Mr. Parsons.

with the subsoil water; if, therefore, the water was taken from the subsoil, there was always a danger of its being contaminated with sewage. With regard to the proper quantity of flush which Mr. Hawksley and Professor Robinson had alluded to, he thought the amount necessary depended entirely upon the construction of the sewers. If badly constructed, the amount of flush necessary to keep them clean was large; if, on the other hand, they were properly constructed with adequate gradients, then a small quantity only was necessary. In Buenos Ayres he believed a 2-gallon flush was amply sufficient to keep the sewer in proper working order.

Correspondence.

Mr. Bruce.

Mr. A. Fairlie Bruce had found, with regard to the subterranean flow of water towards the rivers of the Argentine Republic, that in the province of Santa Fé the same conditions prevailed, there being a general rise in the level at which water stood in the wells as they receded from the Paraná. A considerable supply of clear water had been obtained in several cases by sinking wells in the foreshore at the foot of the Barranca. Its greater hardness was, no doubt, due to the fact that the tosca, through which it had passed, contained a considerable quantity of lime nodules, from which lime was made in some places. As the water which leaked into the tunnel from the Buenos Ayres intake was of perfectly good quality there did not appear to have been any reason for excluding it, the leaks would tend to take up in time if they had not already done so. At Rosario,[1] where, in addition to repairing the existing works, he had carried out an extension of the waterworks, for the Rosario Waterworks Company, the general conditions were similar to those in Buenos Ayres, save that deep water occurred close to the foot of the Barranca; and that the quantity of solid matter in suspension in the water of the Paraná was perhaps somewhat less than in that of the River Plate. There were four settling-ponds, lined with concrete and with no cross walls. The water was pumped into them, and allowed to settle for about forty-eight hours, when it was drawn off by decanting pipes to about 2 feet from the bottom. They required to be washed out about once a month in summer, when the river was high and heavily charged with silt, and about every three months in winter. They worked perfectly satisfactorily, the cost of that which he

[1] Minutes of Proceedings Inst. C.E., vol. cviii. p. 334.

Mr. Bruce. had constructed being only £1 0*s.* 10*d.* per 1,000 gallons of storage. In Rosario the rate of filtration was about 75 gallons per square foot per day, or 6 inches per hour, nearly identical with that adopted at Buenos Ayres. The filtering materials were of about the same thicknesses, but instead of the drains being embedded in the lower stratum, the whole bottom of the filters was laid with bricks set on edge, covered with others placed flat, forming a continuous drain communicating with a central brick culvert, which discharged into regulating wells, whence it flowed to the clear-water reservoir. The head required, when the filters were clean, was between 4 inches and 6 inches; when it exceeded 2 feet 6 inches the filter was changed, as any greater head was found liable to cause the bursting of holes through the sand. About 1 inch of the upper surface was scraped off and removed to the sand-washer. When the total thickness of sand was reduced to 12 inches by successive scraping, the original thickness was restored. Sand which had been used and washed was found to be more efficient than new sand. The cost of cleaning a filter, including sand-washing, was about $\frac{1}{4}$ cent gold per square metre, or 1 cent per 1,000 gallons filtered.

Trouble had been experienced, as described by the Author, from the growth of green slime on the surface of the sand in summer, necessitating changing the filters about every two or three weeks, but as the interest on the cost of roofing the filter beds, as was done at Buenos Ayres, would have exceeded the saving in working expenses by their needing to be cleaned less frequently, it had not been deemed advisable to carry it out. The filters were lined with concrete, made of five parts of broken bricks, three of sand, and one of cement, and cost, including filtering materials, 19*s.* 10*d.* per square yard. There being plenty of good sand and gravel on the islands in the Paraná, it was much more easily obtained than at Buenos Ayres; it was all delivered at the company's jetty, and discharged from the boats by an iron bucket hauled up a wire rope by a steam-winch, at a cost of \$0·64 per cubic metre, equal to 1*s.* 3*d.* per cubic yard. The cost of brickwork and concrete at Rosario, owing, no doubt, to their having been carried out by administration instead of by contract, and also to natural advantages, were, as shown in the Table on the following page, much less than at Buenos Ayres. At Rosario the period of maximum consumption in summer was from 4 P.M. to 6 P.M., and amounted to about two-and-a-half times the mean rate, due to the use of hoses in cooling the Patios.

The arrangement of the distribution pipes in Buenos Ayres seemed unnecessarily complicated, and must tend unduly to reduce the pressure. In Rosario the town was divided into sections three or four squares wide, in each of which was an 8-inch or 10-inch pipe starting from the main, running east and west, and intended to run into a duplicate main round the west and south sides of the town not yet laid. At every square 3-inch pipes were laid, running north and south, communicating at each end with the sub-mains, and having a 3-inch branch, one square long, in each intermediate square, terminating in a hydrant for scouring purposes. All branches were controlled by valves. Air-cocks had not been used in Rosario as the house-services were considered to make sufficient provision for this purpose, and no disadvantage had resulted. Between 8 per cent. and 10 per cent. of the water in Rosario was sold by metre; for the remainder, a conventional charge, or a rate of $3\frac{3}{4}$ per cent. on the rental, was collected. Mr. Bruce.

