Correspondence.

Mr. M. R. Atkins, having been associated with the carrying out of the works at Colombo from 1906 to 1919, and having been concerned subsequently with drainage-works in Calcutta, wished to remark on the relative advantages and disadvantages of the separate and combined systems as applied to those two cities. In Colombo, with a separate system of underground rain-water drains to which all street gullies and surface drains were connected, very careful scheming was necessary to secure sufficient differences of level, between the sewers and rain-water drains and their respective connections, to allow of their crossing and recrossing each other at street-junctions and elsewhere without break of gradient. In many cases the invert-levels of the rain-water drains were below these of the branch sewers; that fact made it possible for the upper lengths of the rain-water drains to be dispensed with, and for the branch sewers to be used as combined drains, which were made to overflow automatically into the rain-water drains at any desired rate of flow without "heading up." The chief disadvantage of that arrangement was the fouling of the air in the rain-water drains by sewer-gas passing through the overflows; but that was obviated by fitting the latter with flap valves. The advantages of the arrangement were its economy and the convenience of having one sewer instead of two in the narrow streets where it was found possible to apply it. The combined system which was in use in Calcutta avoided the complications previously referred to and was well suited to the needs and habits of the population; but it failed to prevent flooding of the streets whenever the rainfall exceeded about ½ inch per hour. It was argued that the rapid flushing-out of the sewers which occurred on such occasions was beneficial, but the system was at best only a compromise, and did not deal with the problem of a tropical rainfall in the comprehensive spirit which modern engineering practice demanded. An interesting adjunct to the sewage-treatment at Colombo, which was not mentioned by Mr. Tickell, was the treatment on experimental drying-beds of septicized sludge from the circular sedimentation-tanks. The beds had concrete floors, with central drainage-channels, and brick walls 3 feet high, so as to provide depth for a 6-inch layer of bricks or drainage-tiles, 12 inches of filtering medium, and 12 to 18 inches of liquid sludge. Different sizes of broken stone had been tried for Mr. Atkins.

Mr. Atkins. the filtering medium, but the best results had been obtained with a 9-inch layer of 1½-inch stone, topped by 3 inches of ¾-inch stone. When the sludge was first run on there was a slow trickle of dirty water through the central drain, but within 10 minutes all trace of discoloration disappeared, and the water became perfectly clear. The sludge settled down to about one-third of its depth as it dried, and was ready for spading within 10 to 14 days, according to the weather. Examination of the beds showed that the sludge never penetrated more than 2 inches below the surface of the filtering material, and cleansing of the bed was effected by removing and washing the top layer of stones without disturbing the remainder. In order to avoid having to wash the stone, Mr. Atkins had tried replacing the 3-inch layer of ¾-inch stone by a layer of coco-nut matting weighted down by flat steel bars. The matting was quite effective in arresting the liquid sludge and could be taken up and cleaned in a few minutes after the dried sludge had been removed by spading. The surface of the stone under the matting was not even discoloured, and the matting showed no sign of rotting after being in use for several months.

Mr. Braine. Mr. C. D. H. BRAINE confirmed Mr. Jameson's statement that there was no nuisance from sewer-gas. The mention of dosing-tanks in the description of the outfall works suggested chemical treatment; but there was no such treatment. The dosing-tanks were shown in *Fig. 1* (p. 87) as distributing-tanks for regulating the flow to the oxidizing-beds. The Aapies river had its source at some large dolomite springs, which were used for the Pretoria water-supply. The Water Court had lately decided that, until permanent gauges had been erected, the combined flow was to be taken as 6,178,000 gallons per diem. The residual flow in the river was extremely small until it had been increased by bath-water, sewage-effluent, etc. The acreage of land available for sludge-drying and for the treatment of the septic effluent was far too small, especially as the sludge was no longer used for making fertilizers. The additional area of 2½ acres required during the hot weather was due to the fact that the summer was the wet season. The attempt to irrigate growing crops with the septic effluent had been unsuccessful. The land used for the treatment of the sludge and septic effluent yielded huge crops of tomatoes, etc., which were self-sown by the sewage. Those, however, were not marketed. At the present time a population of 63,000 was served by sewers and the pail system. The latter applied to about 6,000 houses, and about 3,000 pails were tipped at the two collecting-tanks each night. The tanks were 30 feet square, and about 4 feet deep, with a large screened outlet in the centre. A vertical screen surrounding the outlet was far more effective, and gave less trouble with clogging, than did a horizontal screen covering the outlet. All nuisance was practically prevented by discharging the pails under water. The cleanliness at the collecting-tanks was amazing. During the day there was not a taint in the air. The tanks were about a mile from the centre of the town, whereas the original depositing-ground was 8 miles away; which gave some idea of the saving under the present system. The walls of the oxidizing-beds consisted of dry-stone work, and the smallest medium used passed through a $\frac{3}{4}$-inch screen, anything passing a $\frac{1}{2}$-inch screen being rejected. The sprinkler arms were 80 feet in diameter, and worked under a head of 27 inches. They had been running for 10 years and were still in good condition. Dry grass and weeds, etc., were burned on the surface of the septic tanks and the drying sludge in order to deal with the plague of flies. The deposit of ashes was very effective but it retarded the drying. The tanks were now being roofed with galvanized iron to keep out the rain, and were also being made fly-proof. As there would be ventilation through the wire screens, the heat under the roof might result in more rapid drying. Quite a surprising quantity of sand, ashes, cinders, grape-seeds, etc., was removed from the effluent channels leading from the septic tanks. An experiment had lately been made of spreading 50 tons per acre of sludge, containing 76 per cent. of moisture, on cultivated land, and treating that with 1,500 lbs. of agricultural lime per acre. That has resulted in the rapid humification of the sludge. Mr. Braine.

