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By George E. Waring, Jr., Newport, R. I.

One of the most important questions now before the sanitarian, and very much the most important before the sanitary engineer, is the question of the best methods for disposing of the surface-water of cities and towns; that is, of the rain falling on the natural or unimproved surfaces, on the paved area, and on the roofs of houses.

The direct bearing of this question relating to the degree to which the soil is to be made wet, and the degree to which organic impurities on the surface are to be washed away or to be concentrated in depressions, affects directly the healthfulness of the community. Aside from all sanitary considerations there is a very important one relating to convenience and to the protection of public and private property from injury by floods. That this water must be got rid of, and that it must be got rid of in such a manner as to do the least possible harm to the health of the community, and with the least practicable cost, is a fundamental fact to be borne always in mind. Economy and convenience are sure to assert their importance in any consideration of the subject. The sanitary effect of the method of removal adopted is not so sure to command attention, but it is very sure sooner or later, to assert its influence.

I have been led by circumstances to give especial attention to this subject for a number of years past. I began, as any student of engineering would naturally begin, by accepting as inevitable, or at least as most judicious, the methods of disposal universally adopted. I have ended, as I believe most intelligent and fair-minded men must end, after a careful consideration of all of the arguments bearing upon the case, with the conviction that the prevailing practice has been radically wrong, and that simplicity, economy, and above all, the best observance of sanitary requirements demand in almost all cases, if not indeed everywhere, an absolute separation of household and manufacturing waste from the surface flow.

The almost universal custom concerning the treatment of storm-

water in sewered towns has been a very natural outgrowth of circumstances. The first sewers were simply natural water-courses covered over or continuously bridged to obviate their interruption to traffic, and to protect their channels from the reception of garbage and filth. As the paving and roofing of the area increased, the flow of storm-water became more and more rapid, with the natural result that this discharge was delivered into the covered channels to get it out of the way. To secure a further extension of this convenience, underground branches of these water-courses were laid to other parts of the occupied area until a more or less complete network of covered drains resulted.

The annoyance from the accumulation of foreign substances admitted to these rough channels led to the paving of their bottoms and the walling of their sides, and gradually, through various improvements of form, to the large brick sewer of modern times, and, for minor extensions of the system, to the use of pipes of large diameter.

It is only at a comparatively recent day that the almost universal restriction concerning the admission of filth to such sewers was withdrawn, and that they came to be used for conveying the wastes of human life. The withdrawal of this restriction was about coincident with the introduction of water-supply and of the system of water-carriage for the drainage of houses. No other vehicle for removing household wastes is so convenient or so cheap as aqueduct-water, and the facilities for its discharge which large sewers afford, are sufficiently good to secure the transmission of our off-scourings more or less completely to a distant point.

We have through long practice grown up with the belief that deep sewers are necessary for the removal of storm-water, and this necessity being conceded, we have not unnaturally sought to avoid the mistake of cutting a big hole for the cat and a little one for the kitten by turning both sewage and storm-water into the one large channel. This seems the simplest way to accomplish the end, and it has the sanction of a sufficient antiquity to have commanded general adoption.

In discussing this subject we should try to divest ourselves of the influence of preconceived opinions and of universal habit, and look at it in all its various bearings. The large sewer is the outgrowth of a desire to get rid of surface-water, and incidentally of so much of the soil-water as is likely to make our cellars wet. It had in its inception nothing whatever to do with the removal of filth from houses. This further duty has been thrust upon it simply because it was

capable of performing it without the expense and complication that would attend the introduction of a separate set of works.

In 1842, Mr. Edwin Chadwick, the father of sanitation in England, a most intelligent man but not a professional engineer, made the suggestion and supported it with strong arguments, that household wastes and matters of like character should be provided for by a separate and distinct system of pipes. He has long been supported in his opinion by Mr. Robert Rawlinson, C. B., now the engineer of the Local Government Board, and beyond question, foremost in his profession in England. Practically, no considerable amount of public work has been carried out in accordance with the suggestions of these gentlemen. Communities are slow to try experiments in engineering, and the force of precedent has such effect nowhere else as with the class of minds usually charged with the regulation of municipal affairs. Indeed, it is not clear that the few attempts made in England to carry out the separate system have been altogether satisfactory. The storm-water sewer of the improved modern form has at least the advantage that, from time to time, it receives very copious flushing from the rainfall, so that usually before obstructions accumulate to such a degree as to choke the channel completely, there comes a storm of sufficient volume to wash out the deposits and give the sewers a fresh start. Sewers constructed for the removal of foul sewage only, and without special means for flushing, are quite sure, however small, to become more or less filled with accumulations, especially near their dead-ends. Consequently, in the state of the art a very few years ago there was good reason for hesitating to accept the suggestion for a separate system, and for adhering to a plan which, whatever its faults, had the advantage of always working with tolerable certainty, and moving along our off-scourings toward an ultimate outlet.

