actually require for these purposes a sectional area of 4 square feet, but that practically, in order to provide for sudden storms, this size would have to be at least doubled. A still larger sewer would be necessary for the same population if spread over a larger area. A ¼-inch of rainfall must be provided for.

Brick-work.

We have already intimated that the mains are generally made of well-cemented brickwork, and it is found that in tolerably good soils they may be (especially the elliptical or oval ones) constructed of single half-brick (4½ inches) thickness. Where they are required to be unusually strong, they may be one brick thick. In many towns stoneware pipes are substituted for the brick sewers, in the smaller streets at any rate. At Rugby, 6-inch pipes are used for small streets containing fourteen or fifteen houses. This is, however, too small a size for sewers; they should be,

Pipes for small streets.

as in other towns, 8, 10, or 12 inches in diameter; such pipes (18 inches in diameter?) may be even used for the larger streets, but this economy is especially undesirable, because these pipes, being glazed and impervious, do not at all act as drains; and, in fact, brick mains built so that the subsoil water can enter them (a sufficient fall and occasional flushing being relied upon for the prevention of percolation of sewage into the surrounding subsoil), should be constructed in preference to these pipes in all the large streets in towns where a single system is allowed to remain in use.

Pervious mains preferable.

Nothing need be said here with regard to the connection of the water-closets with the house-sewers, as the description of the pipes used with the better forms of cesspools applies equally in this case: we may just say that they should be 3 or 4-inch pipes of glazed earthenware or stoneware, and trapped at both ends, preferably on the syphon plan. The house-sewers themselves should be 6-inch impervious pipes laid on a solid bed: 9-inch pipes are unnecessarily large as a general rule, although this is a size very frequently adopted. Pipes are preferable to the brick-built sewers, both on the score of cleanliness and economy, and for the smaller streets, as we have before stated, 12 or 15-inch pipes, from the facility they give to the rapid flow of sewage, are perhaps on the whole preferable to brick sewers.

House-sewers.

The junctions of the various branches should not only be made at as acute an angle as possible, but the smaller branches should be somewhat curved, so that there is no angle to offer an obstacle to the free entrance of the sewage into the main. It is desirable also that the points of junction should not be low

Curved at junctions.

down in the main, so that the sewage from the pipes or smaller sewers may not have to encounter any considerable pressure.

Depth.

Drain-sewers must be placed deep enough to drain the subsoil; and, above all, must be placed below all cellars. There are too many instances of cellars having been—or even being continually—flooded, because they were below the level of the sewers. The sewers must drain the cellars; not the cellars the sewers! This is the case especially when the sewage is backed up from the outfall, or when the gradient is small. Thus, at Bedford the street sewers are described in Mr. Austin's Report as "chiefly built with bricks laid flat in the lower part, and without any mortar. In some cases the sewers are at such little depth that cellars of houses are accustomed to receive the foul liquid which filters through these defective constructions."[1] The new sewers in most of the towns have been placed at such depths as "from 16 feet (in the mid town) to 4 or 5 feet in many other parts of the town (Stratford-on-Avon). At Rugby they are "at an average of 11 feet from the surface, varying from 7 to 25 feet." At Worthing they begin superficially, and are 20 feet deep at the outfall. The London sewers vary much in depth.

Below cellars.

Examples.

Incline.

The incline to be given to sewers must necessarily, as we have before stated, depend to a very great extent on the natural inclination of the land itself, but where choice can be had it would appear that house-sewers should have a fall, if possible, of 1 in 20 or 30; the usual fall of 1 in 48 is perhaps sufficient for the pipe-sewers, while for street sewers and mains the

[1] Third Report M. O. P. C. 1860, p. 41.

inclination should vary from that just mentioned to 1 in 200, or 1 in 250. It is certain, however, that in many cases such an inclination cannot possibly be got, and then the engineer must rely upon the good shape of the sewers and sufficient flushing to keep deposit from accumulating.

Not always possible.

As these constructions are really drains used as sewers, their natural outlet is into the nearest water-course or into the sea. In the latter case, and in the mouths of tidal rivers, the tide often passes up them, and backs the sewage into the street sewers, whence it may overflow into cellars, or even come up through the gulley-holes into the streets. This was found to be the case at Dover with the old sewers. When the outlet is into a river, below the level of the water, the sewage is backed up by the pressure of the water in the river, and unless the fall of the mains be considerable, and the velocity of the sewage sufficient to carry it out into the river, it will be as at Cambridge, backed up almost continually, and the main converted into a long cesspool. At Salisbury the outfall is into the Avon by a brick main, the open mouth of which is a foot above the lowest summer level of the water and a foot below the ordinary level. At Worthing the outfall—which is twenty feet below the surface—opens into a tank, out of which the sewage is pumped continually; but when the pump is not at work, sewage accumulates in the well, and even when the sewage has been delivered in amount beyond the capacity of the pumping power, "it has filled the well and backed up the sewers," and, in prolonged wet weather, "has regurgitated into basements of certain houses." At Bedford the chief outfall of the sewage was formerly

Outlet.

Backing up in mains.

Outfall into tank.

into the river above the town, so that the water was polluted with it before it reached the town.

Sluice to shut out tide.

Where the outfall is into a tidal river, or into the sea, a very usual plan is to provide a sluice, which is shut during each high tide ; by this means the tide is prevented from rising into the sewer, but the sewage is backed up in the mains, which become cesspools for the time being: a better method is to have a large receiving tank into which the sewage is allowed to flow during high tide.

Position of outfall.

As a summary, then, the outfall should be so placed —unless it is absolutely impossible—that there is no chance of any resistance being offered to the escape of the sewage ; and it is obviously wrong to allow it to enter into a river close above a town, or even close below it in the case of a tidal river. Whether it is right or not to send it into a river at all is another question, and will be considered in another place.

Subsoil water lowered,

From the Ninth Report of the Medical Officer of the Privy Council we find that in the towns which have been supplied with brick sewers, properly cemented, the subsoil water has in all cases been considerably lowered, unless from some local peculiarity which keeps the subsoil permanently wet. This is the case at Bristol, where, although there is no doubt that in many parts the underground water level has been lowered by the passing of the sewer through the porous soil, yet in other parts the water has kept up some sixteen feet above its natural ebb level by the influence of the floating dock; and it appears "that the wells (generally speaking) are unaffected in their supply of water by the sewerage" (p. 63). At Cheltenham, where Dr. Wright insisted that in the construction of the sewers "the removal of subsoil water was to be kept in view," the drying of the subsoil has been very considerable, although the Chelt is backed up within the town by mill-dams (p. 89). At Macclesfield, it is stated that "there is now no subsoil water above the level of the sewers anywhere, and cellars that used to be flooded are now dried by the sewers" (p. 117). The most remarkable instance of this drying of the subsoil is perhaps to be found in Salisbury, where the soil is a very porous gravel, containing much water. It is stated that in past times "there have been several instances of the Cathedral being flooded by the water of the subsoil; the foundations of the houses are almost without exception damp." The wells are "dug about eight or ten feet deep, the water rising to within two or three feet of the surface." Since the sewerage works have been finished it is said that "in the main sewer a rapid run of water from the subsoil always exists .... cellars of considerable depth can be made, even at the lower parts of the town, and these do not become flooded at any time. On an average the subsoil water has been lowered four or five feet over the city. The Cathedral has never been flooded since the drainage works." (*Loc. cit.* p. 150.)

even when artificially backed up.

Best instance.

Cellars no longer flooded.

From the Rivers' Pollution Commissioners' 1st Report (1868), vol. ii. p. 83, we find, that at Waterloo-with-Seaforth, where the works have consisted of brick sewers, earthenware pipes, and cast-iron pipes, "the extent of well-water is greatly depressed, so much so that many or most of the wells are useless;" but as a general rule the towns in these basins (Mersey and Ribble) do not seem to have had their water-level much altered by the sewers. The level would seem to have been most affected where the subsoil is

Wells dried

Nature of soil.

porous, as at Salisbury and parts of Cheltenham. Where it is a stiff clay it would appear that generally the drying has not been so effectual. This drying of the subsoil appears to have been pointed out to the Health of Towns Commissioners in 1844, by John Liddell, Esq., who says, when questioned upon this point: "I believe the sewer has been useful, and has considerably diminished the surface water, in some places so much so as to reduce the amount of fever."

The drain-sewers, then, as usually constructed, do act efficiently as subsoil drains.

PIPE-SEWERS.

Impervious pipe-sewers.

In some towns impervious glazed stoneware pipes have not merely been used for the house-sewers and in the smaller streets, but have been employed throughout. Thus, at Penzance the storm-water and ordinary surface water is allowed to go along channels in the streets to the sea, while the whole of the sewage of the town passes through impervious pipe-sewers ranging in size from fifteen inches in the main sewer to four inches for the house-pipes. They lie at an average depth of nine feet, and their incline varies from 1 in 120 to 1 in 15. They have "two brick outfalls into the sea, one below low-water mark, while the other is uncovered for three to four hours of the tide; into these outfalls the storm-water is also received." Houses are drained into the sewers on the block plan, the inlets to all drains being trapped. Deposit rarely accumulates in these sewers, and for the purpose for which they are intended they answer well; but it must be remembered that there are no subsoil drains. At Carlisle the same system was

Brick outfalls.

applied by Mr. Rawlinson, the outfall of the sewer being 3 feet 9 inches by 2 feet 6 inches, "with the small but sufficient fall of 1 in 1,000," and the others ranging from this size down to 9-inch street pipes. **Examples.**

At Dover the pipe system of sewers has been added to the old system of drain-sewers, which are still left to carry off the storm-water. The pipes vary from 6-inch house-pipes to 18-inch sewers, which open into a brick main $4\frac{1}{2}$ feet by 3 feet. The pipe system discharges into the sea at low water by gravitation; pumping has had to be resorted to during the spring tides from the flooding of the cellars. **Discharge into the sea.**

At Chelmsford the greater part of the storm-water is allowed to pass off, "by surface channels and by superficial culverts, to the river," while the sewage and house drainage generally is conveyed in pipes to a pumping station at the lowest part of the town. The outlet of the culvert into the tank is "of brick, fifteen inches in diameter, and six feet below the surface." All the other sewers, large and small, are impervious pipes. When pumping is not going on from the tank, the outfall can be closed by a sluice, and then the sewage accumulates in the mains. (*Ninth Report M. O. P. C.* pp. 147, 107, 132, 156.) **Separation of storm-water from sewage.**

Ely and Rugby are both supplied in the same way, the storm-water still going along the old sewers. In Rugby, pipes only six inches in diameter are used for the smaller streets containing fourteen or fifteen houses, and the main outfall is only two feet in diameter. At Stratford-on-Avon the chief difference is that the pipes are larger, the smallest street-sewer being a 9-inch pipe, and that they receive the storm-water, as also the drainage of houses. At **Size of pipes.**

Alnwick and Brynmawr these pipe-sewers are said to act exceedingly well: Gloucester, Southampton, Leamington, and other towns afford instances of the application of this system. The pipes used for these sewers have the advantage of being very strong: they can be much more quickly laid than brick sewers built, and there is, with a proper incline, almost no chance of accumulation taking place in them. They require a much smaller amount of excavation than brick sewers, and they can be made with very various curves to suit different positions. From the Rivers' Pollution Commissioners' First Report (1868), vol. ii., we find that a considerable number of towns in the Mersey and Ribble basins are supplied partly with pipe-sewers, though the mains are generally egg-shaped brick sewers. On the whole, there is no doubt that glazed earthenware pipes act perfectly well as sewers, and efficiently remove all the refuse matters with very little chance of accumulation.

Advantages.

Act well as sewers,

Where the pipe system has been employed, especially if to the entire exclusion of even brick mains, no drying of the subsoil has taken place. At Penzance, "the effect of the construction of sewers upon the subsoil of the town has been inconsiderable, if any. . . . . No wells were affected at all by the drainage works." At Rugby there has been a slight lowering of the subsoil water, but to no great extent. At Penrith, Alnwick, Morpeth, and other places, there has been no change in the subsoil water. At Worthing, however, where there is, be it noted, an egg-shaped brick main, and where the surface water is allowed to run into the pipe-sewers, while the storm-water is partly carried off by the old brick ones, the

but not as drains.

They do not lower the subsoil water.

removal of the subsoil water has been considerable; but this has been to a great extent due to water finding its way alongside of the pipes, the town standing on semi-porous strata. We may note that at Morpeth, although there is no draining of the subsoil water, "the surface is rendered incomparably drier," and the cellars that used to get filled with water in all heavy rains have never been flooded since the sanitary works. At Ashby-de-la-Zouch, it would appear that the subsoil water has been lowered, probably from the water finding its way alongside the pipes, and from the very fact that excavations have been made through the thick tenacious clay upon which the lower parts of the town rest. (*Ninth Report M. O. P. C.*)

Water finds its way alongside of pipes occasionally.

Some of these towns, then, it will be seen, are as a matter of fact provided with sewers much upon the plan which Mr. Menzies has the credit of having first brought prominently forward; that is to say, with impervious pipes for the sewage properly so called, and brick drains for the surface and storm water, the former being laid deeply and the latter being superficial. We have, however, seen that by this system no provision is practically made for the removal of the subsoil water; only the sewage and the surface water is attended to. That this is not sufficient, but that it is necessary for "the subsoil water to be removed, and kept at an adequate depth below the surface by underdrains specially laid for the purpose," as Mr. Bailey Denton says, we shall show when we describe the effect of sewerage works upon the health of towns.

Mr. Menzies' plan.

Necessity for removal of subsoil water.

Where this "separate" system is adopted, Mr. Menzies says that the street gulleys should open into

Street water into drains.

the drains, and not into the sewers; he considers that the street scavenging ought to be sufficiently well done to prevent any great amount of organic refuse matters being washed into them in this way.[1]

FLUSHING OF SEWERS.

Accumulation of deposit.

That in brick sewers, especially badly constructed ones, and in such as have not a sufficient incline, considerable accumulation of semi-solid filth may take place, in spite of the fact that rain and storm water pass along them, has been already pointed out. This happened in the Cloaca Maxima, which got choked up, and had to be cleaned out at a cost to the Censors of 1,000 talents. The old method of removing this deposit was through man-holes by spade and bucket. That this is a very expensive method will be seen from the statement that "the cost of removing deposit from the tide-locked and stagnant sewers in London formerly amounted to a sum of about £30,000 per annum" (*Bazalgette on the Main Drainage of London*), and from another in the Health of Towns Commissioners' 1st Report, that the yearly expense of cleansing the sewers in Westminster was £2,000, the number of loads of deposit removed annually by carting being 6,000. In the same Report (vol. ii. p. 159, &c.) the advantages of flushing by water, instead of removal by the above method, are put forth. It was shown that in some cases where the deposit was three or even four feet thick, and had stopped up the sewer, not only the

Expense of removal.

[1] Paper read before the Institution of Surveyors, April 19, 1869.
[2] Dionysius (Halicarnassus), Antiq. Rom. iii. 200.

street had to be broken up, but the arch of the sewer broken into also, and the soil raised to the surface and carted away, causing a very great nuisance to the neighbourhood. The cost for removing it, if the sewers had man-holes, was 6*s.* 10*d.* a cubic yard; if they had not, 11*s.* a cubic yard, on account of breaking open the arch and making it good again. The results of some experiments that were made to ascertain the flushing power of water are given, and it is shown "that a velocity of six inches in a second would be sufficient for scouring away all the usual sediment, and that a velocity of one foot in a second would sweep away fine gravel." In some other experiments with a flushing-gate, four feet high—the quantity of water headed up for one flush being 26,605 cubic feet—it was found that, by a single flush, brickbats were carried along for a distance of from 261 to 529 feet. By a second flush the foremost brickbat had reached 1,170 feet; "after the third flush the whole were found to have passed a distance of 1,300 feet." The whole bricks were carried from 248 feet to 760 feet by one flush, and by the second flush the foremost brick was carried 160 feet further. These experiments demonstrate very clearly the effectual flushing power of a head of water backed up by a flood-gate. It need scarcely be pointed out that much time and money is saved by flushing. "It was found on calculation that the cost of putting down one of these flushing apparatuses (a mere board dam) was less than cleansing the sewer in the old way, while the apparatus remained for future use at no more expense than the men's labour." In an instance where 6,688 yards of foul deposit had

Evils of old method.

Experiments with a head of water.

Bricks flushed away.

Saving by flushing.

been removed by flushing, it was calculated that—as the whole cost of removing it by hand labour would have been £2,387, while the cost of putting up the inside apparatus and flushing-gate was £1,293, and the cost of men's time £644 12*s.* 7*d.*—"there was then a saving of £455 to the Commission," besides the fact that on account of the side entrances the pavement would no longer require to be taken up as before, and the apparatus would remain to be used when required. In the Holborn and Finsbury district it is stated that at that time (1844) about two-sevenths of the sewers were supplied with flushing apparatus, and that while "the annual cost of cleansing those by the old mode would be £326 17*s.*, the cost for men to work the gates now placed, that is, keeping the sewers clear from deposit, is £106 per annum, leaving a saving of £220 per annum on these two-sevenths." (*First Report H. of T. C.* vol. ii. p 164.)

Several examples.

Paris plan, moveable flushing-gates.

Instead of having flushing-gates at certain points in the course of the sewers, which can be let down so as to dam up the sewage, and cause a sufficient head to sweep the sewer clean when the gate is raised, the Paris sewers are provided with a kind of moveable flushing-gate, carried by a truck running on rails, which are placed one on each side of the actual channel; the truck being driven forward by the pressure of the sewage against the flushing-board, while the latter clears the sewer as it passes, being much assisted by the rush of sewage past its edges, which well stirs up and carries along the mud.

As deposits in sewers are brought about by the irregularity of the flushing that they get from the rainfall, it has been proposed to supplement this when necessary by sending a rush of water down them occasiònally, and this is the method now usually adopted.

To provide a supply of water for this purpose, a plan of collecting the rain-water from the roofs of houses is described by W. D. Guthrie, Esq. (*First Report H. of T. C.*, vol. ii. p. 243), which could certainly be very well adopted in most towns. The water is merely received into cisterns which communicate with the drain-pipes, the aperture of communication being closed by a moveable plug, so that the contents of the cistern can when necessary be suddenly emptied down the sewer so as to clean it. It was, however, recognised by several witnesses who gave evidence before this Commission, that sewers when properly constructed ought to require no such artificial relief. They ought to flush themselves continually, and this plan has been adopted in a considerable number of towns, especially in such as have pipe-sewers placed at a sufficiently good inclination.

Collection of rain-water.

Sewers should flush themselves.

At Bristol the main sewer "is not ventilated or flushed, and is stated to require neither one nor the other, as there is no deposit in it, and never any accumulation of foul gases:" and here we may anticipate a little, and say that foul gases are not formed to any great extent in sewers where no accumulation of filth takes place; it is by the fermentation going on in a semi-solid deposit of filth at the bottom of a sewer that foul gases are generated, and where flushing is adequately performed so that no deposit accumulates, the sewers will be found to require very little ventilation. At Leicester "the sewers are flushed at their two highest points from a thousand-gallon

No deposit; no foul gases.

Various methods of flushing.

tank filled by a hydrant with the water company's water. . . . Without great care in flushing, the sewers are apt to get a deposit of silt." At Cardiff the flushing is performed "by the surplus water from a channel which feeds the docks. . . . For parts where this is not available, a special flushing reservoir is constructed." At Salisbury, with the pipe system, there are flushing wells constructed at the corners of the streets, from which the pipes are flushed through hydrants when needed. "The sewers, after ten years' experience, are found to act well, and to have no deposit but what is easily got rid of by flushing regularly once a fortnight, with extra attention to some sewers that are nearly on a level." At Penzance and Chelmsford the pipe-sewers are rarely flushed, but do not choke or silt up. At Rugby, where the sewers frequently got choked up when the gradient was small, the establishment of flushing chambers to clean such parts has obviated all inconvenience on this head. At Alnwick the pipe-sewers are *flushed once a day*, the contents being removed so rapidly that at night the outfall chiefly consists of water from the waste of the houses and the interception of springs by the sewers. (*Ninth Report M.O.P.C*) At other places, as at Garston, Accrington, &c., watercourses can be turned through them where the fall is bad, or arrangements are made for flushing them by hydrants from the mains at certain intervals.

Deposit effectually prevented, even where insufficient incline.

Streams sometimes used.

With the "separate" system of sewerage, the pipe-sewers might be made to communicate at certain intervals with the rain-water drains, and might be flushed when they required it, by letting water from these latter run into them.

By communication with drains.

It is certain, however, that with well-laid pipe-sewers the flushing caused by the amount of water-closet and house slops will generally suffice to keep them free from deposit.

Dr. Trench, in his evidence before the Rivers' Pollution Commissioners (1868), after pointing out that "in a well-drained midden, not only do the whole fluids reach the sewers, but it may be also asserted that in rainy weather much of the solid matter will be also carried away in a moist and disintegrated state," adds :—

> "Now the difference between the water-closet and the privy is, that in the former the flow of water is so regulated as at once to take the sewage along the private or house drain into the main sewer, from which, as has been proved by experiment, it will reach the river in 60 minutes from the most distant parts of the borough (Liverpool); while in the latter, or privy-drain, no such impetus is given by water as a moving power, and the sewage dribbles into, stagnates, and decomposes in the drain before it reaches the main sewer. Indeed, so perfect is the daily flushing power of what are termed the trough water-closets in courts, that never now we perceive those emanations from the grids at the entrance of courts, which were common during the period of court privies." (*First Report*, vol. ii. p. 303.)

Importance of water-closet to sewer.

With pipe-sewers where the incline is good, as at Brynmawr, where it is stated to be 1 in 30, no flushing whatever is required. The towns examined by the Rivers' Pollution Commissioners show the truth of this statement very forcibly. Wherever there is a good gradient, as at Hurst, Mossley, Toxteth Park, and in most of the main sewers of Manchester, Bolton, and other places, no flushing is required. At other towns, some kind of waste water, as that of a pond or brook, or even of a swimming-bath (Monks Coppenhall), is employed for this purpose. In some the sewers are only flushed by storm-water, while in a

Conclusions.

No flushing required where the gradient is good.

great many instances arrangements are made for flushing them from the mains, either by means of flushing reservoirs, or merely by pipes or hose through the gulleys. Where sewers do require flushing, it is plain that it will not do to trust merely to the rain-water for this purpose. It is during the summer months when there is least rain, and therefore a smaller body of water passing down the drain-sewers of such towns as London, that the great accumulation of filth takes place in them, and it is precisely during the same summer months that these dangerous accumulations are most dangerous, on account of the decompositions which are set up in them and greatly facilitated by the heat of the weather; and so in the case of sewers which do not sufficiently flush themselves because they cannot have a sufficient gradient, it is absolutely necessary that they should be regularly flushed by artificial means.

Not trust to rain-water.

Flushing necessary when gradient is small.

VENTILATION OF SEWERS.

Wherever there is the least chance of any stagnation of sewage taking place, the same changes occur in it as in the case of cesspools, and offensive gases are given forth in large quantity from the decomposing mass. That these gases are of the same nature as those found in cesspools was insisted on by Parent Duchatelet; and with regard to ventilators he says: "Of everything which belongs to the construction of sewers . . . . . there is nothing so important as eye-holes (*regards*)," and he suggests that the sewers should be ventilated by means of a large pipe, such as has been described in the case of the "*fosses per-*

Importance of ventilation.

manentes," because that has been found to be the best way of ventilating these latter. But he recommends, at the same time, that open gratings be placed in the streets at regular intervals, communicating with the sewers. In Southampton, gratings in the road gave off such offensive effluvia that the inhabitants of the neighbouring houses stopped them up with pieces of wood, the result being that the gases forced themselves up through the imperfect traps into the houses.

Rendered less necessary by flushing,

In many towns there is no pretence made of ventilating the sewers, and it is certain that smooth pipe-sewers, regularly flushed, are not likely to require much ventilation. It is only where accumulation takes place in the sewers that gases are formed in any quantity. Dr. Neil Arnott says (*First Report H. of T. C.* vol. i. p. 66) that "flushing, in defective drains, would lessen the quantity of impure air produced in them, but would not free the town from the amount which is unavoidable." At Alnwick, where no special ventilating shafts and no means of causing a draft of air are provided, but where the sewers are flushed *daily*, it is found that no effluvia arise from them, scarcely any even when the man-holes are opened; and that there is no evidence of deficient ventilation of the pipes, or escape of sewage gases into houses. It is certainly, however, not safe to leave the sewers without any proper means of ventilation, as, if by any chance the sewage gets backed up in them, gases accumulate and are forced into the streets and houses through the only available openings, the street gulley-holes and house-drains. This took place, for instance, at Worthing, where, after the dry summer and during the very wet autumn of 1865, the sewage filled the

but not safe to have no ventilators

well into which it is received, and backed up the sewers, driving the foul gas up through the traps of sinks and water-closets. Since that time, however, the sewers have been amply ventilated.

Untrapped street gulleys, The simple method of leaving the street gulleys untrapped, and with an open iron grid, has been and still is too frequently employed. The effect of it is, that the offensive gases are thrown out freely into the streets; and every one will agree with Dr. Neil Arnott when he says, "it is often possible for a person walking in the street in the dark, or with the eyes covered, to tell when he approaches the open grating of a drain by the offensive smell issuing from it." The conclusion is, then, that on account of the nuisance, apart from the question of health, all entrances in the sewers on the street level should be efficiently trapped, and that some other exit should be given for the foul gases. A very common plan is to leave the rain-water pipes, which enter the sewers, untrapped. The objection to this method is, that these pipes are not generally well jointed; but a still greater objection is, that whenever there is a considerable rainfall, the escape of sewer air by these pipes is prevented by the presence of the water coming down them, and so it is driven up into the houses.

or rain-water pipes.

Then we have improvements upon these two methods. Many towns, especially in the North of England, have their sewers ventilated by openings at the level of the street communicating with the man-hole shafts, or with special ventilating shafts passing down by the side of them. But the gases, in order to escape, are obliged to pass through a filter of charcoal. Mr. Thorburn, C.E.,

Special shafts: charcoal trays.

states, in a paper read before the Liverpool Polytechnic Society, that at Birkenhead—

"Each shaft is provided with a galvanised iron-wire basket of a quarter mesh, ten inches square, filled with small wood charcoal for a width of six inches, fixed in a short horizontal gallery, between the opening through the crown of the sewer and the up-cast shaft, terminating at the surface of the street, in a position so as to protect the charcoal from being saturated with the rain-water falling through the surface cast-iron grating fixed on the top of the shaft level with the street. The man-hole entrances are found to act as down-cast shafts, thereby facilitating the draught of gas through the charcoal filter fixed in the ventilating or up-cast shafts very much on the principle of syphon ventilation. These ventilators are found to answer their purpose effectually, and very little, if any, trace of deleterious gas or unpleasant smell is perceptible at the grating in the street. It is estimated that about 90 per cent. of sulphuretted hydrogen or other gaseous emanations from the sewers is intercepted in passing through the charcoal filter."

Birkenhead plan.

Acts well.

The cost of these ventilators is from 16*s.*, or 18*s.* for the smaller ones adapted to court and passage sewers, to £1 8*s.* 3*d.*, the price of the ordinary single ventilator placed on the line of brick sewers. A double ventilator, having a ventilating shaft on each side of the man-hole shaft, and suitable "when two lines of sewers run in opposite directions," costs £2 12*s.* Wood charcoal is found to answer the purpose best, and will be found not to require renewing for a long space of time; "in some cases it has been in constant use for upwards of four years." It is certainly, however, advisable to have it changed much more frequently than this: "it should not be left more than six months without being changed." It is very easy to replace the older filter by a new one, and the charcoal, when burnt, will do again. This system is also in use at Atherton, Denton, Staleybridge, Rochdale, Leaming-

Cost.

Charcoal changed regularly.

ton, and other places, and has been found to succeed very well. Instead of the rain-water pipes, in some cases special pipes passing up to a considerable height above the roofs of the houses have been employed. At Penzance, for instance, "the sewers are ventilated near the outfall by a special pipe to prevent back pressure of air by the tides; and elsewhere by iron pipes carried to the chimney-tops of the highest houses at the highest parts of the town. Rain spouts, so far as connected with the pipe-sewers, are trapped." At Ely the connections with the pipe-sewers "are trapped at every inlet, including the rain spouts, and have only a single ventilating opening by a shaft at their highest point. . . . . Sewer air really does rise in this shaft, though there is no means of artificially making a draught up it." (*Ninth Report M. O. P. C.* pp. 147, 162.) Mr. James Simpson says, in his evidence given in the East London Water Bills Report, that there is great difficulty in ventilating sewers and subways; that putting up plenty of shafts will not do, for the foul air remains in and you cannot move it. The difficulty is to make the draught, and it's not a shaft stuck up that will cause motion. These special pipes should in all cases rise up considerably above the level of the highest buildings in the neighbourhood, and their action is rendered much more certain by furnishing them, as in Liverpool, with Archimedian screw pumps, which are kept constantly in motion by the air. At the town just mentioned there are nearly 1,200 of these at work, and the number is constantly being increased. We may observe of this plan, that it still throws out the effluvia into the air of the town, although the higher level at which it does so affords a greater

Special ventilating pipes.

Difficulties.

Archimedian screw.

chance of the gases being blown away, but that is no reason why these pipes should not be provided with charcoal filters, which would render their working far more efficacious. In his evidence before the Health of Towns Commissioners (*First Report,* vol. i. p. 63), Dr. Neil Arnott says "the drains must be shut up or trapped, and escape allowed for their impure air by lofty chimneys, in which it may be heated and partly burnt;" and he considers that when so treated the gases would rise to a considerable height, diffuse themselves through the air, and "not descend again within a moderate distance." But this procedure cannot be recommended, on account of its danger. Mr. James Simpson informs us that such pipes were made in the borough of Southwark, connecting the sewers with the furnaces of the soap-works, the result being that "an explosion took place that blew all the furnace down;" but, even where explosions have not taken place, another difficulty arises with this method, that, in the case of furnace chimneys, the draught is so great as to open all the traps connected with the house-drains in the neighbourhood; "and when out of work such inlets form outlets for the gases generated in the sewers, and therefore at such times disperse the sewer gases into the air of the streets and dwellings of the inhabitants of the district; or, in other words, such a system is violent, local, and intermittent in its application." (Mr. Thorburn, *loc. cit.*) When house flues are used as ventilators, there is a considerable risk of the entrance of sewer gases into the houses themselves. On the whole, then, the evidence would seem to show that the best plan is to have special pipes, rising high above the roofs of the houses, each provided with an

High chimneys.

Danger of explosion.

Too great draught.

Best method.

Archimedian screw at the top, and a charcoal filter at the base. The upward draught may, too, in many cases be assisted by carrying such pipes along the sides of chimneys, as is done in Paris.

Advantage of "separate" system.

A great advantage claimed for the "separate" system of sewerage is, that the sewers, properly so called, need have no opening, trapped or untrapped, at the street level, as the gulley holes only communicate with the drains; while with the drain-sewers this is necessarily the case.

COST OF SEWERS.

As examples of the cost of sewerage works we extract the following from the evidence procured by the Rivers' Pollution Commissioners (*First Report*, 1868, vol. ii. p. 55, &c.) :—

Manchester sewerage.

At Manchester—where "efficient sewerage works have been carried out in all the streets within the city," the main outfall sewers being principally constructed of brickwork, and the smaller ones of glazed earthenware oval pipes, "the size of the brick sewers varying from 6 feet by 3 feet, to 3 feet by 2 feet; and the pipe sewers from 25 inches by 18 inches, to 12 inches by 9 inches," and there being altogether 63 main sewers of various lengths, making a sum total of 280 miles—the cost has been about £340,000. There is, however, here no special mode of ventilation provided, and no flushing apparatus required. At Blackburn—where "one outlet comprises a main sewer 6 feet by 4 feet, egg-shaped, with tributary main sewers from 4 feet 10 inches by 2 feet 8 inches, egg-shaped, to 2 feet diameter, all of brick, and pipe-sewers from 21 inches to 9 inches diameter; total length of main sewers

Blackburn: brick and pipe.

32 miles; subsidiary mains in back roads from 9 inches to 15 inches diameter, 19 miles"—the cost has been about £90,000. The ventilation here is by spouts from houses, by special shafts opening at the surface of the streets and provided with charcoal ventilators, and by connection with three factory chimneys. No flushing is required, the fall of the sewers being considerable. At Preston, "$16\frac{1}{4}$ miles of stoneware pipes and $8\frac{3}{4}$ miles of brick sewers cost £50,000. Also 30 miles of stoneware pipe-sewers, in streets paid for by owners, cost £9,000." At Gorton, "the sewerage works comprise— Pipe sewers.

1,408	yards of	36-inch	brick	sewers.
1,520	„	30 „		„
980	„	24 „		„
1,165	„	18 by 27 „		„
2,634	„	15 „	pipe-sewers.	
880	„	12 „		„
1,349	„	9 „		„
3,705	„	6 „		„

together with gulleys, traps, man-holes, and lamp-holes, at a total cost of £9,579 11*s.* 9*d.*"

The above instances taken at random will give a better idea of the cost of constructing sewers than would be given by a list of the details of the cost of materials, work, and so forth. It may be noted as a general rule, that egg-shaped brick sewers, half a brick thick, are cheaper than pipe-sewers, when the size is greater than 2 feet by 18 inches; but when less than this size, pipe-sewers are cheaper.

"Separate system" expense.

A great outcry has been raised against the "separate" system on account of its expense. That it is more expensive to build two sets of sewers than one, when we require the drains to be deep enough to drain the subsoil and large enough to carry off storm-waters, is plain enough; but that it is cheaper to make existing drain-sewers do their work properly (as far as this is possible) than to leave them to act as drains only, and to build a separate set of small pipe-sewers for the house drainage, we cannot admit.

"Two opinions."

And when we consider the danger that arises from the drain-sewers overflowing during heavy storms, flooding streets and cellars with diluted sewage, and forcing sewer gases up into houses, and on the other hand the impossibility at such times of any pretence at utilising the sewage, which must then inevitably be allowed to get to the rivers as best it can, and even the difficulty of dealing with it when only diluted with the ordinary rainfall and subsoil water, we must agree with Dr. Rolleston, who says in his article "Sewage and Sewerage" (*Quarterly Journal of Science*, April 1866), that the question of the separation of sewers from drains "does admit of two opinions being held about it;" but we must go farther than this, as we have good reason to believe that he has since done, and, looking at the great size of the outfall works and channels necessitated by the enormous volume of the diluted sewage, and the special disadvantages and extra expenses where irrigation is resorted to (and to which we shall refer again), we are driven to the conclusion that it would be *a very great saving* in the long run to a town to send its rain and subsoil water at once by deep drains into the nearest watercourse, and to construct special pipe-sewers of very moderate dimensions to carry the house refuse away from the town to outfall works, there to be utilised in some way or other.

Great saving in the long run.

CHAPTER VII.

SANITARY ASPECTS OF THE WATER-CARRIAGE SYSTEM.

WE have already given ample evidence to show that the prevalence of sickness in general, and of fevers (especially typhoid) in particular, accompanies the non-removal of excreta and other refuse matters from the neighbourhood of dwelling-houses: it now remains for us to see whether any definite amelioration in this respect has taken place since a more efficient removal of such refuse matters has been provided for a great many towns by considerable improvements in the drains and sewers, and by the more general introduction of water-closets; and, if so, in what this amelioration consists. Happily, plenty of information is afforded us on this head by Dr. Buchanan's researches on the "results which have hitherto been gained in various parts of England by works and regulations designed to promote the public health." (*Ninth Report of the Medical Officer of the Privy Council.*) In twenty-five towns where such works have been carried on, and many of which have been already referred to several times in these pages, in almost every case the general death-rate has been

Has efficient sewerage been a sanitary benefit?

