CHAPTE R XI.

HOUSE DRAINAGE AND TOWN SEWERAGE IN THEIR RELATIONS TO THE PUBLIC HEALTH.

The following is extracted from a report made by the General Board of Health to the British Parliament, concerning the administration of the Public Health Act and the Nuisances Removal and Diseases Prevention Acts from 1848 to 1854.

"Where instances have been favorable for definite observation, as in broad blocks of buildings, the effects of sanitary improvement have been already manifested to an extent greater than could have been anticipated, and than can be readily credited by those who have not paid attention to the subject.

"In one favorable instance, that of between 600 and 700 persons of the working class in the metropolis, during a period of three years, the average rate of mortality has been reduced to between 13 and 14 in 1000. In another instance, for a shorter period, among 500 persons, the mortality has been reduced as low as even 7 in 1000. The average rate of mortality for the whole metropolis being 23 in 1000.

"In another instance, the abolishing of cess-pools and their replacement by water-closets, together with the abolishing of brick drains and their replacement by im-
"permeable and self-cleansing stone-ware pipes, has been attended with an immediate and extraordinary reduction of mortality. Thus, in Lambeth Square, occupied by a superior class of operatives, in the receipt of high wages, the deaths, which in ordinary times were above the general average, or more than 30 in 1000, had risen to a rate of 55 in 1000. By the abolishing of cess-pools, which were within the houses, and the substitution of water-closets, and with the introduction of tubular, self-cleansing house-drains, the mortality has been reduced to 13 in 1000.

The reduction of the mortality was effected precisely among the same occupants, without any change in their habits whatever."

"Sewers are less important than the House-Drains and Water-Closets, and if not carrying much water, may become cess-pools. In the case of the Square just referred to, when cess-pools and drains of deposit were removed without any alteration whatever in the adjacent sewers, fevers disappeared from house to house, as these receptacles were filled up, and the water-closet apparatus substituted, merely in consequence of the removal of the decomposing matter from beneath the houses to a distant sewer of deposit or open water course.

"If the mortality were at the same rate as in the model dwellings, or in the improved dwellings in Lambeth Square, the annual deaths for the whole of the metropolis would be 25,000 less, and for the whole of England and Wales 170,000 less than the actual deaths.

"If the reduced rate of mortality in these dwellings should continue, and there appears to be no reason to suppose that it will not, the extension to all towns which have been affected, of the improvements which have been applied in these buildings, would raise the average age at death to about forty-eight instead of twenty-nine, the present average age at death of the inhabitants of towns in all England and Wales."
The branch of the Art of Drainage which relates to the removal of the fecal and other refuse wastes of the population of towns, is quite different from that which has been described in the preceding pages, as applicable to the agricultural and sanitary improvement of lands under cultivation, and of suburban districts. Still, the fact that town and house drainage affords a means for the preservation of valuable manures, justifies its discussion in an agricultural work, and "draining for health" would stop far short of completeness were no attention paid to the removal of the cause of diseases, which are far more fatal than those that originate in an undrained condition of the soil.

The extent to which these diseases, (of which typhoid fever is a type,) are prevented by sanitary drainage, is strikingly shown in the extract which commences this chapter. Since the experience to which this report refers, it has been found that the most fatal epidemics of the lower portions of London originated in the choked condition of the street sewers, whose general character, as well as the plan of improvement adopted are described in the following "Extracts from the Report of the Metropolitan Board of Works," made in 1866.

"The main sewers discharged their whole contents direct into the Thames, the majority of them capable of being emptied only at the time of low water; consequently, as the tide rose, the outlets of the sewers were closed, and the sewage was dammed back, and became stagnant; the sewage and impure waters were also constantly flowing from the higher grounds, in some instances during 18 out of the 24 hours, and thus the thick and heavy substances were deposited, which had to be afterwards removed by the costly process of hand labor. During long continued or copious falls of rain, more particularly when these occurred at the time of high water in the river, the closed outlets not having sufficient storage capacity to receive the increased volume of sewage,
the houses and premises in the low lying districts, especially on the south side of the river, became flooded by the sewage rising through the house drains, and so continued until the tide had receded sufficiently to afford a vent for the pent-up waters, when the sewage flowed and deposited itself along the banks of the river, evolving gases of a foul and offensive character.

