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THE

SEPARATE SYSTEM OF SEWERAGE:

A Reply to a Paper Published in the Report of the State Board of Health, Lunacy and Charity of the State of Massachusetts, 1880, by Eliot C. Clarke, Esq.

BY GEO. E. WARING, JR.

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THE SEPARATE SYSTEM OF SEWERAGE.

MUCH the most comprehensive, reasonable and temperate discussion of this question, from the adverse point of view, is to be found in a paper by Eliot C. Clarke, C. E., Principal Assistant Engineer in charge of Improved Sewerage, Boston, published in the Public Health Supplement of the second Annual Report of the State Board of Health, Lunacy and Charity of Massachusetts.

As Mr. Clarke, on the whole, favors the combined system, the importance of the subject to the general public makes it desirable that his argument should be carefully reviewed. He begins, after referring to the uncertainty among engineers as to the proper size to be given to sewers, by stating the claims set up by those who advocate the separate system, and these claims he discusses seriatim. (The quotations in this paper, when not otherwise credited, are from the document under discussion.)

"1. The primary object of sewerage — the all-important and only essential requirement of it — is the removal of sewage proper, that is, of water holding in solution or suspension waste organic matters liable to decompose and become noxious. All other functions are comparatively unimportant and secondary and should not be permitted to lessen its adaptability to the essential purpose."

This does not state the case as I should state it. The primary object of sewerage is the removal of fouled waste waters *and of subsoil water*; that is, of the water which fills the interstices of the soil, which finds its way by gravitation into the foundations and cellars of houses, which gives an unstable foundation for pavements, and which on sloping ground is discharged at the surface. In discussing this point Mr. Clarke says: "It is also true that sometimes the removal of surface and *subsoil* water is if not an equally essential still an essential requirement and both for sanitary and economic reasons is usually an important function of a sewerage system." The sanitary argument in this case applies almost exclusively to subsoil water. He says that sewers are often built into thinly settled regions "in order to expedite the removal of rain and soil waters.

The danger from a damp soil and subsoil is not less real, though possibly less in degree and less easily traced to its source than that from the proximity of sewage." This is quite true and is a fundamental basis of all acceptable practice in separate sewerage. He then refers to the oft-quoted statement that chemical analysis detects little difference in impurity between water-closet matter and sewage from which excrement is excluded. Even where excrement is withheld from the sewers, kitchen waste is admitted with much household rubbish and garbage. The materials thus admitted are of precisely the same chemical combination as those which have gone into the human system to produce excrement as one of their products; and, on their decomposition, they are still substantially the same. It is impossible to determine, from the odor, appearance or analysis of the contents of an old cesspool whether excrement has been discharged into it or not. It is doubtless true, as stated, that much horse-manure and other filth is washed into public sewers; but it is also true that it ought to be kept out of them, and that with proper paving and street cleaning, a safer and more profitable disposal of these substances would follow as a matter of course. It is, therefore, not in point to say: "Certainly this first portion of rain, loaded as it is with impurities, the droppings of animals, and much other organic refuse, is as obnoxious as an equal amount of ordinary sewage, and equal care should be taken to get rid of it." It is also not in point to adduce this argument at all unless it is a question of ultimate disposal of the wastes of a town. Whether this street rubbish is removed by sewers or by carts, it had better not be brought into communication with house-drains, as it is in the combined system of sewerage.

"2. The amount of polluted water-supply from any district is so insignificant in proportion to the quantity of rain-water falling on it during rain-storms that sewers designed for receiving storm-waters are thereby impaired as to their efficiency for conveying sewage, because, being much larger than would otherwise be necessary, the depth and velocity of the ordinary flow is less." This statement is too mild. We maintain that storm-water sewers are inefficient for conveying sewage for the reason stated, and for the further very important reason that they become obstructed with mud, stones, brick-