General death-rate lowered.

lowered, and in many cases considerably so. At Cardiff, for instance, it has been reduced from 332 to 226 per 10,000, equivalent to a reduction of 32 per cent. (or, allowing for cholera, of 24 per cent.). At Newport (in Monmouthshire) the reduction has been from 318 to 216, equivalent to 32 per cent. (or, allowing for cholera and dysentery, to 23 per cent.), and in each of these cases the reduction has taken place under each separate head of disease, with the single exception of scarlatina, which has increased 90 per cent. at Cardiff and 18 per cent. at Newport.

Influence on mortality of children.

The mortality of children under one year has been also remarkably lowered in these two places to the extent of 22 per cent. at Cardiff and 21 per cent. at Newport. At Merthyr Tydfil, too, the total reduction has been from 332 to 262, that is, 21 per cent. (or, allowing for cholera, 12½ per cent.) Here the reduction in the case of children under one year old has been 24 per cent., although the deaths from lung-disease in infants have increased 16 per cent. Scarlatina, too, shows an increased mortality of 60 per cent. It will be noted that at each of the above places there has been thorough sewerage by

Large drain-sewers.

large sewers, besides improvements in other ways, especially in the substitution of water-closets for privies, and in the supply of better water. At Macclesfield, where pipe-sewers have been added to the old system, the midden system having been retained, but "reduced to its minimum of offensiveness," the reduction in the total of deaths has been

"Separate" system.

20 per cent.; that of infants under a year old 23 per cent., although the deaths from lung diseases have increased 14 per cent.; and scarlatina—unlike

the preceding cases—has decreased 45 per cent. At Croydon, where the general mortality has decreased 20 per cent., the mortality of infants under one year old has increased 10 per cent. It is said of this that the altered circumstances of the town have brought about a largely increased birth-rate. The general result is, that "of special influence, either in amount or kind, exerted by sanitary works upon children under one year of age, different from that exerted upon the total population, no evidence whatever has been obtained." (*Loc. cit.* p. 42.) **No *special* influence on child-mortality in any case.**

Under the heading of *measles* we find that its mortality has been in many cases considerably diminished, as at Bristol, Leicester, Croydon, Penzance, Ely, and other places. Elsewhere, however, it has in several instances considerably increased, as at Cheltenham, Dover, Warwick, Banbury, and Stratford-on-Avon. This may be in some cases accounted for by the increased density of the population: "the introduction of better drinking-water has not perceptibly affected the prevalence of measles" (p. 43). Of *whooping-cough*, and also of *scarlatina*, much the same must be said, "though, if South Wales be excluded, which has latterly been swept by a scarlatina epidemic that no sanitary influence has been able to resist, there does appear some probable connection between reduced prevalence of scarlatina and diminished crowding in houses;" although the fevers above mentioned have been more prevalent in some towns since the sanitary improvements have been made, they have been less so in others, and in fact they do not appear to be in any way connected with sewerage arrangements. The number of deaths **Measles, whooping-cough, and scarlatina, not connected with sewerage arrangements at all.**

Croup and diphtheria higher mortality.

Typhoid fever: enormous reduction in mortality.

from *croup* and *diphtheria* have in almost all the towns increased during or after the completion of their sanitary works, and in many cases diphtheria would seem to have appeared during these alterations and to have increased after them; thus, at Banbury, the mortality during the execution of the drainage and sewerage works rose from 0 to $0\frac{1}{3}$.[1] During eight years after the completion of these works it was $1\frac{3}{4}$. At Chelmsford, diphtheria only appeared after the execution of the works, and reached a mortality of $6\frac{1}{3}$. At Ely the same was the case—the mortality reached $3\frac{2}{3}$; and at Dover a mortality of $3\frac{1}{2}$ marks nine years after the execution of the sanitary works; "what might be anticipated from the free communication of the town with places in France where diphtheria prevailed early and severely." Newport is indeed the only place in which this disease, although appearing for the first time during the works, decreased considerably after their completion. Here croup remained almost unchanged in its death-rate.

But it is especially in the case of *typhoid fever* that important results have been obtained from the sanitary improvements. At no less than nine towns the diminution in the number of deaths has exceeded one-half, reaching at Salisbury 75 per cent. At ten towns the reduction has been between one-third and one-half; Bristol, with a reduction of 33 per cent., being at the bottom of this list. At Rugby the reduction has been 10 per cent.; at Carlisle only 2 per cent.; but at the former place the water supply until lately has not been good, and the sewers have only been flushed since 1863, before which it is

[1] Per 10,000 of the population.

stated that they "frequently got choked and had to be opened, poked clear with rods, and then washed out" (p. 168); and at Carlisle it is stated that "away from business quarters of the town, and yet not in the suburbs, there remain a number of courts and yards which are full of nuisances, and keep up the memory of what the whole town was in 1849" (p. 108). But it must be mentioned that at Chelmsford and Penzance there has been a slight increase (5 and 6 per cent. respectively) in the death-rate of typhoid fever; while at Worthing there has been an increase of no less than 23 per cent. At Chelmsford, however, "the sewage is delivered into a tank by an outfall sewer which enters some six feet below ground" (p. 45): the result is, that although the opening can be covered with a sluice, and although a storm-water overflow is provided, it is a fact that when the engine is not at work or the liquid accumulates in the well, cellars get flooded by the sewage, and doubtless sewer gases get forced up into houses. With regard to Worthing, we have already remarked on the absence of any provision for ventilation, and on the fact that sewer gases had been forced up into houses through the traps of sinks and water-closets. That this was the cause of the outbreak of fever in 1865 "appears to reach positive demonstration when it is added that the fever almost exclusively attacked well-to-do houses on the higher levels, where the water-closets were inside the houses, and almost entirely spared the houses, mostly of a much poorer sort, situated on lower levels, where the closet was placed outside the house. It was not so in the times of cesspools; then, these low-lying poor houses were far more attacked with fever than the

Causes preventing reduction in some places.

Cases of increased mortality of typhoid fever.

Want of proper ventilation of sewers.

others. Moreover the fever subsided, as soon as openings were made into the sewers, from certain houses where it before maintained itself for months" (p. 45). It must especially be noted that in Rugby, Carlisle, Chelmsford, and Worthing, the "sewage is received into pumping works at the outfall in such a way that sewer gases are necessarily much confined in the pipes" (p. 45). In Leicester, too, the sewage, properly so called, is received in a pumping tank; but then Leicester has a separate system of storm sewers, so that there is much less chance of the liquid being backed up by the accumulation in the well.

Evil due to outfall being low down in tanks.

In Morpeth, where the outfall of the sewer is not into a tank, but where, in many places, the pipe-sewers themselves are below the level of the river, "it happens that in times of flood the sewage is backed up the main sewer for four to five hundred yards" (p. 200). It appears that "occasional outbreaks of typhoid had followed times of flood when the outfall sewer had been under water" (p. 46).

Typhoid from backing up of sewage.

"Many of the public improvements have coincided with reduction of typhoid. . . . It is, however, the purification of atmosphere from decomposing organic matters, that has been most uniformly followed by a fall in the prevalence of typhoid. And this has occurred equally whether the purification has been brought about by the abolition of cesspools or by draining and drying 'middens'" (p. 44.)

Chief cause of decrease.

The mortality from *diarrhœa* has been greatly reduced in many towns where sanitary improvements have been effected, but this reduction is by no means so universal as in the case of typhoid fever, the mortality having in many cases considerably increased.

Diarrhœa: various results.

"*Cholera epidemics* appear to have been rendered practically harmless in the towns examined" (p. 47). As instances of this we may cite the cases of Merthyr Tydfil, where a death-rate of 267 in 10,000 during the epidemic of 1848-49 was reduced in 1866 to 20 by improvements in the sanitary condition of the town, consisting of "imperfect but extensive nuisance removal and public cleansing . . . . by the regulation of common lodging-houses, and, since 1859, by a spontaneous reduction of crowding; since 1861 by the introduction of ample good water, and by the services of an officer of health" (p. 83). Alnwick, with a mortality of 205 in the epidemic of 1849, did not suffer at all in 1854 or 1866. Salisbury, from a mortality of 180, descended to one of 14½, while in 1866 it was untouched. There is *no exception* to this reduction. The case of Ely, of which it is said that "cholera, which had caused scattered deaths only before 1853, produced in that year and 1854 a small epidemic mortality; in 1866 two deaths only from cholera were registered" (p. 166), not being at all an exception, for the small epidemic in 1853-54 which occurred there was just at the very commencement of the sanitary works, and before the houses were connected with the new sewers.

Cholera rendered harmless.

Several instances.

No real exception.

But perhaps the most important result of these researches of Dr. Buchanan is the demonstration of one, at any rate, of the conditions most favourable to the prevalence of *phthisis*; a condition, too, which can in most cases be very easily removed. We were prepared to find that the mortality from cholera and from typhoid fever, and also that the general death-rate, would be diminished by these sanitary improve-

Reduction in death-rate of phthisis.

due to drying of subsoil by main-drainage.

ments; but, as Mr. Simon says in his Report, we were "not in any degree prepared" for "the novel and most important conclusion . . . . . that *the drying of soil which has in most cases accompanied the laying of main sewers in the improved towns has led to the diminution, more or less considerable, of phthisis*" (p. 16). It appears that in such towns as Salisbury, Ely, Rugby, Banbury, and so forth, where, as we have already seen, the drying of the subsoil has been considerable, the deaths from consumption have been reduced by a third or a half of their number. In Leicester, during the time the sewerage works were in progress, and for a short time after, when there was a great reduction in the subsoil water, the death-rate of phthisis "had subsided by 41 per cent. of its previous amount at all ages, and by 32 per cent. in the death-rate of females at the middle age of life. . . . . Since the completion of the works, there is reason to believe that water has risen again in the subsoil, while the phthisis death-rate has somewhat risen also, but still remains much below its original amount" (p. 49). In the towns, on the other hand, where the drying of the subsoil has been inconsiderable, or has not taken place at all, "phthisis has been stationary, or has even increased." In some cases, as at Penzance and Brynmawr, this is due to the fact that the soil already contained little water, and so happened not to require draining; but such cases plainly form no exception to the rule. This drying of the subsoil has, we have already seen, only been effected in towns which have large sewers, or deep storm culverts in addition to the pipe system, that is to say, "which have had special arrangements

Fluctuations in subsoil water and in phthisis death-rate.

Decrease only where subsoil specially dried.

made for drying their subsoil, as Salisbury;" and that on the other hand, where pipe-sewers have been constructed with only superficial culverts for the storm-water, or even without these, no drying has taken place. It is precisely in these towns—as Stafford, Morpeth, Ashby, Alnwick, and so forth, which have not had a special arrangement for drying the subsoil, while provided with impervious pipe-sewers—that the death-rate from consumption has not improved, or has even increased. It must also be especially noticed that many of these last-named towns "have achieved the greatest possible progress in the removal of their filth." At Worthing and Rugby, where the pipe system is carried out, although no special arrangements were made for carrying off the subsoil water, it would appear that a great deal of it gets away—in the case of Rugby by means of the old sewers which are still left, and, in the case of Worthing, along the sides of the pipe-sewers; and this would account for the considerable reduction in the mortality, under this head, of these towns. Carlisle and Chelmsford, on the other hand, have not received any benefit from the reduction of the amount of their subsoil water, because local conditions have nullified this effect. The environs of Chelmsford still get flooded through the action of a mill-dam, and one part of Carlisle is "so low that the subsoil is water-logged at all times, and, in flood, is practically under water" (p. 107). *Lung diseases* (other than consumption) would appear to have undergone no regular reduction in amount in the several towns. In some cases their mortality has increased, especially among old people, "who, it may well be believed, having had their lives prolonged by the subsidence of

Where *only* impervious pipe-sewers, no decrease in phthisis;

except where accidental draining of subsoil.

No benefit where subsoil gets water-logged.

Other lung diseases often greater mortality: reasons.

other causes of death, died afterwards from the lung disorders incident to old age" (p. 50). We cannot refrain from quoting the last sentence of Dr. Buchanan's Summary Report, which expresses the opinion of all who have seen anything of the results of sanitary improvements. "The progress made by the inhabitants of most of the twenty-five towns, in decency, cleanliness, self-respect, and morality, was at the least as striking as the improvement in their health, measured by the mortality returns." These researches show, in the most conclusive manner, that the removal of filth from a town, at once and in the most expeditious manner, is the way to decrease general death-rate, and the death-rates especially of cholera and typhoid fever, and they show also that the introduction of the water-closet system has effected most wonderful changes in these respects; thus proving to demonstration that the prevalence of the diseases above mentioned, which we have before shown to have been co-existent with accumulations of filth, was not merely co-existent with them, but due to them, or at any rate fostered by them; and they have shown that besides this, wherever the sewers have been also subsoil drains, or where special arrangements have been made for drying the subsoil, the death-rate of phthisis has wonderfully diminished. We must therefore conclude that—since most authorities, Parent Duchatelet included, agree that the channels for the removal of excretal refuse should be impervious, and should, where practicable, be merely glazed stoneware pipes—it is absolutely necessary that at the same time there should be a special system of *deep* rain-water culverts to ensure the drying of the surface and of the subsoil.

Improvements in other particulars.

Cholera and typhoid fever can be prevented.

Even phthisis is controllable.

Necessity of "separate" system.

When sewers do not properly perform their duty in removing expeditiously the refuse matter, but from bad construction or from want of flushing are allowed to become partially filled with foul matters which putrefy and give off noxious gases, and when, further, from faulty ventilating apparatus, as, for instance, untrapped gulley-holes, these gases are allowed to escape into the air of the town, all the results of want of removal of excrement may be expected.

Results of bad construction;

Thus, with the system of trusting to the rainfall to flush the sewers, it is found that after heavy storms the sewage, so far from being weaker, is, especially when it comes through badly constructed sewers, very many times stronger than it is ordinarily, and this is simply because it has stirred up and washed away the deposit of filth which has been accumulating.

of flushing only by rainfall.

Dr. Acland has shown us, in his account of the cholera at Oxford, that the virulent epidemics of it are preceded by droughts, remarkable droughts, making the total rainfall of cholera years sometimes as much as 10 inches less than the annual average, and we cannot fail to see the connection of this fact with the greater accumulation of filth that takes place in the drain-sewers under such circumstances.

The outbreak of cholera in the City of London Union Workhouse, in July 1866, the causes of which were investigated by Mr. Radcliffe (Ninth Report of Medical Officer of the Privy Council), was shown to have taken place, in all probability, from a sudden efflux "of sewer air from a drain containing choleraic evacuations," which efflux was favoured, if not caused, by rapid and considerable changes in temperature and barometric pressure. (*Loc. cit.* p. 316.)

Cholera communicated by sewer air.

Drinking water contaminated from bad water-closet pipe.

At Theydon Bois, in Essex, an outbreak was caused in 1865, in the following way:—A man and his wife came home from Southampton, where cholera had appeared eight days before.

"Both used a water-closet on the first floor, between the soil-pipe of which and the well supplying the house with drinking-water, there was (as subsequently discovered) free communication. The water tainted with the diarrhœal discharges was used by the family and the man and boy mentioned, for five full days, during and subsequent to which several of the members were attacked with malignant cholera." (*Ninth Report M. O. P. C.* p. 304.)

Fatal results.

Three persons not using the water, but who had been in communication with the sick, were also attacked. "Of the twelve cases, nine ended fatally, including the head of the family and his wife."

Many similar cases might be given, both with regard to cholera and typhoid fever, but enough has been said to convince us of the truth of Dr. Duncan's remark, that "the prevalence of fever and the rate of mortality proceed inversely as the efficiency of sewerage." (*First Report H. of T. C.* 1844, vol. i. p. 152.)

Water system a great benefit.

The general introduction of the water-carriage system has therefore been a great sanitary benefit, and wherever it has worked badly it is owing to most flagrant mismanagement or want of reasonable precaution.

The great charge brought against it is that of carefully connecting every part of the town, the streets, and even the interior of houses, with a series of filthy underground channels in which foul gases accumulate, and rising to the highest parts escape and pollute the atmosphere. That proper flushing will easily prevent the formation of any great quantity of these gases, we have instances enough to show, and that they may be removed inoffensively by ventilating shafts when they do accumulate, is also certain; but that by careful avoidance of flushing sewers of low gradient which require it, and thereby favouring the deposition of filth, and by neglecting to provide any ventilating shafts, sewer gases may be manufactured in large quantities, and driven effectually into the streets and even into the interior of houses, is an undoubted fact and requires no demonstration. Nay, more than this, apparatus excellent in idea up to a certain point may be so cunningly devised as to act well for a time and under ordinary circumstances, and yet, just when its services are most wanted, to fail in the most abject manner and with the most disastrous consequences, simply because it has been expected to perform two perfectly incompatible functions.

Flushing and ventilation of sewers necessary.

At Croydon the descent-pipes from the water-closets were ventilated by a pipe which passed upwards from them (below the soil-pan and syphon) towards the roof—an excellent plan; but this pipe, instead of rising above the roof and ending in the air, was made *to end near the upper part of the rain-water cistern, and to act as its waste-pipe!* And what was the result? Dr. Alfred Carpenter describes it thus (see *Ninth Report of Medical Officer of Privy Council*, p. 104):—

Ventilating-pipe connected with rain-water cistern.

"On the night of October 17th I was aroused by a loud noise proceeding from the closet; it continued at intervals throughout the next day. Unable at first to account for it, I eventually found that it was caused by the ventilating-pipe doing duty as waste-pipe to the overflowing cistern (during a very heavy rain-fall). There was no room for exit of foul air from the sewer, which, therefore, was forced through the trap of the water-closet, with, at times, the force of steam through the safety-

Sewer air forced into houses.

valve of a steam-engine. The nuisance continued for nearly three days, before the weather would allow the plumber to rectify a mistake which had been committed in the previous summer, the mistake of making the ventilating-pipe do duty for a waste-pipe. The escaped air did not smell offensively, a faint odour alone being recognized; it was therefore thoughtlessly tolerated: the excessive rainfall also prevented much ventilation of the house by open windows. Two or three days afterwards, one of the occupants of a room, the farthest in the house from the closet, fell ill with symptoms of typhoid fever, and in a few days the other person sleeping in that room also showed signs of the disease; no other person in the house suffered from it. Into the room occupied by these two persons the foul air from the closet, as proved by experiment, naturally ascended. Simultaneously with the origin of these cases appeared many others in various parts of the town, and in every case in my own practice in which enteric or typhoid fever occurred, I distinctly traced local causes for the disease in some defective housework. It generally happened that the smell was not enough to lead to the discovery of the defect, a faint odour alone being perceived."

Not offensive.

Typhoid fever appeared.

Always local defects.

It would be difficult to imagine a more ingenious method for delivering sewer gases at high pressure into houses than the one above described, and it succeeded only too well.

But such mistakes occurring simply through want of forethought do not in any way show the incapacity of the water system of removal. That a certain builder chose to ignore the fact that gases cannot freely rise up a pipe while water is rushing down it, and that ventilators are most wanted to be in an efficient state when the sewers are suddenly flooded with water and the gases consequently under considerable pressure; that he considered himself justified in saving a few feet of piping by the proceeding that he adopted; and that the results were most lamentable, are simply facts which show the necessity of educated sanitary inspec-

Mistakes.

tion. They have nothing whatever to do with the general question of refuse removal. Who would think of condemning the introduction of coal gas into houses because there are occasional instances of gas escaping from faulty stopcocks?

Not the fault of the system.

Coal gas is no doubt a very dangerous thing if proper precautions are not taken to ensure its being kept in its own place; but it is not merely its convenience and cleanliness that have caused it to be almost universally adopted in preference to oil lamps; it is a fact that the occurrence of accidents with it can be effectually prevented, and it is for this reason that it is always used in preference to oil lamps, where any danger is apprehended. It is not merely the great convenience of water-closets that has ensured their general adoption, but the thoroughgoing manner in which they remove excretal matters from the premises at once.

Coal gas really less dangerous than oil lamps.

Of the sanitary advantages of water-closets, and especially of the *trough-closet*, over middens and cesspools, Liverpool affords us a most instructive instance. Dr. Trench writes as follows:—

In 1868, "there raged a wide-spread epidemic of typhoid fever in the town, and in the rural districts in the vicinity of the town . . . . . While in the families of the rich in their costly suburban dwellings there was raging a fever, clearly and unmistakably due to the pestiferous emanations from ill-drained cesspools or other collections of filth or decomposing organic matter, the districts in the borough of Liverpool known as the fever districts, and wherein no middensteads or cesspools were allowed by the Council to remain unaltered, continued during the whole period of the epidemic remarkably healthy and free from fever." (*First Report R. P. C.*, 1868, vol ii. p. 307.)

Typhoid where cesspools in rich parts.

Not where trough water closets in poor neighbourhoods.

The experience at Birkenhead of the working of the

"Tumbler" closet works well.

tumbler-closet is equally satisfactory where it has been properly fitted up.

Mr. Thorburn the surveyor finds that as compared with the ordinary privy "the tumbler closet for sanitary purposes is undoubtedly the better of the two."

Wrong principle.

All other systems than that of removal by water go upon the principle that it is not dangerous to leave excretal matters, either in a crude state (pail closets) or mixed with some absorbing or deodorising material (various other forms of closet), for a certain time in or about houses. The fundamental principle being *obviously* a wrong one, it is not to be wondered at that such systems continually fail. When pails get over-filled, or slops are thrown down earth-closets, the results may be better imagined than described; and it has practically been found necessary to construct earth and ash closets so that the fluids may run away into the sewers, while the solids (comparatively worthless as they are) are carefully kept upon the premises, being partially rendered inoffensive by admixture with ashes or earth, or dried by a rotatory disc under the seat, or by some other contrivance.

Harmlessness of earth compost not shown.

"There is one evident objection to all these dry plans, viz. that the excreta are retained about our houses for some time. No doubt when mixed with earth they are inodorous, and it is presumed harmless; but of this no evidence has been given. What would be the result of cholera or typhoid discharges received in earth and allowed to remain in the house?" (Dr. Parkes: *Hygiene*, 3rd ed. p. 354.)

Correct principle.

The water-carriage system, on the contrary, sends all the refuse matters at once to a distance in the cheapest manner possible, by the mere action of gravity: this is plainly a safe principle to go upon, and that it acts in practice may be seen by any one who chooses to examine the fæcal matters in the sewage at the outfall of a town supplied with impervious pipe-sewers properly flushed; he will find them fresh and undecomposed.

The above considerations induce us to endorse the general opinion in this and other countries, that the "*cabinet anglais*" is in all essential particulars far superior to every other form, not even excepting the "*cabinet inodore.*"

Figures are stubborn things to deal with, and the sanitary benefits already obtained by this system are so astonishing, that we have a right to demand from those who would supplant it, proof of much better results realised by some other method, and not mere doubtful probabilities.

CHAPTER VIII.

VALUE OF SEWAGE.—INJURY TO RIVERS.

Average samples, how taken.

The composition of sewage varies so much, not only in different towns with the amount of water supply, but in the same town from day to day, and even from hour to hour, that in estimating the composition of any given sewage it is not only necessary to take samples of it at least once every hour for twenty-four hours, and to mix them in order to procure an average sample, but these various samples must also be mixed in direct proportion to the amount flowing as indicated by the gauging at each time of collection. It is plain that if a gallon of sewage, taken at a time when the liquid is running very low in the sewer, be mixed with another gallon taken at a time when the sewer is much fuller, the mixture does not represent the average composition of the sewage at the two times. A gallon of the one should not have been mixed with the same quantity of the other, but with a quantity proportional to the amount running through the sewer at the time. These considerations not having been borne in mind in the collection of samples for analysis, the results hitherto obtained must be received with a certain amount of caution; but still an average taken of accurate analyses made to ascertain the composition of the sewage of a great number of towns may be fairly taken as representing to all intents and purposes the composition of sewage. Such an average is given in the First Report of the Rivers' Pollution Commissioners (1868), where it is shown (vol. i. p. 29) that in water-closet towns 100,000 parts of sewage contain 72·2 of total solid matters in solution, in which there are 4·696 parts of organic carbon, 2·205 of organic nitrogen, 6·703 of ammonia, an almost inappreciable quantity of nitrogen as nitrates and nitrites, the total of combined nitrogen being 7·728 parts, and the chlorine 10·66. Besides these matters in solution, the 100,000 parts contain 44·69 of suspended matters, of which 24·18 are mineral and 20·51 organic. But it must be carefully borne in mind that this is an average, and that there are extremes. To take the total combined nitrogen as an example, it was found to vary, in the London sewage alone, from about 3 parts to more than 11 in the 100,000, while in all the samples examined its variation was from 2·371—the Norwood sewage, on February 25th, 1869 (which sewage, however, on March 12th contained 9·681 parts of combined nitrogen)—to 24·325 parts, the amount contained in the sewage of Woking prison on July 9th, 1869. These variations are not to be wondered at when not only the differences in the amount of water supply are taken into account, but the fact that in the drain-sewers of most towns the subsoil water, the ordinary rain water, and even the storm water, pass along with the sewage and dilute it. Sewage then, under these conditions, which is very strong at one time,

Average composition.

Great variations,

from various amount of rainfall, water supply, &c.

may become exceedingly diluted at another, and this is the great difficulty that has to be encountered in any attempt at the utilisation of town sewage.

Contents of sewage.

"Sewage is a very complex liquid; a large proportion of its most offensive matters is of course human excrement, discharged from water-closets and privies, and also urine thrown down gully-holes; but, mixed with this, there is the water from kitchens, containing vegetable, animal, and other refuse, and that from washhouses, containing soap and the animal matters from soiled linen. There is also the drainage from stables and cow-houses, and that from slaughter-houses, containing animal and vegetable offal. In cases where privies and cesspools are used instead of water-closets, or these are not connected with the sewers, there is still a large proportion of human refuse in the form of chamber-slops and urine. In fact, sewage cannot be looked upon as composed solely of human excrement diluted with water, but as water polluted with a vast variety of matters, some held in suspension, some in solution." (*First Report of Rivers' Pollution Commissioners*, 1868, vol. i. p. 13.)

Value of excreta.

The quantity of these matters and the value of their constituents as manure can be very easily determined, and we have already seen that the estimated value of the annual voidings of an average individual of the mixed population of all ages and both sexes, is 8*s.* 4*d.* if the amount of ammonia be considered to be 12½lbs.; but if we consider with Messrs. Lawes and Gilbert that this amount has been somewhat exaggerated, and that ten pounds of ammonia is a fair estimate of the average individual amount, the sum of 6*s.* 8*d.* would then represent the total annual value of average human excreta. This is the lowest value that has been assigned to it. If then the number of individuals in a town were known, and the amount of waste water turned into the sewers tolerably constant, as it would be were the rain-water excluded, the value per ton of the sewage varying inversely as the dilution, this value at any given place might be simply calculated from the number of inhabitants, and could be easily corrected by the results afforded by the analysis of an average sample collected in the manner above described. But the actual circumstances of the case and the extreme variety in the degrees of dilution of the liquid in drain-sewers must necessarily give very different degrees of value to the same sewage at different times, not to speak of the diurnal variations necessarily caused in all cases by the fact that the greatest part of the refuse matters is discharged into the sewers in the early part of the day, and comparatively little at night; so that the night sewage is in many towns little else than water.

Calculation from number of inhabitants impossible, from variability of dilution.

The chief valuable ingredients of sewage are, first, the different forms of combined nitrogen, and then, phosphoric acid and salts of potash. "The money value of these constituents *dissolved* in 100 tons of average sewage is about 15*s*., while the *suspended matters* contain only about 2*s*. worth of them." That is to say that 100 tons of average sewage are worth 17*s*., or about 2*d*. a ton. This value, given by the Rivers' Pollution Commissioners (*First Report*, vol. i. p. 52) is very nearly that assigned by Messrs. Hofmann and Witt, in their Report upon the subject. They found that sewage collected on the 13th of May, 1857, at various times, and mixed, contained 94·7 grains of solid matter in a gallon, of which 19 were in a state of suspension, and 75·7 in a state of solution; and on the 11th of June a mixture of samples contained 111 grains, of which 32·7 were in suspension and 78 in solution, and they found that six-sevenths of the valuable matters were in a

Value, 2*d*. a ton.

Composition.

state of solution, and only one-seventh in suspension. They considered that the average might be taken as 100 grains of solids per gallon (*i.e.*, per 70,000 grains), and that therefore 70,000 tons of sewage contained 100 tons of solid matter. Of total nitrogen they estimated 6·7 grains in a gallon, of phosphoric acid 1·8 grains, of potash 1 grain. Now, 100 tons of solid constituents contain eight tons of ammonia, and a ton of ammonia in the form of guano is taken as being worth £56 (a value which is now too low): the total value of the ammonia is thus found to be about £447; and employing the same process for the rest—that is, taking the commercial value of each of the constituents—the 100 tons of solid matters are found to be worth £601 3*s.* 6*d.*, or £6 0*s.* 3*d.* a ton: of these the dissolved matters are worth £5 5*s.*, and the suspended matters 15*s.* 3*d.* Since one ton of solid matter is contained in 700 of sewage, it follows that 100 tons of sewage are worth 17*s.* 7*d.*, or a little more than 2*d.* a ton. Messrs. Lawes and Gilbert, in their paper before quoted, have given a table in which the value per ton of the sewage is estimated at various degrees of dilution, and it is there shown that if the dilution of the dry weather sewage of London be taken, as indicated by recent gaugings, at about "24 gallons per head per day, equal to a rate of 40 tons per head per annum," the estimated value per ton of it is nearly 2½*d.*, if 12½lbs. be taken as the amount of ammonia per head per annum, and 2*d.* if that amount be taken as 10lb. These values decrease with increasing dilution until, when this amounts to 200 tons per head per annum (or 122¾ gallons per head per day), "the probable frequent dilution in wet weather, inclusive of

Quantity and value of constituents.

Dissolved matters far more valuable than suspended only.

Variation of value with dilution.

rainfall and subsoil water," the value is only a halfpenny a ton in the one case and two-fifths of a penny in the other.

In the Third Report of the Sewage of Towns Commissioners (1865), it is considered that 60 tons per head per annum is the average amount of normal, or dry weather sewage in the metropolis.

"It is further variously estimated that by subsoil water and rainfall, the bulk of the fluid will be increased by from two-thirds to an equal volume. Adopting the lower of these suppositions, which, if too low, will allow something for the occasional escape of storm-water, we have the 100 pence worth of constituents distributed through 100 tons of fluid, giving to it a value of one penny per ton according to the estimated market value of its manurial constituents." (*Loc. cit.* p. 42.) Lowest estimate.

If we take now the estimate of Baron Liebig and Mr. Ellis, that 266,000,000 tons is the total annual amount of dilute London sewage; we find that at one penny a ton its value is £1,108,333 6*s.* 8*d.* There can be little doubt that the average of 100 tons per head per annum is greater than the average dilution, so that this estimate is the lowest that can be formed. To take, on the other hand, the value of the excreta of each individual of the population as above given, it will appear that the sewage from 3,000,000 people ought to be worth just £1,000,000, if only 6*s.* 8*d.* be taken as the value of each person's excreta; but that the same quantity would be worth £1,250,000 if the higher value of 8*s.* 4*d.* be taken. The average sewage of the dilution above stated, namely, 100 tons per head per annum, is found to contain 3·91 grains of ammonia per gallon; that is to say, with about four grains of ammonia in the gallon, the sewage may be considered to be worth one penny per ton; or for

Value of excreta.

Rough way of estimating the value of sewage.

each grain of ammonia per gallon the sewage is worth a farthing per ton. We may remark in passing, that very much higher values than this have been assigned to the sewage of the metropolis. Thus, Messrs. Hofmann and Witt considered that the total amount of the metropolitan sewage not including rainfall was about 95,000,000 gallons a day, or about 158,000,000 tons per annum (as 224 gallons weigh a ton), and calculated that it was worth £1,385,540 a year; and they considered that the theoretical value of the excreta of 2,600,000 people was £1,444,177. (*First Report of Select Committee on the Sewage of Towns*, 1862: *Dr. Brady's.*) This estimate, being deducted from the value of the excreta of a full-grown man, is too high for that of a mixed population.

Higher estimates.

The above estimates are quite thrown into the shade by Baron's Liebig's calculations. From experiments of which we do not know the nature, he seems to have come to the conclusion that the annual value of the metropolitan sewage is no less than £4,081,430 sterling. But throwing aside all these higher valuations as either extravagant or unnecessarily high for our purpose, we ask, with the writer of a paper containing practical suggestions for removing all the sewage from the dwellings in and about London, "Shall the sewage of the metropolis, calculated to be worth more than a million annually, *be worse than wasted?*" That sewage is wasted when turned into a watercourse cannot be denied by any one; that it is worse than wasted we shall now proceed to show.

Baron Liebig's valuation.

Sewage "worse than wasted."

INJURY TO RIVERS.

The effect of sending the sewage into rivers is injurious from many points of view. Let us first consider the rivers merely as watercourses, without any reference to the subsequent use of the water for drinking purposes. The Sewage of Towns Commissioners, in their First Report in 1858, make the following statement :—

"The discharge of a large body of sewage into a river or watercourse is frequently not only productive of nuisance and disease to the neighbourhood where it takes place, but its influence extends to distant populations. Many rivers, especially in the crowded districts of the North of England, pass through several towns in their course seawards, and, receiving from each its complement of sewage filth, are even now little better than sewers themselves, although comparatively few of those places have yet carried out any complete works of water supply and sewerage." (*Loc. cit.* p. 9.)

Rivers turned into sewers.

The suggestion implied at the end of this quotation makes us remark that the more perfectly water-closet and sewerage arrangements are carried out, with all the immense advantages from a sanitary point of view we have already shown them to afford to towns, they will only increase any detriment that may be done to the rivers so long as the sewage is allowed to pass into them. Of the Tame, it is stated that before reaching Birmingham it "receives the sewage of a number of towns containing a total population of no less than 270,000 persons. A small stream in itself, it may without exaggeration be said, during dry seasons, to contain, at Birmingham, as much sewage as water. That such a stream, traversing a densely

Still worse since new sewerage arrangements.

populated town, and exposing to the air a large surface of putrid liquid, must be very injurious to health, no one can doubt."

Influence of emanations from river on health not determined.

The influence of the emanations from such rivers upon the health of the people living in towns upon their banks, has not, however, been distinctly traced, owing to the fact that the other causes of disease in these towns throw this one into the shade, and from "the difficulty of estimating apart the influence of the river upon health in the presence of morbific influences so much more powerful than itself."

From the Ninth Report of the Medical Officer of the Privy Council (p. 152), we find that at Salisbury, the branch of the Avon into which the sewage flows "has to be frequently cleaned out, or it would get choked by the sewage and rank weeds;" yet there is very little offence, probably, from the very fresh state of the sewage, the sewers acting remarkably well.

Offensive condition of rivers.

At Stratford, "the river is befouled by the sewage where it enters half a mile below the town, and there is considerable offence to eye and nose at the outfall. Evidently the sewer does not carry off night soil before it has had time to decompose. The river used to be a beautifully clear stream."

Dr. Acland's evidence before the Sewage (Metropolis) Committee, 1864 (Lord Robert Montagu's), shows the condition of the Isis at Oxford: "Masses of black sewage which have been deposited are thrown up to the surface, and, being light, float upon the surface and are carried down, and then in course of time either those masses become disintegrated and generally dispersed through the water, or they get re-deposited." (*Loc. cit.* p. 148.)

With regard to the northern towns, the Rivers' Pollution Commissioners (1868) in their First Report have brought forward a considerable amount of evidence. All the sewers pass into the rivers, and— In northern towns.

"The improvements in the sewerage works of Bury and of the towns above have had an injurious effect on the water of both rivers (the Irwell and Roch), making it more offensive." The people complain that the water "is most offensive to the sight and smell; that it is unfit for use; that even when used for steam-engines it clogs up the boilers and is injurious to the machinery."