"This state of things had a most injurious effect upon the condition of the Thames; for not only was the sewage carried up the river by the rising tide, at a time when the volume of pure water was at its minimum, and quite insufficient to dilute and disinfect it, but it was brought back again into the heart of the metropolis, there to mix with each day’s fresh supply, until the gradual progress towards the sea of many day’s accumulation could be plainly discerned; the result being that the portion of the river within the metropolitan district became scarcely less impure and offensive than the foulest of the sewers themselves.

The Board, by the system they have adopted, have sought to abolish the evils which hitherto existed, by constructing new lines of sewers, laid in a direction at right angles to that of the existing sewers, and a little below their levels, so as to intercept their contents and convey them to an outfall, on the north side of the Thames about 11½ miles, and on the south side about 14 miles, below London Bridge. By this arrangement as large a proportion of the sewage as practicable is carried away by gravitation, and a constant discharge for the remainder is provided by means of pumping. At the outlets, the sewage is delivered into reservoirs situate on the banks of the Thames, and placed at such levels as enable them to discharge into the river at or about the time of high water. The sewage thus becomes not only at once diluted by the large volume of water in the river at the time of high water, but is also carried by the ebb
“26 miles below London Bridge, and its return by the following flood-tide within the metropolitan area, is effectually prevented.”

The details of this stupendous enterprise are of sufficient interest to justify the introduction here of the “General Statistics of the Works” as reported by the Board.

“A few statistics relative to the works may not prove uninteresting. The first portion of the works was commenced in January 1859, being about five months after the passing of the Act authorising their execution. There are 82 miles of main intercepting sewers in London. In the construction of the works 318,000,000 of bricks, and 880,000 cubic yards of concrete have been used, and 3,500,000 cubic yards of earth excavated. The cost, when completed, will have been about £4,200,000. The total pumping power employed is 2,300 nominal horse power: and if the engines were at full work, night and day, 44,000 tons of coals per annum would be used; but the average consumption is estimated at 20,000 tons. The sewage to be intercepted by the works on the north side of the river, at present amounts to 10,000,000 cubic feet, and on the south side 4,000,000 cubic feet per day; but provision is made for an anticipated increase in these quantities, in addition to the rainfall, amounting to a total of 63,000,000 cubic feet per day, which is equal to a lake of 482 acres, three feet deep, or 15 times as large as the Serpentine in Hyde Park.”

A very large portion of the sewage has, to be lifted thirty-six feet to the outfall sewer. The works on the north side of the Thames were formally opened, by the Prince of Wales, in April 1865.

In the hope that the immense amount of sewage, for which an escape has been thus provided, might be profitably employed in agriculture, advertisements were inserted in the public journals asking for proposals for carrying out such a scheme; and arrangements were subsequently made
for an extension of the works, by private enterprise, by the
construction of a culvert nine and a half feet in diameter,
and forty miles in length, capable of carrying 12,000,000
cubic feet of sewage per day to the barren sands on the
cost of Essex; the intention being to dispose of the liquid
to farmers along the line, and to use the surplus for the
fertilization of 7000 acres, (to be subsequently increased,) 
which are to be reclaimed from the sea by embankments
and valve sluice-gates.

The estimated cost of this enterprise is about $10,000,000.

The work which has been done, and which is now in
contemplation, in England, is suggestive of what might, 
with advantage, be adopted in the larger cities in America. Especially in New York an improved means of out-
let is desirable, and it is doubtful whether the high rate 
of mortality of that city will be materially reduced be-
fore effective measures are devised for removing the vast 
accumulations of filth, which ebb and flow in many of the
larger sewers, with each change of the tide; and which 
are deposited between the piers along the river-sides.

It would be practicable to construct a main receiving
sewer under the river streets, skirting the city, from the
vicinity of Bellevue Hospital on the east side, passing near
the outer edge of the Battery, and continuing to the high
land near 60th street on the west side; having its water
level at least twenty feet below the level of the street; and
receiving all of the sewage which now flows into the river.
At the Battery, this receiving sewer might be connected,
by a tunnel, with the Brooklyn shore, its contents being
carried to a convenient point south of Fort Hamilton,—
where their discharge, (by lifting steam pumps), into the
waters of the Lower Bay, would be attended with no incon-
venience. The improvement being carried out to this point,
it would probably not be long before the advantages to
result from the application of the sewage to the sandy
soil on the south side of Long Island would be manifest.
The effect of such an improvement on the health of the city,—which is now in constant danger from the putrefying filth of the sewers, (these being little better than covered cess-pools under the streets,)—would, no doubt, equal the improvement that has resulted from similar work in London.