COST OF BRICKWORK PER CUBIC METRE.

	$ gold
350 bricks at $4·4 per 1,000	1·54
$\frac{1}{4}$ cubic metre of sand at $0·64 per cubic metre	0·16
Labour	1·60
1 barrel of cement	4·25
	7·55
equal to £1 2*s.* 6*d.* per cubic yard.	

COST OF CONCRETE PER CUBIC METRE.

	$ gold
Broken bricks	1·12
Sand	0·24
Labour	0·80
$1\frac{1}{4}$ barrel of cement at $4·25	5·31
	7·47
equal to £1 2*s.* 3*d.* per cubic yard.	

For drainage, Rosario was divided into three districts; the principal one was 19 squares in length, and 10 squares in breadth; it was drained by a main sewer, running along Calle Mendoza in the centre of the district of the new oval section, 6 feet 11 inches by 4 feet $7\frac{1}{2}$ inches, lined with 18 inches of brickwork in cement rendered with cement mortar; the gradient was 1 in 500. It discharged flood-water directly into the river down a flight of altar steps; the dry-weather flow was intercepted and carried out beyond extreme low water in a 24-inch pipe. Subsidiary sewers, iron pipes with turned and bored joints, draining five squares each, connected with the main sewer at the manhole at the street intersections; they began at 15 inches

Mr. Bruce. diameter and diminished to 9 inches diameter. Branch sewers, of stoneware pipes 9 inches in diameter, joined them at ventilating manholes at each street crossing; they each drained one square, and started from a flushing-tank at a depth of $1\frac{1}{2}$ metre. The minimum gradient was 1 in 200. The second and third sections were only fifteen squares and nine squares long respectively, and 4 squares wide, and were drained by egg-shaped sewers 5 feet 6 inches by 3 feet 4 inches. To prevent its flowing into the port, the storm-water from the third section was conveyed to the outfall of the second in a double line of 33-inch pipes. The dry-weather flow from both sections was intercepted and conveyed in a 20-inch pipe to the Mendoza outfall. The subsidiary systems were the same as that he had described. The house-connections were all 6 inches in diameter, laid at between 1 in 20 and 1 in 40 to the house line. No ventilating pipes were placed up the fronts of the houses, as at Buenos Ayres, as it was considered that the manholes afforded enough ventilation. When streets were not fully built up, additional connections were left every 10 metres, closed with stoneware stoppers. Where the depth of the sewer exceeded 2 metres, vertical pipes were laid up to $1\frac{1}{2}$ metre below the surface to reduce the depth of trench required for the branches. Gullies, similar to those at Buenos Ayres, but with stoneware traps, were placed at the street intersections, and as at Buenos Ayres have entirely prevented the streets being flooded as they used to be formerly in wet weather.

The main sewers were constructed at depths varying between 60 feet and 30 feet, and were all tunnelled through the tosca, which, in Rosario, rose to within $6\frac{1}{2}$ feet of the surface; no water whatever had been met with, and many of the headings stood unlined for two years, the marks of the pick being as sharp at the end as when first made. The only trouble experienced in their excavation being due to the difficulty of securing efficient ventilation, the ground, especially in the older part of the town, being saturated with fæcal matter, gave off quantities of sewer-gas, causing many cases of blood-poisoning among the workmen; without ventilating-fans candles would not burn in many cases 10 yards from the shafts. Most of the subsidiary sewers had also been laid in headings, shafts for house-connections being sunk every 10 metres or 12 metres.

In Rosario the natural difficulties encountered were much less than in Buenos Ayres, the only troublesome portion of the work being the laying of the intercepting and storm-water pipes which run along the foot of the Barranca, chiefly in reclaimed ground, Mr. Bruce. where the trenches were liable to be flooded by the river. The breakage in transit amounted to about 1 per cent. in iron, and to about 4 per cent. in stoneware pipes.

