

The dry sludge contains very small proportions of phosphoric acid (approximately 2 per cent calculated as P_2O_5) and potash (approximately 0.4 per cent calculated as K_2O) and its fertilizer value therefore lies entirely in its content of nitrogen.

Much work has been done to find some practicable means of dewatering the sludge so that it may be obtained in a form in which it can be dried in the driers regularly used for handling fertilizer materials. The moisture content of the wet sludge coming from the settling chamber must be reduced from 99.5 to 50 per cent if possible. The importance of this problem is brought out much more clearly when it is considered that such reduction involves the removal of almost 99 per cent of the weight of the wet sludge as it comes from the settling chamber.

Filter pressing in the ordinary type of filter press and in the newer forms, such as Kelly or Sweetland presses, has proved entirely unsuccessful. The filter cloths are very rapidly clogged. A special type of filter press may be developed for this purpose and experiments in that direction are under way. Centrifuges of the imperforate-bowl type have also been tried, but it will be difficult to construct a machine of sufficient capacity to bring the cost of installation to a nonprohibitive amount. After the sludge has been reduced to a 50 per cent moisture content it can be readily and cheaply dried in the usual driers employed for drying organic ammoniates for fertilizers. As available space is an important consideration, an investigation into the possible depth of aerating tanks was made. Two pipes 14 in. in diameter were erected, one 36 ft. and the other 18 ft. high. The air, which was discharged through perforated pipes, was allowed to pass into each unit in equal amounts. The sewage used for this experiment came from the beef abattoir. Samples were taken at regular hours covering several days and the albuminoid, ammonia, nitrite and nitrate nitrogens, and the putrescibility were determined. As the results in either pipe were practically identical it was concluded that an aerating tank of any depth to 36 ft. will produce as good results as a more shallow tank in respect to purification of sewage. Economy in consumption of air should also be considered in this connection.

The bacteriological data are too meagre to warrant conclusions, but two facts are apparent: (1) three or four hours' aeration of the sludge from the settling chamber increases the number of organisms, but further aeration reduces them somewhat; (2) the organisms grow better at 20° C. than at 37° C. as might be expected. Throughout the records there seems to be a correlation between warm sewage temperatures above 75° F. and inactivity of the organisms, which results in an inactive sludge. This may be an obstacle that will prevent the placing of a disposal plant close to the abattoir where the sewage temperature may suddenly change from cold to hot or *vice versa*.

The results of the experimental work warrant the belief that this process offers more promising possibilities than any of the other methods of disposing of packing-house wastes hitherto proposed. The relatively small area required for installation, the comparatively high nitrogen content of the sludge, the comparative clarity and stability of the effluent, and the relatively short time of treatment are perhaps the most important features of the process.

CHEMICAL LABORATORY, ARMOUR & COMPANY
UNION STOCK YARDS, CHICAGO

CHEMICAL OBSERVATIONS ON THE ACTIVATED-SLUDGE PROCESS AS APPLIED TO STOCKYARD SEWAGE

By ARTHUR LEDERER
Chemist, Sanitary District of Chicago

The Sanitary District of Chicago began experiments with the activated-sludge process of sewage purification on the sewage of Stockyards and Packingtown in April, 1915. The operation on the fill-and-draw plan was conducted in two 200-gal.

galvanized iron tanks well into the cold season, being discontinued when the contents of the tanks froze. Certain observations can be explained by the effect of low temperatures on the process. These observations were substantiated on the larger 4-unit installation of the Sanitary District designed to treat 30,000 to 100,000 gals. a day on the continuous-flow basis. This installation was put into operation early in 1916 under the direction of Langdon Pearse.