The history of the drainage of the southern suburbs of Capetown was of interest. Twenty years ago, Woodstock, Mowbray, Rondebosch, and Wynberg were independent municipalities, employing their own engineering staffs, and carrying out more or less isolated programmes of work. During 1903–4 he was engaged on the preparation of plans for the drainage of Mowbray, although it was perfectly obvious that nothing short of co-operation with the adjoining municipalities could result in an economical scheme. It was then found that a gravitation scheme was impracticable, and that the only solution was on the lines carried out by Mr. Lloyd-Davies. The isolated programmes included water-supply. The questions became so acute that the Government appointed the "Peninsular Commission" to inquire into, and report on, the unification of the suburban municipalities. In 1913, the Provincial Council passed a Unification Ordinance uniting Capetown with other municipalities. The cost per head for sewerage-works and water-supply in the residential suburbs of South African towns was always high, on account of the scattered positions of many of the houses. That applied to the Cape suburbs, where a large number of the houses were

Mr. Braine. surrounded by extensive grounds. In the Johannesburg suburbs building-plots more than an acre in extent were common, and some of the gardens included more than one plot. In at least one case the total area was about 5 acres. That meant that the length of sewers per house was vastly greater than under ordinary European conditions. The Liesbeek and Mowbray-Woodstock intercepting sewers ran practically at the foot of Table Mountain slopes—an outlier of this mountain was shown in Fig. 1, Plate 1. The rainfall over the area served varied greatly. At Maclear's Beacon on Table Mountain (3,478 feet) the average rainfall was about 87 inches per annum, at the Royal Observatory (near the Maitland intercepting sewer) it was about 20·74, and at Newlands about 54·65, with a maximum of about 70 inches. It frequently rained in Rondebosch when the weather on the Camp Ground was clear and bright. The wet season was in the winter months—May to October. The ratio of the thickness of the walls to the diameter of the culverts for the "larger sections" was given; but there was no mention of the diameter above which the ratio applied. He agreed that the correct procedure was to graduate the sizes of the sewers to receive storm-water according to rainfall-intensity, and it would have been interesting if the calculations had been given for a definite length of sewer. Unfortunately, no longitudinal section showing the dimensions of a sewer was given in the Paper. For the benefit of engineers living in places where they had to limit their own libraries, and where reference-libraries were not available, he suggested that it would be as well to give the formula used for calculating the sewer-capacities. Details for the numerous Liesbeek river-crossings would be of interest. The use of brushwood in the bacteria-beds was a new departure for South Africa. The Cape Flats had been largely reclaimed by planting Australian wattles,[1] and bush should be cheap; but it seemed doubtful if that method would result in lower maintenance-costs. Useful information might also be given concerning the crops irrigated by the effluent from the humus-tanks, and the profits obtained from the farming-operations.

Mr. Tickell's Paper was an interesting account of a large and important piece of work, which seemed to bristle with difficulties of construction; but how these had been overcome was not explained. It was not easy to follow the Paper, for landmarks were referred to that were not shown on the plan; and while reduced levels were given, there were no sections. In the harbour area there was a trench 43 feet deep and a sewer constructed in liquid peat mud. Mr. Braine could not help wondering if there was no way round, and no

[1] Minutes of Proceedings Inst. C.E., vol. cl, p. 377.

possibility of arrang'ng the pumping-lift so as to carry the sewer over the swamp. No description was given of the Kelani river, and it would be interesting to know why the outfall of the sewer was moved 2 miles upstream. Were the two 48-inch cast-iron pipes found to be cheaper than concrete culverts? With so much work in running sand and near rickety buildings Mr. Tickell must have had some valuable experience that would be highly useful to other engineers. It was to be hoped that he would give some information on those points and also say if any form of cementation process had been tried. It would be interesting also to hear more about the construction of the sewer under two bays of the lake. Special precautions must have been required to prevent the flotation of the sewers. The southern outfall merited further information. A coffer-dam to withstand the full force of the south-west monsoons must have been of very substantial construction. Apparently only the effluent was discharged into the sea. The reduction in the death-rate following the construction of the works was useful information and highly satisfactory; but it was not surprising to anyone who had lived in the Far East and had experienced the reek from stagnating pools of filth. The saving in funeral-expenses was, he thought, a novel and interesting point. Mr. Tickell was to be congratulated on having carried so large a work to a successful conclusion. Mr. Braine.

Mr. EDWARD CAMM was interested in the procedure for designing sewers to receive storm-water. When preparing a drainage-scheme for Accra, Gold Coast, in 1920, he had followed a method similar to that described by Mr. Lloyd-Davies, based on the inverse ratios of the drainage-area and the rainfall-intensity. He had found that previous schemes had adopted rainfall-rates of 5 inches and $2\frac{1}{2}$ inches per hour over the whole of the districts respectively dealt with. The rainfall-intensity curve he had selected as best meeting the observed rates of rainfall at Accra was represented by the equation $(T + 18) R = 135$. That curve gave about double the values of the Capetown curve, namely, for areas of 1 or 2 acres, a rate of 5 or 6 inches, and on an area of about 700 acres, a rate of $2\frac{3}{4}$ inches per hour. The frequency of such high rates was a matter requiring careful consideration. In England rainfall-intensities of 4 and 6 inches per hour had been recorded for short periods; but it might not be an economical procedure to make provision for heavy falls which only occurred at rare intervals. On the West Coast of Africa, however, such intensities had been recorded several times in a year, and consequently drains of large size had to be constructed. In Mr. Lloyd-Davies's scheme the storm-water drainage-area was limited to 100 square feet per house. Special precautions would be necessary to make that limitation effective. Mr. Camm Mr. Camm.

