Mr. F. H. ALCOCK asked if Mr. Davis had found sulphuric acid with the naphthalene in the distillate? He would have thought it important to seek for other acids than picric. There might be present other things than naphthalene and picric acid. It might be advantageous to add a volatile agent to the spent oxide and then distil the naphthalene. Or the boiling point of the liquid containing the naphthalene might be raised by adding salt, shaking the distillate with ether, and then evaporating slowly. He did not agree that the detection in gas works spent oxide was of little importance, because if its vapour could be carried to the houses there would be a better illumination.

Dr. DAVIDSON replied that the vapour of naphthalene would afford no advantage. The boiling point was 218°C . The vapour tension at ordinary temperatures was so low that the gas could not carry 0.008% by volume; and that was only equivalent to the light of a small fraction of a candle-power.

Mr. DAVIS, in reply, said he did not think washing of spent oxide with picric acid would be effective in samples from the Williams process, because ammonia was present. Further there would be a loss of naphthalene before the process was finished owing to time required for washing.

Manchester Section.

Meeting held at the Grand Hotel, on Friday, November 6th, 1914.

MR. JULIUS HÜBNER IN THE CHAIR.

THE OXIDATION OF SEWAGE WITHOUT THE AID OF FILTERS. PART II.

BY EDWARD ARDERN, M.Sc., AND WILLIAM T. LOCKETT, M.Sc.

In a paper* presented to this Section of the Society in April last, a long series of experiments were described dealing with the application of aeration methods to the purification of sewage. It was shown that the accumulated deposit designated "activated sludge" resulting from the complete oxidation by prolonged aeration of successive quantities of sewage, had the property of increasing enormously the purification effected by simple aeration of sewage. The research, which was confined to laboratory experiments, included an investigation of the conditions controlling the oxidising effect of the activated sludge.

The present communication is concerned with outdoor experiments on similar lines to those previously undertaken in the laboratory but on a larger scale. The whole of the earlier experiments were carried out on the "fill and draw" method. Working in this manner with Manchester sewage, it was shown that a highly satisfactory effluent could be produced when the sewage, in intimate contact with one-fourth of its volume of activated sludge, was aerated for a period of from six to nine hours.

Under the conditions of experiment, however, it was necessary to subject the activated sludge to a further period of aeration in order to maintain its highest activity.

It was suggested in the previous paper that improved results might reasonably follow the adoption of a continuous system of working. The following trials were therefore undertaken.

Continuous system experiments.—For the purpose of these experiments a wooden rectangular aeration tank of 35 gallons capacity was employed, measuring 4 feet by one foot, the depth varying from 21 inches at the inlet end to 12 inches at the outlet. The aeration was effected through a series of perforated pipes placed at intervals of 4 inches and fixed latitudinally at a depth of 12 inches

from the surface. In order to ensure the complete admixture of the sludge and sewage, an additional perforated pipe was fixed at the inlet end along the centre of the base of the tank.

The effluent from the aeration tank passed forward to a sedimentation tank of similar dimensions, and means were provided for the removal of sludge from this tank with a minimum amount of disturbance.

The previous laboratory experiments worked on a "fill and draw" method, had shown that, in order to be certain of the complete nitrification of Manchester sewage, a period of from 10 to 18 hours aeration in contact with a certain proportion of activated sludge was necessary. Further, the maintenance of the activity of the sludge was apparently dependent on this complete nitrification. The first experiments on the continuous system were made with a rate of flow of sewage sufficient to fill the aeration tank in 24 hours, with the idea of ascertaining whether, under these conditions, a completely nitrified effluent could be maintained which would thus avoid the necessity for re-activation of the sludge removed from the sedimentation tank.

Examination of the effluents obtained by this manner of operation showed that such was not the case. The amount of ammonia present in the effluent increased as the experiment proceeded and eventually rendered it necessary to submit the sludge to a further period of aeration prior to re-circulation through the aeration tank.