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bats, sticks, leaves, and other road rubbish which is washed into them through the catch-basins, and that the foul sewage from houses is arrested by these obstructions and remains in the sewer to putrefy. To equalize the depth and velocity of flow Mr. Clarke suggests that the bottom of a large sewer (egg-shaped) may be given the same radius as a pipe sewer. This would, of course, give the same depth to the ordinary current of house sewage, *provided* the obstructing materials above referred to as coming from the streets can be excluded, which, in the combined system, they are not and cannot be. He says: "In order that the floating bodies may not strand, the centre depth should probably be at least three inches." This depends on the diameter and inclination of the sewer. In a six-inch pipe laid on an inclination of 1 in 250, where the ordinary flow near the upper end, when a bath or water-closet is discharged, is found in practice to be less than half an inch deep, some solids brought into a sewer by such a stream are stranded. Such stranded bodies are carried forward by a discharge from a flush-tank or otherwise which increases the depth of flow to *one inch* (I speak from observation, not from actual measurement). After the point is reached where the constant flow is an inch deep, there seems to be no stranding of matters delivered into "separate" sewers. In a "combined" sewer constructed with a lower cross section equal to that of a six-inch pipe, the rubbish brought to it from catch-basins would doubtless require the full three-inch stream prescribed and more. This difference is a constant one as applied to the two systems, and its collateral relations have a bearing on other important elements of the discussion. It seems to me that Mr. Clarke has made the mistake of assuming that the substances to be flushed out of the sewers are the same in both cases, and that in both cases the same flushing force is required.

Much importance is attached in his argument to the fact that large sewers of low grade will, during heavy storms, run half full, and that such a flow will flush them completely. This is true; but it is also true that at the tail of the storm fresh obstructions come in from the street, that such cleansing storms occur but rarely, that, even for many weeks together, there is an increasing accumulation in storm-water sewers of putrefying substances awaiting removal, and

that these in the mean time undergo an offensive and dangerous decomposition. Such decomposition results from a radical and inadmissible defect in every sewer in which it takes place. If anything approaching sanitary perfection is to be hoped for, this condition must be rendered impossible. Organic wastes lodging in the sewer must be swept clean out of it within twenty-four hours or less. If left for a longer interval they begin to do mischief. If removed within this interval they are of no consequence. This proposition, I think, will be accepted by all sanitarians as a sound one. The conditions indicated may be secured with the largest combined sewers as completely as with separate sewers; but in the one case we need a trifling amount of water sufficient to transport what enters the sewers from the water-closets and kitchen sinks of a house; in the other we need the great volume necessary to fill the sewer to such a height as to secure a cleansing velocity not only with reference to household wastes, but with reference also to the sticks and stones and rubbish washed in from the streets, some of which generally fail of removal, even during storms, and remain to accumulate organic matters in greatly increased quantity. For the efficient performance of the necessary service in the case of large combined sewers, we need more water than it is practicable to use.

Reference is made to the analysis of the atmosphere of a foul sewer in Boston which failed to detect a dangerous degree of pollution. This point will be referred to hereinunder in connection with Mr. James T. Gardiner's report to the State Board of Health of New York. Concerning the evidence of this analysis and other points which it is assumed that "some zealous advocates of the combined system" might raise, Mr. Clarke says: "these arguments have considerable force; and the answer to them is that, however slight the risk from deposits in sewers may be, still as it is a risk affecting health and even life, it is not right to impose it upon a community if it can be avoided." It can be avoided.

The opinion is expressed that the daily flushing practised with the Memphis sewers, "as it is equally adapted to large as to small sewers, may wisely be adopted for sewerage systems constructed on the combined system." It is not equally adapted to the combined system for reasons fully set forth above.

