XXIV. ON THE IMPORTANCE OF GEOLOGICAL FACTORS IN SEWAGE PURIFICATION.

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(Received July 10th, 1918.)

A GREAT deal of work both from the scientific and the practical points of view has been carried out in connection with the biochemistry of sewage-purification by Letts and Adeney and other investigators for the Royal Commission on Sewage Disposal [1908, p. 5].

It is unnecessary to summarise the results of their work fully, but it may be briefly said that the investigations were concerned first, with studying the nature and course of the complex biochemical processes that go on when organic matter is decomposed by bacterial action, and the influence of various physical conditions thereon, and second, with elaborating and standardising the dissolved oxygen absorption test, commonly called the Rideal-Stewart test, in order to make this test of value in forming an opinion of the quality of a sewage effluent.

The majority of biochemists are now convinced that, although this test takes five days to complete when properly carried out, yet it yields most valuable results; and, as the bacterial processes involved are natural processes going on in river and other waters, it is to be preferred to the various other determinations often used in the standardisation of effluents, *e.g.* albuminoid ammonia, organic nitrogen, oxygen absorbed from permanganate, which are purely arbitrary and artificial and have no relation to the biological aspect of the question. The dissolved oxygen absorption test consists in measuring the amount of oxygen used up in a given period in the bacterial oxidation of the organic matter contained in the sewage effluent. According to Adeney this measures the amount of readily oxidisable carbonaceous matter present in the effluent, very little or no ammonia being oxidised during the five days' period usually given. As it is the quickly fermentable organic matter that will seriously pollute and deoxygenate a river-water, the value of this test is at once evident.

In standardising the dissolved oxygen absorption test the influence of various factors, *e.g.*, time, temperature, dilution, was investigated by the Commissioners [1913, p. 93], and it was recommended that the test should be carried

out for five days at 18° C. The period of five days was chosen, because it appeared that sometimes there was an initial inhibition of the bacterial processes, so that low results might be obtained if shorter periods were employed, and the test would then be too lenient. The standard temperature of 18° C. was selected because it was found to be unusual for river waters in this country to exceed it.

The dilution chosen was 1 in 5, as this was a convenient dilution, and it was found that up to 1 in 5, dilution had little effect on the rate of absorption of dissolved oxygen. The method of analysis is fully given.

Although this test has been worked out in some detail the question as to whether the rate of biological oxidation of the organic matter is affected by the geological source and mineralogical constituents of the water used for dilution of the effluent has not apparently been sufficiently studied. The Commissioners [1913, p. 93] recommend that good tap-water should be employed, but it is obviously difficult to define this expression. In an addendum to another report [1908, p. 433] however it is pointed out that the results may depend on the nature of the diluting water, but examples are not given, except in the case of sea-water, which, although it has no measurable effect on the carbonaceous oxidation and production of nitrite from ammonia, yet was found to prevent nitrification most effectively. Fowler [1912] also states that in the case of a sewage effluent discharged into a river-water, nitrification was prevented by calcium chloride that was discharged into the same river from an ammonia-soda factory.

The importance of geological factors was suggested by some accidental observations at this laboratory. There being two separate water-supplies laid on, the question arose as to which should be employed for dilution of the effluents in carrying out the dissolved oxygen absorption test. One water was hard and calcareous, pumped up from the upper chalk, covered in the particular district by a considerable thickness of tertiary strata (Reading beds, London Clay and Bagshot Sands). The other water was a soft ferruginous upland surface water from the gravels and underlying upper Bagshot Sands, being thrown out by the clayey Bracklesham beds underneath.

*The influence of various waters on the rate of dissolved oxygen absorption
by sewage effluents.*

In the experiments detailed below effluents were diluted with different waters, distilled water, tap waters, and stream waters. The samples of the latter were always taken from the streams into which the effluents were being

discharged. For each set of experiments the conditions were kept constant throughout: dilution, temperature, volume, and period of incubation.

The experimental method consisted in incubating the aerated dilutions of the effluents in well-stoppered bottles for five days at 18° C. and estimating the concentration of dissolved oxygen left at the end of this period. The initial concentration of oxygen was determined by a separate test, and by difference the amount of oxygen absorbed or used up in the oxidation of the organic matter could be calculated.

A large number of experiments on these lines have been carried out over a period of a year. In order to economise space, however, only a few typical results are tabulated in this paper.

The main points emerging from the work are as follows.