As a summary of the evils thus produced the Commissioners remark:—

"The effect of this conversion of the rivers into common sewers is most injurious: all complain, even those who, while suffering from the inconvenience and annoyance which such a state of things entails, add to the nuisance by themselves following the general example. While they whose property happens to lie on the stream, even many miles below the towns, are sufferers in a variety of ways. Are they farmers? Their cattle cannot drink of the stream passing through their meadows. Are they dwelling on or near the bank of the river? They are driven from home by the stench which renders the place unbearable. Are they compelled by duty to remain on the spot? They are subject to perpetual annoyance, and, as alleged, in many instances to ill health. Have they property? Its value is often diminished; a house remains tenantless; land is unsaleable, except at a reduced price." (*First Report*, vol. i. p. 12.) Injuries from pollution of rivers.

Another evil, besides the general one which has been noticed above, is the destruction of fish in the rivers, thus referred to by the Sewage of Towns Commissioners (*First Report*, p. 11):—"The salmon fisheries of Scotland and Ireland not only represent a property of large annual value, but they form the occupations and livelihood of a very considerable population. Apprehensions are already entertained of serious injury by the daily Destruction of fish.

increasing quantity of sewage thrown into the rivers, and efforts have been made with a view of arresting the evil." It is then stated that in the case of Leicester the fish which had been driven from the river returned to it as soon as a process "for neutralizing the offensive and noxious properties of the sewage discharged into the river" had been adopted (the "A B C" process).

Silting up of rivers.

A still more serious question is that of the silting up of the rivers by the deposit of the solid material of the sewage. In the Second Report of the Sewage of Towns Commissioners (1861), p. 8, we find that—

"With regard to the Mersey, there is said to be evidence already that the bed is raised, that the deposit has *permanently* much increased. . . . At Bath the discharge of sewage into the River Avon is said to have so increased of late years as to impede the navigation. . . . The drainage of Glasgow is stated to produce deposits in the harbour of the Clyde at the rate of 100,000 cubic yards yearly, and to entail an expenditure of £8,000 per annum for its removal. . . . The streams flowing through Birmingham are said to have permanently silted up their beds some four feet high, and serious damage to land and property by flooding is the result."

Navigation impeded.

In the northern towns examined by the Rivers' Pollution Commissioners, the amount of ashes and rubbish of various sorts thrown into the rivers no doubt helps to silt them up so fast, but in some of the instances above given this is effected entirely or almost so by the deposit from the sewage itself. In 1867 the secretary of the Thames Conservancy Board drew the attention of the Metropolitan Board of Works to the fact of "the formation of extensive shoals in the River Thames, outside the Main Drainage outfalls near Barking Creek and Crossness," sending also copies of plans and sections made by the engineer

Rubbish and sewage.

Shoals in River Thames.

of the Conservators of the River Thames, from surveys made in 1861 and 1867, "which show the extent to which the deposit of material from the sewer outlets has taken place on the bed of the river." From these it appeared that between 1861 and 1867 the deposit of mud had been very extensive. Near the southern outfall the deposit "occurred to the greatest extent on the lower side, where a depth of fully seven feet has been discovered; in front of and above these works there is also a considerable increase." Near the northern outfall, on the contrary, the greatest accumulation took place on the upper side as far as 2,000 feet above the point of delivery, in several places a depth of seven feet of mud having formed. That this mud, although extending so far above the outfall of the sewer, was really deposited from the sewage and carried up by the tide, is evident from its composition. It was found by Dr. Letheby to contain not less than $15\frac{1}{2}$ per cent. of organic matter, and besides that "an unusually large amount of carbonate of lime in a crystalline condition," which may be taken as evidence "that the alkaline constituents of the sewage are decomposing and precipitating the calcareous constituents of the water and thus adding to the bulk of the deposit." "The result of the survey shows that near the northern outfall a space of more than forty acres, and near the southern outfall of about 120 acres of the bed of the river has been covered by a deposit varying in depth down to seven feet." (Stephen Leach, Esq., Engineer.) Mr. Bazalgette considers "that alterations have taken place in the bed of the river, but that there has been only a very small increase in the total quantity of deposit." He

Southern outfall.

Northern outfall.

Deposit carried up by tide.

Area of deposit.

finds that between the years 1864 and 1867, that is since the outfalls began to discharge, the deposit had increased in some places to the extent of 983,000 cubic yards, and in others had decreased about 923,000 cubic yards, leaving a total increase of about 60,000 cubic yards. But some plans which have been made this year show that the low-water line in some places above the northern outfall has receded to the extent of nearly 200 feet, and that it has receded considerably both for some distance above and for some distance below that outfall; and, moreover, they also show that at the point above this outfall, where the deposit of mud was shown to be 7 feet in 1867, it is now from 8 to 10 feet in thickness, and that near the southern outfall it is in many places from 5 to 10 feet thick. That is to say, that it has considerably increased since 1867, in many places at any rate. In fact, considerable banks of mud are forming on each side of the river, and promise to impede seriously the navigation. That this deposit of mud occurs to such an extent above the northern outfall would be matter of some surprise had we not before us the result of some important experiments by Mr. Frank Foster, subsequently repeated by Captain Burstal, R.N., and Mr. Bazalgette, C.E. With regard to this point it had been already remarked that the sewage discharged "into the river two hours before high water arrived at about the same point above Barking Creek as sewage discharged two hours after high water did by the next flood tide." A float was therefore put into the centre of the river opposite Barking Creek two hours after high water: "at low water the float reached $11\frac{3}{4}$ miles below that point,

Deposit removed in some places.

Narrowing of bed of stream since 1867.

Deposit above outfall.

and returned with the next flood tide to one mile above it, having gone $12\frac{3}{4}$ miles that flood, it being then a period of spring tides." Being left on the river, it was found that between July 13th and July 24th, 1851, it being then a period of neap tides, the float at high water was 13 miles below Barking Creek; that is to say, that it had gone down the river 14 miles during the falling from spring to neap tides. The next spring tides carried it up to "within 5 miles below Barking Creek at high water, having worked up the river 9 miles from high-water neap tides to high-water spring tides."

Experiments with floats,

from spring to neap tides,

"Another experiment was tried at the same place on the 6th of August, 1851, it being then lowest neaps, and the float being put down two hours after high water. It worked up each succeeding high water till top springs on the 12th of August, when it reached $6\frac{1}{2}$ miles above Barking Creek at high water. The float then again worked down the river till the 20th of August, $9\frac{1}{2}$ miles below Barking Creek, being a distance of 16 miles during the falling off of spring tides to neap tides. The excess of ebbs over the floods would in this case have been about 7 miles in 14 days (in the last case it was only 5 miles in 14 days.) The wind and other causes would vary the result, but it may be roughly assumed that a substance in suspension works up the river about one mile a day at each high water as the springs strengthen, and down the river two miles a day as they fall off." (*Report of Mr. Robert Stephenson and Sir William Cubitt, Dec.* 1854. *Bazalgette on the Main Drainage of London.*)

from neap to spring tides.

Rate of motion up and down river.

These experiments prove conclusively that matters suspended in water may, although thrown into it after high tide, be brought back by the next tide considerably above the place of outfall, and there kept for some time; so that it is easy to understand that such matters as do not get deposited when going down the stream may be brought back again and deposited higher up it.

Matters may get deposited above the outfall.

POLLUTION OF DRINKING-WATER.

But, when the water into which sewage is turned is to be used afterwards for drinking purposes, considerations of a still more important nature as regards the health of communities arise. It is certain from what has already been seen, that water containing excretal matters cannot be used for drinking purposes without great detriment to health, and that it in some cases causes very serious diseases. But the question arises as to whether water of a river, which has received the sewage of a town some miles higher up, is purified during its course to such an extent that it may be used with impunity as a drinking water. The evidence collected on this head by the Royal Commission on Water Supply was very various. Dr. Frankland says:—

Is the water purified during the flow of a river?

> "There is no process practicable on a large scale by which that noxious material (sewage matter) can be removed from water once so contaminated, and therefore I am of opinion that water which has been once contaminated by sewage or manure matter, is thenceforth unsuitable for domestic use" (p. 80).

Not fit to drink afterwards.

In another place he informs us that about four-fifths of the nitrogenous matter contained in fresh sewage is decomposed before the sewage, after a run of two or three miles, emerges into the river, and that the remainder "is decomposed with extreme slowness afterwards." In the First Report of the Rivers' Pollution Commissioners, analyses are given which show this fact tolerably clearly. Experiments were made by taking samples of the water of different polluted rivers at various points, making correction where necessary for the influx of unpolluted waters. It appears that when

Nitrogenous matters: partly decomposed soon; rest very slowly.

the temperature does not exceed 64 deg. Fahrenheit a flow of between 11 and 13 miles "produces but little effect upon the organic matter dissolved in the water." To remove all uncertainty from the "variability of the composition of the river waters at different times of the day," experiments were made by mixing filtered London sewage with water; "it was then well agitated and freely exposed to the air and light every day, by being syphoned in a slender stream from one vessel to another, falling each time through three feet of air." The mixture which originally contained in 100,000 parts ·267 of organic carbon and ·081 of organic nitrogen, was found to contain, after 96 hours, ·250 of organic carbon and ·058 of organic nitrogen; and after 192 hours, ·200 of organic carbon and ·054 of organic nitrogen. The temperature of the air during this experiment was about 20 deg. Centigrade (68 deg. Fahrenheit). "These results indicate approximately the effect which would be produced by the flow of a stream containing 10 per cent. of sewage for 96 and 192 miles respectively, at the rate of one mile per hour." They show then that at the above temperature, during a flow of 96 miles, at the rate of one mile an hour, the amount of organic carbon was reduced 6·4 per cent., that of organic nitrogen 28·4 per cent.; while during a flow of 192 miles at the same rate, the amounts of these two substances were only reduced 25·1 and 33·3 per cent. respectively. It is shown that the oxidation of this organic matter is chiefly effected by the amount of atmospheric oxygen dissolved in the water, "such dissolved oxygen being well known to be chemically much more active than the gaseous oxygen of the air."

Experiments.

Extreme slowness of decomposition.

Action of dissolved oxygen.

Slowness of oxidation.

It was found, however, that the action of this dissolved oxygen was not really anything like so quick or so perfect as generally supposed, and that 62·3 per cent. of the sewage was the maximum quantity that would be oxidised during 168 hours, even supposing that the oxidation took place during the whole time at the maximum rate observed, which was certainly not the case. (*First Report, R. P. C.* 1868, vol. i. pp. 18-20.)

Summary of results.

"It is thus evident, that so far from sewage mixed with twenty times its volume of water being oxidised during a flow of ten or twelve miles, scarcely two-thirds of it would be so destroyed in a flow of 168 miles at the rate of one mile per hour, or after the lapse of a week. . . . . . Thus, whether we examine the organic pollution of a river at different points of its flow, or the rate of disappearance of the organic matter of sewage when the latter is mixed with fresh water and violently agitated in contact with air, or finally the rate at which dissolved oxygen disappears in water polluted with 5 per cent. of sewage, we are led in each case to the inevitable conclusion that the oxidation of the organic matter in sewage proceeds with extreme slowness, even when the sewage is mixed with a large volume of unpolluted water, and that it is impossible to say how far such water must flow before the sewage matter becomes thoroughly oxidised. It will be safe to infer, however, from the above results, that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation."

Cannot be sure that the organic matter is thoroughly oxidised.

Mr. Simon's evidence before the Royal Commission on Water Supply, above referred to, shows that he holds the opinion which has been expressed in the above paragraph. He says, "It ought to be made an absolute condition for a public water supply that it should be uncontaminable by drainage." Dr. Angus Smith, while pointing out that the presence of nitrates and nitrites in river water is not a reliable test for previous sewage contamination, says that below Reading the Thames always contains organic impurities.

A water supply should be *uncontaminable.*

Sir Benjamin Brodie says, "Medical statistics will tell you much more about the injurious or non-injurious character of sewage water than any analysis would do;" and he evidently considers that it is not safe to trust even to a long flow of contaminated water for the removal of the injurious organic matter contained in it; in fact, in his evidence given before the Rivers' Pollution Commissioners (1857) he says (*First Report, River Thames*, vol. ii.; *Minutes of Evidence*, p. 49):

Hygienic researches give the best evidence.

> "I believe that an infinitesimally small quantity of decayed matter is able to produce an injurious effect upon health. Therefore, if a large proportion of organic matter was removed by the process of oxidation, the quantity left might be quite sufficient to be injurious to health. With regard to the oxidation, we know that to destroy organic matter the most powerful oxidising agents are required: we must boil it with nitric acid and chloric acid, and the most perfect chemical agents. To think to get rid of organic matter by exposure to the air for a short time, is absurd."

Sir Benj. Brodie's opinion on the oxidation of the organic impurities.

On the other hand, Dr. Miller considers that oxidation goes on in rivers to a very perfect extent, and that river water, after being contaminated with sewage, is safe for drinking purposes, "in the majority of instances." *There may, however, be cases in which danger is present.* Dr. Letheby also is of opinion that the present water supply of London is a "thoroughly wholesome water," and that ordinary sewage mixed with its own bulk of water, after floating a dozen miles or so, is entirely decomposed, and there is "not a particle of that sewage to be discovered by any chemical process." The analyses above alluded to show that this is not the case. Dr. Odling and Mr. Hawkesley appear to have given the same opinion; and the evidence on this side prevailing over the more

Contrary opinions.

cautious opinion that it was certainly impossible to be sure that water which had been once contaminated was ever purified so as to be absolutely safe for drinking purposes, the Water Supply Commissioners came to the conclusion that there was no evidence to show that the water supplied by the London Companies was not generally good and wholesome; and that they could not admit the possible presence of undetected germs of disease as a "conclusive argument for abandoning an otherwise unobjectionable source of water supply." But we have, in Mr. Simon's Report on the Cholera Epidemics of London in 1848-49 and 1853-54, sufficient evidence to show that the localities in which the cholera was especially prevalent were almost entirely determined by the degree of impurity of the water supply. When the Lambeth Company took its water from the Thames near Hungerford Bridge, the people who drank that water died at the rate of 12·5 per thousand. When the source of supply was moved to the Thames at Thames Ditton, the mortality was only 3·7 per thousand, while at the same time, and in the same districts, the mortality among the people who were supplied with water by the Southwark Company from the Thames at Battersea was at the rate of 13 per thousand. During the epidemic of 1866, the causes of which were inquired into by Mr. Radcliffe, the chief field of localisation was, on the contrary, north of the Thames, and especially in the eastern districts, where there were double the amount of deaths that occurred over all the rest of London, and five times the amount of deaths that occurred in the southern districts, which had not only since 1854 been supplied with better water, but had en-

Conclusion of the Commissioners, that the pollution of the water supply was not proved.

Cholera distribution determined by impurity of water.

South of the Thames.

East district, north of the river: 1866.

joyed a freer removal of sewage by the completion of the South Main Drainage Works. In effect, the area of explosion was found to be limited to the district supplied entirely with water by the East London Company, and not only so, but "to approximate with remarkable closeness to the limits of the districts supplied with water from Old Ford."

Cholera area districts supplied with water from Old Ford.

"In the northern districts receiving water from the East London Company, and with one comparatively small exception from Lea Bridge, the number of deaths from the epidemic within this period was 4. In the southern districts, receiving water from Old Ford, the deaths from the epidemic were 391." "The explosion, in fact, was confined to an area supplied with water by one particular company and from one particular source." (*Ninth Report, M. O. P. C.* p. 300.)

The Registrar-General's evidence is also perfectly clear upon this head. He says:—

"Six districts are supplied from Old Ford, and every one has been ravaged by the epidemic. The other 31 districts have, for six weeks in succession, suffered slightly. The 37 districts are subdivided into 135 sub-districts; 21 are supplied with the same water, and have all suffered six weeks in succession; 115 sub-districts have suffered inconsiderably. . . . . By the doctrine of chances, it is impossible that the coincidence between this particular water and the high mortality should be fortuitous in 135 cases during six weeks in succession. The force of this induction extends over all the area of observation in previous epidemics where sewage water has so often led to cholera outbreaks."

Registrar-General's evidence from sub-districts.

But Mr. Radcliffe has gone farther than this, and he has shown that the water delivered from the Old Ford covered reservoirs had been polluted with water from the filthy uncovered reservoirs. In fact, it was acknowledged by the engineer of the Company that at "the close of June or beginning of July—late in the former month or early in the latter—*water was*

Direct evidence of pollution of the water.

drawn from the northern uncovered reservoir into the covered reservoirs to the depth of three inches, to supplement a defective supply from the filter-beds." More than this, it is the fact that on the 26th and 27th of June, 1866, the discharges of the first two patients that died of epidemic cholera in the East districts were poured into the River Lea, "cesspool and canal," at Bow Bridge, about 600 yards below the northern uncovered reservoir; and it is certainly a very probable assumption to make that the water in the old reservoirs got contaminated with cholera evacuations by soakage from this river-canal, the water of which, it appears, rose 2ft. 9in. on the 29th and 30th of June, somewhat above the level of the uncovered reservoirs. This investigation was evidently carried out with such unusual care that no mere opinions can stand for a moment against it, and, taken in conjunction with Mr. Marshall's investigation of the cholera outbreak in connection with the water of the Broad Street pump in 1854, where it was shown that a special pollution of the water was the undoubted cause of the outbreak, and with Dr. Snow's investigation of the causes of some outbreaks at Wandsworth and other places in 1849, must be considered as affording a demonstration of the fact that cholera may be propagated to a frightful extent by the pollution of drinking-water with the evacuations of cholera patients. With such evidence as this before us, and knowing that the water supply of most towns is derived (however undesirable it may be that it should be so) from rivers which have towns upon their banks higher up, it is difficult to understand how the admission of sewage into running streams

Traced with great probability even to the first cases.

Other evidence as to the propagation of cholera.

is not by every one considered to be both disgusting and dangerous. We think the evidence that sewage is *worse than wasted* by being turned into a river is tolerably complete.

The researches of the Rivers' Pollution Commissioners have induced them to suggest, " having in view at present only the chief sources of pollution in the basins of the *Mersey* and *Ribble*, and the methods of cleansing now available, ... that the following liquids be deemed polluting and inadmissible into any stream :—

"(*a.*) Any liquid containing, *in suspension*, more than three parts by weight of dry mineral matter, or one part by weight of dry organic matter in 100,000 parts by weight of the liquid. Definition of polluting liquids.

" (*b.*) Any liquid containing, *in solution*, more than two parts by weight of organic carbon, or ·3 part by weight of organic nitrogen, in 100,000 parts by weight.

" (*c.*) Any liquid which shall exhibit by daylight a distinct colour when a stratum of it one inch deep is placed in a white porcelain or earthenware vessel.

" (*d.*) Any liquid which contains, *in solution*, in 100,000 parts by weight, more than two parts by weight of any metal except calcium, magnesium, potassium, and sodium.

" (*e.*) Any liquid which in 100,000 parts by weight contains, *whether in solution or suspension*, in chemical combination or otherwise, more than ·05 part by weight of metallic arsenic.

" (*f.*) Any liquid which, after acidification with sulphuric acid, contains, in 100,000 parts by weight, more than one part by weight of free chlorine.

"(*g*.) Any liquid which contains, in 100,000 parts by weight, more than one part by weight of sulphur, in the condition either of sulphuretted hydrogen or of a soluble sulphuret.

"(*h*.) Any liquid possessing an acidity greater than that which is produced by adding two parts by weight of real muriatic acid to 1,000 parts by weight of distilled water.

"(*i*.) Any liquid possessing an alkalinity greater than that produced by adding one part by weight of dry caustic soda to 1,000 parts by weight of distilled water." (*First Report, R. P. C.* 1868, vol. i. p. 130.)

Several of the above standards refer to manufacturing refuse and not to sewage, but still it was thought advisable to give the complete list here.

The recommendations on this head that the Commission submitted to Her Majesty were to the following intent:—

Recommendations of the Commissioners.

That the casting of any solid refuse or the discharge of any polluting liquids, such as those defined above, into any river or stream "be absolutely prohibited under adequate penalties;" and that a central authority or board of not more than three persons be established, with power to enforce the enactments relating to the pollution of streams, and to ascertain and cause to be removed the sources of contamination of public and domestic water supply. (*Loc. cit.* p. 136.)

CHAPTER IX.

TOWN SEWAGE.—ATTEMPTS AT UTILISATION.

It being certain that artificial manures, or guano brought from an enormous distance, cannot be always relied upon to furnish a sufficient supply for the cultivation of our land, we must keep in view the obvious absurdity of turning so much valuable matter as the sewage has been shown to contain, into the sea or into rivers, an absurdity pointed out by Parent Duchatelet when he says—speaking against the formation of drains between the cesspools and the sewers so as to get rid as fast as possible of the contents of the former by emptying them into the Seine—"one would lose by this method an enormous mass of manure which our agriculture requires, and the value of which, even now considerable, cannot fail to increase," adding that this proceeding would also be received with repugnance by the people, who are persuaded that they are supplied with the water of the Seine for drinking purposes. All the earlier forms of disposing of excreta have more for their object the utilisation of the manure than the speedy removal of filth from the vicinity of habitations. This removal having now been in every way encouraged by

Absurdity of throwing away manure.

Removal of filth encouraged by connecting closets with the sewers.

the connection of closets of all sorts with the sewers, in spite of the fact that it was before 1815 penal to do so, and being now furthered by the substitution of water-closets for privies on a very large scale throughout the kingdom, it has become necessary to see how the valuable matters, thus as it were thrown away, may be on the one hand prevented from polluting the rivers, and on the other utilised in the most profitable manner possible for agricultural purposes.

Subsidence.

As sewage contains a great amount of suspended matters, it is natural that the first attempts at purifying it should have been by allowing it to stand so that these matters might be deposited and the water be allowed to run away in a somewhat purer condition at any rate; but the suspended matters will not subside in this way to any great amount, or they do so only very slowly, so it was found necessary to resort to

SIMPLE FILTRATION,

Simple filtration,

in order to separate them from the liquid part: in this way a semi-solid mass of black mud was obtained, which was mixed with ashes or with street sweepings and sold as manure, while the liquid part, containing all the soluble constituents and part of the suspended ones, was allowed to flow away in a comparatively clear and inoffensive condition into the nearest watercourse.

Not successful as a method of purification.

"This liquid, however, still contains animal and vegetable matters in solution, and is anything but *water*; it is also liable to speedy putrefaction and consequent noxious smell, with the production of a further quantity of suspended matter, rendering it again, though in a less degree, turbid. In addition to organic matter, the filtered liquid contains of course all the soluble mineral compounds of the sewage, and in most cases is charged with carbonic acid, and with more or less sulphuretted hydrogen, both of these being products of the decay of vegetable and animal matters." (*Professor Way, Second Report of Sewage of Towns Commission*, 1861. *Appendix No.* 6, p. 65.)

In some towns this straining process is still resorted to.

An imperfect sort of filtration is resorted to at Ely, where the solid soil is separated from the sewage by upward filtration, while the liquid part enters the river below low-water mark, of course containing all the soluble impurities. "The solid part is taken out in the winter, mixed with the town ashes and road scrapings, and a bulky manure is obtained, which sells for 2*s*. 6*d*. a cubic yard, and pays in great measure for the expense of dust-removal and labour. Opinions differ as to whether any considerable nuisance arises from the outlet works or the muck-heaps. No complaint comes of nuisance in the river." **Examples of this plan.**

At Rugby, the part of the sewage that is not used for irrigation falls on a series of filtering-beds from which the fluid part runs off in a comparatively clear state into the Avon. "There is no difficulty in disposing of the black solid matter on the filters at half-a-crown a load." **Manure sells readily, but is not valuable.**

At Ashby-de-la-Zouch, solid matters are separated by subsidence in a tank, and by filtering through upright screens: the liquid overflow runs into the brook; "a black rich-looking mould taken from the filtering-tanks is bought with avidity by the farmers." The water of the brook, after receiving the liquid matters, is occasionally used for irrigation.

At Banbury, the sewers empty into settling tanks and filters from which the liquid part flows off into the Cherwell, "and the solid part is mixed with town sweepings and ashes, and sold for manure. . . . At the outfall works carbolic acid and perchloride of iron have been used to further purify the filtered sewage, and to prevent complaints of the pollution of the Cherwell. Nevertheless, nuisance from the river is complained of, and law proceedings have lately been taken in respect of it: any such nuisance is outside the town."

Nuisance to river.

At Chelmsford, filtering-tanks were constructed, separating the solid part—which was mixed with the town ashes and sold to neighbouring farmers—from the liquid, which was discharged into the river. This is, however, now done away with, and the whole of the sewage employed in irrigating some land near the town. (*Ninth Report M. O. P. C.* pp. 163, 168, 203, 142, and 156.)

As this straining obviously does not purify the sewage, though it may still have a valuable application, as we shall hereafter see, many attempts have been made to precipitate the valuable constituents by means of chemical reagents: these form the so-called

"PRECIPITATION PROCESSES."

Some of the more important of them are the following:—

Lime process.

The *lime process* "has been applied to sewage upon an extensive scale at Tottenham, for the manufacture of 'Tottenham Sewage Guano;' at Blackburn, and especially at Leicester, in the production of the so-called 'Leicester bricks.'" In the Ninth Report of the Medical Officer of the Privy Council it is stated that at Leicester "the elaborate outfall works succeed in their object of purifying the river from nuisance. The river used to be very foul, showing a frothy surface and all sorts of colours where the sewage was discharged. Now, with far more sewage discharged, there is only a little discoloration just at the outlet. The fish have come back too; there were none in the river for two miles down" (p. 75). The process consists in the admixture with the sewage of a certain proportion of cream of lime, after which "a copious deposit of highly putrescible mud takes place, while the supernatant liquid flows off in a comparatively clear though somewhat milky condition."

Purification of river at Leicester.

Method of procedure.

"The solid matter which is precipitated to the bottom of the reservoirs is worked back by an Archimedian screw, and thence raised by a string of buckets into troughs on the top of the building, from whence it is conveyed by gravitation into reservoirs prepared to receive it, where it lays until the supernatant water drains off, and the solid matter is disposed of as manure."

Professor Way found from his experiments that from fifteen to sixteen grains per gallon of slaked quick-lime were sufficient to precipitate ordinary sewage, and that no element of agricultural value was preserved by it except the phosphoric acid, of which five-sixths were precipitated.

Result.

The Sewage Commission reported that the process, "though very simple, and the least costly of any," could not be profitable in an agricultural sense, and did not purify the sewage. (*Second Report, S. of T. C.* p. 15.)

The Rivers' Pollution Commissioners (1868) examined this process both at Leicester and Blackburn. They say—

"At both places the method obviously failed in the purifica-

Failure of purification of rivers.

tion of the sewage to such an extent as to render it admissible into a river. At Blackburn especially, the river below the outlet of the limed sewage was in a most offensive condition of putrefaction, our note made at the time of our visit being as follows:—'Horribly offensive, turbid, blackish stream, disengaging most offensive gases, with black masses of putrid mud floating on the surface.'" (*First Report, R. P. C.* vol. i. p. 52.)

Effect on the sewage.

The analytical examinations made showed that the suspended matters were removed to a very considerable extent, 57·56 parts in 100,000 being reduced to 6 on one day, 48 parts to 2·8 on another, and 59·88 to 6·56 on a third; that of the total solid matters in solution, a quantity varying from ten to twenty parts in 100 was removed; that about a quarter of the organic carbon, and from 54·48 to 65·79 per cent. of the organic nitrogen were removed, except on the third day, when the amount of organic nitrogen in solution actually increased; "that is, the amount of organic nitrogen dissolved from the suspended matters of the sewage was greater than that precipitated from solution by the chemical reagents added." With regard to the ammonia, its amount remains about the same, or has actually increased; so that water which is sent into the river not only contains most of the valuable constituents of the sewage, but contains about half of the *putrescible* organic matter, which is precisely the substance that it is required to keep out of rivers. The manure produced is less valuable than might be expected, for the mud, being alkaline, loses ammonia while drying.

Manure loses ammonia.

Its value has been variously estimated at from 12*s.* 9*d.* to 17*s.* per ton, the latter estimate being certainly too high. The above-named Commissioners consider it to be worth 13*s*. 6¼*d*. It is stated that "an exaggerated notion of the agricultural value of the sewage manure has led to a reaction among farmers, who now take away the semi-solid manure sparingly at 1*s*. a ton, while the working expenses of its production amount to 3*s*." (*Ninth Report, M. O. P. C.* p. 75.)

Its theoretical and practical value.

The Rivers' Pollution Commissioners remark:—" In all these places the plan has been a conspicuous failure, whether as regards the manufacture of valuable manure or the purification of the offensive liquid."

A *modification of this process* is in use at Northampton :—

Lime and chloride of iron.

"Each million gallons of sewage is here mixed with twelve bushels of lime and about six gallons of chloride of iron; in hot weather more, in cold weather less. The lime is added first, and then the chloride of iron. The defecated sewage is afterwards submitted to upward filtration through a stratum of calcined iron ore eight inches thick; but we consider that beyond the separation of suspended matters, which would be equally effected by subsidence, this latter operation is nearly useless." (*First Report, R. P. C.* 1868, vol. i. p. 68.)

In the Seventh Report of the Medical Officer of the Privy Council, it is stated that the deodorisation produced by this process was very perfect, and that a complaint which was directed against the sewage works, to the effect that they were a nuisance, was unfounded. (*Loc. cit.* p. 526.)

Successful deodorisation,

The effluent water runs into the River Nen, and although putrefaction is deferred by the presence of the iron salt, it ultimately takes place and fouls the river, so that an injunction has been granted by the Court of Chancery that this discharge into the river shall no longer take place. The result of the treat-

but river is polluted.

Result on sewage.

ment appears to be, that the suspended matters are almost entirely removed, together with about one-sixth part of the ammonia, and rather more than a half of the organic nitrogen. It is plain, in fact, that the only advantage of the chloride of iron is to delay the pollution of the river for a short time, but not in any way to prevent it.

Persalts of iron,

Some experiments with *perchloride of iron* alone, were undertaken by the Sewage Commissioners at Croydon. They concluded that it was a very valuable precipitant, in that when added to the sewage and neutralised by an alkali, a large flocculent precipitate of peroxide of iron was formed, which carried down all the suspended matters, with some of the dissolved organic matter; that it fixed the sulphuretted hydrogen and phosphoric acid, and gave solid and liquid residues, neither of which were noxious or likely to be so. (*Second Report, S. of T. C.* p. 17.)

not successful.

Professor Way's experiments, however, showed that "this process cannot boast, any more than those formerly described, of any power of separating ammonia or other manuring material." (*Loc. cit.* p. 72.)

The chloride of iron is also too expensive, and so the process has been abandoned. Salts of zinc and of manganese have been proposed for the same purpose, and with a like result.

Carbolates and sulphites.

Carbolates of lime and magnesia (Macdougall's powders) have been proposed, but chiefly as disinfectants of the sewage. If added to the lime process they merely assist in delaying decomposition, but do not prevent it ultimately; the same may be said of the *sulphites of lime and magnesia*, which however at the same time decompose the sulphuretted hydrogen.

A process, in which *super-phosphate of magnesia* is the essential precipitating ingredient, has been proposed and tried at various times both in this country and in France. In this country it is known as *Blyth's process*. The plan of it was to add a salt of magnesia and some super-phosphate of lime, or super-phosphate of magnesia and lime water, to the sewage, and it was thought that the triple phosphate of magnesia, ammonia, and water, would be thrown down in an insoluble condition. Had this been the case it would have been, no doubt, an effective and valuable process, and it was even suggested that the magnesian rocks in various countries should be utilised by this process, with the probable prevention of the occurrence of goitre. (Bouchardat). It was, however, unfortunately found that the salt above mentioned is only insoluble in water containing an excess of ammonia.

Blyth's process.

In fact, Professor Way's analyses show that by this no more ammonia is separated from sewage than by the foregoing processes, "whilst a third of the phosphoric acid added in the processes is left in solution, and constitutes an absolute loss to that extent." And the Sewage Commissioners reported that "without accomplishing any part of its intended object, it is the most costly of all the plans that have been proposed." (*Second Report, S. of T. C.*, pp. 72, 15.)

Very unfavourable result.

Very expensive.

Holden's process, which was originally a French plan, is described in the Rivers' Pollution Commissioners' First Report; it consists in adding to the sewage a mixture of *sulphate of iron, lime*, and *coal dust* (clay is also mentioned by the patentee), and allowing it to flow through a series of subsidence tanks, so that a deposit may take place. The result of the examination

Holden's process.

of this process shows that while it "separates the whole of the suspended matters, it not only fails to remove the putrescible organic matters in solution, but actually (as measured by the organic nitrogen contained in these organic matters) increases their quantity. This it does by causing some of the putrescible organic matter in suspension in the original sewage to pass into solution. The effluent water could not therefore be admitted into rivers without causing pollution." It further appears that the amount of sulphate of lime in the effluent water is so great as to give it a very objectionable amount of permanent hardness.

Increases putrescible matters in solution.

Worthless manure.

As to the manure produced, 100 parts of it only contained ·555 of organic nitrogen, ·004 of ammonia, and ·3 of phosphoric acid : "a manure of the above composition may be considered as practically worthless." (*First Report*, *R.P.C.* 1868, vol. i. p. 60.)

Bird's process.

Bird's process, which has been carried on at Stroud and at Cheltenham, consists in the addition to the sewage of *crude sulphate of alumina*, which is prepared by treating pulverised clay with strong sulphuric acid; the mixture is allowed to settle in a depositing tank, and is filtered afterwards through coke. The coke is renewed about once in three weeks, and the foul coke is burnt. The sulphate for a day's use (150,000 to 200,000 gallons of sewage) is prepared by treating six hundredweight of pulverised clay with 120 lbs. of sulphuric acid. The Rivers' Pollution Commissioners report with regard to Stroud, first, that the sewage was very weak, and next, that the effluent liquid, although much improved, was still not of the degree of purity which would render it admissible without nuisance into a clean river. Moreover, if stronger sewage

Effluent water much improved, but not purified.

were treated, the effluent water would doubtless be still more objectionable. The results resemble those of the next process. We may add that at Cheltenham this process has been abandoned, the sewage being now utilised by irrigation.

The process has been abandoned.

Stothert's process consists in the addition of a mixture of "$73\frac{1}{2}$ grains of sulphate of alumina, $3\frac{1}{2}$ grains of sulphate of zinc, and $73\frac{1}{2}$ grains of moderately fine charcoal" to each gallon of sewage; and when this is well mixed with it, "22 grains of slaked lime, equal to $16\frac{3}{4}$ grains of quick-lime, are added."

Stothert's process.

The result differs from that of the lime process only in that the clarification is more complete; that the phosphoric acid is all precipitated, "in the form probably of phosphate of alumina;" and that the manure contains much more worthless matter derived from the precipitant. (*2nd Report, S. of T. C.* p. 70.)

Precipitation of phosphoric acid.

The "A B C" Process (*Sillar's Patent*), which is carried on at Leamington and Hastings, and with which experiments on a large scale have been made at Tottenham and Leicester, consists in the addition to the sewage of a mixture containing *alum, blood, clay, charcoal,* some compound of *manganese,* and various other ingredients in smaller proportions. It will be seen that the only noticeable difference between it and some other processes already described consists in the addition of *freshly-drawn blood,* which is considered an essential feature in the mixture, and of a small quantity of various other ingredients. This "A B C" mixture is allowed to run into the sewer in a small stream as it enters the works, and causes the formation of a precipitate which settles to the bottom of the tanks in the form of a soft black mud. It is

"A B C" process.