Mr. Camm. had had similar restrictions in view when preparing a drainage-scheme for Port Elizabeth; but, owing to the topography of the town, it was decided to take in all the back roofs and yards; the actual area per head, varying with the density of population, was calculated from typical areas. He had expected to see a larger provision for rain-water in the sewers of the Colombo Drainage Works; but he assumed that the figures given, which varied with the proportion of built-up area, included allowances for evaporation and absorption. In the case of Capetown the whole of the rainfall on the 100 square feet per house appeared to be taken as reaching the sewers. At Accra discharges ranging from 8 to 50 per cent., according to the development of the district, had been adopted.

Mr. Mager. Mr. F. W. MAGER observed that, being responsible to the Government for the drainage of several towns in the Federated Malay States, all of which were on the surface system, he found Mr. Tickell's Paper, describing the conversion of the former surface-drainage system of Colombo to the underground system, of considerable interest. The climate, rainfall, and other conditions of Colombo approximated very closely to those of Malaya, and the general problem was the same in all material respects. The dry-weather flow for Colombo was taken at 25 gallons per head of population per 24 hours, and the sewers were designed to take six times that quantity. Twenty-five gallons per head appeared to be low. The standard allowance for town water-supplies in the Federated Malay States was 40 gallons per head, and the maximum daily consumption exceeded the average by 50 per cent.; that, if applicable to Colombo, would leave 25 by $4\frac{1}{2} = 112 \cdot 5$ gallons per head allowance for storm-water, giving 62·5 cubic feet per second discharge to the underground sewers from an area of 9 square miles. The volume in cubic feet per second of the discharge from catchment-areas in Malaya had been found to be as much as $500\ M \times \frac{4}{5}$, where M denoted the area in square miles; for Colombo that would give 2,900 cusecs, so that 2·1 per cent. of the storm-water would be admitted to the sewers. Hence the provision made for storm-water seemed low, even for unpaved areas like the Cinnamon gardens. In the denser paved areas such as the Fort or Pettah quarters, the population was 183 per acre, and the provision for storm-water per acre would be 0·038 cusec. A rainfall of 5·5 inches per hour on a paved area might appear wholly as discharge, and in that case 94 per cent. of the storm-water would be excluded from the underground sewers. But it was stated that only 2 inches per hour was provided for by the rain-water drainage-system; therefore it appeared that there was a large excess of storm-water unprovided for. Consequently a real danger existed of damage by floods to property generally and, by overcharging, to the underground sewers themselves. Experience, however, might have proved these forebodings to be groundless. He would like to have information on this important point. Further information on the subject of house-connections, both in the residential quarters and in the bazaar, would be of interest. Modern sanitary fittings were almost unknown in Malaya, and the results of their use, or rather the neglect of their use, by native servants in better-class residences—and still more by the inhabitants of the native bazaars—was a matter of conjecture. He gathered from what was stated in the last paragraph on p. 78, that the pail system, with all its attendant disadvantages and danger to health, was still in existence over a considerable area. If that were so, then those areas must be little improved from a sanitary point of view, the large expenditure of Rs. 18,000,000 being scarcely justified. The reduction of 18 per cent. in the death-rate might be due to some other cause or causes than the construction of the interesting works described in the Paper. Mr. Mager.

Mr. SAMUEL MCCONNEL observed that probably no subject in the whole field of sewage-disposal had aroused more controversy in the past few years than that of settling-tank treatment. The necessity for early separation of the settling and putrefying processes was generally admitted, but the methods of doing this were many. The rectangular flat-bottomed settling-tanks adopted in practically all large English towns had proved successful and economical, sludge-removal taking place every fortnight or so; but in countries where higher temperatures prevailed, bacterial action was accelerated, and sludge must be removed very frequently, or simple settlement would be seriously jeopardized. This rendered advisable some form of tank so designed that sludge might be removed at short intervals. Tanks of the Dortmund type, as used in Pretoria, had many advantages over the double-storey Emscher type. There was no possibility of the sludge interfering with the settling process; and, where the ground was bad and waterlogged, it was more economical to reduce the depth of the tank and to find capacity for sludge-storage elsewhere. The slope of the bottoms of the Cape Town tanks appeared to be very slight; some means of agitating the settled sludge preparatory to drawing it off would be necessary Settling-tanks similar to those in use at Pretoria could be seen at Brightlingsea treating crude sewage, Skegness also employed this type of tank, but the sludge was drawn off continuously. That suitable tanks could be designed without using excessive depths was shown by the reconstructed rectangular tanks at Colombo. The Emscher tank had gained little popularity in Great Britain, where separate sludge-digestion tanks were almost universally employed. Storm-water tanks, ably advocated by Mr. McConnel.

Mr. McConnel. Mr. H. P. Raikes, M. Inst. C.E., satisfactorily displaced storm-water treatment-beds, which involved great expense in construction, and, owing to their irregular use, were not particularly efficient. The Capetown flats appeared to be an ideal site for sewage-farming, the conditions being very similar to those prevailing in Melbourne, where settled sewage was treated directly on the land without the use of percolating filters, etc. Probably there were local reasons why similar treatment would not be suitable at Capetown. The precast pipes used for sewers were made by the wet process, in moulds. A machine of Scandinavian manufacture was now in use for constructing pipes of a dry mixture, mechanically tamped, which obviated the use of forms. Such pipes could be made with or without sockets very cheaply and quickly, and had displaced the wet cast pipe in many places. In calculating the discharge of sewers, pipes, etc., much labour might be saved by the use of the Hazen-Williams slide-rule based on the well-known formula. By means of that simple instrument the use of logarithms, tables, etc., was entirely obviated.