That the state of the art has entirely changed within the past decade, and that the arguments formerly obtaining against the separate system are no longer valid, I shall propose to show in good time. Let us first consider what are the objections to the present mode of disposing of surface-water by its admission into deep underground sewers traversing every street of the town.

One office of a copious rainfall, one effect which it is sure to produce, is the removal of accumulations of earth and organic matter from the surface of the street. These two very different substances are carried forward together, and are delivered, often at every street corner, into a catch-basin, which quiets the flow and permits the solid substances that it carries to be deposited. The completeness of the

deposit is proportionate to the volume of the flow, and to the specific gravity of these solid matters. So much of the dirt as is carried off from the surface of the street by a light rain is quite completely deposited in the slightly disturbed water of the catch-basin. If the storm is more severe, the erosive action of the surface-water is greater; more solid matters are carried into the catch-basin, and the commotion of the impounded water removes a much larger proportion of the lighter and finer substances. Little by little, as time goes on, these deposits accumulate in various strata of fine dirt, involved organic matter, coarse gravel, and much incidental rubbish. Once firmly settled in the catch-basin, the material remains until removed by hand. While so remaining, its organic portions undergo decomposition, with an insufficient ventilation, and produce resultant gases of an offensive and often dangerous character. These gases, especially during protracted seasons of drought, manifest themselves to the senses of all who pass or who live near to their source. The catch-basin almost invariably has some form of trapping device, depending upon the interposition of a water-seal. In dry weather the water is evaporated, the seal is broken, and an escape is afforded for the air of the sewer.

During a rain the water flowing from the catch-basin into the sewer carries greater or less quantities of foreign substances. In a light rain it may be mainly the coarser and lighter parts of the horse-droppings which so pass. During heavy rains a greater disturbance of the water causes the removal of more of the deposit, some of this being already in an active state of decomposition. All of these substances pass into the sewer, from which they are completely or partially removed, according to the exactness with which its scouring quality has been developed in its original construction.

For the sake of uniformity more than for any sounder reason, this system of storm-water removal is not confined to those parts of the town where storm-water may ordinarily become a source of annoyance or of danger to property, but is made to apply universally to every part of the town, the catch-basins being placed so near together that in an ordinary rain the flow through the gutters is not sufficient to remove anything like all of the filth; much of it is swept together into local deposits, which, under our American system of street-cleaning, remain for an indefinite time, and which are offensive, if not injurious, so long as they do remain.

It is usual in constructing a plan for the sewerage of a town to arrange for the removal of a certain proportion of the water of

storms of a certain amount, what is in excess of this amount being got rid of by storm-water overflows. If the amount of rainfall which it is arranged to remove is very small, the purpose is only incompletely attained. If the provision is for the removal of a large rainfall then the sewers are necessarily too large to be cleansed by lighter rains, and the larger sewers of the system, unless of steep inclination, are very sure to accumulate deposits to a considerable amount. These deposits are less favorably circumstanced as to ventilation than those in the catch-basins; and, while it is by no means universal, it is very general for the larger sewers to be, except immediately after heavy rains, foul with accumulations of organic matter undergoing a decomposition which produces the "sewer-gas" with which we are so familiar. There is doubtless a very considerable production of sewer-gas due to the deposits of street-wash alone; but when we add to these deposits the adhering filth derived from our house-drains, its character is very much aggravated, and the resultant gases become much more pernicious. The confined air of our large unventilated city sewers is rich in the products of this combined decomposition.