Mr. Godfrey. Mr. ROBERT GODFREY considered the Paper of great value to municipal engineers, as in it was shown a system of sewer-ventilation which more nearly approached perfection than any which had hitherto been attempted. He had for some years past contended that every house contributing to the contents of a sewer should also contribute to its ventilation. The model by-laws of the Local Government Board, which were largely adopted in England, did not accept that principle; but, by the regulation insisting on the "intercepting siphon," compelled the sewers to ventilate themselves through the manhole and ventilator covers at the street-level. This was contrary to sound sanitation, and was without doubt the source of more complaint than any other with which a municipal engineer had to deal. The system of house-drainage adopted at Buenos Ayres was most complete, and one which might well be imitated. The inspection-chamber, inserted at all junctions, was a decided advance; and the adoption of the 4-inch pipe for internal drainage was a distinct acknowledgment of the unsoundness of the practice of making drains too large for the flow, as was too general in almost every municipality in England. The minimum gradient of 1 in 40 secured a discharge many times in excess of the quantity of water used per house; and the existence of the intercepting siphon was no longer a source of trouble, as the discharge is into a 6-inch pipe connected to the main sewer. The insertion of a ventilating shaft on the 6-inch pipe on the sewer, at the side of the siphon, completely cut off the sewer from the private drain, and the manhole and ventilator covers were delegated to their proper uses, that of acting as inlets for fresh air instead of outlets for foul air. The dissemination of sewer gas through these pipes 6 feet above the roofs of the houses was undoubtedly the only rational means of reducing the pressure on the aerial contents of the sewer when the liquid contents were suddenly increased by an influx of rain-water. If it was made compulsory in England to adopt the same system of ventilation, there would be an end to the present multitudinous complaints and to the ingenious devices for dealing with sewer air, which had been tried in many cases and had nearly always proved ineffectual.

The nearest approach to this natural ventilation adopted in England was at Torquay, where a pipe 1 inch in diameter was carried from the sewer side of the siphon up to the roof of each

Mr. Godfrey. house. This was done by a voluntary arrangement, but could not be enforced. The 4-inch pipe adopted at Buenos Ayres was much superior. The valuable figures given in Table 5 proved conclusively that there was no danger to public health from the adoption of this method of sewer ventilation. The modification of the Local Government Board by-law, insisting on the intercepting siphon (without ventilation), would be accompanied by a notable improvement in the public health of the great centres of population throughout the country.

Mr. Nyströmer. Mr. C. A. B. Nyströmer desired to touch upon a few points as to the development of the works beyond the stage in which they had been described by the Author. In consequence of the rapid growth of Buenos Ayres, and of the great increase which had taken place in the water consumption, the necessity had presented itself, already some years ago, of constructing the extensions which Mr. Bateman had provided for in his scheme. The average daily consumption, which at that time did not reach $\frac{3}{4}$ million gallons, had increased to about 8 millions in 1891, when the Company handed the works back to the Government; and it had since gradually increased to 18,400,000 gallons in the year 1895, having fluctuated between the limits of 25 millions and 14 millions. Accordingly, both engine-houses at the Recoleta pumping-station had been duplicated; the main engines being finished and brought into service in 1893, and the erection of the new intake engines was approaching completion. In order to supply the want of the latter to some extent, it became indispensable to erect temporarily a 24-inch centrifugal pump, which had been in use since 1892 and still did service, raising the water from the intake tunnel to the settling pools. The duplication of the sewage pumping station at Puente Chico was also about to be begun. The existing filters having become altogether insufficient for purifying the great quantities of water consumed, it had been resolved, early in 1893, to construct additional filters and settling reservoirs, on the basis of a total supply of about 20 million gallons. The site chosen for the new settling reservoirs was between the river and the intake station, the pumps of which would now deliver, under constant head, into a chamber constructed alongside the building; from which the water passed into the old or new reservoirs. These latter covered an area of about 24,500 square yards, and were divided into three large compartments and a lateral channel, by means of which any compartment could be isolated for cleansing purposes without affecting the working of the others. Their total capacity was about 14 million gallons; and the water, guided by the division walls constructed for the purpose, was made to travel a distance of about 3,600 feet, between the inlet and outlet wells, when all the compartments were in use. Ten weirs, the sills of which were placed 6 feet 6 inches below the top water-line, had been provided for regulating the flow of the water and for closing off any portion of the reservoirs. Each weir was supplied with three cast-iron sluices, so made that the water might be drawn from the uppermost or lower layers, according to the season; and all had movable strainers for intercepting floating matter. The cleansing arrangements were similar to those described for the old settling-pools. On account of the greater depth of the weirs, however, the quantity of water which had to run to waste was comparatively small, provision having been made for conveying to the filters most of the water to be drawn off for cleaning any of the compartments. From the outlet chamber, cast-iron mains were laid to the old as well as to the new filters. The pools had to be made chiefly in embankment, and had slopes of 1 to $1\frac{1}{4}$, with double brick lining resting on clay puddle. In order to save space, the ordinary division walls were executed in brickwork and the thicker walls in concrete with brick facings. Mr. Nyströmer.

