With regard to the flushing of sewers, it ought to be borne in mind, that the heavier matters held in suspension in the sewage, or driven along the sewers by the force of its current, never moves with the same velocity as the water, and consequently, with intermitting currents as in house drains, it is often left dry and sometimes becomes indurated, so that it cannot be moved by the succeeding flow of water; hence the necessity of a continuous current of water in all pipe sewers, to prevent the accumulation of matter within them. The sizes of all house drains and pipe sewers should be such, that they should never be more than four-fifths filled with water, or sewage, so as to allow of a free circulation of air through them, at all times, as the air not only facilitates the flowing of the water and promotes ventilation, but it also prevents the accumulation of highly-concentrated gases and their rising through the drains into the houses.

The paper is illustrated by a plan of the sewers of Richmond.

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Mr. Donaldson said, that at present, the drainage was conducted into the Thames, the main and outfall sewers not being yet completed, but it was intended to connect them, ultimately, with the Kennington sewer. The largest pipes he had employed, were 20 inches in diameter, but pipes of that size were rarely made so perfect as those of smaller dimensions, and there was great difficulty in well securing the joints. Where a larger diameter than 18 inches was required, he should prefer, on the score of safety, to construct a brick culvert, of which the cost would be about the same: the Contractors, indeed, finding at the time, some difficulty in obtaining the 20-inch pipes, offered to construct instead, a 30-inch sewer of bricks in cement. If pipe sewers could be made large enough to carry off the surface waters, and strong enough to bear the pressure of the superincumbent earth at great depths, he should prefer them to brick drains, provided the cost were the same; for the damage to drains arose not only from the wear and tear, but also from the rats, who could not attack the pipes, which should be carefully jointed with clay, not with cement. The use of pipes was, however, subject to this inconvenience, that whenever it became necessary to make a new junction, it was difficult to avoid breaking them in opening the ground, and thus a greater expense was often incurred, than would have resulted from the use of brick drains.

Mr. Hertslet said, the most striking feature of the plan was the employment of the separate system. There was no doubt, that sewers were originally intended to carry off the land and storm waters only, and up to the commencement of the present century, no one was permitted to use them for house drainage; but on the introduction of water-closets, permission was given by the Commissioners to connect them with the sewers. The consequence was, that the silt from the streets, mixing with the house drainage, caused a deposit, which could not be got rid of, except by continual flushing, in itself a clumsy expedient. He was in favour of separating the house drainage from the surface drainage, and so allowing what was artificially introduced, to be separately carried away; and he was glad to see that plan had been commenced at Richmond. Having thus a constant quantity of water to deal with, (after it had washed out a given number of houses), a manure of ascertainable value would be produced, not interfered with by the varying storms.

Mr. Thorold observed, that in some cottages he had recently built, he had used separate drains for the storm waters and for the sewerage. He was of opinion, that it was preferable to carry off the surface water in open channels, than to allow it to mix with the house drainage.

Mr. Haywood said, that this was the most extensive scale on which the system of separating the sullage from the pluvial waters, had ever yet been tried, and it was directly contrary to the experience of the last two hundred years. He should hesitate before intrusting the drainage of fifteen hundred houses to a pipe of 21 inches diameter, for whatever precautions might be taken, a great amount of solid matter would get into the sewers, and he much doubted whether this system would, ultimately, be found to be the most economical. He was decidedly of opinion, that all main sewers should be constructed of sufficient magnitude to allow of their being entered for the purposes of examination and of labour, and they should, therefore, be at least 4 feet high and 2 feet 6 inches wide, even if the immediate wants of the neighbourhood did not require such large dimensions, for in a very few years, their real economy would be demonstrated. He had tried back drainage, and it had certainly, in some cases, answered, but in others, in spite of the continual supervision of a man expressly employed for that purpose, and notwithstanding an ample supply of water at the head of each sewer, and a good fall, stoppages had occurred at least once a-year.

He would observe, in conclusion, that the drainage of Richmond presented a fair opportunity for testing the value of the employment of the sewage-manure, instead of turning it into the Thames.

Mr. DONALDSON remarked, that it had been his original intention to collect the sewage for that purpose, but he was compelled to relinquish the idea, because if it had been carried into effect, the funds would have proved inadequate to the full completion of the works.