As this further period of aeration of the sludge apparently could not be avoided, it was decided to increase the rate of flow of sewage so that a mean stay of six hours was obtained, a period which had previously been found sufficient to produce a satisfactory effluent when working on the "fill and draw" method. Working in this manner, it was of course necessary to make provision for the re-activation of the sludge employed. This was accomplished by introducing a separate aeration tank, in which the sludge received from the sedimentation tank was further aerated prior to passing forward to the aeration tank. Throughout the whole of this period the effluents obtained were non-putrefactive and contained varying amounts of nitrate, but the percentage purification effected did not compare with that obtained with a similar period of aeration when working on the "fill and draw" method. Moreover, there was a distinct increase in finely divided suspended matter and the effluents were imperfectly clarified.

Consideration of the possible reasons for this diminished purification, especially in view of the obvious mixing effect due to the admission of air, led to a study of the minimum period of stay in the tank of any portion of the incoming sewage. Such determinations made by replacing the sewage with a salt solution of known strength, showed that with a mean rate of flow of six hours, 3% of the incoming sewage would pass through the tank in less than twenty minutes, and 25% in under two hours. The decreased purification was thus largely accounted for, inasmuch as the sewage which passed through the tank with less than two hours aeration would retain in all probability, a proportion of its colloid matter.

It was thus apparent that satisfactory progress with this method of working was dependent on the design of a tank which without unreasonably increasing the mean rate of flow would allow a certain minimum period of aeration considerably beyond that given by the tank employed.

In the meantime, further experiments, to be described later, working on the "fill and draw" method had given such considerably improved effluents that the possible advantages of a continuous method of working were definitely minimised, especially in view of the fact, that in these latter experiments the manipulation of the activated sludge is obviated. Attention was therefore concentrated on further experiments working on the "fill and draw" method. The authors do not consider the results of the above continuous experiments conclusive, and they hope at a later date to return to this question.

Outdoor experiments on the "fill and draw" method.—In all the previous work the aeration of the sewage was

*This Journal, No. 10, Vol. XXXIII., pp. 523 to 539.

effected through plain tubes. During the progress of this investigation the authors had the advantage of noting the efficient distribution of air effected by means of porous tiles which were being used experimentally by Dr. Fowler and Mr. Mumford in connection with further work on the clarification of sewage by means of a specific organism. A similar method of air distribution was therefore employed in the following experiments.

For these experiments wooden casks of 50 gallons capacity were employed. The aeration was effected by diffusing the air through a porous tile placed on the bottom of the cask. In general the volume of activated sludge was equal to one-fifth of the capacity of the cask, and consequently when in operation the casks were filled with 10 gallons of sludge and 40 gallons of crude sewage. Preliminary trials showed that an average period of six hours aeration was sufficient to produce effluents of remarkable purity, as will be seen from the following table of analytical results, nitrification in the majority of cases being entirely completed.

TABLE I.
Oxidation of Manchester sewage.

Results in parts per 100,000.

	Raw sewage.	Effluent after 6 hours' aeration.	Purification.
4 hours' oxygen absorption	10.90	1.10	90%
Free and saline ammonia ..	3.66	0.43	—
Albuminoid ammonia	1.12	0.085	92%
Nitrite } In terms	—	0.10	—
Nitrate } of NH_3	—	1.79	—
Absorption of dissolved oxygen 5 days at 65° Fah. Royal Commission test ..	—	1.00	—

Note.—Proportion of activated sludge to sewage 1:4. Temperature varied from 15° to 22° C.

Comparison of these results with those obtained when plain pipe aeration was employed, showed at once the beneficial effect of diffused air.

The following experiments relating to the rate of oxygenation of sewage by the use of (a) plain tubes, (b) porous tiles, offer a reasonable explanation of the improvement.

period, (b) 1½ hours settlement, (c) ¼ hour discharge of effluent, and thus each cask received 3 fillings of crude sewage per day, and dealt with a total volume of 240 gallons per day.

As the experiment proceeded it was noted that nitrification of the weaker morning sewage was completed before the end of the six hour aeration period and subsequently the cycle was modified so that the morning sewage was aerated for a period of 4 hours only.

In Table III. are given the average results obtained over a considerable period.

TABLE III.
Oxidation of Manchester sewage.

Results in parts per 100,000.