The new filters required to be considerably larger than those first constructed, and it was desirable to reduce their cost as far as possible. The system of construction previously adopted had therefore to be somewhat varied, and the pure-water reservoirs below the filters omitted. The new filters consisted of twelve independent compartments, arranged in four groups, and had a total sand area of about 32,150 square yards. The filtering materials were composed of 3 feet of fine sand, supported by successive layers of coarse sand, small and large broken granite, and dry-brick channels, having a total average depth of 2 feet 9 inches. The water was intended to be maintained of a constant depth of $4\frac{1}{2}$ feet over the sand. The side and division walls, having a batter of 1 in 6, were constructed in brickwork and concrete, the former being backed with clay puddle; the floors were also laid on a puddle foundation. The filter-beds were designed to be covered over by light groined arches, resting on square brick piers, and on this covering it was intended to place a layer of earth and turfing. This protection was considered advisable, for keeping the water cool and preventing the rapid germination which took place under the direct rays of the sun, as well as on account of the filters being situated near one of the most heavily worked railways, and

Mr. Nyströmer. exposed to atmospheric contamination. For reasons of economy, however, the covering had not yet been constructed. Each of the twelve compartments was provided with inlet, outlet and cleansing wells; and, after cleaning, could be filled from below with filtered water. From the outlet wells, designed to contain an apparatus for varying the velocity of filtration or maintaining it constant, the water passed through cast-iron pipes into the existing pure-water reservoirs, the capacity of which was with proper care sufficient to receive the additional quantity of water produced by the new filters. Each group of these was provided with three sand-washers and paved platforms for depositing and cleaning the sand. Together with the old filters, the total sand area at present available was about 50,400 square yards. But as the consumption was constantly increasing, in a great measure owing to preventible waste, further filter area would soon be required, if the water was to be satisfactorily purified. The complete clarification of the River Plate water was attended with considerable difficulty, on account of the very fine argillaceous matters it carried in suspension, the amount of which was increased not only by the rains falling on the extensive delta of the Paraná, but also by tides and winds which stirred up the mud in the relatively shallow river. In 1877, Mr. George Higgin made experiments for ascertaining the best means of effecting its filtration, and arrived at some valuable conclusions.[1] He considered that sand alone would not remove the turbid appearance from the water, and that a uniform speed of filtration could not be maintained, although the head were kept constant. By interposing a layer of pounded cinders under the top layer of sand he had, however, been able to render the water perfectly clear and bright, even with high velocity of filtration. Mr. Nyströmer had continued those researches on a larger scale, in 1885 and more recently; many of the experiments having been continued uninterruptedly for months. Several of the substances tried, such as pounded scoria, spongy iron, animal and vegetable charcoals, etc., were found capable of removing completely the opaline colour of the water, and more or less perfectly also the yellowish tinge it retained after having been rendered transparent. The analyses proved that the purification was equally satisfactory in other respects. Unfortunately, the application of these purifying agents on a large scale, as well as the cleansing of the filter, proved very costly. It was likewise found easy to effect an entirely satisfactory

[1] Minutes of Proceedings Inst. C.E., vol. lvii. p. 272.

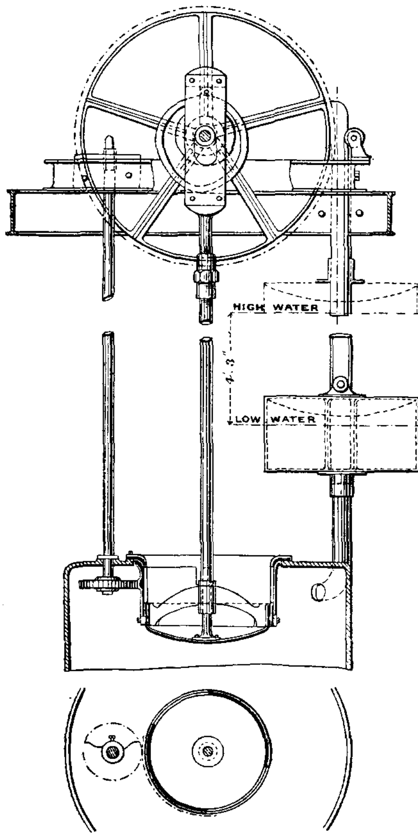
purification of the river water by the use of precipitants, such as ferric sulphate and perchloride, sulphate of alumina, alum and others, as well as by metallic iron. The principal objections to the employment of these substances were their cost, the long time required for the impurities to settle unless the amount of the precipitant was considerably increased, and the speedy obstruction of the filter if used to shorten the process. One of the more important results obtained in the course of those experiments had been that the ordinary filtering sand was quite capable of rendering the River Plate water transparent if the filter was carefully worked. To this end it was requisite that the speed of filtration should in the beginning be almost imperceptible, and be very slowly and gradually increased, avoiding all brusque variations; further that the filter should be charged from below with pure water, in order to avoid subsequent disturbances from rising air bubbles. With similar precautions, the slimy sedimentation of mineral and organic matter which took place on the surface of the sand, rendered the filtration more efficacious, by partially obstructing the interstices of the sand, as it was then thought. Later investigations, by Mr. Piefke [1] and others, had furnished different and probably more correct conclusions as to the action and importance of that layer of impurities for obtaining satisfactory results and for preserving the filtering materials clean. For purifying the River Plate water, the rate of filtration must, however, be smaller than that generally admitted; the descent of the water on the sand should not exceed 3 inches or 4 inches per hour, when the filter was working at its maximum rate. Mr. Nyströmer.