The foregoing relates only to the main outlets for town sewage. The arterial drainage, (the lateral drains of the system,) which receives the waste of the houses and the wash of the streets, is entirely dependent on the outlet sewers, and can be effective only when these are so constructed as to afford a free outfall for the matters that it delivers to them. In many towns, owing to high situation, or to a rapid inclination of surface, the outfall is naturally so good as to require but little attention. In all cases, the manner of constructing the collecting drains is a matter of great importance, and in this work a radical change has been introduced within a few years past.

Formerly, immense conduits of porous brick work, in all cases large enough to be entered to be cleansed, by hand labor, of their accumulated deposits, were considered necessary for the accommodation of the smallest discharge. The consequence of this was, that, especially in sewers carrying but little water, the solid matters contained in the sewage were deposited by the sluggish flow, frequently causing the entire obstruction of the passages. Such drains always required frequent and expensive cleansing by hand, and the decomposition of the filth which they contained produced a most injurious effect on the health of persons living near their connections with the street. The foul liquids, with which they were filled, passing through their porous walls, impregnated the earth near them, and sometimes reached to the cellars of adjacent houses, which were in consequence rendered extremely unhealthy. Many such sewers are now in existence, and some such are still being constructed. Not only are they unsatisfactory, they are
much more expensive in construction, and require much attention and labor for repairs, and cleansing, than do the stone-ware pipe sewers which are now universally adopted wherever measures are taken to investigate their comparative merits. An example of the difference between the old and modern styles of sewers is found in the drainage of the Westminster School buildings, etc., in London.

The new drainage conveys the house and surface drainage of about two acres on which are fifteen large houses. The whole length of the drain is about three thousand feet, and the entire outlet is through two nine inch pipes. The drainage is perfectly removed, and the pipes are always clean, no foul matters being deposited at any point. This drainage has been adopted as a substitute for an old system of sewerage of which the main was from 4 feet high, by 3 feet 6 inches wide, to 17 feet high and 6 or 7 feet wide. The houses had cess-pools beneath them, which were filled with the accumulations of many years, while the sewers themselves were scarcely less offensive. This condition resulted in a severe epidemic fever of a very fatal character.

An examination instituted to discover the cause of the epidemic resulted in the discovery of the facts set forth above, and there were removed from the drains and cess-pools more than 550 loads of ordure. The evaporating surface of this filth was more than 2000 square yards.

Since the new drainage, not only has there been no recurrence of epidemic fever, but "a greater improvement in the general health of the population has succeeded than might be reasonably expected in a small block of houses, amidst an ill-conditioned district, from which it cannot be completely isolated."

The principle which justifies the use of pipe sewers is precisely that which has been described in recommending small tiles for agricultural drainage,—to wit: that the rapidity of a flow of water, and its power to remove obstacles, is in proportion to its depth as compared with its width. It has been
found in practice, that a stream which wends its sluggish way along the bottom of a large brick culvert, when concentrated within the area of a small pipe of regular form, flows much more rapidly, and will carry away even whole bricks, and other substances which were an obstacle to its flow in the larger channel. As an experiment as to the efficacy of small pipes Mr. Hale, the surveyor, who was directed by the General Board of Health of London to make the trial, laid a 12-inch pipe in the bottom of a sewer 5 feet and 6 inches high, and 3 feet and 6 inches wide. The area drained was about 44 acres. He found the velocity of the stream in the pipe to be four and a half times greater than that of the same amount of water in the sewer. The pipe at no time accumulated silt, and the force of the water issuing from the end of the pipe kept the bottom of the sewer perfectly clear for the distance of 12 feet, beyond which point some bricks and stones were deposited, their quantity increasing with the distance from the pipe. He caused sand, pieces of bricks, stones, mud, etc., to be put into the head of the pipe. These were all carried clear through the pipe, but were deposited in the sewer below it.