It is a favorite theory with engineers that complete ventilation will render these gases inoffensive and harmless. Theoretically this may be true; practically it is not true, for the reason that the complete ventilation of a large storm-water sewer is substantially impossible. The truth of this statement is very clearly established by the condition, especially during warm weather, of the Fourth Avenue tunnel, in New York. This is a large underground roadway less than half a mile in length, and containing two railroad tracks. It is entirely open at each end, and its course is in the direction of the prevailing winds. Its roof is pierced with a constant succession of large openings probably from eight to twenty feet in diameter, opening directly to the sky. The constant passage of cars in both directions must act as a very important source of movement in the air. The utmost care is taken to keep the road-bed clean, and the walls and roof are whitewashed with great frequency. Disinfectants are freely used, and every effort is made to secure a pure condition of the atmosphere. The result is, as nearly as possible, a total failure, and at times the whole atmosphere of the tunnel is absolutely sickening. If no better result can be secured under these most favorable circumstances, what are we to expect of a sewer four or five feet in diameter, deep in the ground, foul from end to end, and with no other means of ventilation than a dozen small holes in the covers of

man-holes at intervals of 300 or 400 feet? The condition that we actually find under such circumstances is, almost without exception, unqualifiedly bad. The suggestion has been made that these sewers may be kept safe and sweet by dispensing with the traps on house-drains and furnishing ventilation through the soil-pipe which extends from every connection. So far as the sewer is concerned this would doubtless mitigate the difficulty to a certain degree; but it is certainly of very questionable propriety to establish such a source of foulness as the decomposition of the filthy deposits of a sewer, and then to attempt to alleviate the difficulty by carrying the extremely offensive gases through our soil-pipes.

The ingenuity of the engineering profession has exhausted itself in attempting to get rid of the effect of sewer-gas when once it has been produced. We have never yet reached anything better than the terse recommendation of a London authority to the effect that "we must let the stink out into the middle of the streets."

The conditions by which the world was driven to this very unsatisfactory result were, under the old systems of flushing, substantially unavoidable, and what has been done in the way of city sewerage has been in the direct line of progressive improvement. It seems to me that the time has now come when a new departure should be taken, and when the sewer-gas difficulty should be met by prevention, rather than by attempts at cure. It is clear that under the present combined storm-water and foul sewage system, prevention is simply impossible. The production of foul gases is an unavoidable attendant upon every application of that system. All that is to be said on the other side is that, to withdraw the flushing effect of storm-water, and to leave household wastes to take care of themselves in small pipes, would result simply in an aggravation of the difficulty.

Fortunately, within the past few years the conditions of the problem have been radically changed. Formerly it was restricted by limitations in the matter of flushing. Small pipes could not safely be used for sewage proper to the exclusion of storm-water, because storm-water was needed to flush them out. This statement of the case is practically true, although not strictly true. Flushing by means of man-holes at the heads of the lines, into which water was to be poured, or where a tumbling-tank might be set, or flushing by means of various manual operations, all made the use of small pipes possible, but left it very undesirable, inasmuch as it is always undesirable to rely on manual operations or on the action of moving mechanism to keep sewers in condition. It is therefore quite proper

to say that the possibilities of the art of sewerage underwent a radical change on the invention of Rogers Field's annular siphon for emptying flush-tanks. This invention, which includes no moving parts and the action of which is positive, makes it possible for us to accumulate the flow of a stream yielding not more than five gallons per hour until it shall have filled a tank or reservoir of any desired size, with the certainty that the continued flow of the same stream after the tank shall have become full will cause the whole accumulation to be discharged into the head of the sewer with such rapidity and force as to give it an effective flushing. It is now entirely safe to use pipes of as small size as the quantity of the sewage will permit, and recourse to storm-water flushing is no longer necessary.

Therefore the question of what we are to do with storm-water presents itself in a new form. It seems to me very clear what we are not to do with it; that is, that, in my opinion, we certainly ought not to admit it to sewers which are in connection with the drains of houses. While the impurities of storm-water are by no means the *chief* factor in the production of sewer-gas, the admission of these impurities to large sewers is undoubtedly the most serious *cause* of its production. Fæcal matter carried completely through the sewers and discharged at its outlet within a few hours of its admission would do no especial harm; but fæcal matter added to the accumulations of mud and sand and sticks and rubbish strewn along the usual large brick sewer, in the absence of daylight and practically in the absence of ventilation, is so situated as to produce its very worst effect.