In order to make it possible to maintain a constant rate, the automatic module mentioned by the Author was suggested. But as this apparatus was not well adapted for gradually increasing the speed, another form of regulator had been designed for the new filters. The apparatus, *Figs. 56*, consisted essentially of a float actuating a cam or excentric of such shape that, whatever be the height of water in the pure-water well, it adjusted automatically the size of the outlet openings to maintain a constant discharge. To this end it was made to raise or lower a ring, moving inside the tube which contained those orifices and partially covering these. By means of an outer ring, moving horizontally and capable of adjustment in this direction, it was possible to vary

[1] "Die Principien der Reinwasser Gewinnung vermittelst Filtration," Berlin, 1887; see also Minutes of Proceedings Inst. C.E., vol. cxix. p. 236.

Mr. Nyströmer. simultaneously the length of the orifices and thereby the rate of filtration. Provision was made for keeping the level of water over the sand constant. The new filters and settling reservoirs had been completed since he had retired from the direction of the works, Mr. Charles Anthony, jun., acting as Resident Engineer during their construction.

Figs. 56.



Scale, ¼ inch = 1 foot.

APPARATUS FOR REGULATING THE SPEED OF FILTRATION.

The town of Belgrano, situated nearly opposite the Intake tower, Fig. 1, Plate 1, and now forming one of the more important suburbs of Buenos Ayres, had for a number of years been supplied with water from the river. The works, when taken over by the Government early in 1892, were found altogether insufficient for the demand and the quality of the water open to serious apprehensions on account of the close proximity of the intake to the shore and to a small stream which was exposed to frequent contamination. In view of this and of the recurrence of zymotic diseases in the district, he had received instructions to study and report on the works which should be executed. The intake, filters and engines being in very bad condition and the whole establishment subject to inundations, it would have been expensive and injudicious to extend these installations. To continue the town mains to Belgrano also presented some inconveniences. It was therefore proposed to obtain the supply by constructing a semi-artesian well, and the corresponding project had after some delay been carried out. The ordinary subsoil waters were found at different depths below the surface, according to the height of the ground; but, in the immediate vicinity of populous districts, they could not be accepted as potable, in consequence of the practice of sinking cesspools and drain-wells into this stratum. Lower down, successive water-bearing strata were met with, containing generally brackish water; but at a depth of about 70 feet or 90 feet below low water in the river, a powerful layer of fine sand was found, the thickness of which was stated to be over 75 feet in the neighbourhood of Buenos Ayres. Repeated analyses had proved that the water it contained was of excellent quality, crystalline and very pure, although somewhat harder than the river water. If a bore-hole was sunk into this stratum, the water almost invariably rose above the low-water level in the river, and hence these wells were termed semi-artesian. Wells had been sunk to 250 feet and even 900 feet in depth, and three more water-bearing strata had been found, but of less magnitude and furnishing generally brackish water. A site had been obtained for the pumping station on the eastern margin of the town, and a bore-hole 15 inches in diameter had been sunk to a depth of about 130 feet below the surface, being lined with wrought-iron drawn tubing. The upper portion of the well, for a depth of about 63 feet, had a diameter of 16 feet 5 inches and was constructed in brick-work; it served as a pump well. For the complete installation, two vertical compound tandem engines and two treble-barrel pumps were proposed, one of the sets to be erected at first, and two Lancashire boilers. The yield of the well had been 880,000 gallons per day and would probably increase. The pumps delivered into a service tank, erected near the engine-house, having 44,000 gallons capacity and 58 feet in height above the ground. The tank had a spherical bottom and rested on an annular girder supported by the walls of the water-tower, which had been constructed in brickwork, the bedstones being of granite. The lower floors of the tower were intended to be occupied by offices and workshops. The engines, pumps, etc., had been made by Messrs. Hayward, Tyler & Co., and the general ironwork by the Horsley Company. Most of the mains and distributing pipes were too small or inserviceable, and had to be renewed. Their total length was about 28,250 yards. Mr. Nyströmer.

Mr. Malcolm Paterson had made extensive experiments with soil drains in every position, such as must be found in all systems of drainage, and was satisfied that 2-gallon flushes—in practice often only $1\frac{1}{2}$ gallon—would not suffice to maintain a perfect scour in drains laid at 1 in 40, or even with greater fall, where the length was great, especially when subjected to the check of Mr. Paterson.