"3. The small sewers of the separate system are more easily cleansed by flushing." Mr. Clarke enumerates as the substances which need to be flushed out of sewers, household refuse of various sorts, some manufacturing refuse and *fine sand, which works its way through joints.* In addition to these in the combined system, "road detritus, gravel, leaves, twigs of trees," etc. He describes the action of the flush-tanks at Memphis, and says that "if, instead of these six-inch sewers, larger ones for rain had been built on the same inclinations and with their bottoms shaped like those of the six-inch pipes, the same quantity of water applied in the same manner would have produced a precisely similar effect." In this he overlooks the added matters to be flushed out in the case of sewers connected with streets which, it is fair to presume, would prevent "a precisely similar effect." He shows that a flushing velocity may be produced in a twelve-inch pipe at a depth of three inches, with a moderate increase in the amount of flushing-water, and that this effect may be produced at a somewhat lower inclination. He does not say that the effect would continue for so great a distance,—and it would not. He says that at the usual inclinations twelve-inch pipes have the great advantage over six-inch pipes, that, by increasing the quantity used until they are made to flow half full, a flushing velocity may be secured with slopes about one-third as steep. The amount of water needed will be about four times as much, and where economy of water is important the flush-tanks may be worked with sewage. All this is true; but the point at which the ordinary flow of house-waste would have a sufficient depth to carry ordinary solids would in the twelve-inch pipe be removed to a very much greater distance, and the quadruple quantity of flushing-water delivered at the head of the sewer would have lost its flushing effects long before this distance was passed. He says that sewers may have their flow dammed back by gates to the height of the house-drains, but not much higher, for fear of setting back the sewage into cellars, and that, therefore, the larger the sewer, the greater the flushing head. This does not necessarily hold, for if the small sewer is laid at the same depth as the large one, its flow may be dammed back even into man-holes and house-drains *to the same height above the grade*, as in the case of the large sewer. That is, it is not the diameter of the sewer, but the distance between the bot-

tom of the sewer and the level of the cellar which regulates the flushing head. It is true that flushing by this means will act for a shorter time and for a shorter distance (below the gate) because of the less quantity of water retained; but it is also true that the occasion for flushing is less with the separate sewer than with the combined one. He says: "After placing a dam in either sewer, on removing it the sewage accumulated in the larger sewer falls four times as far, and is opposed by only one-fourth as much surface in proportion to the amount of falling water, as in the smaller one. Neither the main nor the branch sewers, therefore, of a separate system can be as effectively flushed as the larger one of a combined system." This assumes that the head must be regulated by the diameter of the sewer. As it is to be regulated by the difference of elevation between the sewer and the cellar it does not hold. The main and lateral sewers of the separate system require much less flushing than do those which receive street rubbish, and they *can be as effectively flushed as the larger ones.* Referring to the use of the "pill" he says: "This method is said to have worked well, both in large siphons and in pipe-sewers, but it has hardly been in use long enough to afford definite conclusions as to its general applicability and effectiveness. It is equally adapted to the sewers of either system." This method is *said* to have worked well by all who have tried it, including Belgrand who used it in the Paris siphons years ago, Major Humphreys, who has used it regularly in Memphis, and Mr. Fowler, who has adopted it as a main reliance in the flushing of the sewers of New Haven. Simple devices demonstrate their efficiency at once, and this system of cleansing circular sewers has been in use long enough to demonstrate its efficiency. The demonstration is instant. One need only to observe it once to be convinced of its utility. It is not equally adapted to combined sewers although used with them, because these much oftener contain solid obstructions which require the pill to be helped in its passage. Among the substances causing obstructions in sewers, Mr. Clarke mentions those which catch on projecting pieces of cement: in pipe-sewers with gasketed joints, as in Memphis, there are no such projecting pieces of cement. In all my experience I have known of no instance in which grease runs in a liquid state "a hundred feet or more" to congeal on reaching the sewer. In the discussion on

Odell's description of the Memphis work at a meeting of the American Society of Civil Engineers, the distance to which grease passes in the house-drain before congealing was limited to a few feet.

"If the sewers are large enough to enter, that is over two feet in diameter, there is little difficulty in removing obstructions; if smaller the work must be done by means of rods and chains, pushed or drawn from one man-hole to another, at an expense many times greater than that of flushing. In either case the work will be more easily accomplished in the larger sewers of the combined system." From a report of the discussion of the Memphis system at the meeting of the Sanitary Institute of Great Britain, 1880, I quote the following as to the remarks of the President of the Engineering Section, Robert Rawlinson, Esq., C. E.: —

"They were told by one of our present great engineers that sewers should be large enough for men to get into to clean them out. Well, all he could say was, that the Legislature had passed a law to prevent boys going up chimneys, and he hoped a law would be passed to prevent men from going into sewers to clean them out. He, for one, would not have the blood of men who were killed in this work upon him. He mentioned instances of places sewered on the principle laid down in the paper with marked success. He moved a vote of thanks to Col. Waring."