Mr. BAZALGETTE considered Richmond most favourably situated for pipe drainage. A system of brick sewers existed there, sufficient for carrying off the storm waters; the levels of the town were remarkably good, and as the pipes had been carefully selected, and well laid, there was every probability, that they would answer in that town better than in most others. But it should be remembered, that when breakages, or stoppages took place in pipe sewers, the expense of repairs, or removing the stoppages, was tantamount to the re-construction of that portion of the sewer, an operation which always interrupted the traffic along the roads, or streets; whereas larger brick sewers were not liable to breakage, they could, from time to time, be repaired, if necessary, from the inside, without inconvenience to the traffic, and no stoppages could take place in such sewers. Again; the average cost of removing a stoppage from a house drain connected with a pipe sewer, would be from £3 to £4, whereas if the drains were connected with a large brick sewer, one labourer could, by entering the main sewers, examine and relieve the outlets of a dozen house drains in a single day. The first cost of a sewer, therefore, was not the only thing to be considered, for the accidents and injury to trade, consequent upon the obstruction of the traffic, frequently caused a saving in the first cost, to prove, eventually, an unwise economy. He was not an advocate for the general adoption of combined drainage in large cities. There were many instances where it might be advantageously employed, such as in poor and suburban property, with open gardens before and behind the houses; but in business streets, and amidst crowded London houses, combined drainage was frequently attended with the most serious inconvenience, and became a source of litigation and a positive injury to the health of the inhabitants of houses so connected. He considered, that the universal advocacy of any general rules in drainage matters had been, and must continue to be, attended with evil results. The experienced Engineer would adapt the means to the requirements of each individual case, and a beneficial result could only be obtained, by the unprejudiced application of different systems of drainage, to the localities where experience had shown them to be advantageous, rather than by the blind and exclusive advocacy of one system for every variety of circumstances.

Mr. Hosking considered, that pipes were wholly unfit for main sewers, and he had hoped, that they would be no longer used. Substantial brick-built structures could alone, in his opinion, be safely depended on. He thought it essential, moreover, to any system, that the sewers should be ventilated in such manner, that the impure air generated in them, should be drawn up by shafts, and thrown off above the tops of the houses, so as to be dissipated with the smoke and other products of combustion, ejected from the chimney flues.

Mr. Hawksley said, that although pipes might be exceedingly valuable for house drainage, they were of comparatively little use in street drainage, except in those instances where the streets had a great declivity, and there was, consequently, no danger of the sewers being stopped up. In the course of his practice, he had found it desirable, when sewers were required at a greater depth than 10 feet, to construct them large enough to admit workmen, instead of limiting them to the small theoretical dimensions, just sufficient to carry off the calculated amount of water. This system obviated the necessity for opening the ground, which was always, and especially when the depth was great, a source of great inconvenience to the neighbourhood. He also thought, that pipe sewers exceeding 15 inches in diameter, were not so convenient as brick drains, nor indeed so economical in point of first cost; and the latter had the additional advantages of giving less trouble in effecting junctions, and of being available for the purpose of getting dry foundations. He had heard of the supposed excellence of these water-tight pipes, when required to be carried through sand-beds, but he was of opinion, that drains in that position, should, on the contrary, be made so as to allow water to filter into them. The ordinary brick drains, which could be constructed in a variety of forms and applied in any way which circumstances might require, were more convenient, and of more practical application than pipe drains, in the different cases to which he had alluded. Brick sewers possessed greater strength and durability, and when exposed to a great pressure of superincumbent earth, they were evidently better than pipe drains which, if broken, caused great expense and inconvenience.

Mention had been made of the utility of pipe drains as a protection against rats, and of the great facilities they offered for making the work tight; but if a brick drain was well built, no rat could get through it, and with regard to jointing, which it had been said, should be done in clay, unless the clay was kept constantly moist, the upper part would crack and the gases would be emitted.

He thought a better material than earthenware could be used for house drains; he had, in some cases, employed iron pipes, and, except in respect of first cost, he believed they would be found to be the most advantageous.

Back drainage was a subject of great importance, and in a few towns where there happened to be mews at the backs of the houses, it was very convenient to employ that system; but in all other cases, back drainage laboured under the disadvantage of rendering the convenience of one person a source of inconvenience to others, and it generally occasioned much dissatisfaction. In spite of constant streams of water through small pipe drains, it was not possible to keep them free from accumulations caused by grease, hair, and other extraneous matters.

