

Preliminary Note on the Purification of Water by Activated Silt.

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The organic impurities commonly met with in water are of three kinds insoluble suspended matters either 'particulate' or 'colloidal' and substances in true solution.

The first two kinds can be removed either by plain settlement in tanks or by coagulation with alum followed by settlement or filtration, but neither of these methods as commonly carried out affects the matters in solution.

In cases where there is heavy pollution with organic matter these substances in solution may be of an offensive character, even though present in small amount, and what is possibly of greater importance they are apt to lead to an undue consumption of chlorine and the production of unpleasant tastes if this reagent is used for the purpose of finally sterilising the water.

In such cases therefore some process of oxidation of the dissolved impurities is called for.

This has been attempted in the so-called "filtres non-submergés" used some years ago in France in which the water is sprayed over the filtering medium and purified much in the same way as sewage is purified on trickling filters.

Experience in connection with modern high speed water works filters has indicated the importance of periodical aeration of the filter material.

Aeration of course plays its part in the self purification of rivers and streams, but the conditions of efficiency of this self purification are by no means as yet fully understood.

During the summer of 1918 the senior author of this note visited China in order to report on the water supply and sewage disposal problems of Shanghai and Hankow. In the course of this work he was struck by the fact that although practically the whole of China is manured with nightsoil and intersected by creeks so that much impurity must reach the Yangtze and its tributaries, the Han and the Whangpoo, yet apart from the presence of nitrates and of organisms of the coli group, these rivers as a whole and apart from special localities could not be described

as being seriously contaminated. The pollution to which they were obviously subjected appeared to be very rapidly oxidised.

The reason for this was to be found it seemed in the large amount of fine silt carried by these rivers, each particle of silt acting as a nidus for the necessary bacteria.

On examination the silt of these rivers as found in the Whangpoo and deposited in the tanks at the Shanghai Water Works is mostly of a very fine micaceous nature, which hangs suspended in the water for a considerable time.

A similar power of self purification is also to be observed in certain Indian silt bearing rivers notably the Ganges.

It seemed possible that this natural action of silt-laden rivers might be imitated artificially and the dissolved impurities in water oxidised by a process analogous to the "activated sludge" process for purifying sewage, only that in the case of water 'activated silt' carrying a minimum quantity of organic matter would be used.

Consequently a sample of silt from the Whangpoo collected in the tanks at the Shanghai water works was brought back to Bangalore to serve as experimental material.

Silt was also obtained from the water works at Calcutta and at Cawnpore through the courtesy of the engineers in charge.

These silts were mechanically analysed by the method given by Russell in "Soil Conditions and Plant Growth" p. 220-222.

Analyses of Silt. The comparative results, which are somewhat approximate were as follows:—

	Cawnpore.	Calcutta.		Shanghai.
		I	II	
Moisture ...	1.7	2.6	2.3	1.9
Mineral matter soluble in acids.	3.0	9.9	6.7	7.8
Coarse sand ...	.6	1.9	...	.7
Clay ...	12.0	.2	2.5	5.2
Fine sand ...	1.4	50.0	62.9	30.0
Coarse silt ...	40.0	23.0	13.7	27.5
Fine silt ...	39.0	12.3	6.5	24.2

The fractions are defined according to the diameter of their particles thus:—

Coarse sand	...	0.2—1.0 mm.
Fine sand	...	0.037 mm.
Silt	...	0.012 „
Fine silt	...	0.012 to 0.0013 mm.
Clay	...	0.0013 „

In the case of the Shanghai silt from the Whangpoo the fine sand, silt and fine silt were found to consist of mica particles, nearly 80% of the total material was thus composed of mica.

In the Calcutta silt a number of fragments of oyster shell were found which would account for the high percentage of mineral matter soluble in acid.

The nitrogen figures determined by the Kjeldahl method which are indicative of the polluting matter present were as follows calculated on the dried silt:—

Cawnpore	...	...	0.27
Calcutta	...	...	0.67
Shanghai	...	...	0.84

Preparation of Activated Silt.

In order to investigate the purifying action of this silt a portion was made into a thin paste with water and 200 cc of this paste were mixed with three times this amount of water and transferred to a bottle connected with a filter pump by means of which air could be bubbled through the mixture.

The endeavour was made to induce a growth of nitrifying organisms upon the silt by adding some sewage effluent containing nitrifying organisms together with the saline constituents of Winogradski solution to assist their development.

Winogradski solution has the following composition:—

Potassium hydrogen phosphate	...	1.0 gm.
Manganese sulphate	...	0.5 „
Sodium chloride	...	2.0 „
Calcium chloride	...	traces
Water	...	1000 cc

To this solution salts of ammonia or any other nitrifiable substance may be added together with the necessary bacteria, or on the other hand the saline constituents may be added to the

solution already containing nitrogenous matter and nitrifying organisms.

A number of preliminary experiments were made with encouraging results and the following, which was pushed to completion may be quoted in full.

