Aerobic stabilization of sewage solids

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In the United States, most of the plants for treatment of domestic sewage either make use of the trickling filter or the activated sludge process. In either case, it is common practice that the solids accumulating in the primary and final settling tanks be taken care of in a digestor. When the digestor is full, the overflow of supernatant is brought back into the raw sewage and retreated. Through common professional knowledge, everyone realizes that as solids are decomposed anaerobically in the digestor, the bulk of their carbonaceous matter is broken down to methane (CH_4) and carbondioxide (CO_2), and that nitrogen and phosphate tied up in the organic matter is released into the supernatant liquor as soluble compounds. In the aerobic treatment that follows, some of these soluble compounds may be reassimilated into microbial protoplasm and thus be brought back to the digestor. However, the bulk of the nitrogen and the phosphate tied up in the solids, will ultimately be relased as soluble components in the final effluent of the treatment process. When this effluent reaches a stream or lake and is diluted with clear water, these components serve as fertilizers for the growth of algae and other microorganisms which, with the aid of sunlight, can resynthesize nearly as much organic matter as was removed in the original sewage treatment. Therefore, it is my contention that such treatment facilities do not accomplish the purpose for which they are constructed and it would be well to design a method of treatment where this difficulty is obviated.

When I had an opportunity a few years ago to visit Dr. Pasveer, in the Hague, Holland, and to observe his experimental plants using the oxidation ditch as a means of treatment, I was thoroughly convinced that he had developed a process that could conceivably accomplish the desired results. In the Pasveer Process the treatment is exclusively aerobic in

Table I: Results with the oxidation ditch at Noordwijk. [1])
DWF = 263 cu m/day; DOC load = 180 kg/day; BOD load = 94,5 kg/day.
Each figure is the average of the least two samples.

Mixed liquor in oxidation ditch					Effluent					
Month 1959	°C	Sludge		Ash in dry solids %	Susp. solids	DOC ppm	BOD ppm	Nitrogen		Oxygen ppm
		ml/l	gm/l					NH_4 ppm	NO_2 + NO_3 ppm	
April ...	12	270	4.9	27.–	trace	86	1*	54	trace	3.–
May	–	200	2.6	32.–	0	49	0*	16	7	1.4
June ...	19	138	3.–	29.–	0	54	0*	4	5	3.7
July ...	23	136	2.7	29.–	0	81	4*	4	6	2.3
Aug. ...	20	174	3.8	29.–	0	45	1*	2	11	–
Sept. ...	17	190	3.5	29.–	0	40	0*	0.7	15	3.5
Oct.	12	–	–	–	trace	36	6**	0.8	15	2.–
Nov. ...	7	–	–	–	trace	43	6**	2.5	23	–
Dec. ...	5	150	3.–	27.–	0	39	4**	1.6	22	–

*BOD estimation in diluted effluent.
**BOD estimation in aerated effluent.

[1]) No. 34 — Developments in activated sludge treatment in the Netherlands. By A. Pasveer, Research Institute of Public Health Engineering, Holland; Conference on Biological Waste Treatment, Manhattan College, April 20, 1960.

both the removal of BOD and the stablization of the solids. When I examined some of the data he had obtained in these plants (illustrated in Table I), it appeared to me that under the proper methods of operations the Pasveer Process could be effective — not only for the removal of nitrogen and phosphate.

The above mentioned data noted that between the months of May and June the NH_4 nitrogen practically disappeared from the effluent and in subsequent months it remained very low, but the NO_3 nitrogen increased. There is no data given of that amount of nitrogen in the raw sewage compared to the amount found in the sewage effluent and it is presumed that most of this loss is due to the amount that is tied up in the solids, but some of it may have been lost through the process of denitrification. In the effluent where a minimum amount of nitrogen is attained, only small amounts of ammonia as well as small amounts of nitrate are present. Since the data shows this was the situation that prevailed between May and June, it would be most interesting to know the conditions existing during this time and to see if these could be consistenly maintained through proper controls. With this purpose in mind, we initiated experiments in our own laboratory to investegate the feasibility of stabilizing solids by an aerobic instead of anaerobic process, and to determine whether or not the aerobic process would tie up the soluble nitrogen and phosphate compounds so as to remove them from solution.