Mr. Paterson. a disconnecting trap. Such traps he regarded as to a large extent sewer-gas producers, more necessary where a drain lay below the house than where it did not. The liability to disturbance, settlement, bad construction, derangement of flush and obstruction, rendered more flushing power imperative. As to large gullies, it was found that the contraction of a gully, as of all water-ways, induced a better scour, not its expansion, as claimed in the Paper. The ventilation of the branch below the disconnecting trap was right, but was mostly neglected in ordinary provincial practice, and this increased the danger from such traps. Nothing appeared more satisfactory than the freest possible discharge to the outfall, with the soil-pipes outside and used as sewer ventilators. The air in such sewers was sweeter than in those in which the locking-off system as now used was in vogue. In flat districts, and upon long house-drains, a large number of disconnecting traps had been taken out. With such traps the isolation of disease was obviously impossible, since at every flush fæcal gases were pumped out at the surface. The undercutting of the 18-inch trench was of special interest, the only difficulty being how to secure proper ramming at the haunches of the sewer. The adoption of a circular arc cofferdam where the depth was great and struts difficult, was instructive. He asked if these radiating piles were grooved; and what was the fall of the permanent siphon across the Riachuelo. He supposed one reason for its division into three tubes was to strengthen it as a girder. The cement addition to the earthenware pipe spigots and sockets seemed to suggest the Archer form of earthenware pipe-joint which he had used largely. It was a double-socketed joint into which, the edges being closed with clay puddle, neat cement grout was run flush. He had removed and replaced as many as seven of these thus jointed in one length without a flaw, the whole being as rigid as a girder. The testing of the drains in area "B" was severe, but not more so than the normal pressure in a wet subsoil warranted, as even with the best workmanship some leakage could not be avoided in large brick or concrete sewers under such circumstances.

Dr. Preller. Dr. Du Riche Preller observed that the Paper contained no information with reference to periodical chemical tests, or bacteriological tests, of the River Plate water either before or after filtration. The results of such tests would be of interest. The chemical analysis given on p. 6 appeared to be an average one made in London probably many years ago. Although the result was fairly satisfactory, since it showed very little ammonia, no nitrous acid, and not more than 10 parts per 100,000 of solid impurity, it could not indicate the composition of the water under Dr. Preller. varying conditions of so turbid a river as the Plate. In a Paper[1] on the Water Supply, Power, and Electric Works of Zurich, he had shown that chemical analysis *per se*, though valuable as a general criterion, afforded no conclusive test, unless it be supplemented by bacteriological control. At Zurich, where the potable water was derived from the lake and filtered through sand- and gravel-beds with a maximum head of water of only 6 feet, the conditions were particularly favourable, since the lake itself acted as a purifying reservoir; but even here it had happened, when the natural process of oxidation was impeded by the partial or entire freezing over of the lake, that the normal number of bacteria in the unfiltered water of only about 200 per cubic centimetre had increased to more than 2,000 for the same unit. The action of the filters was so efficient that in both cases the filtered water contained not more than twenty bacteria per cubic centimetre, whilst the chemical analysis showed no appreciable difference in either case, either before or after filtration. A tropical river like the Plate must necessarily carry a large amount of decomposing matter, and the bacteria voraciously feeding on this matter probably numbered millions per cubic centimetre, more especially after heavy rains. The reduction of the number of cases of typhoid fever at Buenos Ayres consequent upon the supply of filtered water pointed to the probability of the greater part of injurious bacteria being retained by the efficient action of the filter-beds, while the bacteria passing through the beds and hence contained in the filtered water were, in the main, harmless.

Mr. LEWIS T. WRIGHT observed that it was stated in the Paper Mr. Wright. that the installation of the house-drainage system had already produced an amelioration in the health of Buenos Ayres. It would be very interesting, if it were possible, to study the case of such a city, which had for three centuries been dependent for the disposal of its fæcal matters upon the ready penetrability of the subsoil of its dwellings, and then to trace the effects on the public health of the installation of an elaborate system of drainage. The remark on page 5 that the city was becoming more and more subject to epidemics of cholera and yellow fever was likely to give rise to a false impression, at least as regards the latter disease, for the plague that had followed the terrible Paraguayan War, and commonly thought to have been yellow fever, was previously unknown in Buenos Ayres and had not since visited the city. It

[1] Minutes of Proceedings Inst. C.E., vol. cxi. p. 257.

Mr. Wright. might be supposed, simply regarding the statistics given in the Paper, that the statement put forward was well founded, since, concurrently with the commencement of the use of the sewers for house drainage, there has been a considerable reduction in the mortality. The death rates given in the Paper were not, however, in accordance with the official statistics. Before the recent amelioration in the health of Buenos Ayres could be regarded as due to the inauguration of the house-drainage system described in the Paper, it was necessary to study carefully the mortality figures, since deaths occurred in Buenos Ayres from other causes than those that might be attributed to bad drainage. For instance, in the year 1890 the deaths from the use of fire-arms were about 200 above the average. The most remarkable fall in the death rate occurred in the year 1891, and was almost entirely accounted for by a reduction in the deaths from "epidemic diseases," which were mainly typhoid, diphtheria and small-pox. Small-pox was independent of drainage, and any improvement under that head must be excluded from benefits that might have arisen from improved drainage.

In the following Table would be found the number of deaths from the three principal diseases, together with other statistics, all of which were taken from the "Anuario Estadístico de la Ciudad de Buenos Ayres."