"4. Large sewers develop and contain a greater quantity of noxious gas than small ones, and are not so easily ventilated."

This would be properly stated if the expression were "small *flushed* ones." Mr. Clarke bases his argument in opposition to this statement on the fact that the objection to sewer-gases, or rather their offensiveness, depends on concentration, large sewers having an advantage over the small ones because of the larger volume of air to be contaminated by a given amount of exhaling surface. This would be correct if both sewers were closed. Supposing both to be ventilated by the same openings, it would then be rather a question of the rapidity with which the whole atmosphere of the sewer is renewed, and this certainly must be greater with small sewers than with large ones. "It is possible that small sewers may be more easily ventilated than large ones, but there has been little experiment to verify theories on this point." He seems always, when the indicated proba-

bilities are not favorable to large sewers, to fall back on the shortness of time during which experiments opposing his theory have been carried out. There has been ample experience during many years to show that clean, small sewers, — often clean because small, — contain a much less offensive atmosphere than do larger ones. The sewers of Memphis have now been in use for two years; for nearly this period they have been very largely used. There have been frequent occasions, as in making new house-connections, to open them, and the condition of their air is perfectly known to all who have had to do with them. From the "sewer-gas" standard they are absolutely pure. As they carry offensive matters, they have, of course, a perceptible odor; but in no part and under no circumstances do they give off the least odor of decomposition or anything even suggesting the smell of an ordinary sewer. That the system of ventilation through soil-pipes, which is there universal, would enormously modify the atmosphere of any tolerably clean sewer is undoubted. Mr. Clarke says that such ventilation "is not usually considered good practice." In this I cannot agree with him. For the sake of the house-pipes themselves as well as of the sewers, I think it is easily demonstrable that such thorough ventilation is always desirable.

New light has been directed to this question by the report of Mr. James T. Gardiner, Director of the New York State Survey, and member of the State Board of Health, who considers the question in the light of recent physiological investigations. He says, speaking of storm-water sewers:

"The storm-water falling per hour in violent rains over an acre of closely built up city land is nearly fifty times the amount of the waste-water and sewage produced per hour on the same area. The sewage is, therefore, ordinarily a mere trickling thread in the bottom of a sewer large enough to carry off great bodies of storm-water. In time of rain the sewer will be nearly or quite full of diluted sewage, which is absorbed by the bricks, and leaves a coating on them as the water falls. The powerfully flowing stream of storm-water on subsiding deposits silt in the bottom of the sewer, which obstructs the flow of sewage, giving it time to decompose. Foul gases are then emitted, and it has been popularly assumed that these gases, called 'sewer-gas,' are the cause of disease.

"Physicians are agreed upon the fact that air from sewers passing into a dwelling is very likely to produce serious disease. That this illness is due to a *gas* from decomposing sewage is a mere assumption unsupported by proof. But the hypothesis was hastily adopted by engineers, who naturally inferred that the healthfulness of large sewers would be secured if they could only drive out or sufficiently dilute this gas by ventilating the sewer, or prevent its formation by keeping the stream of sewage flowing uninterruptedly. The discussion of the subject by Mr. Eliot Clarke, in the Massachusetts Board of Health report, and the opinion of other engineers who favor large sewers, seem to be based on this idea.

"It is time, therefore, to call attention to the fact that *no such gas as 'sewer-gas'* exists, and that *there is absolutely no proof that the diseases which attend the admission of sewer-air into a dwelling are produced by gases.* On the contrary the whole tendency of modern investigation is to show that the zymotic diseases are produced by *bacteria*, whose germs are developed under favorable conditions. It is well known that the most favorable conditions for the growth of these low organisms are heat, moisture, darkness, and the *presence of ammonia.* The damp walls of sewers present, therefore, all the requirements for a most flourishing growth of bacteria, whose germs may float off on the sewer-air and be carried into dwellings by mechanical action, as dust is borne on any air current.