	Raw sewage.	Effluent after 6 hours' aeration.	Purification.
4 hours oxygen absorption	10.22	0.86	92%
Free and saline ammonia ..	3.56	0.32	—
Albuminoid ammonia	1.03	0.08	92%
Nitrite } Interm. of NH_3	—	0.06	—
Nitrate }	—	1.87	—
Absorption of dissolved oxygen 5 days at 65° Fah. (Royal Commission test)	—	0.80	—

Note.—Proportion of activated sludge to sewage 1:4. Temperature varied from 16° to 22° C.

TABLE IV.
Oxidation of Manchester Sewage.

Results in parts per 100,000.

	Raw sewage.	Effluent after 4 hours' aeration.	Purification.
4 hours oxygen absorption	10.23	1.03	90%
Free and saline ammonia ..	3.46	0.21	—
Albuminoid ammonia	0.99	0.10	90%
Nitrite } Interm. of NH_3	—	0.07	—
Nitrate }	—	1.60	—

Note.—Proportion of activated sludge to sewage varied from 1:4 to 1:3. Temperature 15°–20° C.

TABLE II.
Rate of oxygenation of raw sewage.

Results in parts per 100,000.

Time.	Excess of air used. Strong sewage.		Average amount of air used. Dilute sewage.		Minimum amount of air used Dilute sewage.	
	Aeration effected by:—		Aeration effected by:—		Aeration effected by:—	
	Plain tube.	Diffuser.	Plain tube.	Diffuser.	Plain tube.	Diffuser.
			Dissolved oxygen content.			
At commencement	.06	.06	.24	.24	.23	.23
After 5 minutes aeration	.23	.53	—	—	.21	.20
" 10 " "	.42	.63	—	—	.26	.46
" 15 " "	.49	.62	.42	.73	.23	.50
" 30 " "	.56	.66	.40	.74	.22	.59
" 45 " "	.56	.64	.56	.76	.22	.66
" 60 " "	—	—	.57	.77	.09	.56
" 90 " "	.57	.63	.63	.79	—	—

In the light of our earlier investigations, it appeared likely from the high degree of nitrification obtained in these preliminary experiments, that the activity of the sludge would be maintained without intermediate aeration of the sludge alone. The two casks were therefore operated according to the following cycle:—(a) 6 hours aeration

In view of these excellent results the period of aeration was further reduced to 4 hours, the casks consequently received 4 fillings per day and dealt with a total of 320 gallons of crude sewage daily.

The results obtained when working in this manner are recorded in Table IV.

The percentage purification was only slightly affected by the reduction of the aeration period from six to four hours.

The effluents obtained throughout this series of experiments were extremely well clarified and in general were superior to those yielded by the best type of bacterial filters.

The outstanding feature of these results is the fact that by employing diffused air the necessity for intermediate aeration and consequent manipulation of sludge was entirely removed and at the same time much better effluents were obtained than those yielded by plain pipe aeration when working with a similar aeration period.

The effluents obtained in the earlier laboratory experiments, when working with a six hours plain pipe aeration period, were liable to absorb an undue proportion of dissolved oxygen, as compared with that absorbed from acid permanganate of potash. It is therefore highly satisfactory to note that in the series of outdoor experiments under observation, the dissolved oxygen absorption of the effluents was remarkably low. This low dissolved oxygen absorption being coincident with a very low free ammonia content, appears to support the theory previously advanced, that the stage to which nitrification has proceeded is not without influence on the amount of dissolved oxygen absorbed.

General remarks. The earlier experiments showed that the question of temperature influenced the oxidation process. The above results were obtained during the summer with entirely favourable temperatures. It is scarcely to be expected that such a high rate of nitrification would be maintained throughout the winter months without the necessity arising of increasing the temperature of the sewage a few degrees, by the use of warm air or by other means.

During the earlier experiments it was occasionally necessary to increase slightly the alkalinity of the sewage dealt with, in order that nitrification should proceed without hindrance. Throughout the present out-door experiments, when working with 20 to 25% by volume of activated sludge no difficulty has arisen in this respect. The alkalinity or basicity of the sewage and sludge has always been sufficient to allow complete nitrification.

The opinion expressed on a previous occasion in regard to the possible retarding effect of abnormal quantities of bacterially inhibitory trade effluents, such as may be present, from time to time, in Manchester sewage, has been confirmed by wider experience in regard to the working of this oxidation process. As an example of this action, it may be mentioned that on September 6th a sample of sewage was dealt with, the 4 hours oxygen absorption of which was as high as 38.4 parts per 100,000, as compared with the usual average of from 8 to 13 parts per 100,000. This high oxygen absorption figure was caused by an undue proportion of tar compounds.