Year.	Population.	Death Rate.	Number of Deaths.				Houses connected to Drains at the end of the Year.
			Epidemic Diseases.	Typhoid.	Diphtheria.	Smallpox.	
1872–1875	437,835	28·87	..	..	..	..	..
1887	437,835	27·59	..	..	..	..	..
1888	455,167	27·16	2,613	388	1,385	657	..
1889	523,452	28·15	1,966	509	905	185	..
1890	547,144	29·99	4,050	628	1,037	2,198	2,287
1891	535,060	24·32	1,477	408	623	275	4,359
1892	554,713	24·00	1,277	214	609	30	10,309
1893	580,375	22·00	1,126	214	658	14	15,002
1894	603,012	22·70	1,091	217	445	15	18,906

At the end of the year 1891 there had been 24,055 houses with water-supply from the mains, and some 30,000 houses without this supply, so that there were about 54,000 houses in the municipality for which these statistics apply. The proportion of the houses connected to the drains was still low; but it would be observed that the great fall in the death-rate was in the year 1891, when but a very few houses had been connected.

Mr. Wright.

Taking the year 1891 into account, as it exhibited a remarkable reduction in the mortality, it might be claimed that the 220 fewer typhoid, and 414 diphtheria cases were due to the use of the sewers by about 6 per cent. of the houses, and in that case a much greater reduction in the mortality from causes attributable to bad drainage might have been expected from the further extension of the system to about one-third of the houses as in 1894. The improvement after 1890 in the public health of the city was, however, not confined to those districts supplied with sewers, but extended to parishes either outside the drainage system or where it had been in operation; and further that this improvement was also noted in the case of typhoid and diphtheria.

As districts not included within the active sphere of the drainage operations might be taken, Sta. Lucia, Flores and Belgrano. (Sta. Lucia was in the low-level district, and in which the system was not in active operation in the year 1892.)

Year.	Typhoid.				Diphtheria.			
	Whole City.	Santa Lucia.	Flores.	Belgrano.	Whole City.	Santa Lucia.	Flores.	Belgrano.
1888	388	45	23	8	1,385	172	36	13
1889	509	65	18	17	905	99	48	20
1890	628	71	43	32	1,037	143	54	33
1891	408	48	21	28	623	90	20	13
1892	214	22	12	8	609	543	34	5
1893	214	28	15	5	658	59	50	19
1894	217	19	19	16	445	63	33	19

The reduction in deaths from typhoid and diphtheria since 1890 was exhibited nearly in the same manner in undrained as in the partially drained city, and it therefore appeared that the reduction was not in any way due to the drainage works. Thus the health statistics did not justify the claim that the drainage works had reduced the death-rate, and the undoubted improvement in the health of Buenos Ayres since 1890 must be sought for in other directions. The health of the city up to the year 1890 was not considered satisfactory, and as yellow fever had moved further south and had firmly established itself in the southern part of Brazil, each approach of summer brought with it a yellow-fever scare, and the authorities were urged to action by public clamour. The compulsory notification of diseases and the rigorous disinfection of infected dwellings must have been of service in protecting the public health, and have been the cause of the reduction in the small-pox, and to this cause rather than to the drainage works

Mr. Wright. must the stamping out of the 1890 epidemic be due. There was also an extension in the paving, which removed a large number of foul, evil-smelling pools of stagnant water from the streets. The artificial immigration fostered by the practice of granting free passages to emigrants from Europe brought a most undesirable class of city loafers, who crowded into the slums, which were not confined to certain quarters of the city, but were found in every part. This immigration almost ceased after 1889, when the Government had exhausted its exchequer.

As regards typhoid, he had had the opportunity of observing in the hospitals that the majority of typhoid patients had been drinking subsoil water, and were mostly residents of the suburbs not reached by the mains of the city waterworks, and he was inclined to believe that the River Plate water as supplied by the waterworks was safe as regarded that disease. Belgrano, which had a separate supply of River Plate water from a different intake had a somewhat evil reputation for typhoid infection, and it was generally thought that the water was the cause and that the intake was contaminated by a small stream flowing into the River Plate near the intake. The plan of allowing a portion of the sewage to flow out of the storm outfalls into the river in front of the city, and at a short distance from the intake, was likely at some future time to lead to evil effects, as the foreshore, at the edge of which was the intake, might become infected.

The water from the mains was never bright and clear as the finest part of the suspended matter could not be removed by sand-filters. It could, however, be rendered bright and colourless by filtration through stone, porcelain, or even one thickness of filter-paper of good quality.