"It is, therefore, most probable that sewer-air brings the germs of disease into dwellings as dust is blown into the window. The foul gases of decomposition may or may not be present, The fatal power over life lies, probably, in the little plant-seed, odorless and invisible, floating upon the sewer-air.

"Large sewers are, then, plantations for the propagation of deadly organisms, the moist, porous walls forming most favorable soil, the ammonia of sewage supplying the manure essential to full development, and the warm, damp air stimulating to the utmost all processes of growth.

"The occasional flushing of sewers, while it may clear out silt and accumulated filth, and thus decrease the amount of heat and ammonia from decomposition, can never prevent the growth of bacteria on the sewer walls, nor will ventilation prove efficient. Every device of engineering has been exhausted to keep large sewers clean and well ventilated, but the air from them is still deadly. Experience, therefore, teaches that there is some radical defect in the system of large or combined sewers, while modern investigations of the origin of zymotic dis-

eases and the mode of growth of bacteria seem to show that sewer-walls are almost ideal hot-beds for the production of fatal organic germs. Perfect plumbing may prevent sewer-air from entering dwellings, but perfect plumbing will always be the rare exception.

"In view of these facts I am forced to conclude that from a sanitary point of view the combined system of sewerage is a failure.

"I visited in London the sanitary department of the Local Government Board which has general supervision of the sanitary affairs of England. The Chief Engineer, Mr. Robert Rawlinson, C. E., and the principal medical inspectors, Dr. Ballard and Mr. Radcliffe, are perfectly agreed that the combined system of sewers is radically defective from a sanitary point of view. In this opinion Dr. Richardson and other prominent sanitarians concurred. At the meeting of the British Association for the Advancement of Science, in York, the leading civil engineers whom I met had abandoned their belief in the 'combined' system of sewers, being convinced that it could not be made healthful.

"While all were agreed as to the failure of the 'combined system,' some of the medical men favor the general introduction of the 'pail system' of Manchester of 'dry removal' of the excreta in tubs, and the use of sewers entirely disconnected from dwellings, to carry off only waste and storm-water; while Mr. Rawlinson and other engineers advocated water carriage by the 'separate system.'" Referring to the Memphis sewers, he says: "The sewers being so small and so well filled by the flow of sewage there is very little exposed wall-surface on which bacteria can germinate, and very little space for storing up germ-laden air. The gases and heat of decomposition, which so powerfully stimulate the growth of organic life, are prevented by thorough daily flushing, which is only possible in small sewers. The smooth glazed surface of pipes is unfavorable soil for vegetable growth, compared with porous bricks moistened with sewage.

"It will therefore be seen that the separate sewers do not afford those favorable conditions for an extensive and rapid growth of bacteria *which are the fatal defects of the large combined sewers.* The smaller pipes move rapidly all sewage from dwellings, without connecting them with foul caverns *whose sides produce low organic life.* Where the separate system, with flush-tanks, is in operation, I can learn of no complaints of 'sewer-gas.'

"The 'separate system' is therefore greatly to be preferred for sanitary reasons." . . .

"Although a number of English towns have wholly or partially

adopted a separate system, and the results have been so good that the engineers of the Local Government Board advise its general use, yet I was informed by the Chief Engineering Inspector, Mr. Rawlinson, that nowhere in England had the separate system been so completely developed and applied as in America, in the city of Memphis. He assured me that English engineers and sanitarians were watching with great interest the working of the Memphis sewerage, considering its results to be a thorough test of the principles involved.

