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ENGINEERING RESEARCH FOR IMPROVING BIOLOGICAL TREATMENT PLANTS

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Biological treatment of sewage has yet to be utilized to its full potential. The writers believe that a more careful integration of the physical and biological rationales behind sewage treatment can offer substantial improvements in the process. Many economically feasible changes in environmental conditions and operational parameters have yet to be exploited. The following data and extrapolated process are given as an example of the engineering-biological approach recommended.

During the aeration of mixed liquor in the activated sludge process, only modest cell population increases occur (*1*). In the temperate zone, it is quite likely that the suboptimum temperatures generally prevailing constitute a factor which prevents the biological process from reaching its full potential. Other important factors include the low concentration of substrates and nutrients present in sewage. The concentration of carbohydrates, for example, is generally two orders of magnitude below that recommended for culturing of many of the microbial species present in sewage.

An interesting insight into sewage treatment mechanisms is revealed in a comparison of the activated sludge process and the trickling filter process. The former is in greater vogue today because it removes a higher percentage of the influent BOD, up to 90%. The trickling filter process effects approximately 60 to 75% BOD removal. However, this degree of removal occurs in only several minutes of contact time between the flowing sewage and the organisms growing on the rocks. Thus, the rate of BOD reduction in the trickling filter exceeds that of the activated sludge process in which 4 to 8 hr. of aeration are required to achieve ultimate effectiveness. Since the average sewage temperature would be common to both processes, temperature is ruled out as the environmental factor causing this difference. It is herein suggested that one important factor responsible for the observed differences in the two processes is the extensive surface area available to the microorganisms on the trickling filter rocks.

It has long been established that many species of bacteria and other microorganisms develop and grow better on surfaces than in free aqueous suspension. In discussing the importance of surface effects on bacteria, Frobisher (*2*) says, "surface forces are, in fact, of the most profound importance in all cell life. . . ." This environmental advantage of the trickling filter might help explain its impressive BOD removal rate. Another factor which might further explain the high rate of BOD reduction in the trickling filter is that the trickling filter rocks might physically concentrate nutrients by adsorption. The resulting propinquity of the organisms and nutrients would promote biological activity. The fact that even extended contact in the trickling filter will not attain BOD levels achieved by the activated sludge process may be attributable to the greater availability of oxygen in the activated sludge process.

It is the purpose of the new process proposed herein to combine the advantages of activated sludge and trickling filter treatments and thereby to accomplish high degrees of sewage treatment in relatively short treatment times. The fundamental concept might be thought of as an activated sludge treatment process containing a recirculating trickling filter.

The new process adds suitable finely divided material to the aeration basin in an activated sludge or aeration type of treatment process. Initially, a charge of the material is added as a slurry to the mixed liquor as it enters the aeration basin. During the aeration process, the material provides suitable surface area for the development of microbial colonies. Simultaneously, nutrients and substrates will be concentrated by the adsorption characteristics of the material selected for the added particulates. Concentration on the material should follow Freundlich's adsorption isotherm (3) $\frac{x}{m} = kC^a$, where x is the amount of substance adsorbed, m is the mass of the adsorbent, C is the concentration of the substrate, and k and a are constants. In this manner, a myriad of favorable ecological niches, or microenvironments, would be established. If the microorganisms intercept the nutrients and substrates prior to physical adsorption by the added material, or if they successfully remove the substances from the adsorption sites, their metabolism and growth should be greatly enhanced because the microorganisms and the substances they require would have been mutually concentrated. The microorganisms grow principally on the solids provided for this purpose. In conventional fashion, they are recirculated through the activated sludge system, but primarily remain on the solids. The small amount of the particulates which escapes in the effluent is made up to sustain the process.

Excess sludge will be wasted in the conventional manner. Depending on economics, the surface solids provided herein can be recovered for reuse or wasted. In the latter case, the total amount of waste sludge volume will exceed that of conventional activated sludge. However, it would probably be easier to handle because of its greater density.

Laboratory work on the fundamental assumptions of the new method has been carried out at Biospherics, Incorporated. Under contract with the Bureau of Coal Research of the Department of the Interior, studies (4) were performed on twelve different types of coal. BOD and phosphate removals were measured in 2-liter flasks containing aerating mixed liquor to which a variety of types of finely divided coal was added. Aeration was continued for 3 hr. Three of the coals considerably enhanced treatment as compared with controls. In two of these, BOD removals were increased, and in the third phosphate removal was improved 23%. Tables 1 and 2 present the results of one of the BOD and one of the phosphate runs. Three-hour aeration periods were provided for each batch of mixed liquor which was freshly prepared from primary effluent and return sludge obtained from sewage treatment plants. No recirculation was possible with the simple apparatus used in the small exploratory program. It is likely that recirculation of the sludge and particulates would further improve treatment in that the microorganisms would have been well established on the particulates from the previous cycles.