It has been found by experiment that in a flat bottomed sewer, four feet wide, having a fall of eight inches in one hundred feet, a stream of water one inch depth, runs very sluggishly, while the same water running through a 12-inch pipe, laid on the same inclination, forms a rapid stream, carrying away the heavy silt which was deposited in the broad sewer. As a consequence of this, it has been found, where pipe sewers are used, even on almost imperceptible inclinations, that silt is very rarely deposited, and the waste matters of house and street drainage are carried immediately to the outlet, instead of remaining to ferment and poison the atmosphere of the streets through which they pass. In the rare cases of obstruction which occur, the pipes are very readily cleansed by flushing, at a tithe
of the cost of the constant hand-work required in brick sewers.

For the first six or seven hundred feet at the head of a sewer, a six inch pipe will remove all of the house and street drainage, even during a heavy rain fall; and if the inclination is rapid, (say 6 inches to 100 feet,) the acceleration of the flow, caused partly by the constant additions to the water, pipes of this size may be used for considerably greater distances. It has been found by actual trial that it is not necessary to increase the size of the pipe sewer in exact proportion to the amount of drainage that it has to convey, as each addition to the flow, where drainage is admitted from street openings or from houses, accelerates the velocity of the current, pipes discharging even eight times as much when received at intervals along the line as they would take from a full head at the upper end of the sewer.

For a district inhabited by 10,000 persons, a 12-inch pipe would afford a sufficient outlet, unless the amount of road drainage were unusually large, and for the largest sewers, pipes of more than 18 inches diameter are rarely used, these doing the work which, under the old system, was allotted to a sewer 6 feet high and 3 feet broad.

Of course, the connections by which the drainage of roads is admitted to these sewers, must be provided with ample silt-basins, which require frequent cleaning out. In the construction of the sewers, man-holes, built to the surface, are placed at sufficient intervals, and at all points where the course of the sewer changes, so that a light placed at one of these may be seen from the next one;—the contractor being required to lay the sewer so that the light may be thus seen, a straight line both of inclination and direction is secured.

The rules which regulate the laying of land-drains apply with equal force in the making of sewers, that is no part of the pipe should be less perfect, either in material
or construction, than that which lies above it; and where
the inclination becomes less, in approaching the outlet, silt-
basins should be employed, unless the decreased fall is still
rapid. The essential point of difference is, that while land
drains may be of porous material, and should have open
joints for the admission of water, sewer pipes should be
of impervious glazed earthen-ware, and their joints should
be securely cemented, to prevent the escape of the sew-
age, which it is their province to remove, not to distribute.
Drains from houses, which need not be more than 3 or 4
inches in diameter, should be of the same material, and
should discharge with considerable inclination into the
pipes, being connected with a curving branch, directing
the fluid towards the outlet.

In laying a sewer, it is customary to insert a pipe with
a branch opposite each house, or probable site of a house.

It is important that, in towns not supplied with water-
works, measures be taken to prevent the admission of too
much solid matter in the drainage of houses. Water being
the motive power for the removal of the solid parts of the
sewage, unless there be a public supply which can be
turned on at pleasure, no house should deliver more solid
matter than can be carried away by its refuse waters.

The drainage of houses is one of the chief objects of
sewerage.

In addition to the cases cited above of the model lodging
houses in Lambeth Square, and of the buildings at West-
minster, it may be well to refer to a remarkable epidemic
which broke out in the Maplewood Young Ladies' Institute
in Pittsfield, Mass., in 1864, which was of so violent and
fatal a character as to elicit a special examination by a
committee of physicians. The family consisted, (pupils,
 servants, and all,) of one hundred and twelve persons. Of
these, fifty-one were attacked with well-defined typhoid
fever during a period of less than three weeks. Of this
number thirteen died. The following is extracted from the report of the committee:

"Of the 74 resident pupils heard from, 66 are reported "as having had illness of some kind at the close of the "school or soon after. This is a proportion of ?? or nearly "90 per cent. Of the same 74, fifty-one had typhoid fever, "or a proportion of nearly 69 per cent. If all the people "in the town, say 8000, had been affected in an equal pro-
"portion, more than 7000 would have been ill during these "few weeks, and about 5500 of them would have had "typhoid fever, and of these over 1375 would have died. "If it would be a more just comparison to take the whole "family at Maplewood into the account, estimating the "number at 112, fifty-six had typhoid fever, or 50 per "cent., and of these fifty-six, sixteen died, or over 28.5 per "cent. These proportions applied to the whole population "of 8000, would give 4000 of typhoid fever in the same "time; and of these 1140 would have died. According "to the testimony of the practising physicians of Pittsfield, "the number of cases of typhoid fever, during this period, "aside from those affected by the influences at Maplewood, "was small, some physicians not having had any, others "had two or three." These cases amounted to but eight, none of which terminated fatally.

The whole secret of this case was proven to have been the retention of the ordure and waste matter from the kitchens and dormitories in privies and vaults, underneath or immediately adjoining the buildings, the odor from these having been offensively perceptible, and under certain atmospheric conditions, having pervaded the whole house.

The committee say "it would be impossible to bring "this report within reasonable limits, were we to discuss the "various questions connected with the origin and propaga-
"tion of typhoid fever, although various theoretical views "are held as to whether the poison producing the disease
is generated in the bodies of the sick, and communicated
from them to the well, or whether it is generated in
sources exterior to the bodies of fever patients, yet all
authorities maintain that a peculiar poison is concerned
in its production.

Those who hold to the doctrine of contagion admit
that, to give such contagion efficacy in the production of
wide spread results, filth or decaying organic matter is
essential; while those who sustain the theory of non-
contagion—the production of the poison from sources
without the bodies of the sick—contend that it has its
entire origin in such filth—in decomposing matter, espe-
cially in fermenting sewage, and decaying human excreta.

The injurious influence of decomposing azotised matter,
in either predisposing to or exciting severe disease, and
particularly typhoid fever, is universally admitted among
high medical authorities.

The committee were of the opinion "that the disease
at Maplewood essentially originated in the state of the
privies and drainage of the place; the high temperature,
and other peculiar atmospheric conditions developing, in
the organic material thus exposed, a peculiar poison,
which accumulated in sufficient quantity to pervade
the whole premises, and operated a sufficient length of
time to produce disease in young and susceptible per-
sons.  *  *  *  *  *  *  To prevent the poison of
"typhoid fever when taken into the system, from produc-
ing its legitimate effects, except by natural agencies,
"would require as positive a miracle as to restore a severed
head, or arrest the course of the heavenly bodies in their
"spheres.  *  *  *  The lesson for all, for the future, is
"too obvious to need further pointing out; and the com-
"mittee cannot, doubt that they should hazard little in
"predicting that the wisdom obtained by this sad expe-
"rience, will be of value in the future management of this
"institution, and secure precautions which will forever prevent the recurrence of such a calamity."

The results of all sanitary investigation indicate clearly the vital necessity for the complete and speedy removal from human habitations of all matters which, by their decomposition, may tend to the production of disease, and early measures should be taken by the authorities of all towns, especially those which are at all compactly built, to secure this removal. The means by which this is to be effected are to be found in such a combination of water-supply and sewerage, as will furnish a constant and copious supply of water to dissolve or hold in suspension the whole of the waste matters, and will provide a channel through which they may be carried away from the vicinity of residences. If means for the application of the sewage water to agricultural lands can be provided, a part if not the whole of the cost of the works will be thus returned.

Concerning the details of house drainage, it would be impossible to say much within the limits of this book. The construction of water-closets, soil-pipes, sinks, etc., are too will be understood to need a special description here.

The principal point, (aside from the use of pipes instead of brick-sewers and brick house-drains,) is what is called in London the system of Back Drainage, where only principal main lines of sewers are laid under the streets, all collecting sewers passing through the centres of the blocks in the rear of the houses. Pipes for water supply are disposed in the same manner, as it is chiefly at the rears of houses that water is required, and that drainage is most necessary; and this adjustment saves the cost, the annoyance and the loss of fall, which accompany the use of pipes running under the entire length of each house. Much tearing up of pavements, expensive ditching in hard road-ways, and interference with traffic is avoided, while very much less ditching and piping is necessary, and repairs are made with very little annoyance to the occupants of
houses. The accompanying diagrams, (Figs. 48–49,) illustrate the difference between the old system of drainage with brick sewers under the streets, and brick drains under the houses, and pipe sewers under main streets and through the back yards of premises. A measurement of these two

methods will show that the lengths of the drains in the new system, are to those of the old, as 1 to $2\frac{1}{2}$;—the fall of the house drains, (these having much less length,) would be 10 times more in the one case than in the other;—the main sewers would have twice the fall, their area would be only $\frac{1}{9}$, and their cubic contents only $\frac{1}{16}$.