I. PRACTICAL.

The Standardisation of Sewage Effluents.

1. The dissolved oxygen absorption figure (five days) for a sewage effluent diluted with hard tap-water (derived from the chalk) was only from one-twentieth to one-half the figure obtained for the same effluent diluted with distilled water, or stream water taken from the stream into which the effluent was discharged.

The following results illustrate this:

Dissolved oxygen absorbed by 100,000 parts of effluent. Dilution made with		
(1) Distilled water	(2) Hard water	(3) Stream water
2.15	0.45	—
1.25	0.17	0.45
8.1	0.46	4.2

2. The dissolved oxygen absorption figure (five days) for an effluent may be considerably lower when the effluent is diluted with stream water than when diluted with distilled water.

Dissolved oxygen absorbed by 100,000 parts of effluent. Dilution made with	
(1) Distilled water	(2) Stream water
1.25	0.45
2.36	1.20
8.1	4.2

In examples 1 and 2 the stream water was taken from a stream flowing over the Hythe and the Folkestone beds, and in example 3, from a river in the Bagshot Sands, receiving hard surface drainage water and sewage from a town.

3. The dissolved oxygen absorption figure (five days) of an effluent was somewhat lower, about 20 %, when dilution was made with a ferruginous peaty tap-water (upland surface supply) from gravel and upper Bagshot Sands than when made with distilled water.

4. The biological oxidation of sewage was almost entirely stopped for forty-eight hours by dilution with a very ferruginous water from the Folkestone beds (iron content of water: 2.5 parts per 100,000). No inhibition, however, at all was noticed after five days. There was no initial inhibition when the iron had been previously removed from the water by means of a Candy-filter.

The following results illustrate this:

	Dissolved oxygen absorbed by 100,000 parts of effluent.	
	48 hours	5 days
Dilution with distilled water	0.92	2.16
„ „ ferruginous water	0.08	2.10
„ „ filtered ferruginous water	0.92	2.06

The addition of soil taken from the ferruginous strata (iron content: 10 %) near the junction of the Hythe and Folkestone beds also inhibited the biological oxidation of sewage.

It is evident therefore that the results obtained with waters of different geological source are most divergent, and it is essential for the routine examination of sewage effluents that a fixed standard be adopted; otherwise the results may vary considerably according to the laboratory in which the effluents are examined and the tap-water employed. At first it might be thought that distilled water should always be used as a diluting medium in the standardisation of effluents, because it is independent of geological conditions and the only factors involved are the organic matter and mineralogical constituents of the sewage itself. The chief purpose however of standardising a sewage effluent is to ascertain whether the effluent is likely to exert a serious polluting effect on the stream or river into which it is being discharged. It is therefore necessary that the experimental conditions should approximate as closely as possible to the natural conditions. It seems reasonable therefore to use the river or stream water as the diluting medium, the sample of water being of course collected well above the point at which the effluent is discharged. It may be expected that different results will be obtained by using different river waters, but if for each effluent to be examined the diluting water is always taken from the river or stream into which the particular effluent enters, consistent results will be obtained, and the test will be carried out under

well standardised conditions. If the river water is taken as the standard diluting medium, the use of hard tap-water or a strongly ferruginous water will clearly make the oxygen test far too lenient. On the other hand, the use of distilled water may render the test somewhat severe, and thus cause effluents to be condemned that would not in reality seriously pollute the water-way.

It is further suggested that in the routine examination of sewage effluents more attention should be given to the conditions of the river or stream below the point of discharge. As a check on the effluent test, it is desirable to determine regularly the dissolved oxygen absorption figure for the undiluted water collected from the river or stream well below the point of pollution, care being taken to ensure that the sample is taken where the effluent and river water are thoroughly mixed.

According to the report of the Sewage Commission [1913, p. 132] the dissolved oxygen absorption figures of waters unpolluted by sewage were always well below 0.4 part of oxygen per 100,000, and, if this limit were exceeded owing to the sewage pollution, conditions were likely to become offensive. It was recommended therefore that sewage purification should be sufficient to prevent an effluent from being of so bad a quality, that the Rideal-Stewart figure of the stream water below the point of pollution exceeded 0.4 part oxygen per 100,000. For average dilution this would mean that the Rideal-Stewart figure for an effluent should not exceed 2.0. This standard however is adaptable to conditions; if the stream were very small, a more stringent standard would have to be adopted; while in the case of a large river, considerable latitude could be given. During the past year many laboratory and field observations have been made in the case of numerous streams in Surrey and Hampshire, chiefly tributaries of the river Wey. As the result of these observations it has been possible to confirm the conclusion that for unpolluted waters the dissolved oxygen absorption figure does not exceed 0.4, and that where effluents are discharged into water-ways, in order to avoid nuisance, the effluents should be of such quality that the streams are kept well within the above limit.