Sediment. stated that this sediment may be used to precipitate a further quantity of sewage. It must then be removed from the tanks, which is done by pumping it up into large receptacles from which it is allowed to run into centrifugal drying machines. From these it is taken in a semi-solid state and spread out to dry on the ground near the works, being sprinkled from time to time with sulphuric acid in order to fix the ammonia which might escape during the drying. The effluent water, after standing for some time in another series of tanks, is allowed to run into the River Leam, and of it Dr. Letheby says, "*the water is practically defæcated*, and I should have no hesitation in saying that water is in a condition to run into a stream of comparatively large volume." The careful examinations, however, which have been made of the results of the application of this process, both at Leicester and Leamington, by the Rivers' Pollution Commissioners (1868), have not confirmed this opinion. From the First Report of these Commissioners it appears that the solid matters in suspension are removed to about the same extent as by the lime process; that the dissolved impurities in the effluent water are markedly augmented; that the percentage of organic carbon removed "was notably in excess of that brought about by the lime process," while that of organic nitrogen (the most important substance, be it noted) was less than in the above-mentioned process, being only from 50 to 58·8 per cent. The amount of ammonia is, as in the case of the lime process, increased in the effluent water, the reason being that none of the ammonia originally present in the sewage is removed from it, while the additional amount is produced both from that con-

Dried and sprinkled with sulphuric acid.

Favourable opinion.

Effect on sewage.

tained in the alum of the mixture and from the action of the chemicals upon the nitrogenous organic matters both in suspension and solution in the sewage. The manure, however, from this process is perceptibly superior to that resulting from the lime process, but the increase in phosphoric acid in this manure is partly accounted for by the addition of an unknown quantity of bone-black to the precipitating mixture. In the Second Report of the above Commissioners the results of some further experiments on this process were recorded, and it appears that at Leicester the clarification was not satisfactory, suspended organic matter remaining to the extent of 1·5 to 3·8 parts in the 100,000; that with regard to the soluble constituents the results were the same as above given; as to the organic nitrogen, "it is precisely here that the process signally fails in accomplishing such an amount of purification as would render sewage admissible into an open watercourse." (*Loc. cit.* p. 4.)

Manure.

Failure in removal of putrescible matter.

At Leamington, the process was re-examined on the 10th May, 1870, when the smell produced by the drying of the manure was exceedingly offensive, and "would be pronounced a nuisance whenever conducted in or near a town;" and, in fact, it had been protested against by some of the neighbours, who described it in the strongest terms as "intolerable," "pestilential," and "bringing, as we are apprehensive, disease and death to our very door." It had even been found necessary to use chloride of lime at the works. So much for the deodorisation.

Nuisance of process.

It was then found that the "A B C" liquid "was discharged into the sewage at the rate of about 210 gallons per hour;" and that it consisted of—

Exact composition of "A B C" mixture.

	cwts.	qrs.	lbs.
Ammonia alum	3	0	0
Clay (moist)	6	0	0
Animal charcoal	0	0	15
Vegetable charcoal...	0	0	20
Epsom salts	0	0	20
Blood in a pailful of clay magma ...	0	0	4

and river water about 1,135 gallons, as stated—analysis, however, indicating that only 1,027 gallons had been used. (*Second Report, R. P.C.* 1868, p. 9.)

This mixture was contained in a tank which was exhausted in four hours and forty minutes. Small quantities of other substances are sometimes added.

Mr. Sillar pointed out to the Commissioners that the outlet for the water used in turning the water-wheel, which did the work of the engine during the night, was through the second set of subsidence tanks; it was not only so, but it was found that from leakage of the penstock and sluice, "even when the wheel was not working, a considerable stream of unpolluted water from the River Leam was mingling with the effluent sewage before it reached the place where our samples were taken." The result of this was shown in the analysis of the sewage after precipitation, but before filtration, as the amount of chlorine was found to be diminished from 11 to 9·5 parts in the 100,000, whilst the "A B C" mixture itself does not appreciably affect the proportion of chlorine. By a simple calculation based upon these considerations, it was found that with one part of sewage ·249 of river water was mixed, while the actual effluent water was found to contain river water varying from an inappre-

Leam water mixed with effluent sewage.

Reduction of amount of chlorine.

ciable quantity to 416 parts for 100 of real effluent water. Another result of the admixture of this river water with the sewage was the occasional appearance of nitrates in the effluent liquid. (pp. 7, 11.)

"The Leamington sewage contains no nitrates, neither does the 'A B C' process produce nitrates. On the other hand, 100,000 parts of water of the Leam contain ·178 part of nitrogen in the form of nitrates; consequently, if 416 parts of Leam water were mixed with 100 parts of Leamington sewage, the mixed liquid ought to contain ·143 part of nitrogen as nitrates. Our analysis shows ·149 parts of nitrogen as nitrates, in 100,000 parts of the effluent liquid, a proportion which indicates a slightly larger admixture of Leam water than that deduced from the chlorine determinations." (*Loc. cit.* p. 12.)

Appearance of nitrates in the effluent water.

The admixture with this large amount of river water of course causes the effluent water to be much purer than the process makes it. It is necessary, therefore, in estimating the alteration produced on the sewage by the mixture, to make a correction for the amount of river water that is thus mixed with the effluent water. This was done; and, further than this, an experiment was carefully tried to ascertain the effect of the "A B C" mixture on fresh London sewage, which "may be regarded as exhibiting the true amount of amelioration which can be obtained by this process, even with the employment of double the proportion of chemicals prescribed by the specification." The results of these experiments show—

Trial with London sewage.

"1. That of the dissolved matters, those left on evaporation were increased in weight by nearly one-half the amount of soluble ingredients added to the sewage; for the 'A B C' mixture making up 100,000 parts with the sewage to which it was added, contained, according to our analysis, 27·8 parts of soluble matters left on evaporation, whilst the increase of soluble

Results.

matters left on evaporation shown in the above table amounts to 13·2 parts.

"2. That the organic carbon in the dissolved matters was diminished to the extent of 37·5 per cent.

"3. That the organic nitrogen in the dissolved matters underwent no alteration; consequently, the organic matters precipitated from solution by the 'A B C' mixture were non-nitrogenous, and therefore valueless as manure.

"4. That the proportion of ammonia was augmented, because more was added in the 'A B C' mixture than was precipitated by the action of that mixture upon the sewage. 100,000 parts of the 'A B C' mixture gave on analysis 132·1 parts of ammonia; there was consequently added to each 100,000 parts of sewage in the 'A B C' mixture, 1·32 part of ammonia, whilst the augmentation of ammonia shown in the above table is ·668 part.

"5. That no nitrates were formed in the operation.

"6. That the total combined nitrogen was augmented by the ammonia added in the 'A B C' mixture; consequently, as regards soluble constituents, the effluent liquid possessed a greater manure value than the raw sewage, the increase in value being due to the ammonia in the chemicals employed.

"7. That the proportion of chlorine remained unaltered.

"8. That the matters in suspension, both mineral and organic, were almost completely removed, although the defecated sewage remained perceptibly turbid." (p. 13.)

Effluent water offensive.

"On no occasion, even when mixed with more than four times its volume of clean river water, was the effluent sewage other than a polluting liquid, offensive to the senses even at the moment of discharge, and always quite unfit to be admitted into running water." That this is really the case is seen from the fact that the water of the Leam is considerably polluted below the outfall of the sewage works.

"Masses of putrid mud, like those we had observed in the filter tanks, were floating here and there on the surface, buoyed up by the gases generated during putrescence." "Sewer fungus was growing abundantly on submerged objects near the banks, and we observed that it markedly increased in quantity as we approached the works on our return up the river." (p. 14.) River polluted.

In fact, it is shown by analysis that the organic nitrogen contained in the river water was increased from ·061 to ·102, the ammonia from ·040 to ·370, and the "total combined nitrogen" from ·272 to ·586 part per 100,000 after receiving the effluent water.

As to the manure produced by this process, it will be anticipated, from what has already been said, that it cannot be valuable. The analysis of some mud from one of the subsidence tanks showed it to contain 2·05 per cent. of total nitrogen calculated as ammonia and 1·98 per cent. of phosphoric acid. Of this manure Messrs. Lawes and Gilbert say:— Composition of manure mud.

"Assuming such a manure to be produced in large quantities, our opinion is that it would certainly be worth more per ton than stable-dung, provided the nitrogenous substance were in an easily decomposable condition, and its nitrogen readily available, and provided the phosphoric acid were also in a readily soluble condition; but if the nitrogen and phosphoric acid were not in such conditions, it may be a question whether the 'A B C' deposited manure or stable-dung would be the most valuable. The result would depend in a measure on the quantity of the respective manures in the market, the cost of carriage, and other local circumstances. Stable-dung would, however, probably have the preference for market gardening." (*Appendix*, p. 31.) Estimation of its value.

From calculations based upon the market price of guano and bone super-phosphate, the Commissioners find that the "A B C" manure appears to be worth about 32*s*. per ton.

"That is to say, 160 cwt. of the 'A B C' manure would be worth as much as 20 cwt. of guano, or 55 cwt. of the super-phosphate, supposing both to have been deposited upon and within the soil. It is plain, however, that this supposition cannot Comparison with guano and super-phosphate.

be realised without a much larger expenditure on the weaker manure, for carriage and labour of distribution, than in the case of guano or of super-phosphate; an expenditure which indeed very soon altogether destroys the commercial value of the manure, as it diminishes in strength." (p. 16.)

But several considerations show that this price is really too high. Dr. Odling, from the examination of the prepared manure, states that "it contains about one twenty-fourth part of the nitrogen which is contained in guano, and less than one twenty-fourth part of the amount of phosphate; so that, estimating it merely as regards those two constituents, it would have been one twenty-fourth part of the value of guano—making no deduction for the amount of dilution." That is to say, he estimates its value at 11*s.* 3*d.* per ton. But it is plain that the value of this, or any other manure, may be raised to any amount by the addition of suitable ingredients, and it appears that "an artificial fortification of the comparatively worthless sewage mud thrown down by the "A B C" mixture is occasionally practised." Drs. W. A. Miller, F.R.S. and W. Odling, F.R.S. found that many samples of the manure "contained large crystals of sulphate of ammonia," which, it was stated by the manager, had been added by mistake for sulphate of magnesia. It must be remembered, too, that animal charcoal, blood, and salts of potash, beside some ammonia-alum, are all contained in the precipitating mixture. The manure produced at present fetches £3 10*s.* a ton. When we consider that the lime mud from the Leicester Sewage Works fetches only 1*s.* a ton, although the theoretical value of it is 15*s.* 5*d.* according to Dr. Voelcker's analysis, we may be certain

Value of 1-24th of that of guano.

Fortified by addition of sulphate of ammonia.

Price it fetches at present.

"that the theoretical value of the Leamington 'A B C' manure will not be nearly realised when its price shall have been determined by the ordinary process of competition with other purchasable fertilisers." Much less will any such extreme price as that being given for it be realised. On the whole it appears that the manure value of the chemicals used in the "A B C" mixture for one day's working is 11*s.* 7*d.*; taking the highest theoretical value given for the manure—about £1 14*s.* 9*d.*—it appears that the "nett result of a day's working was the recovery from the sewage of Leamington of manure constituents worth theoretically £1 3*s.* 2*d.*" It would appear, then, "the 20,000 inhabitants of Leamington would yield annually, by the "A B C" process, manure of the theoretical value of £845 11*s.* 8*d.*, or 10*d.* per head per annum." "The actual value of the recovered manure would, at 7*s.* a ton (about its probable practical value), amount to £255 10*s.* 0*d.*, or 3½*d.* per head per annum." Even if it fetched the theoretical value given above, it would not pay the cost of working. (pp. 17, 18.) **Highest theoretical value.**

"This is an even less satisfactory result than is obtained by ordinary scavenging operations in the Lancashire towns, where manure of the annual value of rather less than 5*d.* per head over a population of more than a million is annually obtained." **Comparison with Lancashire middens.**

The conclusions, then, of the Royal Commissioners are on every point condemnatory of the "A B C" process.

The manager of the Company maintains (letter to the Clerk to the Metropolitan Board of Works) that the conclusions of the Commissioners are unwarranted, especially as regards the admixture of river water with the effluent water, as would have been shown by gauging the effluent water, or by comparing its temperature with that of the sewage; that the "fortification" alluded to took place on that occasion only, and was done without the knowledge of himself or of the Directors; and that the manure produced is proved to be valuable by the avidity with which it is bought up by farmers and others.

General results of personal inspection.

On a visit that we paid to the works at Leamington on July 21st, 1870, we were agreeably surprised to find that, on that day at any rate, the amount of nuisance caused by them was very little indeed throughout the whole of the premises. We could not find any disagreeable smell with the single exception of the air in the subsidence tanks; that was decidedly foul, and moreover issued in a strong current when the trap-door in the roof of one of the tanks was opened. Some experiments in tall precipitating glasses showed that sewage was *clarified* considerably by the "A B C" mixture; but that the supernatant liquid contained a great deal of ammonia. As to the effluent water, it was turbid and had a slight odour and colour. We found it, on a rough and ready examination, to contain a very considerable quantity of ammonia, and on pointing out this fact to the manager he acknowledged that all the ammonia that came to them in the sewage they must inevitably lose, but stated that they got the sewage so fresh that it really contained very little ammonia. It is perfectly certain that this can never be the case, and in fact the analysis of the sewage shows that it contains about from 3 to 10 parts in 100,000: the ordinary quantity being 7 or 8 parts. The sample of the effluent water, which we preserved, became excessively foul in a day or two, although kept in a stoppered bottle, and

Ammonia acknowleged to be inevitably lost.

Effluent water putrefies.

disengaged a quantity of sulphuretted hydrogen gas. It was found by Dr. Russell to contain 2·856 parts of ammonia and 0·080 part of "albumenoid ammonia" in 100,000. As to the river itself, we noticed that near the outfall, especially just about and underneath the weir, the surface of the water was covered with a filthy scum. We could only obtain evidence, with regard to the agricultural value of the manure, from some florists who appeared very well contented with it; but it need hardly be pointed out that with potted plants and so forth a proportion of manure is used which would come to an enormous quantity if calculated per acre, and that no value could be given to estimates produced in this manner. A process which does not even pretend to remove the manurial constituents from the sewage cannot possibly produce valuable manure; and Dr. Odling says:— Agricultural value of the manure.

"No doubt this method, like all other methods of precipitation, does keep out a considerable proportion of filth from the river; but there was a great deal of putrescible matter in the effluent liquid, and in comparing this mode of precipitation with others, it did not seem to me that its alleged superiority had any foundation." Summary of results.

"As regards its superior defæcation of sewage, and the high value of the product yielded," his opinion is especially unfavourable.

We must add to this that the process is about to be given up at Leamington, as irrigation works are being constructed by which the sewage will be utilised on land at a distance of $2\frac{1}{4}$ miles from the town. Process to be abandoned.

It is stated that the process has lately been improved and cheapened by the substitution of a drying-chamber for the centrifugals, and by the use of clay instead of alum.

The fact that a Royal Commission has issued a Special Report on the above process, and that the manure is being sold at so high a price, must be our excuse for describing it at a greater length than the others.

Conclusions.

All these precipitation processes do, then, *to a certain extent*, purify the sewage and prevent the pollution of rivers, chiefly by removing the suspended matters from the sewage; but they all leave a very large amount of putrescible matter in the effluent water, and at least all the ammonia contained in the sewage (sometimes they add to it); the greater part of the phosphoric acid is precipitated by some of them, while they increase the hardness of the river water, a matter of great importance if the stream be a small one.

Ammonia not precipitated.

The manures that they produce are in every case very inferior, as may be expected from the known value of the sewage constituents that can be precipitated. They have all failed in producing valuable manure, because the valuable constituent of sewage *par excellence* is the ammonia, which of course invariably totally escapes in the effluent water, and is lost to the manure: this shows the futility of all attempts to utilise sewage by precipitation alone.

CHAPTER X.

FILTRATION AND IRRIGATION.

FILTRATION.

Several important experiments with regard to the filtration of sewage through various materials were made under the direction of the Rivers' Pollution Commissioners.[1] They pointed out in the first place that " the water bearing gravel of London is supplied almost exclusively by sewage, and the water pumped from the shallow wells in London is little else but filtered sewage;" and, to show the extent of purification which this water undergoes, it is found that it contains very little organic nitrogen and carbon, and very little ammonia, but, instead, a considerable proportion of nitrates and nitrites. Experiments conducted by filtering London sewage through 15 feet of sand showed that, in the first place, " the process of *upward* filtration through sand is inefficient in the purification of sewage from soluble offensive matters; . . . on no occasion was the effluent water in a condition fit to be admitted into running streams:" but that the "process of intermittent *downward* filtration through either sand or a mixture of chalk and sand, effects a

London well-water.

Filtration experiments.

[1] First Report, R. P. C. 1868, vol. i. pp. 60—70.

very satisfactory purification of sewage when the sewage treated amounts to 5·6 gallons per cubic yard of filtering material in twenty-four hours, but that the purification becomes uncertain and unsatisfactory when the rate of filtration is doubled, that is when the sewage treated amounts to 11·2 gallons per cubic yard in twenty-four hours. These experiments also show that the process of purification is essentially one of oxidation, the organic matter being to a large extent converted into carbonic acid, water, and nitric acid: hence the necessity for the continual aëration of the filtering medium, which is secured by intermittent downward filtration, but entirely prevented by upward filtration." In fact, it was found that, by downward filtration through soil, the organic carbon and nitrogen were reduced to about the proportion in which they are contained in the London drinking-waters, namely, to ·5 to ·7 of carbon, and ·06 to ·07 of nitrogen in 100,000 parts; the original amounts in the sewage having been 2·48 of organic nitrogen and 4·38 of organic carbon. On the other hand, the amount of nitrogen as nitrates and nitrites was increased from nothing to from 3 to 5 parts in 100,000. "Only as a source of drinking-water could a stream into which such purified sewage flows be condemned." Some further experiments on downward filtration through the Beddington soil, which were conducted in glass cylinders, showed that "the effluent water was always clear and nearly colourless, at the rate of 3·8 and 7·6 gallons per cubic yard per diem. In respect of organic matter the filtered sewage actually equalled, or even surpassed in purity on four occasions, the water which is sometimes supplied to London for

Rationale of process.

Amount of purification.

Quality of effluent water.

domestic purposes." Further experiments showed that the results are very different with different soils, and that in some cases the nitrogenous matters are absorbed and retained as such, without being converted into nitrates and nitrites, and that this result does not apparently depend upon the presence or absence of light, or upon variations in the temperature.

Intermittent downward filtration is then a valuable method for the purification of sewage, but not for the utilisation of it, as the area of ground is too small and the quantities of sewage turned on to it too large.

It was found that the "light yellowish brown loam from the marlstone of the lower oolite near Dursley, in Gloucestershire," surpassed all the others experimented upon in its power of purifying sewage:—

Values of different soils.

"Whilst one cubic yard of sand, or of Hambrook soil, cannot continuously and satisfactorily purify more than 4·4 gallons of London sewage per 24 hours, one cubic yard of Beddington soil can cleanse 7·6 gallons, and one cubic yard of Dursley soil no less than 9·9 gallons in 24 hours, which is equivalent to the cleansing of nearly 100,000 gallons of sewage per day by an acre of this soil, provided the drains for the effluent water are six feet deep." (*Loc. cit.* p. 69.)

It would appear that the physical condition as regards porosity and fineness of division has more to do with the cleansing power of a soil than its chemical composition has. "At the conclusion of the long series of experiments there were no symptoms of clogging up or diminution of activity, and the effluent water was always bright, inodorous, and nearly colourless." It was found that with Lancashire peat as a filter, the effluent water was not much purified at first, but afterwards steadily improved, giving a "hope that this material would, after a somewhat higher education,

Results with peat.

become an efficient purifier of sewage filtered through it at the rate of four gallons per cubic yard per 24 hours." The Commissioners consider that with a properly constituted soil, deeply drained, and divided so that the sewage could be applied on one part at a time, "the sewage of a water-closet town of 10,000 inhabitants could, at a very moderate estimate, be cleansed upon five acres of land." This process is carried out to a certain extent at Ealing, where, however, from the small quantity of filtering material (60 cubic yards instead of 40,000) and the rapidity with which the sewage passes through the filter-beds, the purification was found to take place only to the extent of arresting the suspended matters; "the effluent liquid retained nearly all the original amount of soluble putrescible organic matter, and was totally unfit to be admitted into running water." (p. 62.)

Filtration at Ealing unsatisfactory.

IRRIGATION.

Introductory remarks.

We find, then, from the preceding chapter and the foregoing paragraph, that, given town sewage, the only way that has yet been discovered of purifying it in any sense of the word is by *intermittent downward filtration* through a certain thickness of soil, and that soils vary very considerably in their power of so purifying it. Some soils appear to absorb the organic matters contained in sewage water in a very perfect manner, and allow very little escape of valuable matter in any form in the effluent water; others still purifying the sewage, but doing so especially by the rapid oxidation of ammonia and organic nitrogenous matters, attended with the formation of nitrates and nitrites which escape in solution in various quantities in the effluent water, and which, although perfectly inoffensive in themselves, still represent so much loss of valuable matter. "A filter is not a mere mechanical contrivance; it is a machine for oxidising and thus altogether transforming as well as for merely separating the filth of dirty water." It is plain that a certain quantity of soil can only do a certain amount of work in this way; that if too much sewage be poured on to it, a certain amount of the organic materials must necessarily escape oxidation, and the effluent water will flow away unpurified. In all the filtration experiments this is found to be the case: when the flow exceeds a certain quantity or a particular rate, the effluent water invariably contains undecomposed organic matter. Thus we see that, as far as the question of purification goes, it is desirable to extend the area of the filter as much as possible; the more this is done the purer the effluent water will necessarily be; but as the only question is not that of purifying the sewage, but there is also that of utilising it, the area over which it is applied must be limited in order that a sufficient agricultural return may be produced to pay the expenses of working the system and to ensure the realisation of a profit. The first thing to be attained is the purification of the sewage to such an extent that the effluent water may be safely allowed to flow into a water-course; the next is the application of it as an agricultural manure in such quantities and in such a manner as to realise the greatest returns per ton of the sewage and per acre of land; and the last, to do this in such a manner that the health of the inhabitants of the irrigated districts shall in no way be affected injuriously by the process.

Functions of filter.

Filter should be enlarged.

Three conditions to be satisfied.

The question then arises, does sewage, as at present applied to land for agricultural purposes in various places, become so purified that the effluent water is untainted by fæcal matter? Let us examine the results of analyses which have been made at various places, of sewage applied to the land, and of the water which flows away in the drains of that land.

Comparison of sewage and effluent water,

But we must here premise that the earlier analyses of this nature are not at all to be relied on, as the methods of water analysis were very imperfect, that of estimating the amount of organic matter in the total solid residue by incineration being entirely fallacious. From the First Report of the Rivers' Pollution Commissioners we find that the raw sewage supplied to the Craigentinny meadows, near Edinburgh, contained 3·613 parts of organic nitrogen and 9·510 of ammonia in 100,000 parts, while the effluent water contained ·682 of organic nitrogen and 1·989 of ammonia; this being produced by the flow of about 700 tons of sewage per hour over less than $2\frac{1}{2}$ acres of land during an hour and a half, the general result being the reduction of the total combined nitrogen from 11·445 parts to 2·320, and total suspended matters from 39·40 to 5·52 parts per 100,000. This, it must be remembered, is the result produced by the application of enormous quantities of sewage to a limited area. The value of the agricultural products having been alone kept in view, it "must not be quoted as a successful example of sewage cleansed by irrigation," "for it is poured over them (the meadows) in such enormous quantity that the soil has not fair play given to it as a cleanser, and the water therefore leaves the grass land still filthy and offensive." It must be noted that

under unfavourable circumstances.

here there are no nitrates and nitrites in the effluent water. (*Loc. cit.* vol. i. pp. 74, 75.)

At the Lodge Farm, near Barking, where the soil is gravelly and very pervious, so that the water cannot travel far upon the surface, and "that after fifty yards at most of surface-flow it sinks, to reappear only at the mouth of the main drain of the farm," it was found that the organic nitrogen was reduced, during fifty or sixty yards of surface-flow, from 3·664 to 1·872; after a further surface-flow, to ·624; and, at the issue of the main drain of the farm, to ·329 parts per 100,000; the ammonia being reduced during the same flow from 4 to ·8 parts per 100,000, while the nitrates and nitrites, which were absent from the sewage, appeared in the effluent water to the extent of nearly 3 parts per 100,000. Plenty of other instances might be taken, all of them showing that the amounts of each and all of the constituents of sewage are considerably reduced by practical irrigation, with the exception of chlorine, which is very slightly reduced, or even sometimes apparently increased, and nitrates and nitrites, which, not existing in the sewage itself, appear in the effluent water, sometimes in considerable quantities; and these results have been obtained even where the object has not been so much the purification of the sewage as the production of a valuable agricultural return. We can go still further than this, and say that *the constituents which are most effectually removed from the sewage are especially the putrescible organic matters;* that is to say, are those which it is our main object to remove both from a sanitary and an agricultural point of view. We have already seen that all other pro-

Better result.

Appearance of nitrates and nitrites.

Effectual removal of putrescible matters.

cesses especially fail in removing these very constituents. With regard to these analyses, however, we must note that the amount of the purification is presented to us by them in an exceedingly unfavourable manner. In all the processes of mere straining or precipitation the amount of effluent water is to all intents and purposes the same as the amount of sewage, and the number of parts of each of the constituents per 100,000 may be fairly compared with the number of parts of the same constituents in 100,000 parts of sewage. But with irrigation the case is totally and entirely different; the amount of effluent water issuing from the drains of an irrigated piece of land, on which crops are growing, is diminished not only by the amount that directly evaporates from the soil itself, which in dry weather must be very considerable, but by the enormous amount that is continually evaporating from every exposed part of the growing plants. This enormous amount will be the more appreciated when we consider the results of its cooling power on a somewhat extended scale.

Results really even better than they appear to be.

Enormous evaporation from plants.

Many are the instances in which the climate of a country has been entirely changed by the destruction of its forests, and we need only state the case of the destruction of many of the large forests which formerly bordered the banks of the Rhine, by which the climate has been changed from a very cold one to a temperate one, the winters never now having anything like the severity they had in former times, when that river was frequently frozen over. (Blumenbach.) This continual evaporation, then, causes a very considerable diminution in the amount of water which can possibly flow away by the drains as effluent water. To determine accu-

Illustration.

rately the amount of this loss would require a special set of observations under such conditions as would ensure the collection of the whole of the effluent water. Such experiments are being carried on by the Committee of the British Association at Breton's Farm, near Romford, and the results of them will be published in due time; but meanwhile we must not consider because we find a certain quantity of organic nitrogen, of ammonia, of nitrates and nitrites, &c. in 100,000 parts of effluent water, that this quantity came from only 100,000 parts of sewage. Even supposing that it did, the analytical results which we have above given, and which are not the best that have been obtained, have certainly never been approached by any other method, and for reasons already given it is hardly possible that they ever will be, so that they are very favourable to irrigation as a means of purifying the sewage. Making the correction indicated, which it is only fair to do, seeing what an important one it is, they become indeed exceedingly favourable. It appears, then, that the first requisition is satisfied by irrigation, and this is borne out by the opinions expressed in all the Reports that have been issued upon the subject. The Sewage Commissioners, in their First Report (1858), showed that they considered that the irrigation of land (in some cases supplemented by other processes) was the best means of preventing the pollution of streams by sewage. In their Third Report (1865) p. 3, they state still more definitely that "the right way to dispose of town sewage is to apply it continuously to land, and it is only by such application that the pollution of rivers can be avoided."

Experiments on amount of loss of water.

Results favourable, even without allowance for evaporation.

First condition satisfied.

We must at once insist upon the condition of filtration, which is an absolutely essential one in any attempt at the purification of sewage. The success of the irrigation process entirely depends upon this. It is not sufficient to let the sewage run over the surface of the land among the crops, and to suppose that it may be purified in this way; it must not merely run on to the land, but also *through it.* The power of the crops themselves in abstracting the manurial constituents from the sewage is doubtless exceedingly great, but it must be remembered that this power chiefly resides in the roots, and that as the soil itself has been proved capable of abstracting these manurial constituents, *à fortiori* will this be done the more completely when the soil is aided by the avidity of the roots of a growing crop to absorb their natural nutriment. The process is, in fact, one of direct conversion of refuse matters into crops; these matters being brought for the most part dissolved in water, that is to say, in the natural condition in which, as far as yet known, they are really capable of being absorbed by plants: although the power of the soil itself (that is, of certain soils) to retain these manurial matters must not be overlooked; neither must the fact that the roots of plants are capable of doing it when the soil is of such a quality that it would not do so to any appreciable extent, and when indeed the plants could not be grown upon it at all if it were not supplied with manure continually. That is to say, that, despite the weighty authority of Baron Liebig, who has maintained the contrary opinion, indisputable facts have most certainly shown that pure sand is capable of supporting large crops when properly supplied with a sufficient

Must not run merely over the land.

Must come in contact with the roots.

Is absorbed by them when soil itself could not retain it;

quantity of sewage. In the Appendix to the Special Report from the Select Committee on the Thames Navigation Bill, the result of an experiment is stated which showed that Italian rye-grass, wheat, and mangolds, could be perfectly well grown on sea-sand ($2\frac{1}{2}$ feet in depth) when sewage was properly supplied to it. The lower portion of the present Craigentinny meadows consisted, 50 years ago, of low moving sand hills, the "Figgate Whins." In fact, it is now useless to deny that sea-sands may in this way be reclaimed and made valuable property, producing annually enormous crops of grass. That it is not advisable to apply the sewage to lands which can absorb it independently of the crops, we do not for a moment wish to maintain; it is plain that when applied to fallow land, as it would often have to be, especially in winter, it is essential that the soil should thoroughly absorb and retain the manurial constituents, or at any rate it must be demanded that they shall be so thoroughly oxidised that the effluent water shall retain none of them in a putrescible condition. But that crops will grow on lands so absolutely worthless that the soil only performs the function of mechanically supporting the plants, if they be supplied with the organic and inorganic matters essential to their growth and which are contained in town sewage, is now an ascertained fact. The condition, then, is simply that the sewage be not allowed to run merely over the land, but through it, so as to come in contact with the roots of the plants. To this end it must be applied *from the surface*, and not by underground pipes, as in this latter case it is plain that it would not wash the roots of the plants, as it is delivered into the soil for the most part below them.

as on sea-sand.

Best to soils which can retain the manure.

Sewage must come in contact with the roots.

In the Report of the Select Committee on the Metropolis Sewage (known as Lord Robert Montagu's), 1864, it is stated that—

Conclusions of Committees:

"No efficient artificial method has been discovered to purify, for drinking and culinary purposes, water which has once been infected by town sewage. By no known mechanical or chemical means can such water be more than partially cleansed; it is always liable to putrefy again. Processes of filtering and deodorisation cannot therefore be relied upon to do more than mitigate the evil. Water which appears perfectly pure to the eye is sufficient, under certain conditions, to breed serious epidemics in the population which drinks it." "Soils, however, and the roots of growing plants, have a great and rapid power of abstracting impurities from sewage water, and rendering it again innocuous and free from contamination." (*Report*, p. 6.)

And again, in the First Report of the Committee on the Sewage of Towns, 1862 (known as Dr. Brady's), we find the conclusion arrived at by Dr. Hofmann, "that all proposals to use sewage, except the proposal to use it for purposes of irrigation, bore in themselves evidence of their impracticability." And, lastly, in the First Report of the Rivers' Pollution Commissioners (1868), vol. i. p. 71, it is stated as the result of the numerous and important experiments conducted by the members of that Commission, that—

That porous soil is the best purifier.

"Considered merely as a mechanical and chemical agency for cleansing the drainage water of our towns, it seems plain that a sufficient extent and depth of porous soil to be used in irrigation, having periodical intervals of rest, during which the soil drains and becomes refilled with air, certainly must be the best possible strainer, oxidiser, and filter of water which, like the sewer water of our towns, contains nauseous organic impurities both suspended and dissolved."

EXAMPLES OF SEWAGE FARMS.

We will now bring forward some examples to show what has been done already in the practical application of sewage water as manure, by irrigation. The Health of Towns Commissioners, in their First Report (1844), give a short account of this process as applied at Milan; the Sewage of Towns Commissioners, in their Preliminary Report (1858), give a somewhat longer account of it: and from these two Reports we gather the following particulars. The city is chiefly supplied with cesspools; there are very few water-closets, and they communicate with cesspools.

Irrigation at Milan.

"It is forbidden to discharge urine into the drains, but there being so direct an interest against the discharge of any fluid into the cesspools (because the inhabitants have to pay for emptying them), it may readily be supposed that no more than is unavoidable finds its way into those receptacles, and that as the streets themselves abound with urinals, the chief portion of this valuable part of the refuse of the town does find its way to the sewers." (*Prelim. Report, S. of T. C.* p. 40.)

The liquid refuse of the city is collected in large sewers, which join one another and meet in a canal called the "Vettabbia." This "is made to ramify and serve for the irrigation of about 4,000 acres of land, after which it falls into the River Lambro, about ten miles below the city." And here we find a remarkable instance of the truth of a fact before stated, namely, that the separation of the solid excremental matters from the sewage does not to any appreciable extent diminish its manurial value, or prevent its being to all intents and purposes sewage—a liquid containing large quantities of highly putrescible matter. The account is as follows:—

Sewage without solid excrement.

"It has been stated how little solid matter is conveyed in this stream; nowhere in appearance is it as muddy as the Thames between the bridges, and yet much of the land irrigated by it becomes so rich that the surface is pared off every few years, Rich manure.

not, as erroneously stated by some writers on the subject, in order to preserve the level of the lands for irrigation, but to obtain the vegetable matter which becomes in time too luxuriant in growth, as material for manure for other lands, for which it is highly prized." (*Prelim. Report, S. of. T. C.* pp. 40, 41.)

It is calculated that to each acre is applied the liquid refuse of about forty persons; "but it must be observed that much of the water is used over and over again successively on lands at lower levels." So far from being a disadvantage in winter, we find that "the Vettabbia possesses also the valuable peculiarity of protecting from frost the meadows it irrigates, owing to the high temperature it receives in its passage under the town." (*First Report, H. of T. C.* vol. ii. p. 405.)

Advantage of irrigation in winter.

"The expense of forming a meadow for irrigation appears to vary from about £8 or £10 to upwards of £40 an acre, according to the original character of the surface. The water is turned on for from six to ten hours once a week throughout the summer months, but a certain portion of the meadows are irrigated constantly throughout the winter, and are then called 'Marcite.'" (*Prelim. Report, S. of T. C.* p. 41.)

A good deal of land around Milan is irrigated with water containing no sewage, and on this land a considerable quantity of manure has to be used; while on the land irrigated with sewage, even the manure of the cattle that are fed on its produce is used elsewhere. "To obtain the same produce from such lands," without irrigation would require manure worth "about £4 8*s.* per acre per annum."

No other manure necessary.

"Some of the meadows irrigated by the sewerage-water of Milan yield a net rent of £21 per *tornatura* (a measure of 10,000 square metres, equal to about $2\frac{1}{2}$ acres), besides a land-tax of 61 francs 10 cents., the expenses of administration, repairs of buildings, and so forth. These meadows are mowed

Rent.

in November, January, March, and April, for stable-feeding; in June, July, and August they yield three crops of hay for the winter; and in September they furnish an abundant pasture for the cattle till the beginning of the winter irrigation." (*First Report, H. of T. C.* vol. ii. p. 406.) Crops.

The deputation appointed by the Sewage of Towns Commissioners considered themselves justified in stating that—

"The experience of the irrigations around Milan adds a striking additional proof to those already obtained of the great value to agriculture of a command of pure water alone, and of the immense increase of that value obtained by the addition of sewage combined with the higher temperature derived by the liquid in its passage through a town." (*Prelim. Report*, p. 44.) Value of water; but especially of sewage water.