Recirculation studies should be made to see if treatment is further improved. Also, continuous cycling would demonstrate whether the results obtained were due to mere physical adsorption of organics and phosphate by the coal particulates. However, the following evidence suggests against this.

TABLE 1. USE OF SUBBITUMINOUS COAL FOR THE REDUCTION OF DISSOLVED BOD CONCENTRATION AFTER 3 HR. AERATION OF MIXED LIQUORS

Date: December 4, 1968

Treatment	Initial	Three hours	
	mg./liter	mg./liter	% change
S_hA_h	29.8	11.0	−63
$S_hC_lA_h$	26.2	12.0	−54
$S_hC_hA_h$	35.5	5.6	−84

S_h = high suspended solids, 2,660 mg./liter
C_h = high coal concentration, 2,000 mg./liter
C_l = low coal concentration, 1,000 mg./liter
A_h = high aeration rate, 600 ml./min.
Coal: subbituminous A coal
Size: 100–200 mesh

In the experiments conducted, the initial mixed liquor samples were taken a few minutes after the coal had been added. By comparing the differences in the initial dissolved orthophosphate concentrations in the flasks containing 0, 1,000, and 2,000 mg./liter coal, estimates were obtained of the amounts of dissolved orthophosphate initially adsorbed by the coal. These estimates indicated that only approximately 8% of the total dissolved orthophosphate was adsorbed initially when 2,000 mg./liter of coal were present in mixed liquor. Also, Johnson et al. (5) concluded that "anthracite coals were generally poor adsorbents." These data tend to support the theory that the increased BOD and phosphate removals achieved with the added coal were predominantly biological.

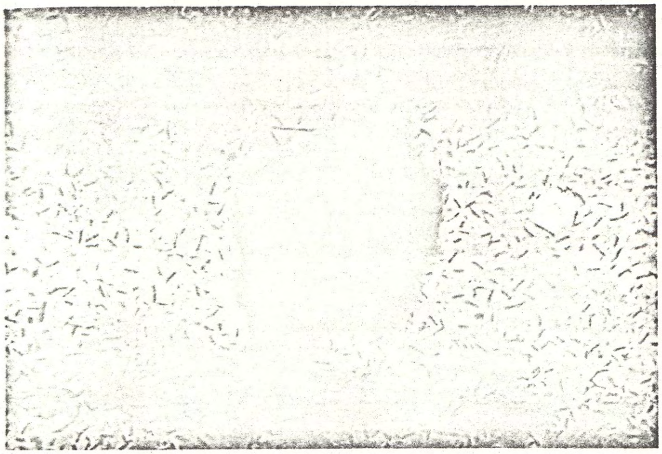
In addition, sequential microphotographs, Figure 1, taken at 1-hour intervals through the aeration process, offer firm evidence of the accretion of microorganisms onto the particulates. The fact that improved treatment resulted from this distribution of the organisms indicates that the particulates did play a role in making the organ-

TABLE 2. USE OF META ANTHRACITE COAL FOR THE REDUCTION OF DISSOLVED ORTHOPHOSPHATE CONCENTRATION AFTER 3 HR. AERATION OF MIXED LIQUORS

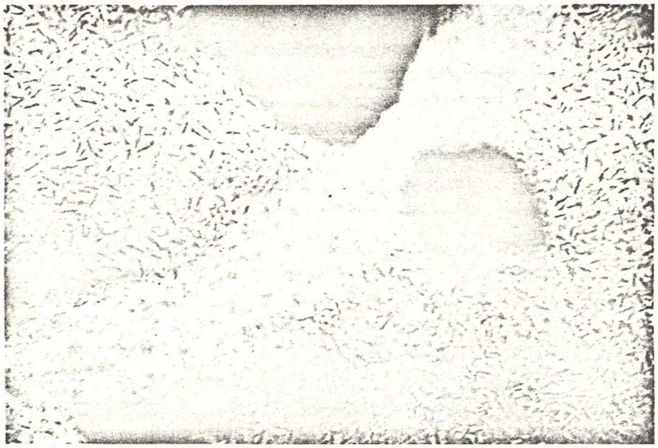
Date: September 25, 1968

Treatment	Initial	Three hours	
	mg./liter	mg./liter	% change
S_hA_h	5.35	2.15	−60
$S_hC_lA_h$	5.25	2.05	−60
$S_hC_hA_h$	5.30	1.40	−74