"On further investigation of the small sewerage plans of Oxford and Dover, which I visited, and other English towns where modifications of the separate system are in use, I was confirmed in the opinion that the separate system of Memphis, designed by Col. George E. Waring, Jr., is much the most thorough and complete which has yet been built on a large scale. Instead, therefore, of describing imperfect English examples of the system, which, although great improvements over the combined sewers, are inferior to the American plan, I shall give the results of a recent examination of the Memphis sewerage, made for the city of Baltimore by Mr. C. H. Latrobe, C. E., a copy of whose report to the mayor and city council I have just received." Then follows the substance of Mr. Latrobe's report, including the following:

"In summing up my impressions as to the separate system as developed at Memphis, I would say that it is well planned and well executed, and fully answers the purpose for which it was intended and which I conceive to be primarily the object of all sewerage, viz.: to carry off all human and industrial waste with rapidity and cleanliness to its ultimate destination.

"The accompanying system of tile-drains has also thoroughly drained (as far as I know) the very tenacious subsoil of the city. As to the storm-water at Memphis, it can safely be left, from all I learn, to take care of itself." Mr. Gardiner concludes thus:

"I am of the opinion that the separate system of small sewers avoids in great measure the inherent sanitary difficulties of the combined plan; and that it is an efficient and economical method of removing the sewage of towns. I therefore recommend the State Board of Health to advise the adoption of the separate system of sewage in those towns which have asked for information on this subject."

Acting upon his report the State Board of Health at its last quarterly meeting passed a series of resolutions, including the following:

"6. That towns having proper water-supply should be provided with a system of small sewers adapted to carry only sewage, including ex-

cre ta, slops, and waste-water, and excluding storm-water, which should be taken care of separately.

"7. That the costly plan of large combined sewers for carrying sewage and storm-water *together* has proved a sanitary failure both in England and in this country; while the 'separate system,' when properly constructed, avoids in great measure the evils from sewer-air, now so common, and is much less expensive for most towns.

"8. That the 'separate system of sewers,' with flushing-tanks, is hereby recommended for general use in this State."

"5. So much smaller sewers will suffice to carry off the sewage only, that their cost need be but a fraction of what would be required to build sewers admitting rain; and by adopting the former many towns can avail themselves of the benefits of sewerage which would otherwise be debarred from it on account of the expense; and in any case the difference in cost would be considerable."

Mr. Clark admits that "the first cost of a system for sewage alone will be much less than that of one admitting rain." He states the case very fairly in comparing the cost of the sewers of Chicago with those of Memphis, and says: "It appears that the first cost of the combined system will be two and one-half times that of a separate system not admitting rain." In my own judgment the average difference will be more than this. He thinks, however, that the question of economy depends upon other considerations which he enumerates, some of which are sound and some are not so. As for example, he charges the separate system with "all pecuniary damage caused by lack of prompt removal of the rain-water, especially the damage to street surfaces which would be gullied and washed away in time of rain." Such washing is of rare occurrence and is so seldom experienced, even in Baltimore, where the surface flow is copious and rapid, that an influential portion of the public have long objected to the adoption of a sewerage system for that city because it would deprive them of the efficient cleansing of the streets by storm-water, which they have always found so satisfactory. He does not charge the combined system with the flooding of cellars, and often of streets and yards by overflows, caused by the gorging of the sewers, during storms, nor does he refer to what is much more serious than cost and

what often happens under such conditions, — the flooding of basements and cellars with filthy sewage.

"6. Rain-water in excess is seldom worse than inconvenient, and, at most places, can properly be allowed to flow off over the surface of the streets, as it does everywhere before the introduction of sewerage."

I should make this stronger and say that storm-water may be allowed to flow off over the surface of the street *with great advantage* so long as it does not accumulate to a dangerous extent. He says: "It is begging the question to claim that since the rain flowed over the surface everywhere before the introduction of sewerage, it can continue to do so; for the same sort of reasoning would apply to the sewage itself." This is true only if there is no difference between running storm-water and foul sewage over the surface. It seems to me a novel view of the subject for a modern sewerage engineer to entertain. He says of rain-water that it is a question how far it can be made to flow in the streets without becoming "too great a nuisance." That is the precise limit to be adopted. My idea would be to keep it in the streets until it does become too great a nuisance, and then to carry it underground. It will be found in practice that the area over which water may be kept on the surface is so great that with proper arrangement the underground storm-water channels will be so much reduced in extent that it is not fair to call them "a second set of sewers," which is a favorite expression with those who argue against the separate system. He refers to the complaint of residents "that the amount of water on the street in time of heavy rain or thaw is a nuisance." But he says that residents are too often exacting in matters concerning their comfort. He does not refer to the more frequent and much more serious complaint of residents whose houses are near catch-basins, — almost invariably offensive; but he does say; "In the latitude of Massachusetts catch-basins also sometimes freeze up and cause trouble, but this can be prevented, or they can be thawed out with salt."