10 grams of dry silt were rubbed down with water and mixed with 600 cc of a sewage filter effluent containing nitrifying organisms together with 400 cc of water. The corresponding Winogradski salts were added together with ammonium sulphate sufficient in amount to bring up the saline ammonia figure to 10 parts per 100,000. Air was then bubbled through the mixtures and the ammoniacal and nitrous nitrogen determined colorimetrically day by day. In 17 days (January 21st to February 7th 1919) the whole of the ammonia as well as the nitrous nitrogen had disappeared.

<i>Date.</i>	<i>Ammoniacal Nitrogen.</i>	<i>Nitrous Nitrogen.</i>
21st Jan.	10.0	0.02
22 "	8.0	0.12
23 "	5.0	0.10
24 "	3.5	0.15
25 "	3.5	0.16
27 "	3.0	0.7
28 "	3.0	0.9
29 "	2.5	1.4
30 "	2.0	1.7
31 "	1.6	1.8
1st Feb.	0.9	2.8
3rd "	0.5	4.0
4 "	0.2	3.2
6 "	0.1	nil
7th "	less than 0.1	nil

From the daily results given in the table it will be seen that the ammonia disappears more quickly than the nitrous nitrogen made its appearance thus indicating the intermediate formation of hydroxylamine as observed by Beesley. (J. Chem Soc. Trans. 1914, p. 1014). Having thus established a growth of nitrifying organisms on the silt it was necessary to work with concentrations of ammonia more likely to be found in polluted water than in sewage.

A mixture of sewage effluent and tap water was therefore made having an ammoniacal nitrogen figure of about 0.1

part per 100,000 which of course is still high even for seriously contaminated water.

This mixture was then aerated with what may now be considered at any rate partially "activated" silt with the following results:—

Date.	Time.	Treated for hours.	Ammonia.	% purification.	Remarks.
13th Feb.	11-45 a. m.	...	0.1	...	3% solution of the effluent from filter beds
do	3-45 p. m.	4	0.08	20	
14th	11-45 a. m.	24	0.01	90	
17th	11-35 a. m.	96	nil	...	New solution.
17th	11-45 a. m.	...	0.08	...	
18th	11 a. m.	about 24	0.008	90	Fresh solution.
18th	11 a. m.	...	0.07	...	
18th	4 p. m.	5	0.05	28.5	
19th	11 a. m.	24	0.008	88.5	

It will be seen that in 24 hours nearly 90% of the ammonia was oxidised.

The experiment was continued, further quantities of polluted water being added from time to time. In addition to the ammonia the oxygen absorbed from permanganate was also determined, a one hour period being taken for convenience instead of the usual "4 hours test." Before applying the permanganate test any nitrites present were destroyed by the addition of urea and dilute sulphuric acid.

The following tables indicate the character of the results obtained:—

Date and time.	Treated for hrs.	Ammonia.	Purification.
21st Feb. 12 noon.	..	1.0	...
22nd	24	0.56	44%
25th	72	0.04	96%
25th	96	0.08	97%
26th	120	0.02	98%
Fresh solution.			
27th noon	...	0.5	...
27th	4	0.4	20%
1st March	72	0.02	96%

Time and date.	Treated for hrs.	Ammonia.	Purification.	Oxygen absorption in 1 hour.	Purification.
Fresh solution.					
3rd March noon.	...	0.20	...	0.20	...
2-30 p. m.	2½	0.11	45%	0.16	20%
Fresh solution.					
4th 10-30 a. m.	...	0.25	...	0.26	...
2-30 p. m.	4	0.14	44%	0.20	23%
4-30 "	6	0.10	60%	...	...
5th 10-30 a. m.	24	0.025	90%	0.13	50%
Fresh solution.					
5th 10-30 a. m.	...	0.25	...	0.26	...
12-30 p. m.	2	0.18	28%	0.20	23%
2-40 p. m.	4	0.15	40%	0.13	50%
4-30 p. m.	6	0.08	68%	...	...
6th 10-30 a. m.	24	0.03	90%	...	...
Fresh solution.					
6th 10-30 a. m.	...	0.2	...	0.32	...
12-30 p. m.	2	0.14	30%	0.24	25%
2-30 p. m.	4	0.10	50%	0.19	41%
4-30 p. m.	6	0.05	60%	...	...
7th 10-30 a. m.	24	0.02	90%	0.1	68%
Fresh solution.					
7th 10-30 a. m.	...	0.15	...	0.28	...
12-30 p. m.	2	0.09	40%	0.22	22%
2-30 p. m.	4	0.06	60%	0.16	57%
4-30 p. m.	6	0.04	74%	...	...

It is evident that an activated silt is being built up capable in 6 hours aeration of removing 75% of the ammoniacal nitrogen and 60% of the oxygen consuming power. In order to see how far aeration in this way is efficient in removing impurities untouched by the usual methods of coagulation with salts of alumina the following experiments were tried :—

200 cc of filter bed effluent was added to 3 litres of water.

One litre *A* of the mixture was analysed without treatment.

One litre *B* was treated with 4 parts sulphate of alumina per 100,000 and after complete settlement was filtered through paper and analysed, the third litre *C* was aerated with activated silt for 5 hours, allowed to settle over night, treated with 4 parts per 100,000 of sulphate of alumina, filtered through paper and analysed.