He saw no advantage in separating the sewage from the storm waters, as there appeared to be little expectation of sewage matter, as a liquid, ever being made extensively applicable for agricultural purposes. He had paid great attention to the subject, and he had found, that in provincial towns, where the inhabitants averaged five persons per house, the sullage water from each house was sufficient, even in dry weather, to satisfy one acre of land; there was, therefore, little prospect in towns containing ten thousand inhabitants, of ever making the sewage water available. It was also necessary to take into consideration, the great number of pipes and extent of privileges, which the distribution of the sewage would demand, privileges which could not, by any possibility, be of a permanent nature, for no enactment could compel the farmer to use and pay for the water in perpetuity. There were also many difficulties of a purely agricultural nature: in a dry season, every one would want the water at almost the same moment, and it was impossible to construct works of sufficient magnitude to transmit it; whilst in wet weather, and when the crops were ripening, it would not be wanted at all. For these reasons, he believed, that sewage water never would be extensively used for agricultural purposes, in this country, and therefore, that it was unnecessary, in laying out any drainage system, to provide for such a contingency. The valuable matter it held in solution, or suspension, could only be rendered available for manure by extracting it in a solid form, and it was more than doubtful whether its fertilizing powers were sufficiently great, to induce its sale at a price sufficient to cover the cost of production and carriage.

Certain experiments had been recently made by the Board of Health, for the purpose, as it would appear, of undermining all existing science in reference to the transmission of water through sewers. Not only had he found great discrepancies between the results stated and those obtained from the best-known formulæ, but they were, actually, not in accordance with each other, when due regard was had to all the minute circumstances which every well-informed experimentalist would take into account. In one of these experiments made with a 3-inch pipe, they reported, that a very large delivery, much exceeding that which any of the received formulæ would give, had been ascertained to take place. For greater accuracy, he had repeated the experiment, with two cisterns of equal capacity, and the result was, that whereas the formula gave a result of 375 lbs. of water, passing through the 3-inch pipe in a minute, the actual discharge was 374 lbs., a difference of only $\frac{1}{3}$, or $\frac{1}{4}$ per cent., whilst the experiments of the Board of Health differed to the extent of, at least, 50 per cent. The formula he had used, was the following:—

$$V = \cdot 77 \sqrt{\frac{h\,d}{l + 2\frac{1}{4}\,d}}$$

V, being the velocity, in yards per second,—$l$, the length of the pipe, in yards,—$h$ and $d$, the head and diameter, both in inches. He laid little claim to this formula, although independently derived, as it did not greatly differ from those discovered by the best experimentalists, both in France and England. Its application to sewers of any description was of great importance, inasmuch as they must be made of sufficient capacity to carry off the storm water. This was, necessarily, an uncertain quantity, but it had been fixed in the blue-books at a preposterously small amount. In the great storm in London, in August 1846, $3\frac{3}{10}$ inches fell in two hours and twenty minutes, and at Nottingham, he had known 1·16 inch to fall in less than half-an-hour; yet the blue-books gave $\frac{1}{4}$, or $\frac{1}{2}$ an inch, as the quantity which would have to be conveyed away in twenty-four hours. Many mistakes had arisen, from sufficient attention not having been paid to the different circumstances, under which water was carried off by sewers. When water fell on slated roofs and flagged surfaces, it made its escape into the sewers almost immediately, and under these circumstances, the drains must be made large enough to convey not less than 2 inches of rain in an hour. But if the area over which the water fell, was considerable, it would be some time before it entered the head of the sewer, and still longer before the water would arrive at the bottom, the time varying, of course, with the extent of that area. The rules promulgated by the General Board of Health were perfectly fallacious, and if small pipe sewers were constructed on the principles laid down in the blue-books, the consequence would be, that on the occasion of any wide-spread storm, the water would not be able to escape with sufficient rapidity, and the whole of the lower parts of London would be flooded.

A mistake had also been made by the General Board of Health, with regard to the friction of water passing through pipes of different materials. It was a well-ascertained fact, that the amount of friction did not depend on the relative smoothness of the surfaces, but on other conditions essentially different; for in an iron pipe, rough from the sand, it was sensibly the same as in a drawn lead pipe; and in a well-laid brick sewer, provided there were no projecting bricks, which would have an obstructing effect, the friction was no greater than in a glazed pipe, and the discharge was, practically, the same in both.

Mr. Leslie said, there could be no doubt, that the experiments instituted by the Metropolitan Sewers Commission, had completely failed. With respect to back drainage, the great difficulties consisted in its interference with private property, in the refusal of the owners to allow the ground to be opened, and in the stoppage at a single junction, injuriously affecting all the drainage above that point. The Commission should only attend to drains carried through the public thoroughfares. He thought that it was not possible to use the sewage water, economically, for agricultural purposes, except under very peculiar circumstances.

Mr. Simpson, V.P., remarked, that he had laid down iron pipe drains, at intervals, during the last thirty years, and he had never found them to have sustained any serious injury from the sewage.