He refers to the fact that the grading of the surface of streets and the elevation of yards as compared with the streets must be modified if storm-water is to flow over the surface. This is often entirely true, and so far as it goes, it is an argument against the separate system

of sewerage. It is, however, a putting of the question of the cost of grading and of convenience into opposition with the vital question of the public health.

"7. Where it is absolutely necessary to remove the rain as well as the sewage by means of underground conduits, two sets of sewers can be built, each designed for its special purpose, and the greater efficiency of both will compensate for the slight increase in cost."

In this statement I only object to the expression "two sets of sewers." As stated above, the storm-water sewers would only be main outlets for various districts chiefly drained of their rain-fall by surface flow. Mr. Clarke says: "To build a separate set of sewers for this alone presents no especial difficulty. The sewers must be as large as if intended to convey the sewage also: therefore if they were placed equally low, the cost of a double system would be two-fifths greater than that of a combined one." It would be so if the storm-water sewers reached everywhere that the separate sewers do, and as stated if they were placed *equally low*. In practice their length would probably average not more than one-fourth of the length of the small sewers, and as complete drainage of the soil of cellars and of houses would be effected by the pipe sewers and their accompanying tile-drains, the necessary storm-water conduits need be carried only sufficiently under the surface to be out of the way, in many cases three feet deep instead of thirteen feet deep. Constructed on this principle, "the two sets of sewers" could not "interfere with each other as to position, and where they cross each other as to their grades." He says: "The small sewers would lack the periodical flushing by rain-water, and during a very light rain of short duration considerable street-refuse may be carried into the large sewers to remain and decompose until the next shower; but as these sewers would not be connected with the houses, this would cause no danger, and, if they were well ventilated, little annoyance." The Memphis sewers have *no* "periodical flushing by rain-water," but a copious flushing every day by automatic flush-tanks. The street-refuse if carried into combined sewers and remaining to decompose, the sewers *being* connected with the houses, the immunity indicated would not exist.

"8. Where the sewage must be raised by pumping, or treated in any way, these operations can only be satisfactorily accomplished if the sewage is unmixed with rain." Mr. Clarke says that where pumping is resorted to a separate system becomes a necessity. For towns discharging their sewage by gravitation, he indicates the use of intercepting sewers large enough for the dry-weather flow, with independent storm-water overflows. He does not pretend that this is more than a makeshift.

His conclusion is thus stated:

"The result of this discussion appears to show that a separate system of sewerage is only necessary where cellars are so low that they must be drained by pumping; that in other cases its only merit is its cheapness; that the saving in first cost of sewers will be about three-fifths, depending on the character of the soil; that the final economy will depend on circumstances; that the system would only be advisable where the branch sewers could incline not much less than one in one hundred; that surface-drainage for rain is attended by a varying amount of inconvenience and damage which increases with the growth of a town."

My own conclusion would be this: The result of this discussion appears to show that a separate system of sewerage is *necessary* where cellars are so low that they must be drained by pumping, and where the cost of a combined system cannot be afforded; that its economy is always very great; that it is entirely efficient with a fall of one in five hundred; that surface-drainage can be prevented from causing inconvenience or damage worth considering, no matter what the size of the town, for an outlay which compared with the extra cost of a system of combined sewers would be trifling; and last and most important, that while combined sewers cannot possibly meet the necessary sanitary requirements, separate sewers can be made absolutely safe, affording the only means now known for the perfect sanitary drainage of a town of any size, and that for these reasons the separate system is always advisable.

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