Experience in England has shown that if the whole cost of water supply and pipe sewers is, with its interest, divided over a period of thirty years,—so that at the end of that time it should all be repaid,—the annual charge would not be greater than the cost of keeping house drains and cess-
pools clean. The General Board of Health state that "the expense of cleansing the brick house-drains and cess-pools for four or five years, would pay the expense of properly constructed water-closets and pipe-drains, for the greater number of old premises."

![Diagram of modern house drainage and sewerage](image)

Fig. 49.—Modern House Drainage and Sewerage.

One of the reports of this body, which has added more than any other organization to the world’s knowledge on these subjects, closes with the following:

"Conclusions obtained as to house drainage, and the sewerage and cleansing of the sites of towns."

"That no population living amidst impurities, arising "from the putrid emanations from cess-pools, drains and "sewers of deposit, can be healthy or free from the attacks "of devastating epidemics.

"That as a primary condition of salubrity, no ordure
and town refuse can be permitted to remain beneath or
near habitations.

"That by no means can remedial operations be so con-
veniently, economically, inoffensively, and quickly effected
as by the removal of all such refuse dissolved or sus-
pended in water.

"That it has been subsequently proved by the operation
of draining houses with tubular drains, in upwards of
19,000 cases, and by the trial of more than 200 miles of
pipe sewers, that the practice of constructing large brick
or stone sewers for general town drainage, which detain
matters passing into them in suspension in water, which
accumulate deposit, and which are made large enough
for men to enter them, and remove the deposit by hand
labor, without reference to the area to be drained, has
been in ignorance, neglect or perversion of the above
recited principles.

"That while sewers so constructed are productive of
great injury to the public health, by the diffusion into
houses and streets of the noxious products of the decom-
posing matters contained in them, they are wasteful from
the increased expense of their construction and repair,
and from the cost of ineffectual efforts to keep them free
from deposit.

"That the house-drains, made as they have heretofore
been, of absorbent brick or stone, besides detaining sub-
stances in suspension, accumulating foul deposit, and
being so permeable as to permit the escape of the liquid
and gaseous matters, are also false in principle and waste-
ful in the expense of construction, cleansing and repair.

"That it results from the experience developed in these
inquiries, that improved tubular house-drains and sewers
of the proper sizes, inclinations, and material, detain and
accumulate no deposit, emit no offensive smells, and re-
quire no additional supplies of water to keep them clear.
"That the offensive smells proceeding from any works intended for house or town drainage, indicate the fact of the detention and decomposition of ordure, and afford decisive evidence of mal-construction or of ignorant or defective arrangement.

That the method of removing refuse in suspension in water by properly combined works, is much better than that of collecting it in pits or cess-pools near or underneath houses, emptying it by hand labor, and removing it by carts.

That it is important for the sake of economy, as well as for the health of the population, that the practice of the removal of refuse in suspension in water, and by combined works, should be applied to all houses, especially those occupied by the poorer classes."

Later investigations of the subject have established two general conclusions applicable to the subject, namely, that:

"In towns all offensive smells from the decomposition of animal and vegetable matter, indicate the generation and presence of the causes of insalubrity and of preventable disease, at the same time that they prove defective local administration;" and correlatively, that:

"In rural districts all continuous offensive smells from animal and vegetable decomposition, indicate preventable loss of fertilizing matter, loss of money, and bad husbandry."

The principles herein set forth, whether relating to sanitary improvement, to convenience and decency of living, or to the use of waste matters of houses in agricultural improvement, are no less applicable in America than elsewhere; and the more general adoption of improved house drainage and sewerage, and of the use of sewage matters in agriculture, would add to the health and prosperity of its people, and would indicate a great advance in civilization."