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RECENT ADVANCES IN BIOLOGICAL METHODS OF SEWAGE TREATMENT

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Present-day agitation by conservationists for sewage treatment has met with considerable opposition both from tax payers and industrialists, and particularly from the latter. This is not because these groups are opposed to conservation measures; in fact, many industrialists are themselves active in conservation work. The fundamental basis for the opposition is the cost involved in the construction of sewage disposal plants. Because of the high cost, the parties concerned take no action until forced to do so. This is true especially of industries, because money spent for the construction of sewage disposal plants represents a dead investment that not only will yield no return, but even necessitates continuous additional expenditure for maintenance. Therefore, in our opinion, what is needed most of all to further the interest of conservation in this respect is to find ways and means of handling wastes at a cost substantially lower than that prevailing at present. During the past few years, the need for such new and less expensive methods has become more and more apparent, and several investigators have sought to discover new means without in any way sacrificing the efficiency of the present methods. Some investigators have sought the answer in chemical treatment, and several new chemical processes have been developed. In most cases, the initial aim has been realized in that the plants can be constructed at a substantial saving over the cost of the commonly used biological methods, but there are two important disadvantages: the degree of purification is considerably lowered, and the cost of operation and maintenance is not compensated for by the saving in initial cost.

In reviewing this situation a few years ago, we came to the conclusion that the chemical method of treatment was not the real answer to the problem, but that a new method of biological treatment had to be found in which the cost of the plant would be approximately that of chemical treatment plants. The most reliable and most extensively used biological method is that of the trickling filter, first suggested by the experimental results at Lawrence, Massachusetts, and perfected by further studies in England. In reviewing the history of the development of this filter, we were impressed by the thought that the fundamental factors involved in its operation had not been adequately studied, and that no one had fully determined its potential capacity. A research project was therefore started a few years ago involving a study of the factors concerned in the operation of such filters, with the thought that a knowledge of these factors would allow an evaluation of the maximum quantity of sewage that a given area filter could treat. It is our desire here to give a brief survey of our findings and conclusions.

The modern trickling filter was first suggested by experiments conducted at Lawrence, Massachusetts, where it was shown that when sewage is allowed to trickle over a bed of rock, bacteria will grow on the rock and absorb the organic matter from the waste passing through. As the dead bacteria accumulate, they are sloughed off and are removed in a settling tank following the filter. Further studies on these filters in England led sanitary engineers to believe that they could operate successfully only when waste is applied intermittently, each dosing period being followed by a rest period. The early investigators perhaps felt that bacteria, after a period of feeding, should be allowed to rest and to consume the food given them. Whether or not their conclusion was justified from the experimental findings, it remains a fact that most sanitary engineers and most boards of health even today believe that intermittent operation is an essential feature of the trickling filter. The experiments in England also led sanitary engineers to believe that trickling filters could purify only from 2 to 4 million gallons of sewage per acre surface per day. In all instances where dosages higher than 4 million gallons were tried, the filters clogged, shutting off the air supply for the bacteria and greatly reducing the efficiency. All investigators of that day, and practically everyone since that time to the present, have been of the firm opinion that 4 million gallons dosage is the upper limit in the capacity of trickling filters, that clogging occurs if higher dosages are used. Certainly the conclusion appears reasonable that if clogging occurs at 4 million gallons, it will occur much more quickly with dosages at higher rates. It is not surprising, therefore, that no one investigated the higher rates.

With standard trickling filter plants, the procedure is about as follows: Sewage first enters a settling tank where it is retained for two hours so as to allow the settling of solids. The supernatant liquid is then sprayed intermittently on a rock filter, which is usually from 6 to 10 feet deep. The liquid flowing from the bottom of the filter passes into another settling tank where the organic matter sloughing from the rock can be caught. The supernatant liquid from this settling tank is ready for disposal in a stream or lake. In properly functioning plants, from 70 to 90% of the organic matter originally in the waste is removed. The solids collected in the two tanks are disposed of in another tank where they are allowed to decay. The residue resulting from decay may be dried on sand beds and used finally as fertilizer.

In examining the trickling filter from the point of view of the fundamentals involved, it appeared to us that an important factor controlling the degree of purification and ultimately the capacity must be the thickness of the water film as the liquid passes over the rocks. It seemed logical that better results should be obtained when the liquid is distributed evenly over the entire surface all the time than when the same volume is put on the bed in large doses followed by rest periods. Under the latter conditions, the rate of flow through the bed during the time the liquid is being applied is very great. Uneven distribution during the dosing period is an important factor in increasing the actual rate of application. Measurements on intermittently operated trickling filters have shown that the actual rate of application ranges from 100 to 600 million gallons per acre per day in filters receiving a daily dosage of say 2 million gallons. The 2 million gallons would be the actual rate of application if the liquid were sprayed continuously over the entire surface, with no rest periods. If trickling filters can remove organic matter from waste being applied at such high rates, it is reasonable to believe that they could work efficiently even at a greatly increased daily dosage if the technique of operation is so adjusted as to make the actual application rate approximately equal to the daily average.