A normal sewage plant, operated in the U. S., generally provides from three to five cubic of digestor capacity, per person, per day. In a standard treatment plant about 0.5 gallons of sludge is collected in the settling tanks, per person, per day. This means the digestor capacity is sufficient for a detention of solids for a period between 40 to 70 days. Therefore, in our experiments we decided to design a method of operations to begin with where the solids wold be detained in the aerobic process for a period of 40 days, then to vary the length of the detention period — up or down — to determine by the results, the minimum detention time required for efficient operation.

For our experimental procedure, we first produced a large, 40 liter capacity glass crock and placed in it 20 liters of clean water. We provided the crock with an aerating device consisting of a porous stone diffuser system which released adequate compressed air into the contents of the crock in the form of small bubbles. The compressor forcing the air into the system was equipped with a measuring device that enabled us to keep an accurate measure of the quantity of air used. Also installed were instruments that continuosly measured the amount of dissolved oxygen in the contents and recorded this on a time controlled graph.

To start the experiment, we added 500 ml. of sludge (obtained from the primary settling tank of the Champaign-Urbana Treatment Works) to the 20 liters of water in the crock. After 24 hours of aeration, we added enough water to replace that lost through evaporation, removed 500 ml. of the mixture, and then added another 500 ml. of raw sludge. Adding sludge to the crock at this rate we had had essentially a 40 day detention period. This procedure was repeated daily until a state of equilibrium was reached and we could find no further increase in the amount of suspended solids in the samples removed. At this point we began our analyses of both the raw sludge added each day and the treated sludge removed-determining tre COD, five day BOD, total solids, volatile solids, ash, Kjeldahl nitrogen, and total phosphate. In addition we also determined the nitrate and nitrite nitrogen contents in the treated samples. During the period of our experiments, sufficient air was introduced into the system to maintain a dissolved oxygen content in the liquid of between 0.1 ppm and 2 ppm.

Using a 40 day detention period, it was evident from data recorded that we were obtaining the results desired; therefore, we repeated the experiments with shorter detention periods. We next added 1 liter sludge each day so as to get a 20 day detention period and in another case 2 liters each day to obtain a 10 day de-

Table II: Experimental results for 40 day detention time at 30° C. All data are expressed in parts per million.

	Raw sludge	Treated sludge	Treated sludge Supernatant*
COD	50,000	20,000	180
5 day BOD	17,000	2,800	7
PO_4	1,420	1,460	4
Kjeldahl N	1,300	1,080	5
Volatile solids	26,000	16,960	480
Ash	12,110	14,100	1,130
Total solids	38,050	31,060	1,610
% Ash in dry solids	32	45	70

Table III: Experimental results for 20 day detention time at 30° C. All data are expressed in parts per million.

	Raw sludge	Treated sludge	Treated sludge Supernatant*
COD	50,000	21,200	178
5 day BOD	17,000	2,880	7
PO_4	1,560	1,510	N. D.
Kjeldahl N	1,380	1,180	N. D.
Volatile solids	25,490	17,500	N. D.
Ash	9,010	10,680	N. D.
Total solids	34,500	28,180	N. D.
% Ash in dry solids	26	38	N. D.

Table IV: Experimental results for 10 days detention time at 30° C. All data are expressed in parts per million.

	Raw sludge	Treated sludge	Treated sludge Supernatant*
COD	50,000	26,000	150
5 day BOD	16,380	4,440	14
PO_4	1,360	1,330	11
Kjeldahl N	1,430	1,230	4
Volatile solids	25,720	16,100	230
Ash	9,650	11,000	640
Total solids	35,370	27 100	870
% Ash in dry solids	27	41	74

* The concentration of nitrite, nitrate, and ammonia in the treated sludge supernatant was in all cases found to be less than 1 ppm.