Mr. Olive. Mr. W. T. Olive thought that the local authority had erred in abandoning his proposal for a gravitation scheme of sewerage for the Southern suburbs, with a sea discharge $4\frac{1}{4}$ miles to the north-east of the sea outfall at Green Point. A similar scheme was carried out by him 27 years ago, as City Surveyor, for old Capetown, and had been in satisfactory use for the last 25 years. It was decided upon after exhaustive examination of all available professional opinion, and of a marine survey made expressly to determine the average resultant trend of the currents of Table Bay, the object being to obviate all treatment-works. Had that proposal for the suburbs been adopted, considerable economy would have been effected, inasmuch as less than one-tenth of the sewage would have had to be lifted, whilst the cost of pumping and treatment of the whole quantity involved in the scheme under discussion would have been eliminated altogether. The same extravagant expenditure could be illustrated, in a minor degree, by reference to Wynberg which he also advised, when called in as consulting engineer, should be given a sea outfall by gravitation. But, in spite of warning, that municipality persisted in having its treatment-works, which in a few years after completion had to be abandoned. The sewage now was carried 5 miles farther into the country, and new works had been built, at further expenditure. That was common knowledge before the Capetown Corporation decided to favour a pumping scheme and sewage-treatment for the southern suburbs. Reverting to the proposal for dealing by gravitation with the whole sewage from the southern suburbs, including Wynberg, the following figures gave the invert-levels, at the leading points, of sewers which would take the sewage from the several suburbs into a joint trunk main having its outlet into the ocean :— Mr. Olive.

	Above L.W.O.S.T. Ft.
For Wynberg	65
„ Claremont	33
„ Rondebosch	20·5
„ Mowbray	12·9

In no case would the falls of those intended sewers reach the following minimum permissible gradients :—

Diameter: Inches	4	5	6	7	8	9	10	12	15	18
Fall: 1 in	70	90	150	200	240	270	300	350	420	500

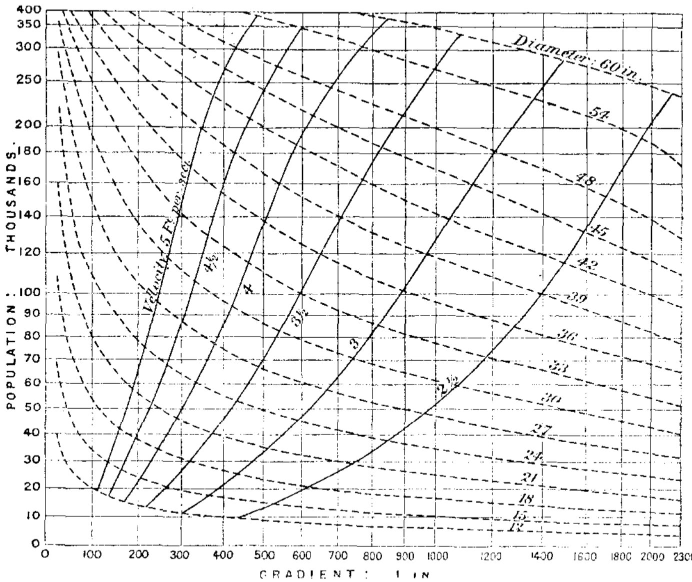
Diameter: Inches	21	24	27	30	33	36	42	48	54
Fall: 1 in	600	700	800	880	1,000	1,050	1,200	1,310	1,550

A water-supply of 25 gallons per head, with one-half in 400 minutes, was taken as a maximum rate. A rainfall-admission of 45 gallons per head was equivalent to a yard-surface of 23·4 square feet at 1 inch per hour. These values for sewage and rain worked out at 0·01 cubic foot per minute per head of prospective population. *Fig. 1* (p. 138) showed the sizes of sewers, as flowing three-quarters full, required for the calculated populations in the respective districts and sub-districts to the gradient available therein.

He regarded the tipping of pail-contents into the main sewers at Pretoria as a reprehensible and retrograde practice. It was almost impossible to dilute it by so-called flushing—certainly impossible with the 20 gallons per pail mentioned. Most modern water-closets received a 3-gallon flush at each operation, a dilution of about 150 times. From the data given the water-consumption was 37 gallons per head per day, so that the solids produced individually were diluted fully 1,480 times, even counting all the population as adults. Moreover, deposits inevitably occurred in the main sewers receiving the tipped stuff, which fermented and fouled the system. The oxidizing-beds dealt with 150 gallons per square yard per diem. As the dry-weather flow was 1,500,000 gallons, there should be 10,000 square yards of beds: in effect there appeared to be 2,240 square yards provided in the four (*Fig. 2*, p. 89). Consequently he concluded that the figure was intended to show only one-quarter of the works, and that the screens, grit-chambers, distributing-tanks, etc., were all quadrupled. The manurial value of sludge had been discovered, but could Mr. Jameson give any information as

Mr. Olive. to the quantity sold and the price realized per ton of dry sludge, and as to the price obtained after adding phosphates?

Fig. 1.



SEWERS AND GRADIENTS RELATION TO POPULATION (SEWERS RUNNING THREE-QUARTERS FULL).