The following results were obtained:—

	Free and saline ammonia.	Purification.	Albuminoid ammonia.	Purification.	Oxygen absorbed in one hour.	Purification.
A.	0.19	—	0.12	—	0.1	—
B.	0.148	22%	0.015	20%	0.06	40%
C.	0.10	53%	0.01	50%	0.04	60%

A second experiment with a fresh lot of sewage effluent gave the following results:—

A.	0.255	—	0.030	—	0.145	—
B.	0.138	22%	0.0156	48%	0.08	44%
C.	0.09	65%	0.0099	67%	0.05	65.5%

It is thus seen that the process of aeration with activated silt increases the percentage purification by 30—40% in the case of free and saline ammonia, 20—30% in the case of the albuminoid ammonia and about 20 per cent in the case of absorbed oxygen. In the foregoing experiment the mixture of the water and silt was not perfect, some of the silt depositing in the corners of the bottle and remaining unmovable.

In consequence a large separating cylinder was made use of, the air inlet tube reaching down to the narrow portion of the cylinder just above the tap. Under these circumstances all the silt was kept thoroughly mixed with the liquid and distinctly better results were obtained more than 40% of the ammonia being oxidised, and 32% of the oxygen absorbed figure being reduced in 2 hours aeration.

Date and time.	Tested for hrs.	Ammonia.	Purification.	Oxygen absorbed in 1 hour.	Purification.
12th 11 a. m.	...	0.20	...	0.24	..
" 1 p. m.	2	0.16	40%	0.18	25%
" 3 "	4	0.076	62%	0.12	50%
" 4 "	5	0.06	70%	...	...
Fresh solution.					
13th Noon.	..	0.28	...	0.33	..
" 2 p. m.	2	0.10	43%	0.28	30
" 4 p. m.	1	0.098	65%	0.15	54%
14th 10 a. m.	22	0.035	91%	..	...
" noon.	..	0.14	...	0.18	...
" 2 p. m.	2	0.08	43%	0.12	32%
" 4 "	4	0.04	71%	...	...

In the foregoing experiments Whangpoo silt was chiefly used. Other experiments were made with silt from the Ganges at Cawnpore with similar results.

Some difficulty was experienced owing to loss of silt every time a sample was drawn out for analysis but in large scale practice this would easily be avoided, as the silt could be returned after settlement to the aeration tank and also fresh activated silt would constantly be brought in with the raw water the operations being analogous to the purification of sewage by activated sludge.

It is quite evident at any rate that the soluble impurities in water can be oxidised and removed in this way, but a good deal of further experiment is required to determine the most efficient and economical method of conducting the process especially with water containing less impurity than the artificially polluted samples employed.

There are obviously certain precautions which will have to be observed in dealing with potable water which are of minor importance in a sewage purification works. It may well be that an accumulation of activated silt above a certain critical proportion may actually tend to pollute, bacteriologically at any rate, a water of high quality, and this will require careful observation, just as a filter requires careful attention lest the limit when it acts as a purifying agent be over stepped and the impurities retained by the filter tend to pollute the incoming water.

Besides suggesting possible improvements in the technique of water purification the above observations have a bearing on the effect of the discharge of sewage into rivers and estuaries.

The possibility that discharges of sewage may affect the rate of deposition of silt has been hinted at in a paper by Dr. Chatley* of the Engineering Department, Whangpoo Conservancy Board. It was found in the course of the experiments described in the present paper that the silt which had been aerated with polluted water for some time tended to settle more rapidly than fresh silt and further experiments fully confirmed this observation.

Small quantities of effluent (about one per cent by volume) from the sewage filters were added to jars of water containing suspensions of silt from the Ganges at Cawnpore and the Hoogly at Calcutta, controls being kept without the effluents.

Every day an equal amount of fresh effluent was added and the whole stirred up and allowed to settle. For the first two

* "Some Problems on Silt" by Herbert Chatley, D. Sc., The Engineering Society of China, 1918-19, paper No. 5, Vol. XVII, page 15.

days there was little, if any, change. After two days however the silt in the water with the effluents began to settle more quickly than in the blanks. In a week it settled within two hours as against at least 36 hours in the controls.

The same phenomena occurred to an even greater extent when septic tank effluent was used as a polluting agent instead of filtered effluent, although it was thought possible that the colloids in the septic tank effluent would tend to hold the silt in suspension.

The effect of aeration was to accelerate this change and it was observed that after continuous use with successive additions of polluted water, the silt from being yellowish or light brown in colour and remaining suspended in water for a considerable time, became much darker in colour and settled very quickly. Microscopic examination showed that the used silt had become converted into dark granules quite different from the original light semi crystalline particles.

This would indicate that as it reaches the limit of usefulness for purification it will be less readily mixed with the water in the aeration tank, and on the other hand it is evident that a continual addition even of small quantities of sewage to a silt laden river or estuary will have a great influence on the rapidity of deposition of the silt and the consequent tendency to shoal formation.

In such a case mere absence of visible nuisance is no criterion of the actual effect of such discharge upon the river.

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