Table V: Experimental results for 7 day detention time at 30° C. All data are expressed in parts per million.

	Raw sludge	Treated sludge	Treated sludge Supernatant*
COD	50,000	27,340	187
5 day BOD	14,520	3,270	15
PO_4	1,500	1,550	9
Kjeldahl N	1,530	1,340	7
Volatile solids	27,880	17,300	400
Ash	10,550	10,750	820
Total solids	38,430	28,050	1,220
% Ash in dry solids	27	38	67

* The concentration of nitrite, nitrate, and ammonia in the treated sludge supernatant was in all cases found to be less than 1 ppm.

tention period. We also run a limited study with a 7.0 day detention period. Data obtained from these experiments will be found in Tables II, III, IV, and V. In these experiments we adjusted the concentration of the raw sludge each time by dilution with water, so as to obtain a sludge with a COD of 50,000 ppm.

In all the detention times studied, we obtained very effective reductions in the five day BOD, with significant removal of both nitrogen and phosphate. After the solids were separated from the suspending liquid, the resulting supernatant liquid containing only very small amounts of soluble nitrogen and phosphate was as clear as tap water, and the BOD was very low. Although the data indicates good results were obtained even with a 7.0 day detention period, we have reason to believe this represents the ultimate limit and that to have a factor of safety one should not expect to successfully operate such a system with less than a 20 day detention period.

Table VI, gives data indicating the

Table VI. A comparison of the difference in the effluents obtained from the experimental aerobic process and from the digestor at the Champaign-Urbana sewage treatment plant.

	Digestor supernatant (70 day detention)	Aerobic process supernatant (40 day detention)
COD	9,800	180
BOD	1,250	7
PO_4	470	4
Kjeldahl N	770	5
Total solids	11,480	1,610
Volatile solids	6,790	480
Ash	4,690	1,130
% Ash in dry solids	41	70

difference in the results obtained in our systems using the aerobic process and those obtained in the digestor of the city treatment plant located at Champaign-Urbana. It is apparent the differences are marked; with the effluent from the digestor containing very large amounts of soluble nitrogen and phosphate compounds, in comparison to the very small amounts found in the effluent of the aerobic process. Detailed information describing the laboratory experiments is published in the May 1965 issue of Applied Microbiology.

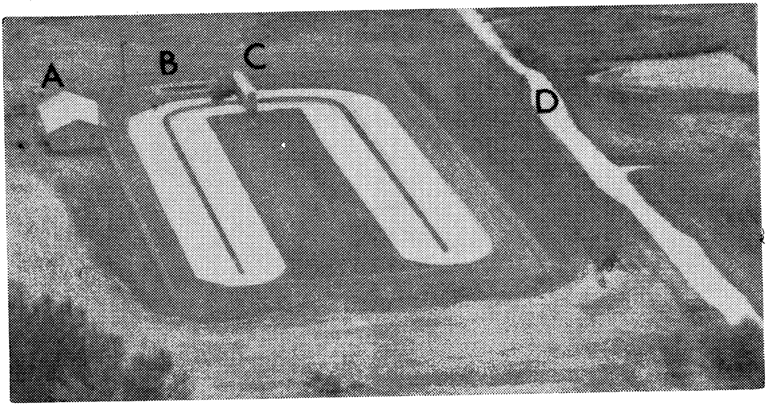
Obtaining good results from our laboratory studies encouraged us to construct a full-scale plant at the city of Glenwood Minnesota. Here we had a city located near a lake into which only they discharged the effluent of a sewage treatment plant. Their previous plant consisted of a typical trickling filter system, using a primary settling tank, a final settling tank, and a digestor. The digestor supernatant was brought back to the raw sewage. The portion of the lake into which the effluent was discharged had become more and more overgrown with algae, so much that recreational uses of the lake were seriously impaired. Therefore, we felt that this was a good place to construct a treatment designed for the use of Pasveer's extended aeration process, in order to see if such an aerobic process, by removing a fair portion of the soluble nitrogen and phosphate compounds from the final effluent, might not thus have a beneficial effect on the lake.