Near Edinburgh, sewage irrigation has been going on for the last 200 years, according to the evidence of Mr. Christie-Miller, the proprietor of Craigentinny meadows, given before Dr. Brady's Committee. The quantities of sewage supplied to those meadows are very enormous; thus in some parts it is applied at the rate of the refuse of 350 people per acre, the quantity being—

"Often as much as ten or fifteen thousand tons per acre during the growing season, besides an indefinite quantity during winter. . . . The stream flows on in almost undiminished foulness to the meadows lower down. . . . . It is plain that an enormous quantity is applied, much beyond the needs of the largest possible crop of grass." (*First Report, R. P. C.* vol. i. p. 75.) Too much applied at Craigentinny meadows.

The proprietor, on the contrary, holds the opinion that the more sewage is supplied the richer is the crop. He says:—

"I do not suppose that any tenant ever complained of having too much water put upon his lot . . . . . they have frequently complained of their not having enough, but we never had a complaint from a tenant that the waterman gave him too much." No complaint of too much.

The increase in the value of the land is very remarkable. Mr. James Smith, in his Report to the Health of Towns Commissioners (1845), on the application of Sewer Water for Agricultural Purposes, says (*Second Report, H. of T. C.* vol. ii. p. 174.):—

Increase of value of land.

"The practical result of this application of sewer water is, that land which let formerly at from 40*s*. to £6 per Scotch acre, is now let annually at from £30 to £40, and that poor sandy land on the sea-shore, which might be worth 2*s*. 6*d*. per acre, lets at an annual rent of from £15 to £20. . . . . . The average value of the land, irrespective of the sewer water application, may be taken at £3 per imperial acre, and the average rent of the irrigated land at £30, making a difference of £27; but £2 may be deducted as the cost of management, leaving £25 per acre of clear annual income due to the sewer water."

"During the past year the highest price attained was £41 17*s* 6*d*. per acre,[1] and from that down to £19 an acre has been realised. The Italian rye-grass on the same farm has varied in price from £32 an acre for the first year's cuttings, to £25 an acre for the second year's cuttings." (*First Report, R. P. C.* 1868, vol. i. p. 75.)

At another farm, where eight acres are supplied with about 3,000 tons per acre annually, "a quantity which, at 1*d*. per ton, if ordinary sewage be taken to be worth so much, many ordinary agricultural crops would easily repay," the Italian rye-grass grown on them has been sold for from £25 to £36 an acre; "prices equal to those obtained at Lochend, where four times the quantity of sewage is applied. It would seem, therefore, that the enormous surplusage of foul water used at the latter place fails to be of any agricultural service." The summer's grass of the lower Craigentinny meadows—

Equal crops with less sewage.

"Is sold by auction to the Leith and Edinburgh cow-keepers every spring, and the maximum value reached last year was

[1] That is to say, that the receipt from a certain quarter of an acre was at this high rate.

£36 15s. per statute acre. The quantity of grass for which such prices are obtained is believed to vary from 50 to 70 tons per acre. And as the means are perfected of distributing the sewage more evenly, and as the subsoil drainage of the land improves, the quantity and price are both increasing year by year. No exhaustion is apparent anywhere. The sewage brings down more than the plants require of every necessary constituent of their food, so that even the poor sea-sand is as fertile as the rest, and the land is getting richer year by year, notwithstanding the enormous crops it yields. Taking the average price of the whole 240 acres to be £24 an acre, we have a total annual produce of £5,760 a year extracted by the land and grass from the drainage of 80,000 people, or 1s. 5d. from each person annually—certainly not a halfpenny a ton, over the enormous quantity of sewage which is here applied. But the area is not sufficient to take up the whole of the filth brought down by the water. A much larger extent of crop could be obtained from the use of it, if there were any land convenient on which it could be applied, or if there were a sufficient demand for the produce of it." (*First Report, R. P. C.* 1868, vol. i. p. 75.)

Results on the whole.

That the results are not as satisfactory to the town as they should be, is seen from the fact that the receipts are £7,000, while the cost of cleansing the town is £13,000; but it is better than quite wasting the sewage, as the cost of cleansing the city would be the same.

Results not satisfactory.

The Earl of Essex, who has applied the Watford sewage for irrigation, gave evidence before Dr. Brady's Committee that the increased value of land per acre, after deducting the price of the sewage, was £2 7s. 6d. clear. It exceeded the rent of the ground. He considers that 60,000 tons are sufficient for fifty acres of land, and he finds that it is stored up as it were in the soil: "put it on when you like, it remains in the soil till it is wanted by the plants." Four or five crops of rye-grass are produced in the season, and "I can fatten nearly two bullocks to the acre, besides

Experience of the Earl of Essex.

seven or eight horses, and as many pigs as I have room for." On thirty-five acres of meadow grass 600 tons an acre were applied, and the result was an extraordinary crop, such as he "never saw before using the sewage." Wheat was also grown, and it was found to increase in value, both in straw and corn; it will thrive very well after Italian rye-grass. 134 tons of sewage were applied to each of two acres of wheat, and from each acre a value of £3 1*s.* 6*d.* over and above that of the produce of any other acre in the field was produced, or 5½*d.* for each ton of sewage applied. The general results of this farm show that at three farthings a ton it will pay very well to irrigate with sewage, and, at a halfpenny a ton, uncommonly well; but that it would not be certainly profitable unless the sewage was got under a penny a ton.

Very valuable results.

Carlisle was the only town which informed the British Association Committee of last year that it has no present or prospective difficulty with regard to the treatment and utilisation of its refuse matters; but we find that only a part of the sewage is utilised by irrigation, the greater part being still allowed to flow into the river; the following account must therefore be taken with this limitation.

Carlisle sewage farm.

The evidence given before Dr. Brady's Committee, shows that the sewage (? part of it) is pumped up from the main sewer (which really goes into the River Eden) on to some land, being mixed as it passes the pump with a small stream containing 1 per cent. of carbolic acid, viz. 1 gallon of carbolic acid, 100 gallons of water, and 5lbs. of lime. It is stated that after this admixture it is perfectly inodorous. It is

Deodorisation by carbolic acid,

supplied to the land at the rate of about 4,000 tons per acre per annum, by means of iron pipes which can be shifted about. There is no disagreeable smell. The crops are stated not to be so forward as those at Edinburgh, the reason assigned being, either that not enough sewage is put on the land (?), or that the carbolic acid "checks its immediate usefulness as a manure." This last is a reasonable supposition; it is certainly very likely that a little too much carbolic acid would have that effect.

Perhaps a disadvantage.

The Rivers' Pollution Commissioners found that the whole of the sewage was absorbed by the sandy soil, so that there was, "properly speaking, no effluent water;" and so, as there was no drain outlet, the result of the purification effected by the land could not be easily shown. Nevertheless, the water taken from a hole three feet deep, dug in an irrigated meadow, was certainly sufficiently pure.

No effluent water.

The sewage of Malvern is utilised on a farm which was originally waste land covered with gorse: large crops have been got from it; the cattle prefer the grass which has been sewaged; the milk and butter are excellent; sheep thrive well.

The cost of the preparation of this farm was, for 147 acres: drainage, £1,000 (£600 for labour and £400 for tiles), and £3 per acre for fitting the surface of the land. (*Mr. M'Cann's evidence: Dr. Brady's Committee*, 1862.)

At Warwick, the sewage is received into a tank at some distance from the town, from which it is pumped through iron pipes up to the highest point of a clay land farm about three-quarters of a mile distant. It is not received in a tank at the farm, but simply

Clay farm at Warwick.

issues from the pipe at the highest point, and flows down through open carriers into the fields. It is stopped at intervals by the workmen, and caused to flow over the land. The sewage is here very dilute, and, as the land is a stiff clay, we were not surprised to find that the part which was at the time being flooded was almost a swamp, and we were told by the workmen that the difficulty of managing a large amount on this very unfavourable soil was, in winter, very considerable. But still we saw the effluent water flowing off at the foot of the fields in a clear stream, which, at its junction with the river some distance lower down, was as bright and limpid and free from any offence whatever as a stream could be. The analysis of this water by the Rivers' Pollution Commissioners shows that the purification undergone by it is exceedingly satisfactory, especially when allowance is made, as it ought to be, for the concentration which the liquid undergoes by evaporation; although it must have been effected almost, if not entirely, by the action of the vegetation itself and of the surface of the soil, for evidently very little of it penetrated to any depth. Although this farm has perhaps as great disadvantages for the application of sewage water as a farm can have—namely, a stiff clay soil, a large quantity (10,000 tons per acre annually) of very dilute sewage (containing only 66·9 parts per 100,000 of total solid matters in solution), which, moreover, has to be all pumped to a distance of three-quarters of a mile from the outfall works,—" nevertheless, the nuisance is sufficiently abated, and large crops of Italian ryegrass have been obtained, for which a ready sale at 10*s.* and 12*s.* a ton, upon the ground, has latterly been

Effluent water purified.

Disadvantages of locality.

Fine crops.

obtained." We find that this year (1870) it has been sold at £1 per ton, and the demand for it is greater than the supply. We also saw some root crops doing very well, some of which had been recently transplanted; and, what is more important perhaps to notice, the example set here is being followed by the neighbouring town of Leamington (where the "A B C" process has been for some time at work), and irrigation works are being constructed for that town, to supply a farm two and a quarter miles off with the sewage, which will have to be pumped all the distance.

Example followed at Leamington.

At the Beddington meadows, near Croydon, the drainage of from thirty to forty thousand people has for the last seven years been disposed of upon 260 acres of land. In the Ninth Report of the Medical Officer of the Privy Council it is stated with regard to this farm, that—

"The sewage after passing over the land contains just one grain of total impurity more than the water of the Croydon Water Works —22 and 23 grains to the gallon. Here the soil is porous gravel. At a second outfall, at Thornton Heath, 250,000 gallons daily are used, on 20 acres of land where grass and market produce are grown, and for most crops it is found to give remarkably favourable results. Here again the soil is gravel. At a third outfall, in Beckenham parish, 37 acres of stiff clay soil are irrigated, and the largest and healthiest crops of all to which the sewage is applied are got from this clay soil, a circumstance that was not expected, while the purity of the effluent water is almost absolute. A fourth outfall goes into the Metropolitan sewers." (*Loc. cit., Appendix*, p. 101.)

Purity of effluent water at Croydon.

Especially good results on clay.

"Very heavy crops of Italian rye-grass have been grown here." (*First Report, R. P. C.* 1868, vol. i. p. 87.)

"As much as 14 to 16 tons per acre are cut early in the month of May, and four or five cuttings a year are obtained,

Crops of grass;

averaging from 8 to 10 tons each per acre. Mr. Marriage has also successfully used dressings of sewage in the cultivation of mangold wurzel; and when wheat has been grown after sewaged grass, he has irrigated the field with advantage even so late as the month of July, when the crop has appeared to be flagging and apparently suffering during a drought."

mangold wurzel; wheat.

Here, too, the results of the purification of the effluent water are, as stated in the Public Health Report above referred to, and also by the Rivers' Pollution Commissioners, exceedingly favourable even in the winter; it "was satisfactorily cleansed, and contained but mere traces of suspended matters." Except on one occasion during the whole year of 1869, organic matters were present in the water, "in proportions considerably below those necessary to render the effluent water an offensive addition to a stream at any season of the year." During a seven nights' continued frost, however, "the purification became markedly impaired." It appears "that the cleansing of sewage is, in the absence of actual frost, less dependent upon season than upon the quality of the sewage itself." As an instance of the utilisation of exceedingly strong sewage by irrigation, we may take the case of Banbury, where the sewers, which were laid in 1854-56, were made to have their outfall into settling tanks and filters, and the solid part thus separated from the sewage, being mixed with street-sweepings and ashes, was sold for manure, while the liquid portion was allowed to escape into the Cherwell. This liquid is now pumped up to the highest point of a farm of 136 acres, which has been leased for twenty-one years at the rate of £4 10*s*. an acre, while the solid part which settles in the tanks is still disposed of in the same manner as formerly. The soil is for the most part a

Great purity of effluent water.

Filtration.

stiff clay, and much of the farm is old grass land which is not specially laid out for irrigation. These facts, and the strength of the sewage—which contained on October 17th, 1868, no less than 111·5 parts of total solid matters in solution, of which nearly 14 parts were total combined nitrogen—make it not astonishing that the purification of the effluent water is not as complete as it is in some other cases; still, the results attained "are by no means unsatisfactory; and they are improving, both as regards the cleanness of the effluent water and the returns from the use of it."

Disadvantages.

Strength of sewage.

"The accounts given of the produce of the land are satisfactory, and it is believed that the farm will soon repay rent and costs and loan; so that the nuisance hitherto created by the town will be ultimately abated without any serious permanent charge upon the inhabitants." (*First Report, R. P. C.* 1868, vol. i. p. 81.)

Produce satisfactory.

Worthing is another instance of a town where the sewage has been for some time utilised by irrigation. Formerly it was allowed to gravitate into the sea, fouling in its way a stream to the east of the town; now it runs into a tank, and is thence pumped up on to about 100 acres of land, although it appears that the night sewage is allowed to flow away. In 1866, Dr. Buchanan stated (*Ninth Report, M.O.P.C. Appendix*, p. 196, foot-note) that these irrigation works "appear to be to the completest extent satisfactory, both in their agricultural and financial results;" and from the account of the Solicitor to the Company it appears that the profits for the year 1869 amounted to £761 18*s.*; the receipts having been £1,807 4*s.* 9*d.* and the expenses £1,045 6*s.* 9*d.* But it must be noted that these expenses were abnormally increased

Satisfactory results at Worthing.

by the "sum of £51 13*s.* 11*d.* for a 'Level' rate made for the protection of various lands from the encroachments of the sea, which is a special and not an ordinary parochial rate," and by some other sums also. This farm consists of about 96 acres, of which about 83 receive the sewage of 7,600 people, the daily volume being about 480,000 gallons (of which 130,000 gallons are spring or surface water). This shows at least a *net profit,* all expenses being paid, of 2*s.* per head of the population. The farm is very favourably situated, the soil being a good free loam, and the natural slopes convenient for the distribution of the sewage. The whole result is a decided success, although the sewage is very weak.

Profit per head of population.

Many other instances might be given of the application of sewage of towns in this way, in all cases abating entirely the nuisance of the pollution of the rivers, and, in several instances, already more than paying the expenditures. Thus, at Norwood the profit in 1869 was £148 5*s.* 9*d.*, the area under irrigation being 30 acres, from which the Croydon Board of Health obtained "a revenue of £22 per acre during nine months of 1868, and £25 per acre in 1869, which, spread over the population to whose drainage it is due, amounts to about 3*s.* 9*d.* per head per annum." At Aldershot Farm it appears that the land is let to neighbouring cow-keepers at £20 an acre: "supposing 40 acres here to yield £20 an acre, and other 40 acres to owe one-half of their crops, or £10 an acre, to the winter sewaging, we have here a return of £1,200 from the waste of 7,000 adults, or 3*s.* 4*d.* per head per annum." The sewage of Woking Invalid Prison has been applied to some

Profit at Norwood; at Aldershot.

very poor sandy soil, so very porous that a dressing of 40 tons of sewage, poured on in three-quarters of an hour at the head of a quarter-acre plot, is almost all absorbed before it reaches the foot of the plot. (*First Report, R. P. C.* 1868, vol. i. pp. 85, 78, 89.)

Result at Woking.

"The four plots of one acre were sown with Italian rye-grass in March, and three crops, averaging more than twelve tons each, were cut during the following summer, the plant having been repeatedly sewaged during the intervals. . . . . . On plots of similar soil, the heaviest and most luxuriant growth of savoys, kale, and cabbage has taken place."

Peat may be cultivated.

It appears, too, that peat when sewaged yields as abundant crops as anything else. It will be an immense advantage if peat bogs can thus be converted into fruitful fields. In all cases the value of the land has been most remarkably increased; it may be converted from perfectly worthless land, certainly not worth half-a-crown an acre, to land "worth £30 an acre to cow-feeders."

At Colney Hatch Lunatic Asylum, the sewage of 2,000 individuals (120,000 gallons a day), is utilised on 70 acres of land, very good crops being produced; two dressings of 250 to 260 tons each are applied.

The sewage is received into a tank, and a deposit forms which is removed twice a year.

Expenses at Colney Hatch.

The plant cost £800, say £40 a year; the eight-horse engine, boiler, and pumps cost £4 a year for repairs; and the working expenses are 10*s.* 6*d.* a day (viz. coals 3*s.*, two men 5*s.*, and interest on capital 2*s.* 6*d.*=10*s.* 6*d.*)

The sewage is not well managed, as half of it gets away unused. (*Dr. Brady's Committee.*)

The results obtained at the Lodge Farm, Barking, Lodge Farm, Barking.

are very instructive. In 1868 and 1869 experiments were tried with wheat, winter oats, rye, and cabbages. In 1868, wheat was sown on a slope of shingle; part was left unsewaged, and yielded 3 qrs. 5 bush. with 3 loads of straw to the acre; part received two dressings of sewage (450 or 500 tons in all) and yielded 5 qrs. 3 bush. with $4\frac{1}{2}$ loads of straw to the acre. The winter oats, with three dressings of about 500 tons per acre in all, yielded 8 quarters of corn with 3 loads of straw per acre. The rye, with two dressings of 450 to 500 tons in all per acre, was thrashed in the field in July, and yielded 6 quarters with 3 loads of straw. The season of 1869, which was a less favourable one, still produced excellent results:—

Cereals: great success.

"The wheat has yielded 4 quarters per acre, the winter oats no less than 11 quarters per acre; the barley ripening unkindly only $4\frac{1}{2}$ quarters per acre; but it must be remembered in all these cases, that the field, naturally a poor gravelly soil, was then yielding its third successive grain crop."

Great variety of crops.

It should be stated that at this farm all kinds of crops have been grown. We have a list before us of no less than *thirty-eight different vegetables* which have all flourished upon it, beginning with cereals—including maize—passing through various forms of grass, pulse, greens, root crops of all sorts, potatoes, salad plants, and fruit in the shape of strawberries, raspberries, currants, and gooseberries.

Return per head.

"The Lodge Farm experience, confining it to its growth of grass, may be said to represent a return of 5*s*. annually from every individual contributing to the sewage used upon it. Supposing the water supply to be over 30 gallons a head, each person will make 50 tons of sewage annually, corresponding to the production of 10 cwt. of grass worth 10*s*. a ton." (*First Report, R. P. C.* 1868, vol. i. p. 77.)

EXPERIMENTS ON VARIOUS CROPS.

The Sewage of Towns Commissioners instituted a series of important experiments to show the value of sewage and the amount of the crops that could be got from it by irrigation. From these they concluded—

"That the most beneficial and most profitable method of disposing of sewage where circumstances will admit of this use of it, is by direct application in the liquid form to land; where such applications can only be conveniently effected near habitations, it may be desirable to employ some deodorising agent, but usually, if proper arrangements are made for conveying sewage on to the land, this expense need not be incurred." (*Second Report, S. of T. C.* 1861, p. 40.) Conclusion, S. of T. C.

"By the application of large quantities of dilute town sewage to permanent meadow land during the spring and summer months, there was obtained an average increase of about four tons of green grass (which, owing to the lower proportion of dry substance in the sewaged grass, was equal to only about three-fourths of a ton of hay) for each thousand tons of sewage applied, until the amount of the latter approached the rate of about 9,000 tons per acre per annum. The largest produce obtained was about 33 tons of green grass per acre. The period of the year over which an abundance of green food was available, was with the largest amounts of sewage between five and six months." (*Report by Mr. Lawes, loc. cit.* p. 36.) Experiments of Mr. Lawes. Produce.

This grass was shown to be suitable for fattening oxen, especially if a little oilcake was given in addition. Milking-cows give considerably more milk in proportion to the solid matter contained in their food when fed on sewaged than on unsewaged grass, though they give a less quantity in proportion to the quantity of fresh grass consumed. "Milk to the gross value of £32 per acre was obtained where the largest quantity of sewage was applied. The gross value of the milk from the increased produce of each thousand Fattening oxen. Milking-cows.

tons of sewage was between five and six pounds." Sewaged grass contains less dry substance than unsewaged grass, and a given weight makes less hay, but the dry substance of sewaged grass generally contains a higher proportion of nitrogenous compounds than that of non-sewaged grass. (*Loc. cit.* p. 37.)

More nitrogenous matter in sewaged grass.

In the Third Report of the Commission (1865) the following results are recorded (pp. 72, 73) :—

Early and late crops.

"By the application of sewage to grass-land during the winter a very early cut or bite of green food may be obtained, but the amount of increased produce due to the winter application is comparatively small for the amount of sewage employed."

"The period during which an abundance of green food was available, was extended considerably at the end as well as at the beginning of the season, and the more so the larger the quantity of sewage applied, almost up to the highest amount employed, viz. 9,000 tons per acre." A poorer soil "gave fully as much produce per acre, under the influence of liberal dressings of sewage, as the naturally much more fertile soil." While from the average of three years, and from the two fields on which the experiments were conducted, "the amount of produce obtained, without sewage, was about 9¼ tons of green grass per acre per annum, equal to about 3 tons of hay; and with 3,000, 6,000, and 9,000 tons of sewage per acre per annum the amounts were respectively about 22¼, 30¼, and 32½ tons of green grass, equal respectively (reckoned according to the percentage of dry substance in each) about 5, 5¾, and 6½ tons of hay."

Poor soil as fertile as good one.

Increased amounts of produce

But the largest quantities obtained were as much as 35 tons of green grass in one field and 37 tons in the other, equal respectively to 6 tons 12¾ cwt. and 7 tons 1cwt. of hay. These crops were produced with 9,000 tons of sewage per acre per annum. The increase in the crops was not proportional to the increased amount of sewage, for the increase per 1,000 tons was, when 3,000 tons were applied, about

not proportional to increased amount of sewage.

5 tons of green grass; when 6,000 tons were applied, 4 tons $2\frac{1}{2}$cwt.; and when 9,000 tons were applied, 3 tons $3\frac{1}{4}$cwt. The results obtained with Italian rye-grass gave about the same increase of produce. Fattening oxen consumed more sewaged than unsewaged grass to produce a given rate of increase; but, reckoned as dry solid substance, the amount consumed was less to produce the same result. It was found advisable to give oilcake in addition, and the money return was not nearly so favourable with fattening oxen as with milch cows. With regard to the weights of sewaged and unsewaged grass which produced a given quantity of milk, the results were the same as before, all of them showing that the dry solid substance contained in sewaged grass is more nourishing than that contained in unsewaged grass.

Fattening oxen less return than with milking-cows.

"On the average, about six parts by weight of fresh grass yielded one part by weight of milk. By the aid of sewage, the time that an acre would keep a cow, and the amount of milk yielded from the produce of an acre, were increased between three and fourfold." (*Third Report, S. of T. C.* p. 74.)

Sewage-grown Italian rye-grass was found to be more favourable for the production of milk than meadow grass (the result of only one experiment). From these experiments it is calculated that "with an application of about 5,000 tons of sewage per acre per annum to meadow land, an average gross produce of not less than 1,000 gallons of milk per acre per annum may be expected . . . . an average gross return of from £30 to £35 per acre, in milk at 8*d.* per gallon, may be anticipated." With regard to the grass, it has been stated that the proportion of nitro-

Favourable food

Return from milk.

genous substances was greater in the sewaged than in the unsewaged grass. It was also found that this quantity was much higher in the solid matter of the grass grown towards the end of the season; and it would appear that the greater productiveness in milk and in increase of flesh, observed as the result of feeding with sewaged grass, depends more on the *quality* of these nitrogenous matters, and their ready assimilability, than on the actual percentage of them. The milk obtained was greater in quantity, when compared with the amount of dry solid substance in the grass, with the sewaged than with the unsewaged grass. It was, however, slightly less rich, but when some oilcake was given with the grass its richness was notably increased. An experiment was made on the effect of sewage irrigation upon oats: this showed that when only 135½ tons of sewage per acre were employed, "the gross value of the increased produce amounted to more than 5*d.* per ton of the sewage employed, or to about three times the market value of the constituents of the sewage, supposing them to have been extracted and dried; and in another experiment, in which 510 tons were applied per acre, the gross value of the increased produce amounted to about 1½*d.* per ton of the sewage employed." (*Loc. cit.* p. 78.) These experiments were made under exceptional circumstances, with dry weather, a very productive season, and sewage of about double the strength of the London sewage. These results with oats, as well as those obtained by the Earl of Essex with wheat, show in both cases "a very high gross money return per ton of sewage employed." The general conclusions of these Com-

Quality of the nitrogenous matters in the grass.

Quantity and quality of the milk.

Experiment upon oats.

Excellent results.

High return.

missioners are—that sewage should be applied, to obtain the highest value from it, "in small quantities per acre, and in dry weather;" that 5,000 tons per acre applied to properly prepared grass land would produce the most profitable result; and that the effluent water would be sufficiently purified. That the above quantity would represent the sewage (including rainfall and so forth) from fifty individuals, so that "a population of three millions would require about 60,000 acres constantly under irrigation." That the greater proportion of sewage would have to be used on grass land, because the expense of distributing it by means of piping and hose-and-jet to arable lands instead of by open carriers (as to grass land), would be too great to warrant the large employment of it in this way. We shall see that this method of distribution is not by any means necessary in the application of sewage to arable land any more than it is to grass land. The Commissioners concluded from their experiments "that the farmer would not pay three-farthings, and probably not a halfpenny per ton the year round, for sewage of the average strength of that of the metropolis (excluding storm-water), delivered on his land." It is pointed out by the Sewage Committee, 1862 (Dr. Brady's), that the reason that such an unfavourable monetary value was got by Mr. Lawes was, that the sewage was applied in a manner likely to cause waste, and in too large a quantity; and the case of Annerley schools was instanced, where 9*d.* a ton was got in value from the sewage, and where it was found that 1,500 tons per annum, distributed by hose-and-jet (*i.e.* distributed carefully), produced an equal result with from

Should be applied in small quantities per acre.

Conclusions, as to value.

Too much applied in above experiments.

8,000 to 9,000 tons distributed by gravitation (probably not with sufficient care, or proper laying out of ground); and Philip Miles, Esq. gave evidence before the same Commission that he had about doubled the value of fourteen acres of land by carefully utilising the sewage of thirty people upon it, and that he calculated that there was realised a clear profit of £1 a year for each person's sewage, instead of Mr. Lawes's 1*s*. or 2*s*. There is nothing impossible in so high a profit; it merely shows the great value of the water itself—a consideration which may come to be an important one in future valuations of sewage.

Very high profit by economical use.

The above experiments are, however, most valuable from many points of view; but they do not give any account of results with other crops than grass and oats, and so we must turn to the results obtained at Lodge Farm, Barking, and at Breton's Farm, near Romford, in Essex. At the latter place we find from the evidence given by Wm. Hope, Esq., V.C., before the Reading Local Board of Health, that he rents a farm of 121 acres at £300 per annum, and that he pays in addition £600 a year for the sewage of the town of Romford delivered on to the farm, being equal to two shillings per annum for the sewage per head of the population, and that moreover he "agrees to bear the Board harmless in respect of all actions for any damages or nuisance." On this farm he has grown successfully all the crops above mentioned as grown at the Lodge Farm near Barking; and on the 6th of August, 1870, we saw very fine crops of almost every kind growing there, and remarked that several of them bore excellent evidence to the fact stated, that roots bear transplantation remarkably well when

Breton's Farm.

All kinds of crops.

supplied with sewage. A crop of maize was exceedingly luxuriant, and gave every promise of ripening, and the only fault that could be found with a plot of oats was that they were too thick, the ears being especially heavy and of very remarkable length, in some cases as much as 27 inches. It may be stated as a proof that strawberries (a very valuable crop) thrive well when supplied with sewage, that those the Lodge Farm produced (in 1869) were the finest in Covent Garden Market, and fetched the highest price. Beet-root promises to be a crop of the greatest importance in sewage farms, and the manufacture of sugar from it would certainly realise a very large profit. Professor Voelcker finds that the best beet-roots grown in Holland, Suffolk, and Scotland give from nine to ten per cent. of sugar at the outside, while the roots grown at the Lodge Farm, with London sewage, give 13·19 per cent. of it. There seems no reason why hops should not be manured with sewage, and indeed they would appear to be a crop especially suited for it, as they require to be manured while growing. From a paper read by Mr. Hope at the Institution of Surveyors, on November 22nd, 1869, we find that he considers Italian rye-grass to be the staple sewage crop, and that it will produce, under proper cultivation, ten crops, averaging nine or ten tons each per acre, in one season, by the application of a sufficient quantity of sewage—the grass being sown in the month of August; and that from the farmer's point of view the dilution of the sewage of a town should not be less, if possible, than from 25 to 30 gallons of liquid per head of the population daily. The sewage of 35 to 40 persons per acre is a sufficient average for a term of years.

Straw-berries.

Beet-root.

Italian rye-grass.

Dilution of sewage.

THE SEWAGE FARM.

In order to obtain ground for the utilisation of the liquid sewage of a town where no private individual or company can be found to undertake to do so, paying the town for the privilege, it has been recommended by the Rivers' Pollution Commissioners (1868), that—

Power to take land.

"Subject to proper regulations to prevent abuse, additional powers be given to corporations, local boards, manufacturers, and others, to take land compulsorily, under 'Provisional Order,' for the purpose of cleansing sewage or other foul liquids, either by irrigation, filtration, or otherwise." (*First Report*, vol. i. p. 136.)

Well then, suppose the sewage to be carried out of a town in a covered sewer to the ground which has to be irrigated. This sewer would, of course, have to pass on its way, in many cases, through private property, and to this end the Commissioners recommend that the authorities above mentioned should have power—

Compensation for damage to private property.

"To obtain, if required, easements for the construction of culverts and outfalls for drainage through private property, making compensation only for damage actually done; reserving, however, to the owner the right at any time afterwards, if he could show further damage, to have further compensation."

In cases where the proprietors of land through which the culvert passes are desirous of obtaining sewage as manure for their own land, they could be allowed to take it at suitable places upon a payment for it according to the quantity required. It has

Invariable price.

been proposed that no difference should be made in the price of sewage at different distances from a town, but that it should be uniform, "upon the principle of the penny postage." Where the ground to be supplied is on a lower level than the town, the sewage would simply be allowed to run continuously without the interposition of any tank, unless it were considered advisable to have one for keeping the night sewage until the next morning, or unless it were proposed to strain or filter the sewage in some way before sending it on to the land, in order to separate the suspended solid matters. And here we must remark on the immense advantage that it would be to supplement the irrigation in every case, as is done at the North Surrey District School and some other places, by some method of simple filtration. In this way the most offensive and least valuable part of the sewage is separated from it before it is allowed to spread itself over the ground. The sewage is not by it appreciably diminished in strength, while the black mass remaining on the filter-beds could be mixed with town sweepings, or, in stone countries, where ashes are not required for brick-making, with these latter; and in this way a solid manure would be prepared very similar to the contents of ash-pits and middens, and which might, in some cases at any rate, be made to pay wholly or in part for the cost of scavenging the town. We find, from the Report issued by the British Association Committee of 1869-70, that at one or two towns, and especially at Dundee, the contents of ash-pits and middens are made to pay for the cost of scavenging; while at the town mentioned, a profit of about $1\frac{1}{3}d.$ per head of the population is realised. The contents of the Lancashire ash-pits are so valuable in

Filtration advisable,

to separate the offensive matters suspended,

and utilise the ashes and street sweepings.

Lincolnshire, that they sell for prices which pay for the cost of their transport thither, but which do not, as we have seen, nearly pay for the cost of scavenging the towns. From these cases we may conclude that the manure prepared by filtration in the above-mentioned way, though possibly it might not be quite so valuable, would still help considerably to pay the expense of collecting ashes and street sweepings. But this way of preparing it would have the inestimable advantage of not being carried on all over the town from day to day, a practice which we have seen to be an especially unhealthy one. It would also, as a secondary advantage, afford the possibility of keeping all the ashes separate from the manure in countries where either the ashes are valuable of themselves, or, on the other hand, render the manure by their admixture with it, as is often the case, totally unfit for the soil. At the school above mentioned, it was found that four tons of clay ashes, with a quarter of a ton of peat charcoal, produced, by filtration of sewage through it, eight tons of manure at the end of a month. The effect of this manure on the crops, at the rate of two tons per acre, was equal to that of 20 tons of ordinary farm-yard manure. The comparison was made by treating two plots with the quantities just mentioned for three seasons in succession: the result was that the crops were "as nearly similar as could be." This manure was found to be worth 10*s.* a ton, and the two tons per acre about equivalent to 4 cwt. of guano; but with crops subsequent to the first crop, the result was far superior with the sewage or farm-yard manure than with the guano. As to the expense of production, it was found that the peat charcoal cost

Result would help to pay for scavenging the town.

Can preserve the ashes separate, where advisable.

Experience at North Surrey District Schools.

Value of the solid manure.

£3 3*s*. a ton (fine ashes, however, would in many towns be a worthless product, and so their expense would be that of carting). The clay cost 3*s*. a ton to burn it when on the spot, so that the filter, consisting of four tons of burnt clay and a quarter of a ton of charcoal, cost £1 8*s*. 9*d*., and produced eight tons of manure, worth £4. This manure being used for swedes and mangold wurzel, gave a result of 25 tons an acre: an unknown quantity of potatoes were also supplied with it. Wheat was sown after these roots, and produced five quarters to the acre, "except where guano was used, when the crop was considerably lighter, both in straw and corn." It must be noted that the soil of this farm is mostly a stiff clay. (*First Report on Sewage of Towns*, 1862: *Dr. Brady's Committee.*)

Costs.

Results on crops.

Whenever sewage has to be pumped, some sort of straining, through gratings or otherwise, *must* inevitably be resorted to in order to separate off the larger solid bodies that are brought down with it, and that are of the most varied nature.

Separation of larger suspended substances.

In the cases, too, where simple filtration has been applied as the sole means of purifying the sewage, the manure has generally sold easily, and the filtrate which was allowed to run away, has sometimes rendered the brook into which it has run valuable as an irrigating liquid for farms lower down.

But where the land to be irrigated is above the town, so that pumping must be had recourse to, as at Warwick, Banbury, Romford, and so forth, it must be received into a tank or well, which should be covered, and provided with a high ventilating chimney. It is essentially necessary that it should so enter such tank

Receiving-tank.

that there is no chance of sewage being backed up in the sewer: and here we see the advantage of keeping the storm-waters out of the sewers; until this is done, it must happen, *in cases where the sewage has to be pumped*, that the well will get filled faster than the pumps can empty it, that the sewage will be backed up in the sewers with the ill effects already described, and that it will overflow from the tank; indeed, it would be necessary to provide a storm overflow for it: and although it may be contended that the sewage is so excessively dilute in such case that no harm would arise from its being allowed to enter the river, yet the answer must be that the manure would be lost, that the same amount of sewage would still enter the river although with a larger body of water, and that in towns where accumulation takes place in the sewers on account of their faulty construction or of want of regular flushing, the sewage so escaping is actually very much stronger than it is in ordinary times. The pumps must, of course, be double, so that one may be used when the other is out of order, or even that the two may be used at once if necessary.

Disadvantages of storm water.

Power of pumps.

One horse-power will lift 3,300 gallons of water one foot high in a minute, so that about 300 horse-power *nett*, working constantly, is required to raise ten million gallons 100 feet in twenty-four hours. Strong iron pipes are the only ones that are suitable on a large scale for pumping through. At Bedford, where the water supply does not much exceed 150,000 gallons daily, but where, from subsoil water, the amount of sewage to be pumped is as much as five or six hundred thousand gallons daily, two 12-horse-power engines are employed, each of

Example of power required.

which can lift 2,000 gallons a minute to a height of 20 feet—obviously more than enough for the amount above given, and this is to allow for storm-water. The sewage is then pumped up to the highest point of the land to be irrigated, and here, as may be seen at Warwick, there is no necessity for a storing reservoir.