Hon. R. C. Parsons. The Hon. R. C. Parsons, in reply, said, although he was not in possession of the exact cost of filtering the water used in Buenos Ayres, he was of opinion that it did not nearly reach 1 cent gold per 1,000 gallons as stated to be the cost in Rosario by Mr. Bruce, who had, however, omitted to state how often it was necessary to clean the filters at Rosario. Should their construction or the turbidity of the water of the Paraná be such as to render it necessary to renew the sand more frequently than at Buenos Ayres this excessive cost might be accounted for. The advisability of roofing the filters had been very carefully considered before it was finally adopted at Buenos Ayres, and it was determined that not only would the cost of cleaning the filters be considerably reduced, owing to the process of filtration being carried on in the dark, and the formation of vegetable growths thus prevented, but

Hon. R. C. Parsons.

also, in the hot season, when the temperature was tropical, the water would be cooler and of greater purity when supplied to the city. From the description given by Mr. Bruce of the system of piping adopted in Rosario, it appeared that the principle followed was almost identical with that in use in Buenos Ayres, except that instead of two distributing mains laid under the pavements on either side of the streets, one was provided under the centre of the street. This course had been adopted in Buenos Ayres, as the streets were so narrow, and in most cases tramway rails were laid in them, the passage of the cars along which would have been seriously impeded whenever it was necessary to make a connection to the distributing main were it laid under the roadway. In a large system of street mains very serious inconvenience would be met with should it be necessary to empty and refill a main if air-valves were omitted, as the house-owners would, in that case, be a considerable time before they blew off the air and obtained the water they required. The opinion that the system of ventilating-pipes, as adopted in Buenos Ayres, was unnecessary, and that the street man-holes give all the ventilation required, had been formerly held in England, but it was now very generally admitted that the ventilation of sewers might with advantage be improved, and he considered that if this was he case in a country possessing a temperate climate, it was absolutely necessary in a country where the heat was tropical, and which was subject to visitations of cholera and yellow fever. The designs of the additional settling-pools and filters, described by Mr. Nyströmer, had been prepared by Mr. Parsons' firm, but had been modified when executed by the Government under the direction of their engineers. From careful observation of the working of the settling-pools described in the Paper he had noticed that by introducing cross-walls the current of the water, as it flowed along the channel formed by them, had the effect of stirring the deposit and preventing it from settling. He was therefore of opinion that it was preferable to construct a settling-pool rectangular in plan, allowing the water to enter along one end and to be drawn off along the other, the necessary precautions being taken to prevent local currents from being set up, which would carry the turbid water direct from the inlet to the outlet. The Argentine Government had preferred, however, to construct the new settling-pools on the same principle as those described in the Paper, which had worked successfully, and not introduce any extensive modifications in the designs.

A new form of apparatus for regulating the velocity of flow through the filtering medium, *Figs. 56*, had been described by Mr.

Hon. R. C. Parsons. Nyströmer. The parabolic module of the apparatus described in the Paper had been replaced by a circular slide-valve worked by a cam actuated by the float which maintained a constant flow. The volume passed was also capable of being regulated by a hand-wheel at the side by rotating the casing of the valve. He considered the module described in the Paper met the requirements of the case as well as the modified apparatus, and it further possessed the great advantage that none of its working parts, which were liable to become corroded or encrusted, were below the water, as was the case in the module described by Mr. Nyströmer.

With reference to the water-supply of Belgrano, the water derived from the lower water-bearing strata, provided it remained uncontaminated by the sewage which was found in the strata above it, was no doubt suitable for domestic purposes. This subterranean water, was, however, hard, as stated in the Paper, and when the source from which the city was to be supplied had been considered it had been decided that water derived from the River Plate, when properly filtered, was most reliable and best suited to the requirements of the city.

He had carefully considered the question of the amount of water necessary for the flush, referred to by Mr. Paterson, as it was of the greatest importance in Buenos Ayres to use as little water as possible for this purpose; and it was obvious that, whilst a 2-gallon flush was sufficient to cleanse a sewer of a certain diameter, if another sewer be laid with the same gradient, but of twice the diameter, it would require a very much larger quantity of water to produce the same cleansing effect. The sewers and house-drains in Buenos Ayres had been kept as small in diameter as possible, conformably with their not being liable to become blocked, and he believed that the 2-gallon flush mentioned in the Paper was amply sufficient to keep them cleansed. In reply to Dr. Du Riche Preller, he believed that some bacteriological tests had been made, but up to the present he had not received the results.

It had been stated by Mr. Lewis T. Wright that it was asserted in the Paper that the house drainage had produced an amelioration in the health of Buenos Ayres. This, however, was not the case. A Table was given showing that the improvement in the health of Buenos Ayres had progressed as the house-drains had been connected. It was impossible to say what portion of this improvement was due to the drainage and what to the water-supply, which no doubt played a very important part, as Mr. Wright admitted. There were also other influences at work, such as a closer inspection of nuisances and the municipal regulations, with reference to the reporting of infectious diseases, which no doubt combined to improve the general health of the city. The statistics given had been obtained from official returns, but it had been necessary to condense the Paper as much as possible, and consequently the figures given in the Tables were in a somewhat different form from those given by Mr. Wright. Hon. R. C. Parsons.

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21 January, 1896.

SIR BENJAMIN BAKER, K.C.M.G., LL.D., F.R.S., President, in the chair.

The discussion upon the Paper on "The Sanitary Works of Buenos Ayres: Sewerage, Drainage, and Water-Supply," by the Hon. R. C. Parsons, was continued and concluded.