Mr. Roechling. Mr. H. ALFRED ROECHLING observed that Mr. Jameson used some words and terms which were not clear to him, e.g., "elongated horizontal flow." It was stated that "crude sewage might be primarily separated from organic matter." To what process and to what stage of the organic matter did Mr. Jameson refer? Mr. Roechling had never heard of a process in which separation of the major from the minor portion of sewage was attempted. He assumed that the term "sweet sewage" meant fresh sewage. On p. 93 Mr. Jameson used the expression "molecule of liquid sewage." Did he do so in a strictly physical or chemical sense, or did he merely wish to indicate minute particles of sewage? On the same page he mentioned "colloidal matter or humus," and this seemed to indicate that colloidal matter and humus were synonymous terms. Such a conception was not adopted in this country. It was quite true that the meaning of the word "colloid" had undergone some slight change, but not in the direction in which Mr. Jameson apparently used it. Colloids formed the domain that lay above molecular and below macroscopic dimensions. Although humus might consist of colloids

Mr. Roechling.

and other matters, it could not be said that colloids were humus and vice versa. In sewage colloids were partly-dissolved matters existing in a state of pseudo-solution, together with matters in emulsion. In true solutions the particles had been split up into their molecules, but in colloids the disintegration had not yet proceeded so far, and it was therefore a characteristic of colloids to render a liquid turbid (colloids mainly in the "hydrogel" or "gel" state) or to give it a mucilaginous or opalescent character (colloids entirely in the "hydrosol" or "sol" state). Colloids were easily subject to changes both in the direction of true solutions and in that of undissolved substances, the former change being brought about by anaerobes in putrefaction, the latter by aerobes in a biological-treatment plant. In town-sewage colloids were chiefly of an organic nature, mostly sulphurous and nitrogenous compounds, whereas in factory-wastes inorganic colloids such as iron salts might also be present. Both the reversible and the irreversible kinds of colloids were present in sewage, and the organic colloids were the carriers of putrefaction and the cause of the water-retentive powers of sludge. It was probably correct to say that, after the removal of the suspended matters by preliminary treatment, 50 per cent. of the remaining organic matter to be dealt with in a filtration-area was in a colloidal state. He assumed that the expression "functional response of self-cleansing flow" (p. 94) meant the effect of a self-cleansing velocity. On the same page it was stated that the humus contents of a percolating-bed were driven out "ahead of the flush." Were the humus contents driven out by air or by the liquid with which the bed was dosed? If the air were driven out in front of the liquid, at a velocity sufficient to cause the humus to be removed, the rush of air must be very considerable to remove the material caked on the medium of the bed. It was desirable to preserve the air in the bed as far as possible, and not drive it out by sudden rushes of the liquid. He was afraid he could not agree with the theory of evolution advanced by Mr. Jameson. What had been described was rather retrogression than progressive development, and dealt with only a portion of the question. From a purely physical standpoint, sewage consisted of the liquid and the various matters suspended and dissolved therein, and three distinct stages in artificial sewage-treatment were generally recognized, namely, the removal of the suspended matters, the purification of the liquid, and the disposal of the sludge. Mr. Jameson dealt only with the first stage, and, further, he omitted any reference to the activated-sludge process, which probably formed the latest stage of the artificial treatment of sewage. The Cameron septic tank was only a revival, on a larger scale and under a different

Mr. Roechling. name, of the "cesspit." Hence that tank had now ceased to be employed for sewage-treatment. The Travis tank and the Imhoff or Emscher tank—the latter being to all intents and purposes a Travis tank with some slight modifications, which did not affect the principle and which were no improvement—stood upon a different footing altogether; but they represented only a modification of the apparatus used and not the principle of the general treatment. Mr. Jameson's third stage was again a retrogressive step, a reversion to an old type previously used, and, to some extent, abandoned again. To call the tank a "Watson-Dortmund" tank was a complete misnomer. The tank was a common vertical tank, such as was used for the first time for sewage-treatment in Halle a/S in 1886. It was then slightly altered by Mr. Kniebuehler, of Dortmund, who introduced about 1888 a spreader at the outlet of the inflow-pipe; afterwards it was used in other parts of Germany, generally without Kniebuehler's spreader. But it did not prove of much advantage over horizontal rectangular tanks, first used in this country, so that its higher cost—especially where large quantities of subsoil water were met with—was not justified, and in this country it had never been employed on a large scale. One of the reasons urged against it was the percentage of water—about 95 per cent.—contained in its sludge, as against about 90 per cent. contained in the sludge of horizontal tanks. Some 30 years after its invention Mr. Jameson had used this tank for the very purpose for which it had been originally intended, so that even his fourth stage of evolution foreshadowed for South African practice was non-existent. Mr. Roechling regretted that the diagrams given in the Paper were not drawn to scale. Were the analyses of sewage and effluent those of chance samples only, or were they averages of collective samples taken over an extended period? He regretted also that no figures of the capital or working costs of the plant had been given. From a Government report he inferred that Pretoria had spent about £175,000 on storm-water drainage and about £300,000 on the sewerage of parts of the town, which figure, he surmised, included the cost of the sewage-treatment works, or a total of about £475,000. The total municipal debt at the end of 1920 was about £1,545,287. If those figures were correct it followed from the figures given in the Paper that the cost per head of population of the sewered area was nearly £16 for storm-water and sewerage, and about £10 for sewerage only. These were high figures. The volume of the dry-weather flow of sewage was about 50 gallons per head, and taking 30 gallons as an ample allowance for the water-supply per head, 20 gallons were left to be accounted for. He thought that additional quantity was

Mr. Roechling.