We have thus seen the sewage, filtered or not, delivered on to the farm in one of two ways; it now remains to consider the most suitable manner of spreading it over the ground. The most obvious way is that of the "Marcite" meadows at Milan, namely, to let it run everywhere, in fact to produce "water meadows," separated from the land around by a bank. The disadvantages of this plan agriculturally are, that it water-logs the soil, and that it is not suitable to all crops, injuring the upper parts of the plants; neither does it allow of *intermittent* downward filtration, which admits air, so essential to the growth of plants and to the purification of the sewage itself, especially when the land is fallow; so that the effluent water would not be purified at all times, as we have seen that it is not, by *continuous* downward filtration. It has been proposed also to carry the sewage to the plants by *subterranean* irrigation; that is to say, by porous pipes laid deep enough in the ground to be out of the way of the plough: and indeed it is suggested that sometimes the ordinary drainage pipes may be used for this purpose by stopping up their outlets during the time that the irrigation is going on. This method is so obviously a bad one that it scarcely requires any further remarks. The sewage is sent into the ground below the roots of the plants instead of among and above them, as it

Submersion not advantageous.

Subterranean irrigation very bad system.

should be. The downward filtration which we have insisted on as the very principle of irrigation is abandoned, and it is plain that the greater part of the manure must be lost.

Hose and jet: advantages.

The next plan, which has found a great many supporters, is that of *underground pipes and hose-and-jet* distribution. The advantages claimed for this plan are that by it every plant and every square inch of ground can be thoroughly supplied with the manure, and that it is the only method that is suitable for a variety of crops. That this is certainly not the case has been amply proved by experience. The objections, on the other hand, to this plan are, its great expense both as regards plant and labour; the fact that it applies the sewage to the tops of the plants rather than to the roots; that a stronger flow is required in order to overcome the friction in the pipes; and that it is well calculated to cause a nuisance to the neighbourhood. It is a plan that has been very successful on a small scale, but that could never be used on a large one; and Messrs. Lawes and Way concluded from their experiments (*Sewage of Towns, Third Report*, 1865) that sewage was not applicable to arable land because of the great expense that would attend its distribution by means of pipes and hose and jet. For this reason it had failed on the Duke of Northumberland's land near Alnwick, where the tenants gave it up rather than pay the cost of its application. This is entirely condemnatory of the hose-and-jet system, but it hardly warrants the assertion that sewage is inapplicable to arable land. (*See* paper by Messrs. Lawes and Gilbert in the *Journal of the Chemical Society*, April 1866.)

Disadvantages.

Failure of hose and jet.

The only method, then, that we have left is that of open surface channels, which has now come to be tolerably generally admitted to be the correct one. It becomes interesting to know whether the sewage is likely to lose any proportion of its most valuable constituent, ammonia, by passage in open channels (particularly if open conduits be used for carrying it from the town to the farm.) The Rivers' Pollution Commissioners (1868) made some experiments on this point. (*First Report*, vol. i. p. 93.) They found that on exposing a solution of carbonate of ammonia containing 9·75 parts in 100,000, in a layer of 12½ inches deep, continually to a strong draught of air, the loss from it during the first three days was perfectly inappreciable, and in 16 days only amounted to 1·5 part per 100,000; while even the loss of another solution containing 9·25 parts, and in a layer of only two inches deep, was after 24 hours absolutely inappreciable, and after three days the solution still contained the same proportionate amount of ammonia; that is to say, it lost ammonia precisely in proportion to the evaporation that took place; or, in other words, the difference between the volatility of the ammonia and that of the water in such solution and after such a time is, under the most favourable conditions, inappreciable. "Even after the lapse of three days the proportional loss amounted to little over 13 per cent. At the rate of only one mile per hour, sewage would during this time have travelled 72 miles." The layer two inches deep lost over 13 per cent. in three days, while that 12½ inches deep lost only 2½ per cent. in the same time; that is to say, that, seeing the sewage in a conduit would be generally of some such depth as this or deeper, "the appreciable loss of fertilising effect,

Open channels.

Experiments with a solution of carbonate of ammonia.

Inappreciable loss of ammonia in twenty-four hours.

Open culverts. from the evaporation of carbonate of ammonia during its flow along a conduit of any length likely to be constructed, need not be feared." Dr. Hofmann, too, stated before Dr. Brady's Committee, that after a flow of 10 miles in an open culvert (with a medium temperature) it would be in very much the same condition as before. The objection raised to open conduits therefore vanishes, though in many cases it would no doubt be advisable to cover them over (as the Romans did their aqueducts) in order to prevent improper substances being put into them. Iron carriers. For carriers raised above the ground, wherever it is desirable to use these, sheet-iron has been found to be a very suitable material. It should be well painted inside and out; no accumulation takes place in it, and a suitable incline for these carriers is that of five inches in 100 yards. The beds should run at right angles to these carriers, and the carriers be so placed that the beds slope from them. At intervals along the carriers, taps of some simple construction should be placed, so that the sewage may be turned on when required for any particular plot. Concrete carriers. Where iron carriers are not necessary, concrete ones are found to answer well, and at some places, as at Bedford, 15-inch pipes are used for this purpose. If the sewage were well filtered, the use of concrete would be the less necessary, although concrete carriers would always be preferable to open ditches. With unfiltered sewage they are absolutely necessary, Deposit in bad carriers. as the deposit from it cakes on the sides of the ditches and produces an offensive smell. This we have noticed at Croydon, in the Beddington meadows. When the sewage is delivered by pumping to the highest point of the farm, and the ground is very sloping, it may be preferable to resort, as at Warwick, to the "catch-water" system, which consists in running carriers down the slope of the hill and along the fields, so that they are more or less parallel to each other, and the overflow from the higher ones falls into those below. With a general slight fall of the land, the "*pane and gutter*" system, in use at Croydon, may be employed. By it the sewage is taken by the minor carriers along the fields *across* the direction of the greatest fall, and allowed simply to spread over the surface of the beds from above downwards; but as a general rule the best plan is doubtless the "*ridge and furrow*" system, in which each plot consists of a ridge, that is to say, falls away on each side from the centre. At Bedford, the beds "are about 70 feet wide on the side, with a fall of 8 or 10 inches from the central carrier to the mid-way furrow;" while at Breton's Farm a breadth of 30 ft. (15 ft. "on the side") has been found most suitable.

Laying out of the ground.

"Catch-water" system on hilly ground.

Pane and gutter on gentle slopes.

Ridge and furrow, best plan, as a rule.

The simplest contrivances only are necessary to stop the sewage from certain beds and turn it on to others. Along the summit of each ridge is merely a small furrow through which the sewage is allowed to run; the workman should walk down the bed with an iron plate in his hand, with which he stops the sewage at intervals, so as to force it to run over the surface of the bed on each side of the small carrier. It is not very material whether this be done from above downwards or from below upwards; in fact, it may be done alternately by going down one bed and up the next, the sewage being turned on and off, as required, by a boy.

Distribution of sewage to the beds.

At Carlisle the sewage is distributed over the land

Portable carriers.

by means of light portable iron troughs, which can be shifted about by the workman so as to deliver it at any required point. One great condition for the successful purification of the sewage is that the land should be well drained; and clay lands must be broken up and treated with town ashes and lime, so as to facilitate the drainage, otherwise the sewage will run over the surface and run the risk of not being purified. Six feet deep is a good average depth for them on tolerably porous soil.

Drains.

Advantage of "separate" system.

As to the dilution of the sewage, it is certain that it would be more valuable as a general rule to the farmer if the rain and subsoil water could be kept out of it, as by a separate system of drains and sewers, although it is also certain that in many cases this proceeding would render the sewage too strong; so that it would be advisable that it should be possible to connect the drains with the sewers, not merely, as above stated, for flushing purposes, but, when required, to dilute the sewage. That this is true is seen from the fact that at Breton's Farm it was necessary, during the past very dry season, to turn all the effluent water sometimes, and invariably the greater part of it, back into the tank, to be re-pumped over the grounds with the sewage. To show the advantage of liquid manures over solid, we may quote Alderman Mechi's evidence before Lord Robert Montagu's Committee. He says that farmers would find it worth their while to take regular supplies of sewage, "even if they paid $2\frac{1}{2}d.$ or $3d.$ per ton, because, if it suits me at certain seasons during the summer, when there is growth, to pay $2d.$ a ton for water to wash in the guano, which does answer, it would answer to pay (although we should like to

But sewage may require dilution.

Necessity of water.

have it cheaper) from 2*d*. to 3*d*. per ton for sewage." (*Committee on Sewage*, 1864, p. 141.) Though it would probably not answer, at first at any rate, to pay that price for it, except when water is most wanted.

With regard to the question of its use in winter, when it must also be pumped on to the land, we may point out that most lands have the power of purifying it, and of retaining its valuable constituents boxed up, for use at a future time; and that, moreover, it is certain that by sewaging through the winter a very much earlier crop is got in the spring. The evidence from Milan must also not be omitted, showing a great advantage to the crops from the *warmth of the water* passing away from the town. **Value in winter.**

The amount of labour that must be expended on carefully irrigated lands is doubtless much greater than with ordinary farms, this being chiefly occasioned by the enormously increased crops and their rapid growth—the farms becoming market gardens. Thus work is provided, and well paid for too, as shown by the results obtained on all the well-managed farms which we have described; the farmer being always sure of his crops, as he is perfectly independent of the long droughts which we get in the summer, just when a little rain would be worth anything to the land. **Increase of labour.** **Certain crops.**

The difficulty arising in very wet seasons would be to a great extent got over by keeping the rain and subsoil water out of the sewers; while in summer the irrigation farms are often the only green spots in the country, fertile oases dispersed only too sparingly throughout a desert of parched vegetation. **Wet seasons.** **Droughts.**

ADOPTION OF SEWAGE IRRIGATION.

In the First Report of the British Association Sewage Committee, p. 28, it is stated that "in only 15 places out of the 96 where the water-carriage system of removing excretal refuse is adopted, either generally or partially, is the sewage applied for irrigating land," while twelve other towns were about to do so or contemplated it. We must now add to the list of towns then given, those of Romford, Warwick, and Cheltenham, which have adopted the irrigation system, and Leamington, where it will be at work before long: Oxford too is about to adopt it. From abroad we find that "already Dantzick and Frankfort-on-the-Maine have determined to follow the English example." (*Sewage Irrigation, by Adolphus Fegebeutel.*)

Towns employing sewage irrigation.

"The agricultural value of the sewage water now poured uselessly into the Baltic has been proved by an experiment made last year on a very small scale, by irrigating pure sea-sand with the water of one of the principal canals of Stralsund: the results corroborate the favourable reports received from England, rye-grass having been cut every month from 12 to 18 inches high; Bokhara clover has also grown well on the irrigated sand." (*German Quarterly Review of Public Health.*) The engineers to the municipality of Paris remark in their Report, in speaking of irrigation: "The agricultural results are not to be doubted. We are on a gravelly soil which calls for the alluvium formed each day by the traffic and life of two millions of inhabitants. We enjoy a temperate climate invigorated by a radiant atmosphere, all is possible—grass, vegetables, flowers, and fruits; and we have, for disposing of the produce, an unrivalled market, 'Les Halles' of Paris. It is therefore time to will and to act."

Foreign opinions and results.

French Engineers' Report, 1870.

Professor Dunkelberg, of Wiesbaden, also holds the opinion that "the irrigation system can alone cover the expenses and deliver the manure in the simplest and most efficient manner for the farmer;" and he recommends that a bill be passed by the North German Confederation to the effect that all sewage should be fully utilised in the irrigation of land, and no longer suffered to pollute any running water. Michel Lévy also gives in his unqualified adhesion to the irrigation system. He says (*Traité d'Hygiène*, tome ii. p. 433):—

Recommendations to Prussian Government.

"All will go to the sewer, and, by the prolonged sewer ramified to a distance, on to the earth in its natural form. Excrement, urine, slops, residues of every kind, all this constitutes the richness of the liquid manure, carted (*charrié*) by the sewers; it is useless to collect it in large tanks, to manipulate it, to transform it; the spreading of it over the soil, directing it by inclined culverts upon the lands which have need of it, preserving the purity of the waters, of the streams, and of the rivers; such is the end that more than one city has already reached, that London actively pursues, and that the force of circumstances will induce the administration of our capital to search after; but not without great expenditure, of which the repayment is sure."

Michel Lévy's testimony.

Lastly, Dumas, when inspecting the Barking Farm, expressed his opinion in these words—which, coming from the mouth of such a man, are worth volumes of unauthorised statements:—"*Oui, l'eau doit être la charrette de l'engrais.*"

Dumas' opinion.

We conclude, then, from the facts brought forward in this chapter—

Conclusions.

(*a*.) That by careful and well-conducted sewage irrigation, especially with the application of moderate quantities per acre, the purification of the whole liquid refuse of a town is practically perfect, and has been ensured in cases where it was not at all the object of the agriculturist; and that it is the only process known

Purification of the liquid refuse practically perfect.

by which that purification can be effected on a large or small scale.

Increase of value of land; (*b.*) That perfectly worthless land, blowing sea-sand for instance, can be made in this way to support large and valuable crops.

of crops. (*c.*) That the quantity per acre of all crops obtained from even the best land is enormously increased.

Needlessness of artificial manures. (*d.*) That it reduces to a great extent, or renders entirely unnecessary, the usual amount of artificial manures of all kinds, by supplying a manure especially adapted, from its complex constitution, for the nourishment of crops, supplying it moreover in a state of solution, that is to say, in the most readily absorbable condition, and supplying at the same time that most necessary aid to vegetation, water, which often converts what would otherwise have been a heavy loss into a very handsome profit.

Farmer independent of drought. (*e.*) That by it the farmer is rendered entirely independent of drought, so that he can be practically certain of his crops, and moreover be able to transplant them as much as he pleases.

Pays, and will pay. (*f.*) That with all these advantages, it is no wonder that it has been found to pay; and when its management is more thoroughly understood, it will doubtless be found to be a valuable source of income to the towns. In fact, in the words of the Rivers' Pollution Commissioners (1868), "Intermittent filtration is a costly process with no possibility of any return, whilst irrigation, although it may in the first instance require a larger outlay of capital, affords a hopeful prospect of a return for the capital invested."

CHAPTER XI.

INFLUENCE OF SEWAGE-FARMING ON THE PUBLIC HEALTH.

As far as nuisance is concerned, there is no doubt that if irrigation farms are badly managed they may be made a nuisance to the neighbourhood. Ordinary sewage is only in a very slight degree offensive when fresh, as everyone knows who has examined it. Thus Dr. Hofmann says, in his evidence before the Select Committee on Sewage, 1862 (*Dr. Brady's Committee*) that sewage at the mouth of a sewer is "comparatively little offensive," and that irrigation is possible without annoyance, except in very hot seasons; adding, that sewage is only offensive when kept in tanks. What is really the most offensive part of sewage farms, is the black slimy mud which collects along the sides of carriers when they are not made of concrete, and when the sewage is not filtered before being sent on to the fields. We think that it is essential that the sewage should be filtered or strained in the manner practised at several places. There is no reason to spread a layer of comparatively worthless and necessarily offensive filth over the surface of the soil.

Fresh sewage not offensive.

Offensive deposit in bad carriers.

Necessity of filtration to obviate this.

At Carlisle, indeed, the sewage is deodorised by admixture—as we have before stated—with carbolic

Deodorisation with carbolic acid.

acid. The deodorisation is complete, "no nuisance is made by them (the works) or by the refuse water discharged into the river" (*Ninth Report, Medical Officer of the Privy Council*); but it would appear, as may be expected, that this addition is, to say the least, no improvement to the sewage regarded as manure. The Earl of Essex says that the irrigation of fields creates no more nuisance than the application of any other manure. This is certainly the case, and indeed no irrigated fields that we have seen give offence to be compared for a moment with that produced by the application of stale farm-yard manure. But this is not enough; the careful application of sewage which is fresh and not offensive in itself does not as a matter of fact produce any offence at all at the time, and need never do so if the simple plan above mentioned is resorted to, as it is at the North Surrey District School and other places.

Nuisance: that of ordinary manure; or is less.

Need not be any.

Dr. Cresswell says of the farm at Norwood: "As for effluvia, I will not say that there does not exist any, but it is so seldom perceptible that a house built within 200 or 300 yards would command the same rent as if half a mile off."

Smell during application.

The Earl of Essex says (Dr. Brady's Committee) that there is a smell during the momentary application of the sewage; "five minutes after there is not the slightest smell whatever, the bad smell is entirely absorbed by the land."

It is agreed on all hands that the nuisance created depends on the quantity of sewage applied, and on the way in which it is applied; thus at Beddington there is "occasional nuisance owing to foul ditches, or perhaps to the ponding of foul water in hollows on the land."

Dr. Ligertwood, surgeon to the 8th Hussars, stationed at the Piershill Barracks, says: "These fields are certainly a source of nuisance to those living in barracks, from the offensive emanations given off from the open ditches conveying the sewage, and also from injudicious flushing of the fields; the stench in barracks is sometimes quite sickening. All this might, however, be remedied by the sewage being conveyed to the fields in covered ditches or pipes, and outlets placed on the pipes in the fields at proper intervals for irrigating." (*First Report R.P.C.* 1868, vol. i. p. 90.)

Nuisance from bad management.

No such nuisance ought to exist, as it is simply the result of carelessness, and it is the duty of the Medical Officer of Health to see that it is prevented.

On the other hand, Dr. Alfred Carpenter says:—

"At Norwood, moreover, a public footpath passes right through the irrigated fields, which is traversed by hundreds of persons for exercise and recreation, especially on Sundays. The persons so using the footpath have been frequently surprised when they have been told that their walks for pleasure have been taken through the sewage farm of the Croydon Local Board of Health. The path is much more frequented than other footpaths in the neighbourhood, which would not be the case if the fields were the nuisance they are supposed to be."—(*Some Points in the Physiological and Medical Aspect of Sewage Irrigation*, p. 35.)

No nuisance if well managed.

We can most fully bear witness to this fact; persons who have accompanied us to see sewage farms have been invariably surprised at the absence of nuisance.

The opponents of the Irrigation system have often put very strongly forward the nuisance that is caused by badly-managed irrigation farms as an argument against the *system*, and have appealed to the opinions of medical men and others as to whether such a condition of things is *likely to be* healthful or otherwise; they have, however, rather neglected to bring forward the facts which have been ascertained on this head. This we now purpose to do.

SANITARY EVIDENCE.

Submersion plan: paludal diseases.

Sewage farms are not meant to be marshes. Where they are so, that is, where the system of submersion is carried on, as is the case at Milan, there can be no doubt that the diseases of marshy districts are generated in their neighbourhood. The Sewage Commissioners, in their Preliminary Report (1858), p. 42, state that near to Milan they found that—

> "The population who lived in the midst of and close upon irrigated lands are subject to the same diseases as are common wherever extensive tracts of vegetation are alternately covered with water, and then exposed when comparatively dry to the action of the atmosphere under a hot sun."

Limitation of fever area.

But even here, under the sun of Italy, and with the fields turned confessedly into water meadows, the intermittent and remittent fevers do not extend beyond a quarter of a mile from the marsh; and it was found that "although those irrigations have been brought close to the walls of Milan, and in some instances carried even within the walls, ague is never endemic in the city, nor is any other form of marsh-disease known spontaneously to arise within it." The soil is, however, very porous, so that the water does not stagnate on it for a considerable length of time. The

Commission, however, got at Milan "striking evidence of the conditions under which irrigation with water containing no sewage may be so conducted as to produce with certainty a marked injurious effect upon the health of the neighbouring population;" and also of "the conditions under which entire immunity from disease may be secured." They could obtain "no evidence whatever of the slightest increased injurious tendency of the irrigations conducted with the waters of the Vettabbia, beyond those of other districts around where plain water is employed." With regard to *typhus* and *typhoid* fevers, it is stated that they are not more prevalent near to the irrigated meadows than anywhere else. As to *cholera*, it appears that in a farm "irrigated entirely with the waters of the Vettabbia, though there have been three visitations of epidemic cholera in Milan and the neighbourhood, no case of the disease occurred during either of these attacks."

Irrigation with water containing *no* sewage: danger.

Conditions of immunity.

No influence on typhus and typhoid fevers.

Especial freedom of irrigated land from cholera.

This evidence, which is sometimes brought forward against the establishment of irrigation farms in England, simply shows what was perfectly well known before, that in the neighbourhood of *stagnant marshes* intermittent fevers are almost invariably endemic. The irrigation at Milan is copied from the fields where rice is cultivated around the same city, and where the water is allowed to remain and to stagnate; this is necessary for the cultivation of rice. The ordinary irrigated fields of Milan are not only irrigated by submersion, but they are not drained, and the porosity of the soil is alone relied upon for carrying off the water. In fact, the Commissioners came ultimately to the conclusion that no increased amount of disease could

Intermittent fevers caused by stagnant marshes.

Faults of system at Milan.

nothing to do with sewage.

be traced to the admixture of sewage with the water of a "marcite." No one proposes to introduce water meadows or rice plantations into England, and the only thing that might be reasonably feared from sewage irrigation is increase of typhoid fever or of cholera, the evidence from Milan on this head being particularly valuable and especially favourable.

No danger from typhoid fever or cholera.

To come, then, to the evidence obtained from sewage farms properly so called: and first as to Edinburgh, where sewage has been so long employed in this manner, and even in a somewhat careless way. Professor Christison's evidence is very conclusive upon this point. He says of the irrigation fields:—

Irrigation farms.

No disease caused.

"I am satisfied neither typhus, nor enteric fever, nor dysentery, nor cholera, is to be encountered in or around them, whether in epidemic or non-epidemic seasons, more than in any other agricultural district of the neighbourhood."—(*First Report R.P.C.*, vol. i. p. 90.)

Dr. Littlejohn, too (the Medical Officer of Health of Edinburgh), although looking "with prejudice and displeasure on the existence of sewage meadows in its suburbs, had not been able to connect the ill-health of certain localities in Edinburgh with the Craigentinny meadows as its cause." With regard to the barracks at Piershill, which are stated to be "the most healthy in Scotland," there is certainly no injurious effect on the health of the soldiers from the irrigation of the fields. During the time that the cholera was epidemic at Leith and Edinburgh, "not a case occurred at Piershill Barracks (1865-66.)" The same fact was observed at Barking: when the sewage of North London, where the cholera was prevalent, was poured over the irrigated fields, "no case of

Health of soldiers at Piershill barracks.

No cholera.

cholera happened at the farm or near it." At Norwood, Dr. Cresswell says that when the works were badly managed, "the irrigation fields *as a marsh* produced malarious diseases, and, in this case, intermittent fever amongst the children living in the vicinity." When a marsh, intermittent fevers.

Since that time he says: "I have been able in no case to trace any illness to these fields." In a school of more than thirty inmates, standing close to the fields, there has not been a single case of illness from preventable diseases. He concludes that, "when this system of sewage irrigation is *well managed*, the health of the inhabitants in the immediate vicinity is in no way influenced by it," and this on a deep clay soil. We find from the Ninth Report of the Medical Officer of the Privy Council, that at Worthing the irrigation works "do not cause any description of nuisance or injury to health." At Colney Hatch Lunatic Asylum (*see* Report of Dr. Brady's Committee), the irrigation "is certainly not injurious to health;" this being the opinion of the medical officers who see it daily. When well managed, no evidence of disease caused by it.

Dr. Cobbold has, in a *brochure* which he published in 1865, stated that he has great fear of the spread of entozoic disease by means of sewage irrigation. He says, speaking of the *Bilharzia*, a parasite which "infests the blood-vessels" of the natives of many parts of Africa, but which has occasionally been transported to England, so that its eggs may get into the sewage:—

"If without due consideration you adopt any one of the gigantic schemes now in vogue, you will scatter these eggs far and wide, you will spread them over thousands of acres of ground, you will place the larvæ in those conditions which are

Apprehended danger from spread of entozoic disease.

known to be eminently favourable for the development of their next stage of growth, you will bring the latter in contact with land and water snails, into whose bodies they will speedily penetrate; and, in short, you will place them in situations where their yet higher gradations of non-sexual growth and propagation will be arrived at. After all these changes there is every reason to believe that they will experience no greater difficulty in gaining access to our bodies here in England than obtains in the case of those same parasites attacking our fellow-creatures, whose residence is found in Egypt, in Natal, in the Mauritius, or at the Cape."

And he asserts his "persuasion that the 'profuse distribution' of sewage tends both directly and indirectly to propagate no inconsiderable variety of parasitic diseases." He then goes on to describe the various evils that may result from the abode of parasites within the human body.

Beyond all doubt Dr. Cobbold is the man above all others who has the best right to give an opinion upon any question relating to entozoa; and anything on that subject which comes from so great an authority must be considered with the utmost attention; but still we should endeavour to see how far facts justify so very important a conclusion, involving as it does a sweeping sanitary condemnation of the irrigation system.

Facts demanded.

Fresh excremental matters have been distributed in enormous quantities on land, for some thousands of years in China and in other Eastern countries, and for many years around the city of Milan, where "it is admitted that the common mode of disposing of the fæcal matter is a nuisance, but that it is a source of disease is denied on all hands." (*Sewage of Towns Commissioners.*) Sewage is, too, and has been for a long period, distributed over the lands around the same city. For more than two centuries sewage irrigation has been practised near Edinburgh, while during the past sixty years regular records have been kept of the particulars relating to it there, and for several years it has been employed around a certain number of English towns. Surely, with all these cases, some facts as to the increased prevalence, or otherwise, of hydatid disease in cattle, or of intestinal worms in man, in connection with sewage farms, have already been obtained. But not a single fact is advanced; it is not even hinted by any one that such diseases *are* more frequent where irrigation has been going on so long; and as to the *Bilharzia*, next to nothing is known of the migrations of its larvæ, while even in Africa "the disease is said to be more virulent in the summer months." ("Entozoa:" Cobbold). Despite our numerous communications with that country, this disease has not been known to spread either in England or in France, probably because our conditions of climate, &c., are not suitable either to the unknown "hosts" required by the larvæ, or to the transformations of the parasite itself.

Instances of long-continued application of *fresh excrement* and sewage to lands.

We are not aware that any facts had been afforded by the experience at Edinburgh or elsewhere, in support of Dr. Cobbold's conjecture, that sewage farming will cause the spread of entozoic diseases; neither do we find that since the publication, in 1865, of the pamphlet referred to, any new facts have been ascertained in its favour, unless it be the one stated by Dr. Cobbold in the discussion on a paper read by Dr. Letheby before the Metropolitan Association of Officers of Health (May 21st, 1870),

No facts brought forward.

Parasites found on Craigentinny meadows.

that "a handful of large entozoa parasites had been taken from the Craigentinny meadows;" but he was at once answered by Mr. Holland, who "believed that the danger of spreading disease by the irrigation system was purely imaginary. Where was the evidence of *disease having been produced* where the system was adopted? He had made inquiries on the subject, and could find none. At Carlisle he asked whether the sheep had the rot, and was answered that they had not. At Edinburgh, cows had been fed with grass from the irrigated meadows for 60 or 70 years, but there was no evidence of the prevalence of disease among them," that is to say of entozoic disease. (The italics are ours.) On the whole, then, we can find no evidence of entozoic disease having been spread by irrigation farming: so important a question as this deserves, however, further diligent research. (See Appendix.)

No evidence of entozoic disease at Carlisle or Edinburgh.

Diminution of death-rates near sewage farm.

The death-rate at Norwood, as a mere matter of fact, has very considerably decreased since the establishment of the sewage farm there. In the three years before that took place (1865) it was over 18 per 1,000; since, it has decreased, being lowest in 1868, viz. 12·07; the population being about 5,000. At Beddington, too, where the farm is to the west of the town, the Medical Officer "can safely say that a continuance of west wind is always accompanied by a diminished amount of ordinary sickness in the district, and our annual mortality of the parish is generally below 20 in the 1,000." (*Dr. Carpenter's Paper*, quoted p. 273.)

Diminished sickness.

Improvement in health of children.

It is stated by Dr. Buchanan, in his recent Report to the Privy Council, that the health of the children living in the midst of the irrigated districts, far from suffering, has actually improved. (*British Medical Journal*, Sept. 3rd, 1870.) In fact, the evidence appears to go to show that sewage fields, when properly managed, are *certainly* not injurious to health, and may possibly be even advantageous to it.

Conclusion. That the results of irrigation farming, properly carried out, may be a positive advantage to the health of neighbourhoods, has been shown to be possible in different instances. We need hardly point out that such might be expected to be the case from the luxuriant healthy vegetation which is supported upon sewage farms. The able researches of Dr. Daubeny, late Professor of Botany and Rural Economy at the University of Oxford (*Journal of the Chemical Society*, January 1867; or "Miscellanies," by Charles Daubeny, M.D., F.R.S., vol. i. page 55), have shown that the leaves of growing plants continually evolve ozone; and Mantegazza's more recent experiments have carried this further, and shown that during the oxidation of the essences of plants large quantities of ozone are produced, so large as to constitute a simple and valuable method for the preparation of this substance. Dr. Daubeny, indeed, had suggested that in some cases the coloration of the test-papers might be due "to the essential oil emitted by the flower," but he does not seem to have thought that the essential oil itself was capable of ozonising oxygen. The more important and more general observation is, however, that made by Dr. Daubeny, and he himself was perfectly aware of its importance: he says, speaking of "the uses which ozone subserves in the economy of nature:"—

Leaves of plants evolve ozone.

Purifying influence of ozone.

"When we consider its remarkable oxidising properties, and the rapidity with which any organic matter, dead or living, undergoes a slow combustion in its presence, it seems reasonable to conclude that this principle is an important agent for destroying putrescent animal and vegetable matter by oxidation, and thus for restoring to the atmosphere its purity."

One of Dr. Daubeny's first memoirs confirmed the fact that plants restore more oxygen to the air by day than they consume by night, and determined "the description of solar rays which was most instrumental for that purpose." He exclaimed, when publishing his last discovery—

Means by which vegetable life purifies the atmosphere.

"Should I now have succeeded in establishing to the satisfaction of the scientific world that these same green parts of plants, at the very time that they are emitting oxygen, convert a portion of it into ozone, I might hope that these researches of my later years will serve appropriately to wind up those undertaken in my younger ones, by showing that vegetable life acts as the appointed instrument for counteracting the injurious effects of the animal creation upon the air we breathe, not merely by restoring to it the oxygen which the latter had consumed, but also by removing, through the agency of the ozone it generates, those noxious effluvia which are engendered by the various processes of putrefaction and decay."

Dr. Alfred Carpenter, of Croydon, has (in his paper already referred to) given the results of his experiments on the presence of ozone in the air over irrigated fields; he says (*loc. cit.* p. 31)—

Ozone in air over irrigated fields.

"I have found distinct traces of ozone in the Beddington fields, when there has been none in the town: it has been noted how very rapidly metals rust upon sewage farms,—this easily accounts for it. The surface of the meadows has been tested at various times in the very hottest days of July, when no ozone has been detected in the town, but it has been generally found present over the sewage grass, on those parts of the farm in which vegetation was most luxuriant."

Should it then be a cause of wonder if we find that the persons living on and near farms covered with a flourishing vegetation are less subject to diseases than those who live on the country around, which is burnt up, and the vegetation of which is withered by the heat of the summer sun?

We have good reason to expect that this will be found to be the case, and that the utilisation of the sewage of towns on the land near them, while preventing the pollution of drinking-water and the spread thereby of cholera and typhoid fever, will at the same time maintain the purity of the atmosphere around and about the towns, and that the result will be, especially when combined with that produced by the increased demand for labour and the more plentiful supply of food, a diminution of the general death-rate. Summary.

APPENDIX.

As false ideas with regard to the composition of human excreta are very widely spread, we think it advisable to give the results obtained by the comparison of a great number of analyses of fæces and urine; they are taken from a paper read by Mr. Lawes, F.R.S., before the Society of Arts, March 7th, 1855.

These analyses are only sufficiently complete in the case of males from fifteen to fifty years of age, the mean amounts in ounces of the various constituents during twenty-four hours being as follows:— Composition of excreta.

	Fresh Excrements.	Dry Substance.	Mineral Matter.	Carbon.	Nitrogen.	Phosphates.
Fæces .	4·17	1·041	0·116	0·443	0·053	0·068
Urine .	46·01	1·735	0·527	0·539	0·478	0·189
Total .	50·18	2·776	0·643	0·982	0·531	0·257

From this table it will be seen that the amount of valuable matter contained in the urine is greater under every head than that contained in the fæces; the nitrogen being no less than nine times, and the phosphates nearly three times as much by weight in a given time. It should be added, however, that some analyses made by Messrs. Lawes and Gilbert show that the amount of phosphates in the fæces is not nearly so small as that above given, and is, in fact, not far below the amount contained in the urine, the relative amounts in ounces during twenty-four hours being as follows:—

Amount of phosphates.

	Fæces.	Urine.	Total.
Man, 46 years . .	0·147	0·178	0·325
,, 50 ,, . .	0·148	0·213	0·361
Mean of 3 boys, 5, 10, & 12 years	0·057	0·076	0·133

The total amount of fæces as given above is rather less than the amount determined experimentally by Messrs. Lawes and Gilbert, and we may consider that the weight of the urine passed is nine or ten times as great as that of the fæces; now, as the total urine is worth about six times as much as the total fæces (see page 54), it follows that a given weight of fæces is more valuable than the same weight of urine in the proportion of nine or ten to six.

Comparative value of urine and fæces.

While remembering that the fæces are more valuable than the urine, *weight for weight*, we must not forget that the urine passed by an individual in twenty-four hours is worth six times as much as the fæces passed in the same time.

TREATMENT OF EXCRETAL REFUSE.

A curious example of the large undrained covered cesspool is described in the Indian Sanitary Report for 1870 (p. 151), as existing at Belgaum, in the Bombay Presidency.

"There are no public latrines, but a curious system of latrine caverns or pits in the court-yard of every family, excavated to a considerable depth, platformed over, the whole generally covered with a tiled hut. These latrine caverns have existed from time immemorial, and are said to number 2,240. The arrangements for removing the soil, if any, seem very defective. Though the water supply is abundant, the wells are often situated in close proximity to these latrine pits. Latrine caverns.

"The police were located in wretched dilapidated huts, surrounded by open cesspits, with no provision for drainage. The whole ground in and about the lines pregnant with abomination."

And this with a mean temperature of 74°·42 Fahr.; yet, "as usual at Belgaum, there was comparative immunity from fever," and a table is given showing "that Belgaum has long possessed a reputation for salubrity." The reason for this is doubtless to be found in the fact that "the town is laid out with some regularity, and the principal streets are kept in good order," while the native dwellings are said to be clean inside, although "the exteriors and surroundings are very foul." Reasons for salubrity.

With regard to the midden system, we obtain some additional information from the Appendix to the Report of the British Association Sewage Committee of 1869-70. (*B. A. Report*, 1870, p. 56.)

The town of Bury, in Lancashire, is almost exclusively a privy and ash-pit town; the population is about 40,000.

"No special treatment is practised previous to the removal of the contents of the privies, beyond the addition of ashes. This accession of ashes, together with the necessity of conducting its removal at night, materially reduces the value of such mixture as a manure, and the whole quantity only yields an annual return to the Commissioners of 100*l*. Value of midden refuse.

"The street sweepings are also removed by scavenging, and cost the Commissioners not less than 629*l.* 11*s.* 8*d.*, while, from the want of some yard or other storage ground, they have to be disposed of to farmers at their own price, and only yield the insignificant return of 25*l.* to 30*l.* per annum."

The "remarks by a sub-committee, consisting of Messrs. Grantham (chairman), Corfield, Hope, and Williamson," are to the following effect:—

Failure at Bury.

"The figures obtained in Bury of the ash-pit system, as carried out there, prove that financially it is, so far as Bury is concerned, a total and complete failure, as the gross return is only a little over one halfpenny per head of the population annually. Of course it is not fair to judge of a general system from a particular instance, and the subject should be further investigated."

Some analyses of the sewage "show that although the sewage from a town managed on the Bury system is weaker, and therefore less valuable and proportionately more difficult to deal with than the sewage from a water-closeted town, yet that its purification is just as imperatively necessary."