The object of this paper is to elaborate certain chemical and biological facts, which have presented themselves in the course of operation, and not to furnish any prescription for the treatment of the stockyard waste. The features of operation now being worked out will require much time and experience before final recommendations can be made. Economically the continuous-flow process seems preferable, but it has certain disadvantages which the fill-and-draw plan avoids. Experience from our own experiments and those of others will probably indicate the solution. Like other sewage-treatment processes, this is governed primarily by the composition of the waste. The process, being largely biological in nature, is greatly influenced by the temperature of the sewage. In this respect the stockyard waste lends itself readily to the process, the temperature varying between 60° and 90° F. throughout the year at the Center Avenue outlet. The fall of temperature in the plant is only a few degrees in the coldest winter weather. By far the greater percentage of the sewage treated is packing-house waste. The variation in discharge and composition between day and night waste is extremely marked. The free oxygen demand is approximately 8 to 10 times greater than that of the domestic sewage of Chicago. The changes of the nitrogenous constituents during the aeration process have been carefully studied. Our experience has coincided, so far as I am aware, with the experience of other observers. During the warmer season a decrease of ammonia nitrogen to about 1 or 2 parts per million and an increase of nitrite nitrogen to 5 or 10 parts per million indicate complete oxidation and clarification. When colder weather set in, however, this ceased to be the condition with the small galvanized iron tanks, which were easily affected by changes in temperature of the air. Absolute stabilities were reached in cold days with ammonia nitrogen actually increasing several hundred per cent and with little, if any, change in the nitrite and nitrate nitrogen. The reduction of the organic nitrogen was just as marked as in summer. Clarification was very satisfactory. The results mentioned are those noted when the effluent showed a relative stability of 100 or thereabouts. With the small galvanized iron tanks, in which the warm sewage quickly chilled, it took longer in cold weather to obtain such high stability, but the chemical results were consistently as noted.

It is clear that the mechanical features of the process outweighed the biological features. The higher putrescible colloids have simply been whipped out of suspension by the continuous agitation. Repeated observations indicate that the mere mechanical removal of the colloidal matter from sewage brings about an improvement far out of proportion to the actual percentage of substance removed. There is no doubt, however, that there is some biologic activity even in a liquid near freezing; otherwise the persistent increase in ammonia nitrogen could hardly be explained. Various active protozoa, such as infusoria and trachelomonas, also were noted in the sludge at all times. More highly developed animal or plant organisms were not found. Our work indicates that the temperature of the liquid treated will be a controlling factor. On a large scale changes in temperature will probably be much smaller than on the very small scale of 200-gallon steel tanks exposed to weather.

During cold weather, removal of colloidal matter was the only immediate indication of accomplished oxidation. Determina-

tions of turbidity in connection with the methylene-blue putrescibility test can establish a fairly definite working relation. Tabulation of a large number of results shows that the stability is 100 with turbidities of 10 parts per million or less. With a turbidity of 15 parts per million the relative stability varies usually between 50 and 100. With turbidities exceeding 15 the quality of the effluent shows rapid deterioration. With turbidities ranging from 20 to 25 the stabilities are usually less than 50. To compare turbidities exceeding 25 parts per million with stabilities appears unsafe; such stabilities are, without exception, very low. Recently, with the advent of warmer weather, nitrite nitrogen is again increasing in the effluent and no doubt the ammonia index will again serve the purpose. The determination of other constituents, such as the organic nitrogen, albuminoid nitrogen, permanganate oxygen consumed, chlorine, and the bacterial content are merely of scientific interest. They are not essential to routine control. This holds good to a certain extent for the dissolved oxygen, but it is quite conceivable that the rate of deoxygenation at a given temperature can be made to serve as an index of the degree of stabilization accomplished. The quantity of the settling suspended matter in the final effluent merely indicates the efficiency of the settling process and has nothing to do with the activated-sludge process proper. Packingtown sewage completely oxidized by the activated-sludge process is clear with a slightly yellowish tint barely noticeable in small bulk.

39TH ST. PUMPING STATION
CHICAGO, ILLINOIS

DEVELOPMENT OF THE PURIFICATION OF SEWAGE BY AERATION AND GROWTHS AT LAWRENCE MASSACHUSETTS

By H. W. CLARK

Chemist and Director, Water and Sewage Laboratories
Massachusetts State Department of Health

What is now known as treatment of sewage by the activated sludge process has been in operation at the Lawrence Experiment Station of the State Department of Health of Massachusetts since early in 1912. During a series of experiments made at the station in 1911 it was found that the presence of certain algal growths in bottles of weak sewage caused a purification of this sewage. This happened even in sealed bottles and with the liberation of oxygen. It was found also that these growths, aided by forced aeration, effected remarkable purification.¹ Immediately following this early work, *i. e.*, in the spring of 1912, extensive experiments were begun in regard to what could be accomplished in the actual purification of sewage by aeration aided by growths. For several months this work was carried on in gallon bottles and carboys and we found that by 24 hrs.' aeration of sewage containing growths of various kinds we could obtain an effluent which was stable with nitrates at times equal to 15 parts per million and containing only 33 per cent as much organic matter as the untreated sewage. A shorter period of aeration gave clarification and stability but nitrates were not formed. The sewage was emptied from the bottles daily, only the growths and sewage slime being left.² This work was shown to Dr. Gilbert Fowler of Manchester, England, in the fall of 1912, and was his first view of sewage purified by what is now known as the activated sludge process. On his return to England he and his colleagues, Ardern and Lockett, began similar work and when Ardern and Lockett's paper was published³ a year and one-half after his visit to Lawrence, Fowler's statement in regard to this English work and its results was as follows:

"It is only right to admit that the work was really due to a visit to the Experiment Station at Lawrence where he (Fowler) saw sewage which had been completely purified by 24 hrs.' aeration."

¹ Mass. State Bd. Health Rept., 1912, 344-45.

² *Idem.*, p. 291.

³ J. Soc. Chem. Ind., 33 (1914), 18.

Ardern and Lockett state in the paper just mentioned:

"In November, 1912, Dr. Fowler visited the States * * *. Shortly after his return he described to the authors, work in progress at the Lawrence Experiment Station on the purification of sewage in the presence of organisms. Dr. Fowler suggested that work might be carried on on similar lines."

As a result of the first few months' work at Lawrence it appeared that offering a considerable surface to which growths would become attached might favor the purification of sewage by this method; hence, a tank containing a few pieces of slate separated from each other at intervals of an inch or more was put into operation late in 1912. Spongy gelatinous growths, brown and gray in color, soon covered these slate layers and sides of this tank, and, of course, sewage slime was also prominent.¹ These growths, aided by aeration and the circulation of sewage in the tank by the air currents, collected not only the suspended matter of the sewage but also a large percentage of the colloidal matter. Oxidation occurred and again, as in the bottle experiments, stable and well clarified effluents low in organic matter were obtained.

This Lawrence work to the end of 1912 was summarized by Dr. McLean Wilson of England, in his recent address at Manchester as President of the Association of Sewage Works Managers, as follows:

"Many investigators, including Drown, Dupre and Dibdin, Mason and Hine, Black and Phelps, Fowler and others, had sought to purify sewage by direct chemical oxidation by means of air currents and had failed. At Lawrence, however, the efficiency of growths in the purification of sewage by aeration was discovered" * * * and this changed the current of investigation along this line of work.

During the past three years the work at Lawrence has been continued both along the aerated slate-tank method and also by that method known more commonly now as the activated-sludge process, and various articles have been published by us in the *Engineering Record* and elsewhere in regard to it. Fairly complete accounts have been given also in the report of the Lawrence Experiment Station during recent years. More than a year ago an article of mine appeared in the *Engineering Record* comparing Lawrence and Manchester (England) work along this line. Up to that time we had shown, as stated in that article, that it was possible by 5 hrs.' aeration of sewage in the Lawrence tank, with the use of 50,000 cu. ft. of air per hour per million gallons of sewage treated ($\frac{1}{4}$ cu. ft. per gal.), to render the tank effluent stable during more than 70 per cent of the time. 10 hrs.' aeration with the same volume of air per hour per million gallons of sewage rendered the tank effluent stable 90 per cent of the time. By 5 hrs.' aeration, 80 per cent of the total suspended matters were collected and removed from the sewage, and by 10 hrs.' treatment, 90 per cent. Five hours' aeration removed the soluble organic nitrogen, including colloids, to the extent of 35 to 40 per cent, and this removal was increased to 60 per cent by 10 hrs.' aeration. The albuminoid ammonia was reduced about 60 per cent by 5 hrs.' and 80 per cent by 10 hrs.' aeration.

Statements have been made in engineering journals in this country and abroad that the Lawrence aerating tank containing slate is a contact filter. This is not true, however. In a contact filter at least 65 per cent of the total space is filled with filtering material allowing 35 per cent for air and sewage. In our aerating tanks, of slate colloids not more than 3 to 7 per cent is filled with slate or other material, leaving 94 or 95 per cent of space free for sewage and air. It has been stated, also, that at Lawrence the object of our work was to prepare a sewage for filtration. This is untrue, of course, for as mentioned above we produced by aeration as early as 1912, an effluent practically

¹ Mass. State Bd. Health Rept., 1912, 292.