Mr. Lavers said, that although pipes might be well adapted for house drains, he entertained great doubts as to their suitability, or economy for sewers, even under the favourable conditions presented at Richmond; circumstances, might, indeed, allow of their being so used, but he would make brick sewers the rule, and pipes the exception.

With respect to the area of pipes, he was decidedly of opinion, that they had been used of far too small a size, for both sewers and drains. The constant, indeed daily occurrence, of stoppages, not unfrequently involving expenses equal to the original cost, was a serious matter for consideration. These stoppages were generally to be attributed to the insufficient capacity of the pipes, and he thought, that their diameter should never be less than 6 inches for house drains and 12 inches for sewers. No surface waters should be allowed to enter, as road drift, straw, and other substances carried with them, would inevitably choke up the pipes; but if separate sewers were to be provided for the surface waters, there could be no economy in using the pipe system. He strongly objected to sewers being constructed for one purpose only, as they never could be made generally available, and in his opinion, the area of a sewer should be sufficiently large to carry off, if required, the soil, the surface and the storm waters. Neglect of this precaution had, in a case which came under his notice, led to connecting an old brick barrel drain of 5 inches in diameter, with a pipe sewer of only 9 inches diameter.

The question of gradient appeared, in many cases, to have been thought unworthy of consideration; but the Author of the Paper had evidently paid great attention to this point, and if such gradients as those of which he had been able to avail himself, could be always secured, pipe sewers might be used with success.

Mr. Haywood would mention one fact strongly corroborative of the advantages attending capacious brick sewers. Although in the city of London, twelve thousand houses drained into the sewers, yet there were not, annually, twenty stoppages which required the breaking up of the public streets. The causes of obstruction were, when they occurred beneath public ways, generally, easily detected by passing up the main sewers, and were remedied at an average expense of not more than a few shillings each. For house drains he preferred pipes up to 12 inches diameter, as the work could not be made smooth inside, when the brick drains were small. Within the last three years, eighteen hundred pipe drains had been laid down within the city of London.

Mr. R. Stephenson, M.P., V.P., said, that being one of the Commissioners of Sewers, he felt the greater interest in this important subject, which involved so many questions of detail. He hoped, that those Engineers to whom the sewerage of large towns was intrusted, would carefully record the practical results of their experience, and the various difficulties which might arise. He did not attach much importance to the different forms, whether elliptical, or circular, which might be given to sewers, but the relative advantages of pipe and brick drains and the proper sizes to be employed, were questions deserving the most mature consideration.

Mr. Donaldson said, he was directed to prepare a scheme for the drainage of Richmond by means of tubular pipe sewers: the size and sort of sewers, therefore, were not altogether a matter of choice. Seeing that several of the sewers must be of a considerable length, it was his duty to provide against obstructions, and he had, consequently, allowed the road surface water to pass through the existing road drains into the river, in order to avoid the risk of the sewers being choked up by the road drift. With larger main sewers which could be cleaned out, the admission of the surface water would have been less objectionable. As to the question of separate, or united drainage, he would not insist on the entire exclusion of all surface, or rain water, but he regarded it as unquestionably wrong, to combine the common brooks, or water-courses with the sewers. For house drains and for short branch sewers, he preferred pipes to brick drains, but all main sewers in principal streets should be of such a size, as to allow of the passage of workmen for the purposes of examination and repair, without difficulty, or danger to life.

It had been argued with some degree of plausibility, that a general system of sewers was somewhat analogous to the pipes for water supply, but though there might be an apparent resemblance between the systems, the one was quite the reverse of the other. The water-supply pipes having one well-guarded inlet, admitting pure water only, with, perhaps, ten thousand outlets, the chances of obstruction might be taken as 1 to 10,000; whilst the sewers had ten thousand inlets, admitting not only impure water holding matter in solution and in suspension, but other substances also, which must be pushed, or rolled through the pipes by the mechanical force of the current, and which, if once stopped, could not again be put in motion; the chances of obstruction in the sewers were, therefore, 10,000 to 1. With a good fall and a constant current of water, pipe sewers might be kept clear by frequent flushings; but unless the current were constant, so as to prevent the deposit from becoming indurated, occasional flushings would be of no use. Wherever such sewers were of any great length, small catch-pits and side entrances should be constructed, at suitable intervals, to collect and remove any solid substances that might get into them, by which means, the chances of obstruction would be materially diminished.

Mr. Rendel,—President,—said, that the discussion had shown the great difference between mere theoretical speculations, and actual practical experience. In all questions of sewerage, Engineers must deal with towns as they found them, and not according to pre-conceived opinions, which did not always find their application.