Gain at a few towns.

In only three towns of the two hundred tabulated by this committee is a gain obtained from the sale of midden and cesspool contents and other refuse, over and above the cost of scavenging. These are Dundee, which has already been noticed, where 630*l.* a year, or $1\frac{1}{3}d.$ per head per annum, is made; Stockton-on-Tees, with 100*l.* a year, or 1*d.* per head per annum; and Fareham, with 7*l.* a year, or $\frac{1}{3}d.$ per head per annum.

Loss at most places.

"In all other recorded cases the scavenger receives a payment in money, as well as the refuse, for doing the required duties. The greatest losses are experienced at Liverpool, where the scavenging costs 41,866*l.* a year, or 19·7*d.* per head; and at Scarborough, where it costs 2,050*l.*, or 22·4*d.* per head. At Malvern the cost amounts to 18·0*d.* per head; at Oldham, 13·1*d.*; at Bradford, 19·3*d.*; at

Rochdale, 11·2*d.*; at Bridgenorth, 10·2*d.*; at Torquay, 10·2*d.*; at Newcastle, 17·5*d.*; at Cardiff, 11·3*d.*; at Llanelly, 15·3*d.*; at Aberdeen, 11·2*d.*; and at Edinburgh, 11·7*d.* per head per annum." (N.B.—The above sums are in pence and decimals of a penny.)

These figures show that, as we have before stated, the midden and ash-pit system can only be an economical success in exceptional cases; as a matter of fact, it usually entails a considerable annual expense.

At page 57 we stated that the "pail system" has been the most successful of all the scavenging plans, in an economical point of view.

In the prize essay by MM. Renard and Frontault, published in 1870, in the "Annuaire de la Société des Agriculteurs de France," an interesting account is given of the success which attends the careful employment of this system in the department of the Alpes-Maritimes. Success of pail system.

"The fæcal matters are collected as they are voided, before fermentation, in 'tinettes' of 60 litres (about 13 gallons), which are emptied at the foot of the trees into two holes, 18 in. broad and 10 in. deep, placed one on each side of the tree; these are then covered in with earth.

"This process is especially applied to orange trees, which are planted 400 to the hectare (nearly 2½ acres). The fæcal matters are often paid for at the rate of 5 or 6 francs per cubic metre (3*s.* to 3*s.* 7*d.* per cubic yard), even at the spot where they are produced, in spite of the quantity of water which they contain. A household averaging four persons produces about 3 cubic metres (nearly 4 cubic yards) annually, from which it obtains an income of from 15 to 18 francs (12*s.* to 14*s.* 5*d.*), a very valuable thing for poor families. Value of excrement.

"At Grasse and at Nice human manure is the manure *par excellence.* It is used in the cultivation of corn, of green vegetables, and of flowers to be employed in perfumery, notably violets and roses; but after it has begun to ferment. The peasants exhibit an astonishing zeal in collecting it; one sees them walk a league, 'pour ne pas perdre leur déjection,' and when they buy fæcal matters in the town, generally Collected by peasants.

in casks, they do not omit to taste them, in order to ascertain their degree of concentration. They keep them in large jars of 2 or 3 hectolitres (44 to 66 gallons), placed at various parts of their fields. This plan is, moreover, easily managed in that country, where, as is well known, a plot of 2 hectares (nearly 5 acres) is a large one.

"With this manure, combined with irrigation and the sun's influence, they obtain a fabulous produce; a certain farm of 17 hectares (42 acres) yields 45,000 francs (1,800*l.*), nett, annually."

Cultivation of scented flowers.

It will be observed that in these countries human excrement is especially used for plants from which scents are manufactured, a flat contradiction to the the counter statements that have been made on this head.

Our authors also quote largely from a report by M. Simon, who was sent by the French Government on an agricultural mission to China, where, as has been already stated, the same plan has been at work from time immemorial. As an answer to how it is that so dense a population can be supported in a country, M. Simon says :—

Reason of prosperity of China.

"The reasons of it are manifold. Without doubt, the climate, the industry of the Chinese, even their sobriety, and the fertility of the soil, to a certain extent explain it; but the principal reason of it is, assuredly, the skill with which the manure is collected and distributed."

Then, after describing the extreme care given by the Chinese to their plants, he adds :—

"The liquid form in which one most often sees the manure in China renders it especially fit for this use, so that it can be distributed during the growth of the vegetation as well as before it. Some of the manure is not, however, naturally in so convenient a form, but the Chinese reduce it to the liquid or to the pulverulent condition by special manipulations."

Utilisation of excreta.

M. Simon adds, that human manure is applied to all crops, and that "sometimes it is placed at the entrance to the carriers, and the water dilutes it and carries it along," while at others it is mixed with an argillaceous earth, and dried in the form of small bricks; it then goes by the name of *taffo*, and, according to the evidence of one traveller, "has no other odour than that of the violet!"

This method, no doubt, appears nasty to us, but M. Simon well says of it, "I ask myself if it would not be better to offend the noses of the passers-by, than to throw into the river quantities of excremental matters which by their decomposition become veritable causes of disease (*infections morbifiques*) to the people lower down."

Manufactured manures.

MM. Renard and Frontault describe a number of processes for manufacturing portable and inodorous manure out of the crude contents of the French *fosses*, the most notable being those of the "*Compagnie Chaufournière de l'Ouest.*" The solid matters from the *fosses* are mixed with quicklime, and a manure known as *la chaux animalisée* manufactured; the liquids which pass through the *séparateur* of the *fosse mobile* are received in a compartment which contains powdered slaked lime, by which they are absorbed and *la chaux supersaturée* formed: or the urine is collected and allowed to stand for two hours in vessels with lime at the bottom; it then becomes inoffensive, and is known as *les urines imputrescibles*, while *taffo*, *taffo enrichi*, and *phospho-taffo* are dried excremental matters mixed with various kinds of refuse, and with other substances which add to their value as manure.

It is not necessary for us to enlarge upon these or other methods of treating crude excretal matters, especially as there can be no doubt that the most profitable way to employ them is to apply them at once to the soil without any preparation at all.

Liernur's system.

In the *Engineer* of December 7th, 1866, a full description of Captain Liernur's system (noticed at page 40) is given; from this it appears that the manure is to be sent in air-tight barrels to the farms, and there applied to the land during the process of ploughing; the plough is so constructed that the barrel can be placed on it, and the manure is discharged from the bung-hole of the barrel into the furrow made by the ploughshare, and immediately covered in with earth by a kind of shovel which trails behind. A special kind of plough adapted for manuring meadow land is thus described:—

Special ploughs.

"A sort of knife makes a running incision in the sods, while a hollow foot attached to it makes a cavity under them. In this cavity the manure is poured, through a hole which passes through both the knife and its foot. After its passage the sods close immediately again, partly through their own weight and partly through elasticity. A layer of earth should be left between the sods and the manure, to decompose the latter, and prevent its hurting the grass plants."

These plans are worthy of the attention of towns where the pail system is at work.

X charcoal.

As a substitute for ordinary ashes, or for vegetable charcoal in the dry ash closets, Mr. Edward Stanford, F.C.S., has proposed carbonised excreta which he calls X charcoal; the deodorising powers of this substance are said to be very great; the objections which arise, apart from those common to all conservancy processes, are the difficulty of avoiding offence in the preparation of the carbonised excrement, and the loss which must be entailed during carbonisation; the special advantage is that no extraneous material is required.

With regard to the *Dry Earth System*, the latest Indian Report[1] goes to show that it may be successfully applied to scattered houses, barracks, &c., but that it is unsuitable for towns.

Dry earth system.

"The system had not been authoritatively introduced, but, more or less efficiently carried out, was the recognised system adopted in barracks, hospitals, and lines of native regiments. It is, in fact, the only system possible in the large majority of stations in the Madras Presidency, where the water supply is scanty and precarious. Sewerage by water-carriage may be applied in some of the new stations, where the barracks and subsidiary buildings are located within a moderate area, but could not be applied to officers' homes, and cantonments at large, scattered over an area of many square miles of ground." (*Loc. cit.* p. 132.)

Suitable where water supply is scanty.

"The results reported are considered to prove the superiority of the system in regimental latrines over any other that has been tried." (*Ib.* p. 72.)

On the other hand, Miss Nightingale, in her remarks on the *Progress Reports*, says (p. 43):—

"In the documents received here no reference is to be found to the surface or subsoil drainage of stations; no reference to sewering of buildings. Dry earth conservancy is apparently the only thing attended to, although is it not simply a matter of common knowledge that the dry earth system makes little difference in the amount of dangerous impurity contained in the fluid sewage of a station or town?"

While the Army Sanitary Commission speak, if possible, still more strongly in condemnation of this system as applied either to towns or stations. In their replies to Dr. Cuningham, the Sanitary Commissioner with the Government of India, they say, after mentioning the results of the experiments conducted by the Rivers' Pollution Commissioners (p. 206):—

"It follows, that to trust to dry earth conservancy for improving the health of towns, while ordinary station or town drainage is

[1] Report on Measures adopted for Sanitary Improvements in India, from June 1869 to June 1870.

Does not provide for refuse water.

permitted to soak away in cesspits or on the surface, is simply to poison the subsoil with sewer-water, which, if collected and conveyed in drain-pipes, would become a valuable manure. The question may now be considered as settled by scientific investigation, that the sewage of inhabited buildings should be treated as a single element, whether as regards health or agriculture, and also that to divide this sewage into two parts, and to remove the parts separately, is, as we have stated elsewhere, to pay double where one payment would answer every purpose."

And not only so, but (*loc. cit.* p. 38) :—

Unsuitable for large cities.

"From the quantity of earth required, and the practical difficulties attending its cartage, distribution, removal, &c., the Commission considered that the dry earth system could not be generally introduced into a large city like Bombay."

Dr. Rolleston, in his papers recently published in the *Lancet* (January 7th and 14th, 1871), has shown clearly enough that enteric or typhoid fever is one of the goal fevers in India; but Dr. Buchanan thinks (*Lancet*, February 4th, 1871), that so many fevers are included under this term, that no conclusion can be drawn as to the effect of the dry earth system on the prevalence of enteric fever. Future careful observations will no doubt settle this point, but in the meantime we think that Dr. Rolleston puts the case very fairly when he says :—

"I have upon other occasions pointed out times and places in which a dry earth system of conservancy may have claims upon our favourable consideration; those times, I have always held, are not times of epidemics; those places do not lie within the *enceinte* of large towns."—(*Lancet*, Jan. 14th, 1871.)

Summary.

There can be no doubt that a well-managed dry earth conservancy system, or midden and ash-pit system, is better than no system at all, but it by no means follows that they are free from danger. They both go upon a wrong principle: we do not want conservancy at all; our first object must be to get rid of refuse-matters, and not to see how long we can keep them about our houses in a *presumed* harmless condition.

Chesshire's Intercepting Tank is a variety of the "fosse mobile," which has been already described; its object is, then, to separate the solid excreta from the urine, which is allowed to run away into the sewers.

Description of tank, &c.

"The plan or form at present preferred is that of an iron box, large enough to hold the solid part of the excreta of an average household for from eight to twelve months, and yet, when full, within the power of two strong men to lift. This box is 2 ft. 4 in. long by 18 in. wide, and 18 in. deep. The pipe from the privy or closet passes into the top of the box, by preference at the opposite corner to the outlet or waste-pipe, which, placed at the bottom of the box, is divided from the main part by a perforated grating, extending across the corner and the whole height of the box. Except as to the inlet and outlet pipes, the box is hermetically sealed, though the lid can be readily removed when it is desirable to empty it. The connection of the inlet and outlet pipes to the box can also readily be separated and remade without the assistance of a plumber.

"A full box can be removed, and an empty one put in its place, in five or ten minutes, and this, if necessary, may be done in the day-time, without any annoyance to the household, neighbours, or passers-by. The removed box, full as it is of most valuable manure —in fact, a human guano—may now be carted away, and its contents reduced, by a liberal admixture of fresh loam or water, to a strength suitable to the crop or soil to be fed with it."—(*Prospectus of Patentee.*)

Surgeon T. G. Hewlett, Health Officer and Coroner to the City of Bombay, writes as follows of one which he substituted for a water-closet and cesspool:—

"An earth closet was inadmissible within the house, so I placed within the cesspool one of Chesshire's intercepting tanks. That is almost hermetically sealed, as it is double syphon-trapped. The solid matter, paper, &c., is arrested by a screen which permits the passage of water, which flows away through a syphon-trapped glazed pipe, and eventually discharges itself at a distance from the house, Good results.

beyond the property, into a surface drain. The smell, both inside and outside the house, before much complained of, has entirely disappeared. The iron tank will require cleaning periodically—the patentee states, once in six months; but this is a matter for experience to decide."—(*Report of a Sanitary Tour, by Dr. T. G. Hewlett*, in the *Appendix to the Report on Measures adopted for Sanitary Improvements in India, from June* 1869 *to June* 1870, p. 233.)

It will be seen from the above quotation, that Dr. Hewlett considers this intercepting tank superior to the earth closet for the interior of houses; he, however, only regards it as a substitute for the cesspool, for after examining it at Birmingham he writes :—

Better than cesspool.

"This appears to be a better form of cesspool, and may be worth trying in places that have no regular system of drainage."—(*Loc. cit.* p. 242.)

Where useful.

In places not provided with impervious pipe sewers this would be found a valuable addition to the ordinary water-closet, as it would prevent the most offensive part of the excreta from passing into the pervious drain sewers, and so *lessen* (though certainly not prevent) the formation of sewer-gases, and the percolation of offensive and injurious matters into the soil and into wells. We do not, however, think that the necessity of having impervious sewers would be obviated by this proceeding, and the sewage would still remain to be purified.

We are very glad to have Dr. Hewlett's opinion so forcibly expressed with regard to the kind of closet which is best suited for poor districts; he says in the Report of his Sanitary Tour :—

"The trough water-closets in use at Liverpool, and the self-flushing tumbler water-closets at Leeds, where they answer remarkably well, appear to me to be the best kind for use in poorer districts, especially for closets which are frequented by more than one family."—(*Report on Measures adopted for Sanitary Improvements in India, from June* 1869 *to June* 1870, p. 231.)

SEWER AIR—VENTILATION—FLUSHING.

The results of some "Experiments on the Air in Sewers and Drains" are given in the Report of the British Association Sewage Committee for 1869-70. The specimens were collected from various street and house sewers, chiefly in the Paddington district, *during the month of August*, so that there was every probability of the air being as foul as possible. They were chemically examined by Dr. W. J. Russell; the most impure air that was examined contained 0·51 volumes of carbonic acid, 20·7 of oxygen, and 78·79 of nitrogen, in 100 volumes; or, as compared with ordinary atmospheric air, the nitrogen was rather less in amount, the oxygen a little less, and the carbonic acid about twelve times as great. In so far as these constituents are concerned, this air was purer than that in many crowded rooms, insomuch as in them the oxygen is decreased in a much greater proportion; but it is certain that these constituents of sewer air are not those which it is most important to examine, for another specimen taken from some which "was blowing up the drain at the time, and had a disagreeable smell," gave only 0·12 volumes of carbonic acid, and as much as 20·91 of oxygen, while it contained no "combustible gases."

Composition of air in sewers.

Dr. Russell also passed some of the sewer air "through plugs of clean cotton wool, which had been heated from 110° to 120° C." in order that any spores or other mechanically suspended impurities might be arrested.

Heisch's test.

"One specimen of the wool, through which about 5,000 cubic inches of the sewer air had been transmitted, was put into distilled water with a little white sugar, to see if any germs, similar to those lately described by Professor Heisch, would become visible. The liquid was examined in a week's time, but none of the germs found."—(*British Association Report*, 1870, p. 73.)

This experiment was repeated with some air from another sewer, with the same negative result. Only the smallest trace of ammonia was found on a careful examination, while no sulphuretted hydrogen could be detected.

"These experiments must be looked upon as simply tentative, but certainly indicate a purer air in these sewers than might have been anticipated."

Some of the plugs of cotton wool through which the air from the different sewers had been passed were sent to Mr. M. C. Cooke to be examined microscopically.

Microscopic examination.

"The results generally indicate comparative freedom from organic bodies," he reported; nevertheless, spores resembling those of several fungi and filaments "greatly like the mycelium of some minute fungus," beside starch granules, fragments of cellular tissue, of the fibrils of feathers, &c., were found, especially in the specimen through which most air (7,000 cubic inches) had been passed. In another plug through which 5,000 cubic inches of air from the same sewer had been passed, "no fungi spores were detected," but it "was largely charged with minute cubic and rhombic crystals, which polarised well," so that it is very likely "that the same sewer would at different periods of the same day give a different result in the organisms with which the air is charged."—(*Loc. cit.* pp. 74, 75.)

Air less impure than expected.

The general results of these experiments, so far as they go, is, then, certainly that the air in the sewers is much less impure than one would have expected; and it must be remembered that the air examined was taken from the drain-sewers of London in the middle of August of a very unusually hot summer (the mean temperature of the air during August 1870 was 62·8 Fahr. in Marylebone, and the highest 85° Fahr., as recorded by Mr. Henry Segrave). This is, doubtless, partly to be explained by the fact that the lighter sewer gases escape through the open grids, and are replaced by common air.

Necessity of sewer ventilation.

On page 149 a statement is quoted from the Ninth Report of the Medical Officer of the Privy Council, to the effect that the sewers of Bristol, which are neither flushed nor ventilated, require neither the one nor the other. We find, however, from a paper read by Mr. Sneade Brown before the Social Science Association at Bristol in 1869, that sewer gases certainly found their way into houses, especially in the upper parts of Clifton. He speaks of being "startled by an irruption of sewer gases, which permeated the house with their faint sickly odour, and made themselves particularly perceptible when the kitchen range was heated."

Sewers should certainly be regularly flushed, unless the gradient is sufficient throughout their whole length to keep them free from deposit; but, as we have said on p. 153, it is not safe to leave them without proper ventilating shafts, even when they are flushed regularly.

Dr. Hewlett, in the Report of his Sanitary Tour,[1] says:—

[1] See Report on Measures adopted for Sanitary Improvements in India, from June 1869 to June 1870, p. 230.

"Perfect ventilation of all the sewers is essentially necessary. I have seen many methods adopted to effect this most difficult but all-important question. Either, as Mr. Rawlinson always orders with so much success—to quote again from Dr. Davies—'by ventilating shafts in connexion with every man-hole along the course of the main sewer, at an average distance of 40 yards from each other, each ventilating shaft being fitted with trays filled with finely-broken vegetable charcoal, through which the gases must pass before they escape into the street.'

Best ventilators.

"In Liverpool Mr. Newlands has used for the last eighteen years, and has greatly extended the introduction of, the Archimedean Screw Ventilator. . . . This invention appears to me to be likely to be of infinite use in India, not only for ventilating sewers, but also buildings, as it ensures a rapid exhaustion of the air below, and will act incessantly whenever there is, as in Bombay, a continuous current of air."

Cambridge was one of the towns reported on by the British Association Sewage Committee of 1869-70; it was found that (*see B. A. Report*, 1870, p. 60)—

Backing up of sewage.

"The outlets of the public and private sewers are all under the level of the surface of the water in the Cam, consequently the sewage is backed up in the sewers for a considerable distance, and the subsoil is constantly saturated with both water and sewage in the lowest parts of the town.

Contamination of wells.

"Inquiries were made into the state of some of the wells belonging to private houses, and it was found that they were all contaminated by sewage, owing to their proximity to the sewers in the streets and to the drains on the premises—so much so, that the water cannot be used for drinking, but only for washing."

Sewers must be impervious.

This is the natural result of the *drain-sewer* system, and led the Sub-Committee before-named (see page 288), "to give expression to the conviction forced upon it in the course of its inquiries, that all sewers properly so-called (that is to say, drains into which refuse from human habitations is admitted) ought to be constructed of materials which are altogether impervious, and that a separate system of pervious drains, similar to agricultural drains, should be constructed where necessary to dry the subsoil. "*The Sub-Committee is of opinion that the further construction of pervious sewers should be prohibited by Parliamentary enactment.*" (The italics are ours.)

PRECIPITATION PROCESSES.

Two other *precipitation processes* are now on their trial; the one, the phosphate process of Messrs. David Forbes, F.R.S., and A. P. Price, has been experimented upon at Tottenham.

It "consists in treating the sewage with a solution of the native phosphate of alumina dissolved in sulphuric or hydrochloric acid. This solution is in itself a powerful antiseptic and disinfectant, completely arresting further putrefaction, and depriving the most fœtid sewage of its offensive smell, causing at the same time the supernatant water to be clear and colourless, even if tinctorial substances of great intensity be present in the liquid."—(*The Phosphate Process for the Utilisation of Sewage*, by David Forbes, F.R.S.) **Phosphate process.**

It is suggested that the process in this stage would be a valuable preliminary to irrigation, as the offensive suspended matters would be precipitated, while the supernatant water would contain, besides dissolved organic matters and ammonia, a considerable quantity of soluble phosphates, so necessary for general farm crops. If, however, irrigation be not resorted to, the process is completed by the addition of a sufficient quantity of milk of lime to neutralise the liquid and precipitate the phosphates in solution. **Preliminary to irrigation.**

The native phosphate of alumina (containing from thirty to forty per cent. of phosphoric acid, equal to from 65 to 87 per cent. of tribasic phosphate of lime) costs £3 10*s.* a ton; it requires to be pounded and treated "with sulphuric acid in the proportion of one ton of the phosphate to from twelve to fourteen cwts. acid." It thus forms a brown stiff paste, which is dissolved in water, and allowed to flow into the sewage.

Proportion of phosphate to sewage.

It is stated that "although in some cases less than half this quantity was found to be sufficient, the actual amount now employed on the large scale at the Tottenham sewage works is in the proportion of one ton of the crude phosphate to 500,000 gallons of sewage."

With regard to the precipitate and its value as manure, an analysis by Dr. Voelcker shows it to contain 28·52 per cent. of phosphoric acid, and 20·11 per cent. of "organic matter and water of combination," containing, however, only 0·57 per cent. of nitrogen, equal to 0·69 per cent. of ammonia.

Value of precipitate.

Dr. Voelcker says of it:—"It possesses valuable fertilising properties, and, in my opinion, a sewage manure equal to the sample analysed by me will command a ready sale at £7 7*s.* per ton." It must be remembered, however, that its chief value is due to the phosphoric acid which is put into it; indeed, as Mr. Forbes himself says:—

Ammonia lost.

"It is not pretended that this process extracts anything like the entire fertilising ingredients contained in the sewage, since it is admitted that by far the largest portion of the ammonia present in the sewage flows off with the effluent water, and is consequently lost unless this water is employed for the purpose of irrigation.

"The precipitate is in itself, however, a valuable manure, which is mainly owing to the most important and characteristic feature of the phosphate process, in which it differs from all processes now in use, which is that the substances employed in effecting the purification of the sewage are only such as augment greatly the agricultural value of the precipitated deposit, which can be increased at pleasure by merely adding more of the phosphate, so that it can by this means be rendered sufficiently valuable to bear the cost of transport to a distance from the seat of manufacture."—(*Loc. cit.* p. 11.)

Value of deposit due to phosphate employed.

It is then admitted that all the ammonia, and at any rate part of the organic matter in solution, are left in the effluent water, and what remains to be seen is if any, and if so how much, of the phosphoric acid added goes away in the effluent water. It will be remembered that in Blyth's process, although after the treatment with superphosphate of lime and sulphate of magnesia, "lime water was then added, sufficient to precipitate the whole," yet this did not prevent "a third of the phosphoric acid added in the processes" from being left in solution and lost.

Possible loss of phosphate.

Whether this be the case or not with the present process, no hope is held out of profit from its employment apart from irrigation; "the profit, if any, will be but small, and not sufficient to encourage the belief that the ratepayers can altogether escape putting their hands into their pockets in order to cover the expense of disposing of their sewage."—(p. 13.)

We must, indeed, at once acquit Mr. Forbes of any belief that his process can be a substitute for irrigation where this is possible; he himself says:—

Not a substitute for irrigation.

"There can be no question whatever but, that when the local circumstances of climate and soil are favourable to irrigation, and the conditions essential to its success properly observed, that sewage irrigation is the most natural and effective system for the utilisation of sewage, since it is only by this means that we can render available the whole of the ammoniacal salts upon which so very much of the fertilising value of sewage depends."—(*Loc. cit.* p. 6.)

May be combined with it.

He believes, however, that by precipitating the offensive suspended matters with a mixture which enormously increases their value without adding useless ingredients, by completely deodorising them and the effluent sewage, while at the same time rendering this latter much richer in phosphates, this process will be found to obviate the objections at present raised against irrigation farming.

Summary.

This process, then, is not capable *alone* of utilising sewage, and there is little prospect of the effluent water from it coming up to the required standards of purity, as "it is not pretended that it attains any such high degree of purity as to admit of comparison, otherwise than in appearance, with the water supplied for the water-works, and it should be recollected that the object of the process is to purify sewage, not to manufacture drinking water out of it."—(p. 10.)

Whether it will answer to use it as a preliminary to irrigation, with the view of removing all offensive smell, and rendering both the deposit and the sewage more valuable, can only be determined by trial on some irrigation farm ; the condition for success must be that all the valuable matter added be recovered and utilised, otherwise a loss would be entailed.

Hillé's process is now at work at Wimbledon ; it consists in the addition to the sewage of a mixture consisting of 100 lbs. of lime, 6 of tar, and 12 of calcined chloride of magnesium, with a certain quantity of some other substance of the nature which we were not informed ; the lime is slaked, and while it is hot the tar is added and thoroughly incorporated

Chloride of magnesium with lime and tar.

with it; after the addition of the magnesian salt, &c., and sufficient water to make the mixture flow through a large tap, the whole is thoroughly stirred up together.

The sewage of about 5,000 people, being about 180,000 gallons a day, is received into a small tank into which the precipitating mixture runs continually from the vat in which it is mixed; thence the sewage, completely deodorised, passes into a circular tank 20 feet in diameter, where the deposit settles while the effluent water is filtered through a basket containing 9 inches of charcoal into a small tank, whence the overflow passes into another, and thence into the brook, or rather ditch.

Deposit of little value

The deposit is taken out of the large tank twice a year; it is a black mud, slightly offensive when fresh, and has not been found valuable as a manure.

Small costs.

Two mixings of the above quantities of the precipitant are required per diem, and the cost of working the process is at present 6*s.* 3½*d.* a day without labour, and 5*s.* 6*d.* a day for the labour of two men.

The chloride of magnesium is at present imported from Germany, and costs £8 a ton, delivered; it is a refuse from salt works, and could doubtless be got cheaper in England; the process is self-acting during the night, and might be to a great extent made so during the day; certainly a much larger amount of sewage could be managed at the same cost for labour.

Summary of results.

This is then a deodorising process, which does not profess to recover a valuable manure from the sewage, but to purify the effluent water so that it is inoffensive, and to do this in the cheapest possible manner.

It therefore entails an almost entire loss of the valuable constituents of the sewage, and the effluent water doubtless contains, as that of all the other precipitation processes does, organic matters in solution, ammonia salts, &c., and cannot be supposed to be so purified as to be admissible into a stream which afterwards supplies drinking water.

WEARE'S CARBON FILTRATION PROCESS.

A method for the purification of sewage described as the "Carbon Filtration Process," has been patented by Messrs. Weare & Co., of Newcastle-under-Lyme. It consists essentially in the filtration (intermittent as far as may be) of the sewage though several tanks containing town ashes and vegetable charcoal.

Filtration through charcoal.

The system is in operation at the Stoke-upon-Trent Workhouse, where the tanks are entirely under ground, and the process is carried on without being perceived at all by the passers-by. The large tank into which the sewage is received directly from the workhouse is double, so that one half can be used while the other is being emptied; in this tank most of the suspended matters are retained, while the fluids pass through a perforated dam and a filter of coarse ashes, and are conveyed by a pipe to a series of three smaller tanks, containing vegetable charcoal and fine ash; passing through these in succession, the water is still further purified, and then allowed to escape into a drain.

Analysis of effluent water.

The analyses of this effluent water show that it still contains a certain though small amount of organic matters and of ammonia, and more especially that it contains a very large amount of mineral matters, no doubt derived from the ashes. It is stated that it does not putrefy.

The manure produced must of necessity be a valuable one, as it consists of excretal matters with vegetable charcoal and a certain amount of ashes. The process is a rational one, and deserves further investigation; the deodorising powers of vegetable charcoal are beyond dispute, as also is its property of absorbing many substances from their solutions. The question which of course arises is, can it be prepared at a sufficiently cheap rate to make it available in the large quantities in which it would be required if the above process were applied to purify the sewage even of small towns? It is very possible that sea-weed or peat charcoal may be found to satisfy the above conditions, at any rate in certain localities.

Manure valuable.

Summary.

IRRIGATION FARMS.

The necessity of separating the grosser suspended matters from the sewage before allowing it to run on to the land is becoming more acknowledged every day, and may be accomplished in various ways. Simple depositing tanks are used in several places, and they seem to answer the purpose very well, the chief objection to them being the offence caused in removing the accumulated deposit; this might, however, be obviated by the use of some cheap deodoriser, as we have before suggested. Filtration through beds of gravel has been tried, but presents few advantages; coarse ashes and charcoal, as in Weare's process, certainly form a much better filter bed,

Depositing tanks.

and have the advantage of being deodorisers, and of forming a more or less valuable solid manure.

Latham's Extractor.

Lastly, there is Mr. Baldwin Latham's ingenious contrivance, which is in use at Croydon, of which Dr. Hewlett says, in the account of his sanitary tour, that he believes that it will supersede all other plans for attaining the object required; he thus describes it:—

"In the middle of the stream of sewage at the outfall has been erected a turbine, which, acted upon by the cleansed sewage-water, revolves between itself and the main stream of sewage an iron wheel, about 14 feet diameter and about 2 deep, which is divided from the outer edge to the centre into compartments which intercept the solid matter (consisting of all kinds of filth, among which I saw a dead dog, a tin biscuit-box, road drift, &c.), which is carried up until the compartment is over the central line, when the solid matter falls over the central axis, which is furnished with an Archimedean screw, which worms it to a point outside the end of the axis, where another screw conveys it to waggons standing ready to receive it, and by which it is periodically removed; while the side of the wheel furthest from the incoming sewage is covered with galvanized iron network, through which the strained water passes."—(*Report on Measures adopted for Sanitary Improvements in India, from June* 1869 *to June* 1870, p. 232.)

Irrigation at Cheltenham.

We have already mentioned that Bird's process has been abandoned at Cheltenham in favour of irrigation (see page 211). At this town the Commissioners have bought a farm of 131 acres, situated at a considerable distance from the town and below it, so that the sewage is delivered on to it by gravitation. The sewage is received into two tanks, the one near the lower part of the town and some three miles from the farm, the other at Hatherley, on the outskirts of the upper part of the town, and about $1\frac{1}{2}$ miles from the farm; at these spots it formerly passed into the two small streams, the Chelt and the Hatherley brook (which discharge separately into the Severn), rendering them foul nuisances. Now, after depositing the greater part of the suspended matters in the tanks, which are constructed with several compartments (the sewage passing from one to the other, either over weirs, or from below upwards through rough filter-beds, so that the floating matters are stopped as well as the heavier suspended matters), the sewage passes onwards through two impervious pipe sewers to the farm; the longer of these, the one from the Chelt tank, is 15,400 feet long, and has a fall of 25 feet, the average fall being 8 feet in a mile, although at one place the fall is only 1 in 1,693; while that from the Hatherley tank is only 8,400 feet long, and has a fall of 10 feet. Tanks. Outfall sewers.

The sewers are well laid, and no deposit ever takes place in them; man-holes are placed along them at such distances that a candle let down through one can be seen from the next, so that the sewers can at any time be easily examined from end to end. A great deal of surface water gets into the sewers, but means are being taken to separate this as far as possible.

The surface of the farm has for the most part a good natural inclination, and the soil is generally a stiffish clay; it was already laid out in ridges and furrows, so that it was suitably arranged for running the small carriers along the summits of the ridges; the land is almost all old pasturage, only a few acres having been sown with Italian rye-grass. With regard to the question of irrigating old meadow land with sewage, it must be remarked that near to the Chelt tank there are two meadows which have been irrigated Old pasture land for the last five years, and which are now in excellent condition; cattle are grazed on them and thrive remarkably well, and the only complaint that the farmer has to make is that he cannot have sewage on all his meadows.

The farm is obviously too small for the purification of the sewage of so large a district, including as it does from 45,000 to 50,000 inhabitants, but a great deal of land is available along the course of the sewers, and the farmers are only too glad to prepare their land to receive the sewage and to pay for the privilege of having it. The purification is effected in great measure by surface action, but it is very thorough, and the pollution of the brooks, and the nuisance caused thereby, have been stopped.

Farmers appreciate sewage.

Costs.

The cost of establishing the farm was £18,000, of which £10,500 were spent in the purchase of the 131 acres of land, and £7,500 in the construction of the outfall sewers and in the laying out of the land. The previous value of the land was from £2 10*s*. to £3 per acre at the outside; last year it let on an average at £7 5*s*. per acre, the highest price realised being £8 13*s*. per acre for a lot of 24 acres, and the lowest £5 18*s*. per acre. "The total of the letting was £863 16*s*. 6*d*. for the year, exclusive of the value of the piece of land kept by the surveyor for experiments." To this must be added the amount received for the sewage supplied to other farms, and also for the manure made by mixing the deposit in the tanks with town ashes and street sweepings, for which from £200 to £300 is obtained yearly, so that it appears that the Commissioners have in the first year gained enough to pay the interest on their loan and a

Receipts.

moiety of the capital expended in permanent works (outfall sewers, &c.).

The land was let under the following conditions: the tenants to be allowed either to graze or mow the land; the sewage to be applied *at the discretion of the surveyor;* the right of underletting not conceded; and a tenant desiring to erect any building on the land to be allowed to make arrangements for the removal thereof on the expiration of his tenancy. Conditions of rental.

We find that there was at one time a complaint made that certain wells had been poisoned by filtration into them of sewage water from the farm; on investigation the following was found to be the state of things. At one house where the well was complained of, "the ditch is actually polluted with the soakage from the privy, and also receives the slops and liquid drainage from the house, so that it is quite impure and offensive; and this ditch is not very many yards from the well in question. . . . The other house . . . also drains into the ditch to a considerable extent, and, as I have for a very long time noticed, it is thus at certain times rendered very foul and impure."—(*Surveyor's Report.*) The facts speak for themselves. Alleged pollution of wells. Real causes.

On visiting this farm in the autumn, and again during the coldest week of the past severe winter, we found no nuisance on either occasion, and, on the contrary, the brooks are clear streams instead of open sewers disseminating foul effluvia all around, as they formerly were. On account of the stiffness of the soil the water does not percolate easily, but it does not remain long enough on the surface to become stagnant, and the land soon regains its accustomed firm- Purification of brooks.

ness and dryness. During the winter there appeared to be no great difficulty in managing the irrigation, but the ice in the small carriers had to be broken to allow of the free passage of the sewage along them.

Breton's farm.

An account of sewage irrigation as carried out at Breton's farm, near Romford, is given in the Report of the British Association Sewage committee for 1869–70. (*See B. A. Report*, 1870, p. 71.)

From it we find that the agricultural results with almost every kind of crop were very encouraging, even when the comparative advantage accorded to irrigation by the extreme dryness of the season is allowed for, while the purification of the sewage was exceedingly satisfactory, and indeed surpassed anything of the sort that we have yet seen.

Composition of the soil.

The analyses given of the soil show it to have been a very poor one, 31·65 per cent. of it consisting of stones too large to pass through holes of a sieve which were 3·88 millimetres in diameter, while of the 66·43 per cent. of soil which passed through the sieve (the rest consisted of roots, &c., and moisture lost at 100° C.), no less than 60·70 parts were insoluble in strong hydrochloric acid, the remainder consisting chiefly of ferric oxide, alumina, and lime, with traces of potash, soda, phosphoric acid, &c., while the loss on ignition was only 1·69 parts.