The effect of four hours aeration of this sewage in contact with the usual proportion of activated sludge was to produce an effluent whose oxygen absorption was 3.1 parts per 100,000, showing a purification of 92% on the original sewage. As might be expected, however, this abnormal sample of sewage exerted subsequently a deleterious effect on the activity of the sludge, more particularly in regard to the nitrification change. By increasing the aeration period to six hours over a period of a week, the sludge practically regained its original activity. In another instance more difficulty was experienced in re-establishing active nitrification.

Experience with this method of sewage purification has clearly indicated the necessity for adequate scientific control in order that the oxidation process may be maintained at its highest efficiency. The complete success of the process is dependent upon the maintenance of the activity of the nitrifying organisms, which, unless thoroughly established, are very susceptible to adverse conditions.

The difficulties previously mentioned concerning the maintenance of the activity of the sludge should not arise when dealing with domestic sewage, but where Manchester sewage or a strong trade sewage of similar

character is concerned, it is obvious that careful attention will have to be paid to the varying nature of the sewage treated, with special reference to the presence of abnormal quantities of inhibitory trade effluents.

On the average, the amount of air used in the cask experiments described previously, has not exceeded 15 cubic feet of free air per square foot of tank area per hour. Special attention is being devoted to the question of the minimum air supply essential to the proper working of the oxidation process.

The important question of accelerating the rate of initial accumulation of activated sludge is also being closely investigated. Slurry obtained from percolating filters has been found useful in this respect. Experiments are also in progress to determine the most economical proportion of sludge to be employed.

The outdoor experiments described in this communication, are at present being translated on to the working scale by the use of a tank of 20,000 gallons capacity. On the basis of the cask experiments, it should eventually be possible to deal with 60,000 gallons of sewage per day in this tank, the area of which is 400 square feet.

For the present the authors do not propose to refer to the question of cost other than to say that the results which have been described show such a marked advance on those hitherto obtained, as to add great force to the remarks made in the previous paper, in regard to the practical application of this method of sewage purification.

In conclusion, the authors have again to express their sincere thanks to Dr. Fowler for his continued interest in this research, and they wish to place on record their appreciation of his invaluable enthusiasm in regard to the progress of the experimental work.

The authors' thanks are also due to the Worshipful Company of Grocers for facilitating the progress of this research, by the election of one of them to a Research Scholarship.

They are indebted to the Rivers Committee of the Manchester Corporation, for permission to publish these further results of their investigations, which have been carried out at the Corporation Sewage Works, Davyhulme.

THE PURIFICATION OF SALFORD SEWAGE ALONG THE LINES OF THE MANCHESTER EXPERIMENTS.

BY S. E. MELLING, F.I.C.

Prior to the reading of the paper on the oxidation of sewage without the aid of filters by Arden and Lockett (see this J., 1914, 33, 523), I had, through the courtesy of Dr. Fowler, seen certain work carried out at Davyhulme upon raw sewage with activated sewage-sludge, under laboratory conditions.

At that time, these gentlemen, having already built up a reserve of the activated sludge to establish finally the principles of its action upon sewage under aerobic conditions—details of which were embodied in their paper and have been subsequently elaborated—were considering ways and means of translating the experiments on to a much larger scale.

As an official closely concerned with the problem of sewage disposal in the neighbouring Borough of Salford, it appeared to me very desirable to make some out-of-doors investigation along similar lines, particularly since we were fortunately situated in regard to the requisite air supply for extensive experiments.

Whatever measure of success has been met with in so far as clarification and purification are concerned, it must be made very clear at the outset that the all-important question of cost has not yet been shown. The results which have so far been obtained are such as to warrant an extension of the work, and we look forward with confidence to the time when this method shall reveal itself as altogether rational for the treatment of sewage.

A few words are necessary here in explanation of the plant which the Rivers Committee of the Salford Corporation placed at the disposal of Mr. W. H. Duckworth, the Manager of the works, and myself for the work.

The method of treatment at Salford is chemical precipitation of the screened sewage (lime and iron salts)