2. THEORETICAL.

So far only the practical question of standardisation of effluents has been considered. We have also to enquire into the cause of the marked inhibitory effects described in the previous section. As already stated the hard tap-waters that were found to inhibit the biological oxidation of sewage were municipal water supplies obtained from borings in the chalk, which was covered in the particular districts by the Woolwich and Reading beds, London Clay and

Bagshot Sands. The waters contained a considerable amount of calcium bicarbonate and calcium sulphate (total hardness 24.0, permanent hardness 6.5, temporary hardness 17.5). Magnesium however was found to be absent. When the hard water was deprived of all calcium carbonate by boiling and filtering, it no longer exerted an inhibitory action on the processes of biological oxidation. This was taken as presumptive evidence that the inhibitory factor was calcium bicarbonate. If this were the case, it was thought that the addition of solid calcium carbonate should also inhibit the oxidation of a sewage effluent, as there should be sufficient carbon dioxide present to form soluble calcium bicarbonate. Preliminary experiments however showed that the biological oxidation was apparently accelerated by the addition of calcium carbonate. This was not due to impurities in the latter, as by itself it did not use up any dissolved oxygen. It was noticed however that when chalk was added to a sewage effluent, the initial titrations came out about 40 % lower, *i.e.*, there was an apparent loss of dissolved oxygen in the short time (thirty minutes) occupied in the estimations. It was ascertained by syphoning the liquid free from chalk before titration, that various chalks, *e.g.*, pure calcium carbonate, chalk from Upper, Middle and Lower Chalk Formations, and also chalk marls, did not adsorb dissolved oxygen from aqueous solution, and that accurate results were always obtained if care were taken to remove the chalk by syphoning off the supernatant liquid before estimating the concentrations of dissolved oxygen. It would appear that when the chalk was not removed before the titrations some of the dissolved oxygen was carried out of solution mechanically during the effervescence due to the CO_2 liberated by the action of the sulphuric acid added upon the chalk.

Subsequent experiments in which the precaution of removing the chalk before the commencement of the estimation of the dissolved oxygen was always taken showed that the addition of calcium carbonate had practically no effect on the rate of biological oxidation of sewage. The addition of magnesium carbonate had however a very pronounced inhibitory effect. There being no magnesium present in the hard waters used in the experiments described above, nothing definite can thus be said at present as to why these hard waters when added to sewage so strongly inhibited the processes of biological oxidation; and further work must be carried out on this subject.

In the case of ferruginous water from the Folkestone beds which was found to inhibit temporarily the oxidation processes, it is probable that the inhibitory factor was ferrous carbonate, which is known to be present in such waters, and to have a toxic effect on organisms.

MAIN CONCLUSIONS.

The work so far described is only of a preliminary nature, but is sufficiently advanced to show that in the dissolved oxygen absorption test for the standardisation of a sewage effluent, in order to obtain reliable results, it is important to employ, as a medium for diluting the sewage effluent, water collected from the river or stream into which the effluent is discharged, instead of the laboratory tap-water which is commonly used.

It is further recommended that, as a check in routine work, the river or stream water below the point of pollution be regularly tested, in order to ascertain if its dissolved oxygen absorption figure be below or above the limit of 0.4 part per 100,000.

It is too early yet to define the precise conditions and the extent to which geological factors may influence the processes of sewage purification. The results given in this paper have been obtained in connection with experimental work on sewage effluents in a restricted area, where the tap-water was yielded by sedimentary rocks of a simple kind—chalk, gravel, and sands. These results however suggest that, under different geological conditions, waters from other sedimentary rocks, and also waters associated with the detritus of eruptive rocks, where the active chemical constituents have been or are released may be expected to affect profoundly the biological processes of oxidation.

The practical biochemical work of this investigation has been carried out by one of us (E. A. C.) at the Hygienic Laboratory, School of Army Sanitation, Aldershot, while the geological aspect of the subject has been worked out by A. E. C.

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