Comparison of sewage and effluent water.

From the analyses of the sewage as pumped on to the land, and of the effluent water, it appears that the total amount of solid matters in solution is not much altered by the process, that the suspended matters are reduced to an almost inappreciable quantity, that the ammonia is reduced from 3 or 4 parts to quantities varying from 0·046 to inappreciable traces in the

100,000 parts; and the albumenoid ammonia from 0·14 or 0·2 part to from 0·031 to 0·056 part in the 100,000 parts, while instead of these, nitrates and nitrites which are not found in the sewage appear in the effluent water to the extent of from 1·5 to 2·3 parts per 100,000.

The sewage from the town is really stronger than the figures above given would indicate, but the sewage pumped on to the land contained a large quantity of effluent water from the land which was returned to the tank to dilute the sewage.

The produce of the farm has been especially fine, and the prices obtained for it very high, but for these we must refer to the Report from which we have quoted; it is sufficient here to say that it is finally proved "that sewage in its liquid state can be practically applied to apparently every kind of crop." One especially important observation is recorded:— **Produce and prices.**

"In Plot N, bed 1 (0·252 of an acre) was sown on April 27th with a new kind of American oats, which were cut on August 22nd, and yielded twenty-eight bushels, equal to fourteen quarters, per acre. At the beginning of June this crop was seriously damaged, and in danger of being destroyed, by the ravages of the *Oscinis vastator*, one of the smallest but most destructive of those 'grubs' and 'wireworms' which at times cause such injury to cereal crops in this country. The remedial effects of sewage irrigation under similar circumstances having been previously observed elsewhere, two heavy dressings of sewage were applied to this bed during two successive days, the result being that the grubs were entirely destroyed, and the greater part of the crop was saved. It is proposed to conduct some experiments to ascertain whether this result could be accomplished by the use of pure water, or whether, with the physical effects of immersion, sewage applied in this way combines the action of some agent or agents which act as a specific poison to organisms of that type."—(*Loc. cit.* p. 65.) **Destruction of wire-worms by sewage.**

Quantity of sewage applied.

As to the quantity of sewage applied to the land, it appears that in all probability "400 tons per acre is the largest quantity that has ever been applied in any one dressing; and if we assume that the first dressing all over was at the rate of 400 tons per acre, that the second dressing was at the rate of 200, and that the subsequent dressings were at the rate of 100, we shall not be far from the truth."—(p. 69.)

The drought last summer (1870) was so severe that even the irrigated lands did not get as much water as they required, and so it is not to be wondered that the contrast between the crops they yielded and those yielded by other lands was more marked than ever:—

Comparison with other farms.

"A small field of between three and four acres in the adjoining farm was sown with peas for picking green. These the farmer tried to sell on the ground for £8 an acre; but he was unable to sell them at all, and at last left them to ripen. They still remain unsold, and are estimated to be worth from £5 to £6 an acre, while the straw was so stunted that there were not two loads from the whole area."—(p. 69.)

On Breton's farm four beds in Plot B, "equal to 1·96 acre, were sown in the first week in April with 'Champion' peas for eating green, which were sold in July for £30, the buyer picking them and leaving the straw."—(p. 63.)

"In the next field beyond the peas (farmed by one of the best agriculturists in the county, a man of superior education and agricultural knowledge, who has farmed the same land for years past with immense care, having planted small hedges here and there to give shelter and break the wind, and having grubbed up the old hedges, and having further collected the stones off the surface of the land, and who applies farm-yard manure, guano, bones, &c. with both liberality and judgment) were sown onions, and these onions the farmer said that he would gladly sell for one-fifth of their cost."

Let this be compared with the prices realised for the beds of onions on Breton's farm, viz. £36 per measured acre for two of the beds, and £46 per acre for another. Prices for onions.

"Again, upon the small meadow at Breton's marked U, comprising altogether, after deducting ponds, &c., only $5\frac{1}{4}$ acres that can actually be mowed, the two crops of hay already got in amount to 9 loads ($3\frac{3}{4}$ and $5\frac{1}{4}$ respectively); and a third is growing, which with care and energy, and the assistance of a large barn, may easily be got in in the present month (September), is estimated as equal to the first, making a total of $12\frac{3}{4}$ loads in one season from $5\frac{1}{4}$ acres. The tenant of Breton's has a large meadow, about three miles nearer London, sloping down to a brook shaded by trees, and which ought to suffer less than most from drought; yet off an available area for mowing of 27 acres he was only able to get four loads of hay, and there is scarcely any aftermath at all. In potatoes and carrots the figures run in about the same proportion between the sewaged and the unsewaged ground, while of green crops without sewage there were simply none."—(p. 70.) Failures from want of water.

From a paper read by Mr. Henry John Morgan, before the Institution of Surveyors, on March 27th, 1871, we find that the results obtained at the Lodge farm, Barking, have been very satisfactory in so far as the obtaining of large and valuable crops goes, but, as the writer says, "it would not be safe to base calculations of what price a farmer could usually afford to pay for the sewage, upon the amounts which have been realised by us at a time when drought had deprived the market gardeners round London of their crops." Lodge farm.

The past year, although a very favourable one for contrasting irrigation with other methods of manuring, was not so for obtaining the largest possible crops, as even with the aid of irrigation enough water could hardly be got on to the land: in other Influence of drought on comparative results.

words, a less dry season would certainly show larger absolute, though smaller comparative results, in favour of irrigation.

Madras sewage farm.

The "Report on the Measures adopted for Sanitary Improvements in India, from June 1869 to June 1870," contains an abstract of Captain Tulloch's report on the Madras sewage farm, of which report it is stated (p. 25) that it enters "fully into the economic bearings of the experiment, and, viewed in this light, there seems little doubt of its proving a great financial success." From this report it appears that a great variety of crops have been successfully grown, while even during the monsoon the difficulty of dealing with the excess of water does not seem to be at all insurmountable.

Leicester County Asylum.

The Leicester County Lunatic Asylum has afforded another instance of successful sewage irrigation, and an especially interesting one, as accounts have been kept for some years, and the profits realised are known exactly; the results have been described and compared with those obtained from the A B C process at Leicester, by Henry Waugh, Esq., C.E., in a pamphlet, "On the Disposal of Sewage in Towns."

It appears that the sewage of about 500 persons, amounting to about 11,500 gallons a day, "flows continuously, day and night, over a few acres of ground cultivated by the patients of the Asylum."

Profits from irrigation.

The profits have risen with the number of patients, and now, after payment of rent, taxes, labour, and interest of money, "the average net profit at present amounts to about £550 per annum" (p 12).

"The earth over which the sewage has been run for eleven years has no unpleasant smell or appearance. It was tried under all circumstances, from quite dry to recently irrigated; and in no instance was there any unpleasant odour. The gardener, his labourers, and the patients who work with them, enjoy excellent health; and, in fact, the general health of the Asylum is so good as to offer the best testimony to the absence of all danger from the experiment; and, let it be remembered, this is not a question of carrying the fluid sewage to a considerable distance before using it; the outfall of the drain, and commencement of the distributing canals, being within 50 yards of the main buildings of the Asylum." No injury to health.

Here, then, the sewage has been purified, the effluent water being "pure, clean, and soft," there has been no detriment to health, and "the land has paid for this good treatment at the rate of £1 1*s*. per head per annum." We are informed that the value of the labour of the patients has been calculated and subtracted from the receipts, and we think that enough has been said to justify the statement made by Mr. Waugh :— General results.

"Every town of England has now in its own power the means of greatly reducing its local taxation, by converting what has always been a dangerous nuisance into a fruitful source of revenue; improving, at the same time, the health and comfort of the community."—(p. 20.)

It has been stated that the contagious diseases among cattle, and especially foot and mouth disease and rinderpest, will be spread by irrigation farming. The evidence hitherto obtained does not support this assumption; it rather goes to show that, as in the case of cholera, soil and growing plants really have the power of separating poisonous matters from the sewage, decomposing them and rendering them harmless. Contagion among cattle.

The following interesting case is recorded in the report of the engineer to the Croydon Board :—

Rinderpest not propagated.

"Eleven head of cattle were affected with rinderpest; they were in a homestead at the head of the farm, and, at the time of the outbreak, forty head of cattle were pastured in the lower fields, and twenty cows, with twenty calves, were in the lower buildings. The whole of the drainage from the upper buildings passed over the adjoining land to the outfall; and although the cattle were pastured on the irrigated land, and were watered by the effluent water after it had passed over the land, not a single case of cattle-plague occurred amongst the animals on the lower portion of the farm."—(See *Dr. Alfred Carpenter's Paper on the Physiological and Medical Aspect of Sewage Irrigation*, p. 45.)

THE ENTOZOA QUESTION.

The only facts that we were able to adduce with regard to the possible spread of entozoic diseases by sewage irrigation were the general ones that such diseases had not been shown to be more prevalent either among cattle or among men living in irrigated districts, or even in countries where fresh human excrement is used as manure.

Since the foregoing pages were published, two papers on this subject have been communicated by Dr. Cobbold to the Association of Medical Officers of Health; they will be found in the *Medical Times and Gazette* for January 28th and February 25th, 1871.

No evidence of spread of entozoic diseases by sewage irrigation.

From a careful perusal of them, it clearly appears that up to this time there is yet no evidence whatever to show that entozoic disease has been caused in a single case either in an animal by feeding on sewaged produce, or in a man by eating the flesh of an animal so fed.

The objection that animals may be suffering extensively from entozoic disease without its being recognised during their lifetime, and that very few persons are qualified to recognise even measly meat when it is placed before them, entirely falls to the ground in the case of men, even if it be considered to hold good in that of cattle.

Had the communities which have been so long fed upon the flesh of animals fattened on sewage-grown produce been more troubled with entozoa than others, we should certainly have known of it. As a matter of fact, we do know where entozoic diseases are prevalent; we know that the population of Iceland is much troubled with one entozöon, that of Norway, Lapland, &c., with another, and that of the Punjab with a third; so that until it is shown that these diseases have been increased in men where sewage irrigation has been adopted, we have no sort of right to say that they will be; the facts are certainly on the other side.

Countries where they are prevalent.

Moreover, in the "Report on Measures adopted for Sanitary Improvements in India, from June 1869 to June 1870" (page 72), we find under the head "Entozoa in ration cattle," that "throughout the Punjab during 1868, 1,038 head of cattle, or 6·12 per cent. of those tendered for rations, were found infected." Although this has nothing to do with sewage irrigation, it shows that in some places at any rate where entozoic diseases are prevalent in cattle they are recognised, and that there would be no great difficulty in showing that the cattle on irrigation farms were more infected with them than other cattle if such were the case. This has not been done, although since 1865 attention has been drawn to the subject.

They are recognised in cattle.

But Dr. Cobbold has stated that he considers the A B C process and the dry earth system to be, from the entozoic point of view, safer than sewage irrigation; on this head we may quote somewhat at length from the leading article on the subject which appeared in the *Lancet* of February 4th, 1871 :—

Other systems not less dangerous.

"Upon what evidence, then, does Dr. Cobbold state that one system is safe and the other dangerous? None whatever. There is not a single fact brought forward to show that the A B C process is capable of destroying parasitic ova, or that they perish when covered up in earth. On the latter point, all the analogies and facts are as yet against the inference. Parasitic diseases existed long before water-closets and sewers. It is well known that the ova can be dried without destroying their vitality; but there is no evidence to show that they are able to exist in sewage, or to resist the conditions of sewage transit. The more perfect the preservative action of the earth-closet, the more sure is the transmission of living ova to the land; whilst it seems to us at least as probable that the ova will survive the muck-heap as that they will fail to be destroyed by the sewer. Does Dr. Cobbold mean to say seriously that it is less dangerous to spread a field with manure than to irrigate it two or three times a year with sewage? In the one case the matter remains upon the surface, and adheres to the blades of grass; in the other, when properly administered, it at once sinks into the ground. In the one case the grazing cattle cannot fail to eat it; in the other it is beyond their reach. Dr. Cobbold has not adduced a particle of evidence to prove that the system of sewage irrigation is *more* likely to extend the spread of entozöotic disease than is that of putting manure directly on the land; whilst, on the other side, we have the evidence of Professor Christison, that he had never been able to refer a single case of parasitic disease to the sewage irrigation, so badly carried out at Edinburgh."

Liquid *v.* solid manure.

Bilharzia: new facts.

The vital powers of the eggs and larvæ of entozoa are well known to be, in many cases at any rate, very considerable indeed, but as far as the *Bilharzia* is concerned we have now some definite facts to go upon, and we are bound to add that it is Dr. Cobbold himself who has brought them to light. He says with regard to the larvæ of this formidable parasite (*Med. Times and Gazette*, February 25th, 1871) :—

"The strength and vigour of the escaped larvæ appeared to depend upon the relative quantity and purity of the water in which the larvæ were immersed. In weakly-diluted urine they soon perished, and even also in water where only a small quantity of decomposed vegetable or animal matters had been introduced. On August 16th I placed about 1,000 eggs in a quart of clean water, to which less than a drachm of urine had been likewise added. In forty-eight hours not a single living embryo could be found. In fact, I subsequently ascertained that I could not keep the embryos alive for twenty-four hours in any water in which I had accidentally or otherwise introduced the smallest trace of mucus, blood-corpuscles, urinary crystals, or decomposing matter of any kind. All sorts of re-agents speedily killed the larvæ," &c.

Its larvæ perish in foul water.

"As regards *Bilharzia*, therefore, the above data, now publicly brought forward for the first time, undoubtedly appear to favour the notion that little harm can result from sewage distribution, so far at least as parasitism is concerned."

Whether the eggs and larvæ of other entozoa do arrive in a living state on sewage farms, we do not yet know, but if anything is likely to be injurious to organisms whose natural habitat is the acid excretion of the human intestines, we should suppose that it would be immersion in a liquid containing much urine, which so soon becomes alkaline from the conversion of the urea into carbonate of ammonia. We think with Dr. Cobbold, that "how long they are able to retain their vitality when dispersed by sewage and other means is a point worthy of further inquiry;" and as one fact towards the solution of this question, we quote the following passage from the Report of the British Association Committee, to which we have already alluded (*B. A. Report*, 1870, p. 52):—

Question of vitality of larvæ in sewage.

"Some specimens of sewage-grown rye-grass, carrots, turnips, onions, beet, and lettuce, from Breton's farm, were sent to Mr. M. C. Cooke, M.A., for examination, with a view to the possible discovery of entozoic eggs or larvæ. He states that 'the rye-grass was mouldy, but only from such moulds as are the result of decay from the damp grass having been kept several days enclosed;' and he summarizes the results of his examination of the vegetables as

Sewage-grown produce free from objectionable organisms.

follows:—'I find nothing whatever to report against any of them. They all seem to me in excellent order, and free from parasitic insects, or from fungi of any kind.'"

Plain water irrigation.

Dr. Cobbold informs us that he has thought that the plain-water irrigation practised in the Punjab may, on account of the dirty habits of the natives, have something to do with the prevalence of entozoic disease there: we submit that the filthy practices alluded to (the deposition of excreta indiscriminately about the fields, around the villages, &c.), are in so many countries the great cause of the spread of such diseases, that there is no reason for supposing that the irrigation has anything to do with it.

Summary.

We see no reason, therefore, to alter our opinion that it has not yet been shown that sewage irrigation has ever increased the amount of entozoic disease in men or cattle, still less that it is likely to do so to a greater extent than any other method of utilising human excrement; and even were this shown to be the case, the danger would be to a great extent obviated by some such preliminary treatment, with a view to the separation of the suspended matters, as we have already insisted upon.

Necessity of meat inspection.

We ought certainly to have all meat inspected by competent persons before it is exposed for sale; by this two ends would be secured—we should find out where entozoa are most prevalent among cattle, and we should be able, if all infected meat were cut in slices and well boiled before being sold, to prevent the spread of entozoic diseases among men, and so indirectly among cattle too.

ADDITIONAL APPENDIX.

Pipe sewers in running sand.

When pipe sewers have to be laid in loose sandy soils, considerable difficulties arise, which usually effectually prevent their being impervious; indeed subsoil water gets into them, and issues from their mouths as soon as they are laid: this is "in consequence of the cement, even when covered with a clay lute, getting washed into the sewers before it has time to set." Cast-iron pipes have been proposed in such circumstances, but Messrs. Reade and Goodison, of Liverpool, have in the "British Association Report for 1870" (*Transactions of the Sections,* p. 222), described a plan by which the difficulties just alluded to are obviated.

"They have introduced a subsoil-drain and pipe-rest (manufactured by Messrs. Brooke and Sons, of Huddersfield) of the form of the letter ⌂, which is first laid in the bottom of the trench and jointed with clay, like an ordinary pipe-sewer. This has the effect of lowering the subsoil-water, so that the sewer proper can be laid upon the moveable saddles or rests (fitting the curvature of the drains and the sewers) undisturbed by water or running sand. By these means the cement joints can be made perfect all round, and have time to set before the trench is filled up. True gradients are insured, as the pipes can be leisurely laid; and as the pipes are jointed over the *middle* of the subdrain, a continuous foundation is secured. A more perfect drainage of the subsoil is also found to result, the general level of the water being reduced to nearly the level of the invert of the sewer."

This plan is well worthy of consideration, as there are many places where difficulties have arisen in the laying of pipe sewers so that they shall be, and remain, impervious.

Since the preceding appendix was printed the Third Report of the Rivers' Pollution Commissioners (1868) has appeared, and we think it desirable to include some extracts from that Report, although it chiefly refers to the "pollution arising from the woollen manufacture and processes connected therewith."

With regard to the Midden system, it appears that (*loc. cit.* p. 7)—

Midden system at Leeds.

"There are in Leeds about 6,000 water-closets, besides a number of trough and tank closets, and some 10,000 privies, middens, and ash-pits, all of which are connected with the sewers. These are cleaned periodically under the direction of the Sanitary Committee of the Corporation, at a cost of about 12,000*l.* a year, and the Corporation receive about 6,500*l.* a year for 70,000 tons of refuse; the cost of cleaning them exceeding the amount received for the manure by 5,500*l.* a year. This scavenging process, which thus costs about one shilling annually per head of the population, while about 6½*d.* a head annually is obtained for the excrementitious matter removed, is at the same time most offensive. 'The cleaning of the privies, middens, and ash-pits is complained of as a nuisance affecting the health and comfort of the inhabitants. The stench in Leeds from 10 P.M. till 4 A.M., while this operation is going on, is described as something fearful.' "

Nuisance.

Several interesting examples of the pollution of well-water by excrementitious matters are given. Such water is described as "the bright and sparkling, but often dangerous, beverage drawn from shallow wells sunk into ground reeking with excrementitious matters" (p. 36).

Thus at Kidderminster, of a well that was pointed out "as yielding water of average quality," it is stated that "it is only five feet deep, and contained a liquid which was very similar in composition to that which we have obtained in our laboratory by allowing London sewage to soak slowly through five feet of gravel. The drinking of such water, especially in periods of epidemic disease, cannot but be fraught with great risk to health"—(p. 41).

Polluted well-water.

The water from a well at the Blue House School in Frome actually "contained unoxidised sewage matters, besides exhibiting a very large anterior pollution of the same kind."

Of the water of a well in Durham, described as "one of the best," it is said:—

"This water, though clear and sparkling, is shown by our analysis to be little else but the percolations from sewers and cesspits; 100,000 lbs. of it contain the inorganic remains of as much excrementitious matter as is present in 62,360 lbs. of London sewage, whilst the large proportion of chlorine which it contains, shows that a good deal of urine mixes with it; indeed, the pump is in a back-yard, close to a privy and ash-pit, and the waste water from the pump-trough passes down a sewer-grid close to the pump"—(p. 44).

Often clear and sparkling.

Though supplied by cesspools.

Witney derives its water supply from wells from six to fifteen feet deep.

"The water of these wells is frightfully polluted, and entirely unfit for human consumption; one of them which we have analytically examined is supplied chiefly from percolations from sewers and cesspools, and contains a large proportion of unoxidised sewage matter, besides ammonia from urine"—(p. 45).

It is plain from these instances that shallow well water, however bright and sparkling it may be, is not by any means a desirable beverage, and may be a very dangerous one; and the depth of the well is merely a question of degree in most cases.

Well-water in towns suspicious.

It is the old tale of the Broad-street pump over again: people prefer the cold, clear water from a well sunk, it may be, "in the foul soil of an ancient town," to the filtered water pumped them from the river (and with some reason too, for they know that the latter has been directly polluted), until a day comes when the poison of cholera or typhoid fever is introduced, and is distributed with the water to perhaps a whole district.

Filtered river-water.

But if well-water is not fit to drink, is it right to filter polluted river-water, and make people drink it? This question is best answered by a description of the state of the rivers in and below some large towns, and has been already treated of in our chapter on the Pollution of Rivers. Of the *Worth* (below the town of Keighley), a tributary of the *Aire*, one witness says (p. 4):—

State of the Worth.

"Formerly trout were very plentiful in the stream, but now no living thing can exist except rats, which feed on the dead carcases of animals thrown in. The river, for more than half a mile above my works, is very seriously polluted by town sewage and refuse from manufactories and works; and in the summer the stench is so bad that the smell is perceptible for more than half a mile off."

The *Bradford Beck* is, above the town, clear (although not altogether in an unpolluted condition), and "appears to abound with fish" (p. 5).

Polluted state of various rivers.

"In passing through Bradford it receives, besides the sewage of 140,000 people, the drainage and refuse of numerous factories."

"The *Bradford Beck* as it leaves the town is a black, filthy, and offensive stream; even above the sewer outfall it was, at the time of our inspection, emitting offensive gases, and could scarcely be distinguished in appearance from the sewage itself."

The sewage of Leeds, to the amount of 11,000,000 gallons daily, enters the Aire (p. 7).

"Twenty years ago the river was comparatively clean; it is now a black and greatly polluted stream."

"Both the river and its affluents flowing through the town are, especially in time of drought, very foul, and consequently prejudicial to the health and comfort of the inhabitants."

"At a distance of about ten miles below Leeds, and immediately above Castleford, the *Calder* joins the *Aire*. The inhabitants complain of the stench and filth brought down to them by both rivers. At the weir beside the Aire and Calder corn-mill here, not only the water, but the foam upon it, was black at the time of our inspection; and the miller and his men complained of the frequent nausea which they suffered from the sickening filthy stench to which they were continually subjected"—(p. 8).

Nausea caused by effluvia from river.

But it may perhaps be thought that such water would never be used for drinking purposes: this idea will soon be dispelled. The *Calder*, already somewhat polluted, "receives the water of the *Hebble*, a stream which brings down to it a very filthy contribution from the town of Halifax." Further on it is joined by the *Colne*, a "foul stream," which has been so polluted by Huddersfield as to have more than doubled its proportions of organic carbon and organic nitrogen, and to be "said to be a source of ill-health and discomfort;" and about six miles lower down "it receives the water of a small beck, an extremely filthy stream, which brings down the drainage of Batley and Dewsbury." This river receives, lastly, the sewage and "many kinds of liquid refuse" of Wakefield, a town of 26,000 inhabitants, and is so discoloured that at times it may be used as ink, and the Commissioners actually give a facsimile of a memorandum made with it, "the pen having been dipped in the river water immediately below the outfall sewer of the town, at a time when there was an unusually filthy discharge from it." Below the town "the river was turbid, and of a dark

An extremely polluted river.

brown colour; an oily film floated on the surface, and the water emitted a mixed odour of sewage and gas tar." It will scarcely be credited that "*at a point somewhat below this, 'about a mile below the main sewer outlet,' the water supply of Wakefield is taken from the river*" (pp. 11 & 12. The italics are ours). Of this water "a volume of 1,000,000 gallons is daily pumped from the river."

Supplies drinking water.

We should think that no one will be found to disagree with the Commissioners when they say:—

Remarks of Commissioners.

"Although 'the water is filtered by a patent process,' it is difficult to conceive anything more disgusting and dangerous to health than a populous community thus systematically, and by an elaborate and costly arrangement of reservoirs, pumps, filters, and distributory apparatus, drinking its own filtered sewage, taken from a stream in a black and putrescent condition"—(p. 39).

The water as supplied to the town was examined on two occasions, at an interval of a year. It "was chemically less contaminated than might be expected, yet on both occasions it contained a large proportion of nitrogenous organic matter. It was of a greenish yellow colour, and on one occasion very turbid."

This case speaks for itself: it would be difficult to find one which would do so more eloquently. Is it necessary to show that people would be more healthy if they drank pure water? Plenty of proof of this has been given in chapters ii. and vii. Here is another case:—Dewsbury, Batley, and Heckmondwike are now supplied with unpolluted water "from about 2,000 acres of gathering ground."

Advantages of unpolluted water.

"The authorities in all three towns concur in stating that the health of the people has improved since the introduction of this mountain water in the place of the previous supplies from polluted rivers and wells"—(p. 38).

Need any other reasons be adduced for purifying the rivers than that their state is detrimental to health? Let us hear what the manufacturers at Leeds say on the point (p. 7) :--

"If the river were rendered clear and colourless, it would be a direct money value to us of from £60 to £70 a year." Of clean rivers.

"If the river were rendered clear and colourless, it would be of considerable money value to us, but we cannot give the amount."

"If the river from which we might derive a supply of water were rendered clear and colourless, it would be a direct money value to us of £100 a year."

And so on. In fact the Commissioners came to the conclusion that on the whole "the foul condition of these rivers is really one of the heaviest taxes which manufacturing industry has to bear."

These rivers must be cleansed by intercepting the foul liquids—not only the sewage, properly so called, but the refuse from manufactories, which is in some instances very valuable. Thus the waste liquor discharged into the Severn from the flannel works at Newtown contains in 100,000 parts no less than 1733·4 of suspended organic matters, 446,353 of dissolved organic carbon, 91,185 of dissolved organic nitrogen, and 80,012 of ammonia (p. 25). Waste liquors from manufactures.

"The composition of the waste liquor from flannel washing proves it to be, in the case examined, a most valuable manure, one hundredweight of it being worth, for this purpose, more than one ton of London sewage. The discharge of such liquors into rivers is a reckless waste."

The important question then arises, if these liquids may not, any more than sewage, be turned into rivers, what is to be done with them?

Several remedies are proposed in exceptional cases, but the only one which admits of almost universal application is *irrigation* on land, or, where this is Purified by irrigation.

impracticable, *intermittent downward filtration* through a sufficient depth of soil. When these foul liquids have been so treated the effluent water was so purified as to be admissible into a stream.

But if these liquids are purified by filtration, or by irrigation, will it be advantageous to irrigate crops with them? This has been tried in a very rough and ready manner at several mills; at one near Shepley it was found that the produce of some old grass land was increased by irrigation with "the soapy, greenish, greasy mill drainage," but that "the coarser grasses, strengthened by the irrigation, had killed the finer, and the quality of the produce was injured" (p. 31).

Better not utilised alone.

These liquors, therefore, may not be suitable for irrigation if used alone, except perhaps in the case of "strong and rapidly growing plants." It is probable that the organic matters and ammonia are contained in them in too high a proportion as compared with the potash and phosphates; but from their composition there can be no doubt that "their utility for this purpose would be much augmented if they were previously mixed with several times their volume of town sewage" (p. 30). Where this has been done the result has been satisfactory.

May be mixed with sewage.

"At Cullingworth, near Bingley, the drainage of a large mill—mingling here, however, with that of the village—flows on to some hill-side grass land, and produces a large growth of grass before finding its way into the stream. The result here, if not attributable wholly to the fertilizing effect of dirty wool washings, at any rate proves that such dirty waters, with the spent liquors from dye-works, may be discharged into ordinary house sewage without injury to its value as manure"—(p. 31).

Filtration through soil or ashes.

Where irrigation is impracticable, intermittent downward filtration through soil, or through banks of cinders and ashes, is shown to be quite competent to purify these foul liquids. In one case where the latter plan was pursued "the effluent water was colourless and nearly free from suspended matter," while "in respect of soluble polluting ingredients it did not transgress our standards of purity" (p. 34).

It seems probable that "the addition of a slight excess of lime to the liquid before filtration" would hasten the nitrification of the organic matters and ammonia, and so prove advantageous.

With regard to intermittent downward filtration for the purification of sewage, the Commissioners say:—

Comparison of Irrigation with Filtration.

"Whereas 100 acres or more might be needed to cleanse, certainly to profitably utilise, the drainage of a town of 10,000 people by means of irrigation, it would need but three acres of a porous medium, six feet deep, worked as an intermittent filter, to oxidise, and therefore purify, the drainage water of such a town, provided the mass of earth through which it percolated were frequently and effectually aërated, and the foul liquid were so added that every part of this aërated filter had its equal share and equal interval of aëration"—(p. 51).

Nuisance of filtration; how lessened.

The "formidable nuisance" which would possibly be created by this immense filter would be greatly lessened by the separation of the suspended matters by precipitation, "whilst it would probably reduce by one-half the size of the filter necessary for cleansing a given volume of sewage."

Where filtration may be adopted.

"This alternative method of dealing with the sewage difficulty may therefore be adopted with advantage by towns in steep and narrow valleys where a sufficient area of land for irrigation cannot be obtained below the sewer outfall, and where the cost of pumping on to higher lands would be excessive" (p. 51).

But filtration through soil should only be resorted to where it is absolutely impossible to procure land for irrigation on account of the natural conformation of the country; for, as the Commissioners say (p. 51)—

> "It is the great advantage of the irrigation remedy for this class of river pollutions that their filth is not merely destroyed, but converted into wholesome food. Valuable marketable products are obtained, and thus the expense of the process may be recovered."

General results.

The important point brought out by this Report is, then, that the same method of purification which is alone capable of dealing with town sewage, may be employed in the case of these refuse liquors; that although it may not be advantageous to use them alone for irrigation, yet they may be mixed with the town sewage, and the whole purified and utilised together; that is to say, that the water-carriage system combined with irrigation, or with intermittent downward filtration through soil, is capable of treating all such refuse liquors as do not contain anything injurious to crops; in other words, it can remove, purify, and (in the case of irrigation) utilise all liquids containing putrescible organic matters, leave an effluent water which does not transgress the proposed standards, and so prevent the pollution of the rivers.

SUMMARY.

Having reviewed the most important methods that have been practised for the removal of refuse matters from towns, we have been led to adopt the following definite principle: that the method which does, in practice, where it is anything like efficiently carried out, remove at once and completely from the vicinity of habitations the various sorts of refuse in the most expeditious manner, is the one which must be the most conducive to health.

Principle arrived at.

We have pointed out that the principle of all dry methods of excremental removal, without exception, is to leave the excremental matters in and about the house for a certain time—so long, in fact, as they do not become an absolute nuisance. We maintain that this is essentially wrong in principle, and we point in support of our opinion to the facts with regard to the state of the health of the inhabitants of midden-closet towns. Many instances more than those we have quoted are daily coming under our notice. As to the dry earth system, its principle is the same, though its action is more thorough. Although it has been shown to have a great advantage where it has replaced midden heaps and cesspools, we maintain, with Dr. Rolleston and with

Dry methods *all* violate it.

Deodorisation and disinfection not the same thing.

Dr. Parkes, that it has not been shown that the compost is disinfected as well as deodorised. And until this is proved to be the case it is safer to resort even to the offensive pail system, where excrement cannot be allowed to remain within dwellings for any length of time on account of the great nuisance that would be caused by it, than to a plan which destroys the warning but is not proved to have removed at the same time the danger. It has at various times been proposed to deodorise coal gas: the result of this would certainly be that accidents by poisoning and by explosion would be increased to an enormous extent. We know that the poisonous ingredient *par excellence* of coal gas—the carbonic oxide—is perfectly inodorous; we know also that the emanations which produce typhoid fever are not offensive or disagreeable to the smell; and it is a *presumption*, as Dr. Parkes says, to suppose that all danger of their production is removed by mixing the excrement with earth. But even were this presumption to become a demonstrated fact, the greatest objection to the earth system (one which is essential to it because it is a dry system) would still be as strong as ever; viz. that whenever the earth supplied happened to be in too small quantity, too moist, or of bad quality, or the air to be very damp, or the compost wetted through carelessness or otherwise, the danger of infection would at once arise. How frequently one or more of these conditions would be fulfilled need hardly be pointed out.

Comparison with coal gas.

Miss Nightingale well says, in her remarks on the *Progress Reports* in the Indian Sanitary Report (1870), p. 45: "The true key to sanitary progress in cities is, water supply and sewerage. No city can be purified sufficiently by mere hand-labour in fetching and carrying."

"As civilization has advanced, people have always enlisted natural forces or machinery to supplant hand-labour, as being much less costly and greatly more efficient."

We turn, then, to review briefly the results already attained by the water-carriage system, despite all the disadvantages of it (when badly carried out), which have been put forward in these pages. We know what it has done; we know that in the towns where it has been introduced in conjunction with other sanitary improvements, it has been the means of practically annihilating cholera; we know that it has been very little less effectual in the extermination of typhoid fever. We are sure that it is the speedy removal of the refuse matters that has accomplished this, because, in towns where free exit has not been allowed for the sewage from the sewers, the death-rate of typhoid fever has only very slightly diminished, or has slightly increased, or even (in one case) has very considerably increased. Such cases, although deplorable in themselves, are instructive to the sanitarian in pointing out beyond the question of a doubt that it is especially the improved sewerage arrangements that have effected these results. We have seen, too, that by the construction of deep drain-sewers the mortality from phthisis has been diminished to a very remarkable extent, amounting in one case to nearly half the former number of deaths.

Results attained by water-carriage system.

What the drain sewers have shown.

And although we have, for a multiplicity of reasons, felt ourselves justified in condemning the drain-sewer system, we have certainly to thank it for the discovery of the all-important fact that one of the most potent causes of phthisis is a water-logged subsoil; so that while we advocate impervious pipe sewers, we must also insist that towns shall be provided with deep subsoil drains.

Not only this, but we have also seen that these special improvements have been accompanied by the still more important one of a reduction in the general death-rate, amounting to about a fifth part of the previous number of deaths in nine out of the twenty-five towns reported on by Dr. Buchanan.

Sewage; how got rid of.

Having then, the sewage to deal with, the first object must be to get rid of it in an unobjectionable manner, and the next to utilise it if possible.

Plenty of evidence has been given to show that it must not be sent into the rivers, as has heretofore been almost invariably done; and that it is only a little less objectionable to resort to this plan after a preliminary straining off of the suspended matters.

Filtration.

We have, however, seen that by intermittent downward filtration through soil (and perhaps, where convenient, through ashes, &c.), sewage can be adequately purified, so that the effluent water may be turned into a stream; by this plan, however, the manure which is so much wanted is almost entirely lost, the greater part of it escaping in solution in the effluent water in the form of nitrates and nitrites.

Precipitation processes.

As to the utilisation of sewage, we have shown the futility of all attempts at precipitation of its valuable constituents; in fact, " it is hopeless," as Dr. Hewlett says, "by either one or any of these operations to render the effluent water anything else than sewage."

Irrigation.

Finally, with regard to irrigation farming, the facts that we have brought together seem to us to show clearly that it satisfies the three conditions which we laid down (p. 227); the sewage is purified, a profitable agricultural return is ensured, and the health of the neighbourhood is not endangered.

Conclusion.

We are, then, reduced to the following simple issue: wherever it is possible, irrigation should be carried out, the sewage having been previously freed, by one or other of the methods described, from the offensive suspended matters, which must be deodorised to prevent the production of a serious nuisance. Wherever, on the other hand, irrigation is practically impossible, intermittent downward filtration, through soil or other suitable material, affords the means of satisfactorily purifying the sewage.

We have collected the facts, arranged them, and weighed the evidence afforded by them; it is for the future to decide how far our conclusions have been warranted.

THE END.

INDEX.

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