subsoil water which found its way into the sewers through leaky pipe-joints. The subsoil under Pretoria was saturated with subsoil water, and the analysis of the dry-weather flow of sewage confirmed his view as to this influx. The sewage was weak, and the late Royal Commission remarked on such sewage that, as a rule, it contained much subsoil water. Another point of confirmation of this view was the flow of water in the main sewer between 2 a.m. and 5 a.m., which he estimated, from the particulars given in the Paper, at 36,000 gallons per hour. In his view the subsoil water should have been excluded from the sewers when they were laid, as that precaution would have saved extra expense in treatment. The omission of the intercepting trap to house-drains was a mistake. If there was nothing to be removed from the street-sewers, why should they be ventilated through the house-drains? The flow of air in house-drains could not be regulated; it was very often in a downward direction towards the street-sewer. A Departmental Committee of the Local Government Board (now the Ministry of Health), came in 1911 to the conclusion that the free ventilation of sewers appeared to be unnecessary. It was, however, quite a mistake to assume that no sewer-gas was produced in public sewers, as experience has proved that, however well a sewerage system was designed, carried out, and maintained, nobody could control either accidents at the time of the minimum flow, through substances getting into the sewers, or accidents to the sewers themselves. A disconnecting trap, properly designed, fixed, and maintained, need not become blocked; where blocking did occur, the fault was generally a local one which could easily be remedied. Although it had not been possible up to the present to establish a clear connection between sewer-gas and some epidemic diseases, the methods of investigation were still somewhat crude. It seemed not impossible that, with more refined tests, specific disease-exciters or volatile ptomaines might be discovered in sewer air; and in matters of health it was very unwise to sail too close to the wind, as prevention was far better than cure, even if cure was at all possible. A great deal had been made, by the opponents of the intercepting trap, of the Departmental Report previously referred to; but the view of it taken by the Ministry of Health was quite conclusive in this respect. Although that Report was made in 1911, the Ministry of Health had issued, since July, 1921, model by-laws, in which the intercepting trap was still maintained, and all that they had done was to give local authorities on their application a provisional option to omit the disconnecting trap, where the house-drain was connected with a street-sewer; but where the house-drain was connected with a cesspit the Ministry still insisted on the trap. Mr. Jameson

Mr. Roechling. employed 10 acres of land for the treatment of the effluent from the sludge-digesting tanks, and 25 acres which were cultivated and presumably treated with some portion of the effluent from the percolating-beds. He hoped Mr. Jameson would make that point clear. There was apparently no effluent from the land treatment. It was not stated what quantities of floating and suspended matters were arrested at the screens and in the detritus-tanks, but he thought that the matters retained in the latter could only be of trifling amount, owing to their form and the short sojourn of the sewage in them, although it was stated that the sewage was practically quiescent in the centre. This view was confirmed by the short time occupied in cleaning the detritus-tanks.

The work done by the vertical settling-tanks was disappointingly small, the retention of suspended matters being only about 50 per cent. Horizontal tanks in this country and on the Continent frequently retained 80–90 per cent. of the suspended matters, and produced sludge with only 90 per cent. of water, whereas the Pretoria sludge had 96 per cent. of water. In vertical tanks the water-content of the sludge was frequently higher than in horizontal tanks, and had the latter been constructed, the great expense of deep foundations in water-logged subsoil would have been saved, and the quantity of wet sludge might have been reduced by about 38 per cent., which would have been equivalent to a reduction of nearly 85 per cent. in the work of the percolating-beds. He was of opinion that the effluent from the settling-tank could no longer be called fresh sewage, as during its passage through the sewers and its sojourn in the tank it must have become septicized to a considerable extent. In this country sewage became septic on an average after about 9 hours, and in the great heat of Pretoria the time must be much shorter. That view was confirmed by Mr. Jameson's remarks about the septicity of the pail-contents and the rapidity with which matters retained in the detritus-tank and vertical settling-tank became septic.

Mr. Jameson stated that 1 square yard of the percolating-beds dealt with 150 gallons in 24 hours, but Mr. Roechling found that, with only twelve beds at work, the rate was 224 gallons per square yard, equivalent to 112 gallons per cubic yard. Mr. Jameson had stated further that by using only twelve of sixteen percolating-beds, with four as a stand-by, the beds would have an almost indefinite life, that no difficulties with humus-like material had been experienced, and that there was no need to extract this matter from the effluent in special tanks. Mr. Roechling found some difficulty in accepting these statements, and, unless the work done by the filters at Pretoria was entirely different from what it was in Europe, he felt sure that sooner or later they would become choked. Those

Mr. Roechling. beds received about 16 tons of wet sludge per million gallons; and as only about 2 tons was left in the final effluent, it was clear that about 14 tons was deposited in them, which was equal to 21 tons per day. If, as it appeared, each bed was worked continuously for say, 6 months, each cubic yard of filtering material received about $\frac{1}{4}$ ton of wet sludge in that time, which in volume was equal to about $\frac{1}{3}$ cubic yard. That quantity was approximately equal to the pore-volume of a cubic yard of the filtering-material, so that at the end of 6 months the percolating-bed would be completely filled, to the exclusion of air, unless in the meantime a continual removal of the retained matters had taken place. In addition, it was quite possible that fungoid or other growths formed on the surface and these might cause further difficulties. They had experience at Pretoria of the clogging of filters when dealing with night-soil sewage. If no humus-like material was found in the effluent, the matters brought on to the beds must have remained in them, and that view, was supported by the statement that after, say, 6 months of continuous work each bed had to be given a rest of about 2 months, during which the self-purification processes would be at work. Mr. Jameson mentioned the Hampton theory, with which he appeared to agree, and it was an essential point in that doctrine that the pseudo-dissolved solids, deposited in the filters as solid matter, remained and increased in them, thus increasing the absorbing area and the efficiency of the filters, until they became choked. The view that the purifying effect of percolating filters was chiefly brought about by bacteria was no longer tenable; their participation in this work seemed only to be indirect, and recently the view had been expressed that practically all the pseudo-dissolved solids were retained in the filters purely by mechanical action, leading eventually to choking. The work done in the Pretoria filters formed an interesting subject, and he trusted Mr. Jameson would throw further light upon it in his reply. Nothing was said about nuisances from smell and flies from the filters, but he could not help thinking that, under the Pretoria conditions, such nuisances must be very pronounced at times.