The fact that these filters actually clog when more than 4 million gallons are applied per acre surface per day must be faced, and means must be found to prevent this clogging. About four years ago, some experiments were conducted on a municipal sewage treatment plant that gave us some valuable leads in this connection. This plant had a round filter, and sewage was sprayed on the rock by means of a rotating arm. At the beginning of each dosing period, this arm is standing still; as the water begins to flow, the arm gradually begins to turn until it makes about two revolutions per minute. We noticed that a large amount of organic matter was sloughed off the rock at the beginning of each dosing cycle, and that this sloughing ceased when the arm had reached its full momentum. To verify this observation, we deliberately blocked the arm, and noticed that the sloughing continued for an extended period. Now, at the beginning of the dosing cycle, when the arm was standing still, the actual rate of application was considerably greater than when the arm was turning at its full velocity. It appeared that the high rate of application initiated the sloughing. This led us to the theory that the trickling filter might function efficiently at high rates providing the dosage is high enough to bring about a flushing action.

The idea that trickling filters must be operated intermittently did not appeal to us. From the point of view of bacteriologists, there is no reason to believe that bacteria have to rest between meals. In fact, all evidence indicates that bacteria grow best when fed continuously. We therefore decided to construct an experimental plant to try out continuous dosage at high rates. The first plant, built about four years ago, was started at a dosage rate of 10 million gallons, and soon clogged. We cleaned the rock by hosing, and started again at a dosage of 20 million gallons. Continuous sloughing occurred, and after the proper flora had developed, a high degree of purification was maintained. This result was verified on a second experimental filter which was operated for a full year, and also on a demonstration filter built at Chicago and operated by the Chicago Sanitary District. The Chicago filter has been in operation for about a year and a half. The general conclusion has also been confirmed on a trickling filter handling creamery waste at Lakeville, Minn., which has been in operation for about two years. Independent of our work, two other investigators have made similar observations. Jenks, in California, and Levine, in Iowa, have shown that trickling filters can be successfully dosed at high rates. We therefore believe this to be a proven fact.

In this work we have observed that certain factors are of fundamental importance in the operation of trickling filters. The most important of these is aeration. The early investigators recognized that provision had to be made for the admission of air into filters, but no effort was made to determine the factors responsible for the flow of air through them. We have conducted studies on an experimental filter constructed in the laboratories of the chemical engineering department of the University of Minnesota, and have learned that the only important factors are temperature differences between the water and air, humidity differences in the air inside and outside the filter. When the temperature of the surrounding air is higher than that of the liquid, there will be a downward draft; when the reverse situation exists, the draft will be upward. A higher humidity inside the filter than outside will bring about an upward draft. Since efficient functioning of these filters is dependent upon good aeration, means should be provided for forced draft at those times when liquid and air temperatures are about equal, usually a short period each spring and fall. In our hands, filters provided with forced draft have given better results than control filters without the forced draft.

Even when filters are dosed continuously at fairly high rates, the water will flow through the bed in channels, and not all the rock surface is wetted. The filter fly, which is sometimes a nuisance at trickling filter plants, lives and breeds on the dry portions of the rock. When a filter is dosed continuously so that the top of the bed is always wet, the flies remain inside the bed and do not become a nuisance.

The observation of channeling led us to experiment with an artificial filter medium composed of vitrified clay molded in such a way that when the filter is complete, it consists essentially of a series of 1-inch tubes extending from the top to the bottom of the filter. The filter surface, then, is composed entirely of vertical walls. This provides more surface per cubic foot than is obtainable with ordinary rock, and provides a filter which is rather difficult to clog. Filters made of these tile have given somewhat better results in our hands than natural rock filters. By the use of such media, it is possible to eliminate the primary settling tank, thereby decreasing the cost of construction of the treatment plant.

We are now studying a plant which operates as follows: the raw waste is first passed through a cutting machine which cuts the solids fine enough to pass through a 1/8 inch hole. Such equipment is standard in sewage treatment practice, and is not expensive to operate. The waste then flows directly on a tile filter, at a rate of 20 million gallons per acre per day, and into a final settling tank. The solids collecting in this tank are dewatered either on a sand bed or in a suction filter after being passed through the filter several times so as to stabilize them by aerobic oxidation. In this particular plant, we have cut the cost of construction to approximately 1/3 of the cost of an old type plant. By duplicating the old type plant in all respects except in the filter, it is possible to cut the cost of construction about 40%, chiefly by cutting the size of the filter to about 1/10th that considered essential in earlier practice.

It is our conviction that the cost of treatment plants using the trickling filter can be decreased at least 40% over prevailing costs, and if the plant now under observation proves successful, we will be able to decrease the cost still further.

DAILY LIGHT RATION AND GONADAL ACTIVITY IN THE ENGLISH SPARROW, *PASSER DOMESTICUS*

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Full spermatogenetic activity may be induced in male English sparrows by artificially lengthening the days (exposure to 60 or 100 watt incandescent bulb) during the fall and winter.

In the present study male birds were capped during the exposure period to determine the importance of ocular stimulation in testicular hypertrophy. The experiment was begun on November 5th. After a 6-week period it was found that the gonads of 6 out of 9 capped birds were spermatogenically inactive. The testes of 3 contained spermatocytes, but no sperms. 13 out of 15 uncapped birds showed testicular enlargement, 11 of these gonads containing mature spermatozoa. 9 caged controls and 2 controls from nature had quiescent testes.

Female birds require a longer period of light stimulation (70 or more days if experiment is begun in early November) before significant enlargement of ovary (and oviduct) takes place. The oviduct enlarges under the influence of secretion by the ovary of theelin or a theelin-like substance. Injections of theelin during January and early February induce precocious oviduct hypertrophy. The ovaries of such birds are small compared to the enlarged ovaries of light-treated birds.