As I have already said, the question: What shall we do with storm-water? is the most pressing one in sewerage engineering at this time. Our practice has been almost universally to deliver it into deep sewers. This, I venture to say, is generally a mistake, and is almost always quite unnecessary. Proper provision being made for the drainage of the sub-soil, our only care with regard to the rainfall is to provide means by which it shall escape without material inconvenience to traffic; that in its escape it shall wash the street gutters, and that the greater storms shall not harm public and private property. There is nothing in the nature of rain-water which makes its temporary presence on the surface of the ground injurious to health. There is no reason why it may not be discharged over the surface of the streets and along the gutters, provided its volume is not so great as to interrupt or seriously to interfere with traffic. Therefore, as the roadside gutters are in full view, and may easily

be kept clean and in repair, there is no reason why the water which falls from the heavens may not flow through them, for at least so far as they are able to keep it within bounds. Sooner or later, in the larger cities, the water of copious rains will get beyond its bounds, and the flow of the gutters will spread out over the street or will rise on to the sidewalk. After the discharge of a certain number of gutters has accumulated, there may be danger, during violent storms, of injury to the pavement, of the filling of cellars, or of serious interruption to travel. Then, but not until then, it will become necessary to carry the flow below the surface of the street and lead it to a safe point of outlet.

Now there is a great difference between carrying storm-water underneath the surface of the ground and only at points where there is danger of serious flooding, and the present practice of carrying the whole rainfall from the hill-tops as well as from the valleys, first into foul and costly catch-basins and then into deep and costly sewers. In my judgment, the latter course is, to use the mildest expression, unscientific and unpractical; while the other fulfils the best requirements of common sense. If the art of town drainage had never been practised, and if the proposition were made for the first time to Mr. Chesborough, or to Mr. Lane, or to Mr. Moore, or to Mr. Shedd, or to Mr. Philbrick — all skilful engineers — I am sure that it would never occur to one of them to get rid of it by channels from ten to twenty feet below the surface of the street and extending under all the streets of the city. It has been led there only by the conditions under which the work of sewerage has been developed. The occasion for its being taken there no longer exists, and an entire reformation in this part of the work is demanded.

It would be absurd for any one at this early day to prescribe any substitute for the old practice as being the best. All that it is safe now to say is that storm-water should be kept on the surface of the streets as long as possible, and that when its accumulations must necessarily be carried beneath the surface, they should be carried only to such depth as is requisite to get them out of the way and to prevent the filling of their channels with ice during slight flow in cold weather.

It will probably be a long time before we arrive at the perfection of this method of delivery. We shall have annoyances of various sorts, and we shall doubtless encounter some serious difficulties in the matter of the crossing of streets. Until some substitute is devised for depressed gutters we shall receive a certain amount of

unfavorable comment from those who enjoy a level and uninterrupted roadway. Let us remember, however, that all of these drawbacks relate solely to the personal convenience of the people, and that they involve no serious dangers. That we may not be appalled by the idea of creating such annoyance, let us consider for a moment the other side of the question. Leaving now entirely aside all consideration of sewer-gas, the cleansing of large sewers, etc., think for one moment of the effect of the rapid delivery through sewers of storm-water which, if flowing more slowly through the street gutters, would do no material harm; think of the gorging of the large sewers of Providence, and the back-flow of sewage-matter through the kitchen sinks and basement water-closets of some parts of that city; think of the vast trouble of a similar kind that has occurred in Brooklyn, where not only have the houses themselves been invaded by sewage matter during heavy storms, but where the man-hole covers have been lifted, and the torrent has poured over the surface of the streets and of the sidewalks; think of London, the theatre of the proudest achievements of the drainage engineer, a city whose intercepting sewers are a model for the world, and all of whose ills were supposed to have been cured by Sir Joseph Bazalgette's achievements — but where, alas for the hopes of the engineer! he has been, if not hoist by his own petard, drowned in his own sewage.

Many of the lower parishes are crying aloud for relief from the stinking floods with which the new sewerage system is deluging their poor inhabitants. The storm-water has been got rid of with a vengeance. It has been robbed from the surface of the streets where it would have done good sanitary service in flushing the gutters, and has been delivered into sewers of great velocity to accumulate at the lower levels far beyond the capacity of the pumps to remove it, and has become the curse of wide, low-lying areas, where but for the sewers it would at least have arrived so gradually as to have done infinitely less harm.

In closing, permit me to formulate my opinion on the subject by saying that the present manner of disposing of storm-water in sewered towns by removing it from the surface where it is needed, to the sewer where it creates a nuisance, is a "relic of barbarism"; and — I beg that my respected friends of the engineering profession will pardon me — that its continuance indicates an over-riding of reason by tradition.