Mr. Jameson mentioned the standard of purity for effluents laid down by the late Royal Commission on Sewage Disposal, and stated that no difficulty was experienced in complying with it; but Mr. Roechling thought that statement was hardly correct. It was not clear from the analyses whether the 5-days dissolved-oxygen test had been made on the whole effluent, including the suspended matters, as insisted on by the Royal Commission. As to the suspended matters, the Pretoria effluent was only just within the limit, but by the 5-days dissolved-oxygen test it did not comply with the standard. Further, Mr. Roechling. the standard of the Royal Commission required eight dilutions in the stream which took the effluent, and, as in the Aapies it only received three dilutions, the requirements of the Commission for a more stringent standard should be applied. He regretted that nothing had been said about the condition of the Aapies below the works, and he would be glad to know whether any of the usual flora associated with sewage-effluents had been started in it, or whether at Pretoria a different flora had made its appearance.

The experiments in sludge-treatment at Pretoria had been made over and over again elsewhere. From the figures given in the Paper he calculated that each sludge-digesting tank received about 4,000 gallons of liquor in 24 hours, containing about 31 per cent. of wet sludge with 96 per cent. of water, and 69 per cent. of septic sewage. The tank held about 23½ days' flow, but, as the outlet was now left open permanently, it could only contain in addition to the same, so far as he could estimate from the information in the Paper, about 6 days' flow. That meant that, on the one hand, the liquid and its sludge contents were only exposed for 6 days to septic action in the tank, and that, on the other hand, every day at least 4,000 gallons of very foul liquid escaped from the tank and had to be purified on land. If 6 days were sufficient for the formation of a thick scum, it showed how very rapid the putrefactive changes were at Pretoria; but he thought it was probably due to the method of working that it took a whole year to reduce the water-content of the upper layers in the tank from 96 to 76 per cent. He was surprised to learn that it took 1 to 2 months to dry the sludge on the land, and he thought that could only be due to the large amount of colloids it still contained. It was said that in the Imhoff tank the water content of the sludge was reduced in about 6 months from about 95 to 75 per cent., and that after removal from the tank the sludge took only some 10 days to dry on land. It would be interesting to know what became of the gas formed in the tanks, which he estimated at 5,000 to 10,000 cubic feet daily. Without the formation of gas the sludge could not rise from the bottom; and, if a thick scum were formed, the gas would have to force its way through to escape. If it had been necessary to discharge the liquid from the sludge-digesting beds into the Aapies, no doubt great difficulties would have been experienced before now, and it was only owing to that convenient back door of land-treatment that the difficulty had been avoided so far. The land did the heaviest work at Pretoria.

He missed from the Paper a justification for the adoption of an artificial treatment of the sewage. South Africa was mainly an agricultural country, where every drop of liquid was required on the land, and he thought it was the duty of the designer of a sewage-treatment plant in such a country to adopt land treatment, unless there were absolutely compelling reasons against it. Land treatment was the only natural treatment which could not be improved upon: with artificial treatment there was no finality, as with further investigations new methods would be suggested. Some might even think that the Pretoria methods had already been superseded by the activated-sludge process. Even if sufficient land could not have been found in the immediate neighbourhood, the works could have been located in the nearest open country. Land would always realize its value, but artificial sewage-purification works had no value when they had to be abandoned. He was pleased to note that under the guidance of Mr. G. Storrar, the Town Engineer, and Dr. J. J. Boyd, the Medical Officer of Health, the management of the Pretoria Sewage-Works was so efficient, as he was satisfied from long experience that the success of any works, good or indifferent, depended very largely on the skill shown by the management. Mr. Roechling.

Mr. F. C. TEMPLE observed that South African and Indian experience appeared to agree as to the desirability of dealing with the sewage as fresh as possible: if the sewage was fresh, the sewers could be ventilated through house ventilating-stacks, rendering the master trap unnecessary. Recent experience in India also showed the advantages of making each part of a disposal-system as simple as possible, and of dividing the processes into separate tanks instead of attempting to deal with two processes in combined tanks. Revolving sprinklers operated by the flow of the sewage had not found much favour in India, for their action was interfered with by strong winds. It was difficult also, on account of caste rules, to find men to keep them in order. It was not easy to determine the average strength of the sewage at Pretoria, which appeared to be about 38 gallons per head in dry weather. That was weak compared with that of an up-country town in India. It was not clear whether the sewage of 10,000 persons, handled by the pail-removal system, to which 54,000 gallons of dilution water was added, was included in the 1½ million gallons. The strength of that part of the sewage was 5½ gallons per head, which was strong. The sedimentation-tanks had a capacity of one-sixth of the total daily volume, which was 240,000 cubic feet; thus the tank-capacity was 1 cubic foot per head of population served, which was just half the size of septic tank found most satisfactory in India. Presumably the use of separate septic tanks for the sludge made it possible to reduce the size of the sedimentation-tanks. The sixteen oxidizing-beds, each being 30,240 cubic feet in content, contained a total of nearly 484,000 cubic Mr. Temple.

Mr. Temple. feet of filtering medium. That was 12 cubic feet per user—four times the quantity allowed in many Indian installations. With so much filtering medium the high standard of the effluent was not surprising. The type of modified grit-chamber was interesting. It would be useful to know why the drop at the end of the chamber was so great, and whether so much head must necessarily be lost.

The Colombo drainage-system was surprising in its size and character to one who had worked for many years for eastern municipalities. For an Indian municipality to embark upon a sewerage scheme at all was rare. To construct a separate system was still more rare, for very few towns would face the cost. It would be interesting to know whether any fall of rain since the rain-water sewers were constructed had caused flooding. He had on many occasions discussed the Colombo disposal-works with Mr. M. R. Atkins, M. Inst. C.E. There was some unexplained difference in the behaviour of the septic tanks, as originally constructed, from that of some tanks in India. At first the tanks had a capacity of about 2 cubic feet per head of population served, which agreed with Indian practice. They were then admittedly overloaded, and produced much gas, the ebullition of which brought sludge to the surface. In India such overloading had produced in some tanks where the dilution was small (about 3 gallons per head), masses of scum consisting of almost unchanged fæces, with a highly-offensive and putrefactive effluent, and in others, where the dilution was great (about 40 gallons per head), practically no scum, and an effluent that was little else than an emulsion of crude sewage. In neither had there been an excessive quantity of gas. The entire difference of behaviour in the sewage was due perhaps to some difference in the design of the tanks. It would be interesting to know why 20 minutes' flow had been taken as the size of the detritus-tanks, and 12 hours' dry-weather flow as the capacity of the septic tanks, and why the particular size and depth had been chosen for the continuous-flow filters.