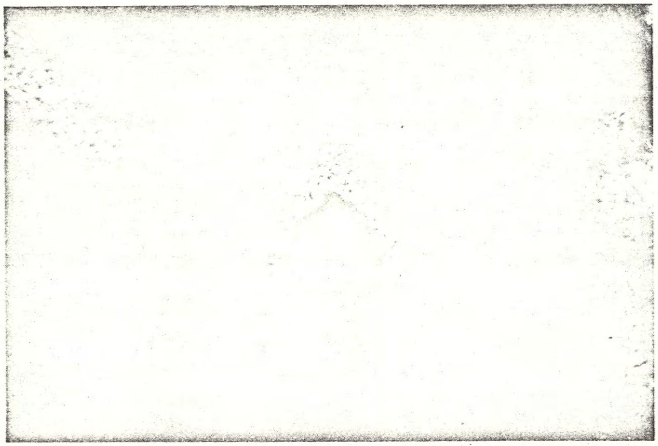
S_h = high suspended solids, 1,810 mg./liter
C_h = high coal concentration, 2,000 mg./liter
C_l = log coal concentration, 1,000 mg./liter
A_h = high aeration rate, 600 ml./min.
Coal: anthracite, meta anthracite
Size: less than 325 mesh



At 0 Hour of Aeration



At 1 Hour of Aeration



At 2 Hours of Aeration

At 3 Hours of Aeration

At 4 Hours of Aeration

Fig. 1. Microphotographs of coal particles in mixed liquor at various times of aeration.

ics and phosphate more readily available to the organisms.

There are numerous materials other than coal (to which the scope of the contract limited past work) which are suitable candidates for use in the proposed process. These include glass, ceramics, plastics, and a wide variety of other synthetic and natural products. The materials may be impervious or porous, solid or hollow. The particle size(s) may be mixed or segregated. The material should be of a selected or contrived specific gravity to provide uniform mixing in the aeration basin. The quantity of the surface may be varied by selecting particle size to obtain the desired surface area-to-sewage volume ratio. The surfaces may be textured or smooth to obtain the desired characteristics.

Specific gravity may be used to assure convenient separation of the sludge from the mixed liquor and to facilitate the return of the surface material and attached organisms to the aeration chamber. Separation could be accomplished by settling or flotation in the secondary clarifier as dictated by the specific gravity. The specific gravity may be engineered so that the sludge laden particles will settle more quickly than sludge alone. A clearer, plant effluent will be produced. In addition, the greater settling rate will result in a shorter period during which the sludge remains in the secondary clarifier. This will prevent or decrease the onset and duration of anaerobic conditions. The amount of phosphate leaking out of the sludge into the plant effluent will thus be reduced. A denser sludge will also result, reducing the pumpage necessary to return a given quantity of sludge. The denser sludge, in turn, would require less volume in the aeration basin, thereby permitting greater detention time, if desired. Should the moving surface material have a specific gravity of less than 1, the sludge particles could be separated by flotation, and the advantages listed above would still pertain. Perhaps it would even be easier to maintain aerobic sludge in this fashion.

A schematic of the proposed process is shown in Figure 2. With the preceding discussion as a basis, the operation of the system is self-explanatory. In summary,

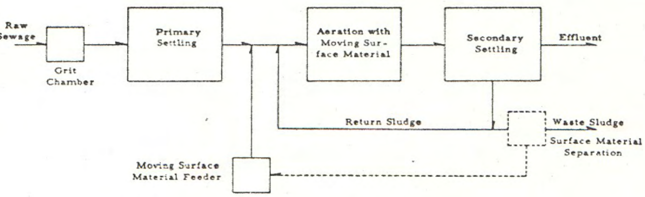


Fig. 2. Moving surface process.

the new process has potential for improving BOD removal, improving phosphate removal, improving solids removal, and reducing required capacities of the return sludge line, aeration basin, and final clarifier.

As a next step in developing the process, a careful search will be made for candidate natural and synthetic materials for use as added surface. The geometry and texture for the particles will be designed. Laboratory evaluation will then lead to pilot plant operation of the entire proposed system. Technical and economic evaluations of the results will be made in order to establish a potential place for the system in existing and new sewage treatment plants.

ACKNOWLEDGMENT

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