The plant, designed for a population of 4,200, was constructed during spring last 1964. It consists of a double loop ditch with four brush aerators each six feet long. A control building was constructed containing a laboratory, the wet well, the dry well, and the pumps. After the raw sewage has passed trough a bar screen, the pumps deliver it directly to the ditch. The ditch has a capasity of 450,000 gallons, is 1200 feet long, has a cross-section area of about 50 square feet, and a water depth of three feet. Figure I is an aerial photograph of the plant.

Aerated sewage overflows from the ditch into a rectangular settling tank. The settable solids are returned to the ditch by a pump working continuosly at the rate of about 200 gallons per minute. The supernatant flows from the settling tank trough a chlorination chamber before it is discharged into the small spring-fed creek that flows into the lake.

The plant started operation last June. We were, however, most concerned about the effect of low temperatures on the process, but the plant has now operated through one winter extended periods in which the temperature was from - 15 F. (- 26 C.) to - 25 F. (- 37 C.) for a period of two days. There was no ice formed on the ditch until after the temperature dropped belowe - 25 F. At temperatures of - 35 F., we found about one inch of ice disappeared as soon as the temperaturse was back to - 25 F. The temperature of the sewage entering the plant was approximately 55 F. (13 C.), the typical tem-

Figure I: Ariel view of sewage treatment plant at Glenwood Minnesota.



A: Laboratory and pump house. B: Settling tank. C: Brushes.
D: Creek carrying effluent to lake.

perature for ground water in this area. When the temperature of the air was 15 F., the temperature of the water in the ditch was 33 F. (1 C.). We did encounter some diffilty with ice forming in the rectangular settling tank where the flights scrape the solids to one end and return at the surface to serve as skimmers. Ice on the surface of this tank blocked the flights, so it was necesarry to cover this tank during the winter. This was done by installing a temporary cover that can be removed in the summer. A house was constructed over the brushes which probably prevented the formation of the ice on them.

We obtained a demonstration grant from USPH that provides us with funds to make a detailed study of this treatment in order to determine the most efficient method of operation that will give a minimum amount of soluble nitrogen and phosphate in the final effluent discharged to the lake. The laboratory at Glenwood is being equipped with proper facilities and supplies for our use in these studies, and we hope to have them initiated by April 1, 1965.

In the meantime, we have visited the treatment plant and made spot checks and analyses of some 24 hour composities. From the included in Table VII, it is apparent the system is producing exellent results as far as BOD removal is concerned, but the results were variable as far as removal of nitrogen and phosphate is concerned.

Table VII: Data on 24 hour composite samples taken at Glenwood Minnesota

	Summer: July 1964		*Winter:* January 1965	
	Raw	Effluent	Raw	Effluent
Day time air temp.	24 C.	24 C.	— 20 C.	— 20 C.
Sewage temp.	18 C.	22 C.	13 C.	1 C.
Total flow (gal.)	370,000	370,000	250,000	250,000
BOD (5 day)	134	9	210	12
Kjeldahl N	29	4	40	34
NO_3 nitrogen	0	6	0	2.6
Total solids	840	710	780	580
Volatile solids	280	270	380	240
	Summer		*Winter*	
Dissolved oxygen in the ditch (ppm)	.3 Before brush	1.6 After brush	7.0 Before brush	7.6 After brush

The factors which may cause the variable effects in the removale of nitrogen and phosphate and which can be studied at the plant are:

1. The amount of suspended solids carried in the ditch.
2. The depth of submergence of the paddles of the brush - which determines the amount of oxygen incorporated.
3. The variations in temperature from season to season.