The sewerage system described by Mr. Lloyd-Davies was stated to be "partially separate," the sewers being designed to carry the rain-water falling on only 100 square feet per house. That being so, the necessity for such elaborate methods of calculating the size of the sewers was not clear. Whether the storm-water overflows came into action after the storm-water had entered the sewers, and acted by extracting it, or at the points of inlet to the sewers to prevent its entrance, was not stated. The latter alternative was much to be preferred, but the former appeared to have been employed. It would be interesting to know why six times the dry-weather flow had been selected as the capacity of the pumps, and one-quarter of the average dry-weather flow as the capacity of the storm-water tanks. The reinforced double-storey tanks at the disposal-works were designed to deal with the whole of the daily dry-weather flow in 18 hours. No reason was given why that figure had been selected, and it was not stated whether it referred to the ultimate sewage of 290,000 persons or to the present population. The sewage was taken as being about 25 gallons per head. Indian experience tended to indicate that for a 25-gallon sewage a 12-hour period in the tanks was sufficient. In other words, for an average sewage the capacity of the tanks should be about 2 cubic feet per head, so that 25 gallons, or 4 cubic feet per head, would pass through in 12 hours. The depth of the percolating-beds did not appear to be given, so it was not possible to ascertain how much filtering-medium was provided. Mr. Temple.

Mr. TICKELL, in reply, stated that the omissions remarked upon by Mr. Braine were due to lack of space. The Paper on Colombo described a work of 20 years duration, and many interesting details had been necessarily omitted. The position of the Northern outfall had been selected so as to give the shortest length of main sewer. The reasons for abandoning the original site at the mouth of the Kelani were stated in the paragraph commencing "The Drainage Scheme." The cast-iron outfall pipes were only of short lengths and avoided heavy construction at the river-bank. The excavations in treacherous ground were carried out under very careful supervision by experienced foremen. Vertical runners, 9 inches by 2 inches by 12 to 15 feet long, were kept driven down a little below the excavation; 10-inch by 4-inch walings and struts were used, and cross polings and straw were put behind the uprights. In crossing the lake and standing water in the swamps an embankment was tipped ahead of the work, which acted as a coffer-dam on each side of the trench. Subsoil drains were laid in the bottom of the trenches, leading to sumps where pumps were kept going day and night. The coffer-dam in the sea at the Southern outfall was of substantial design with a framework of 12-inch by 12-inch timbers which formed a gantry for the steam pile-driver. The piles were 12 inches by 6 inches, close-driven, except at the deepest end, where steel interlocking piles were driven. The work was made sufficiently watertight to be pumped out, and the concrete bed and the cast-iron pipes were laid in the dry. With regard to the provision for discharge in the rain-water drains, experience had proved that the capacity of the drains actually built was sufficient. Considerable areas which were subject to flooding in rainy weather had now been reclaimed. It would have been manifestly extravagant to construct rain-water drains to carry off the record rainfall of 5 inches in an hour, Mr. Tickell.

Mr. Tickell. which might not recur for many years. During such a storm all the streets were flooded and water was everywhere flowing off the surface, and filling all drains and surface channels. The existing rain-water drains cleared the streets usually within an hour after a storm. The provision for rain-water in the sewers (six times the dry-weather flow) was an almost insignificant fraction of the rainfall, but it had so far proved to be somewhat in excess of the requirements; it might, however, be anticipated that, with the extension of house-connections, more rainwater would reach the sewers in future. The proper design for sanitary appliances for use by Orientals had been carefully considered, and a pamphlet on the subject prepared by Mr. Tickell had been published by the Ceylon Government to encourage their use in Colombo. The delay in making house-connections had been repeatedly brought before the Municipal Council, and it had been pointed out that the benefits of the expenditure were not being reaped in consequence. But the sanitary condition of every district had been immensely improved by the introduction of the public latrines connected with the sewers.

Mr. Lloyd-Davies. Mr. LLOYD-DAVIES, replying to the Discussion and Correspondence, stated, with reference to Professor Snape's remarks, that the sludge was allowed to remain in the lower chamber of the double-storey tank until complete digestion had been attained. The period required varied under different conditions, and seldom exceeded 4 months. It was not advisable to decant the sludge before putting the tank into operation again. The character of the sludge agreed with the description given by Mr. O'Shaughnessy: it was quite inodorous, very mobile, and did not attract flies. Referring to Mr. Midgley Taylor's and Mr. G. W. Humphreys's queries, the land on the Cape Flats would readily absorb the effluent from the purification-works, but it was not suitable, in Mr. Lloyd-Davies's opinion, for the treatment of crude sewage without nuisance, owing to the fineness of the sand. The major portion of the sewage from the unified area of Capetown was discharged into the sea at points outside the limits of Table Bay, where the prevailing conditions were fairly favourable. The conditions within the limits of Table Bay were unfavourable for the discharge of crude sewage, and there was no eligible site for a pumping-station and purification-works along its shores.

27 February, 1923.

WILLIAM HENRY MAW, LL.D., President, in the Chair.

The discussion on Main-Drainage and Sewage-Disposal Works was continued and concluded.