# SEWAGE WORKS JOURNAL

VOL. XVII | JULY, 1945 | NO. 4

## *Special Features*

Modified Aeration—Setter, Carpenter, Winslow, Shapiro and Hogan

Thermophilic Digestion—Fischer and Greene

Effect of Heavy Chlorine Dosages—Griffin and Chamberlain

Survey of Research Projects—Research Committee

**1945 Convention Postponed!**

**See Page 851.**

OFFICIAL PUBLICATION OF THE

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

# POSTPONED!

## The
## ANNUAL CONVENTION

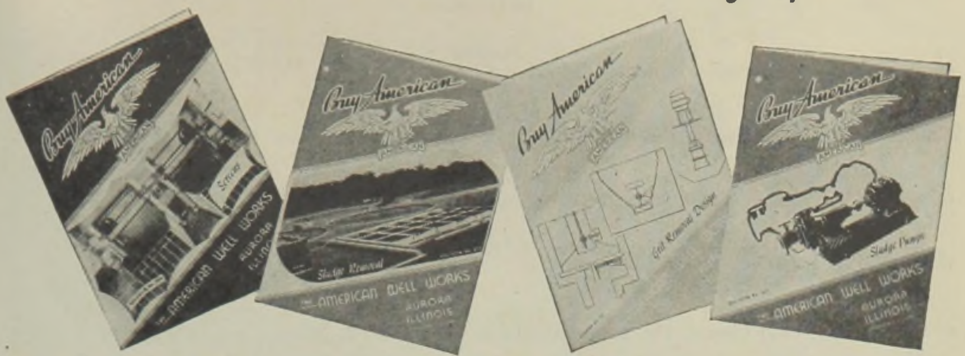
*OF THE*

## Federation of
## Sewage Works Associations

*Originally Scheduled to Be Held at Toronto in October, 1945*

See Page 851 for Details

# *American Waste Treatment Equipment*



**Bulletin No. 249 —**
"Grit Removal Design"—The theory, practice and equipment for grit removal.

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"Pre-Aeration-Grease Flotation"—The application of beneficial pre-treatment for new and existing plants.

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"Rotary Distributors" — Distributors to meet all field conditions. Recommendations for filters.

**Bulletin No. 261—**
"Sludge Pumps" — Information on pumps, sludge pumping, typical piping layout and pipe friction curves for sludge.

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"Screens"—Complete information on the removal and cutting of screenings.

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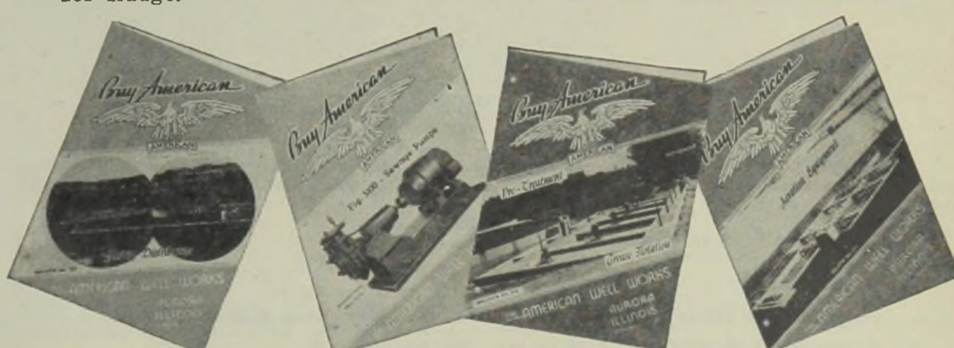

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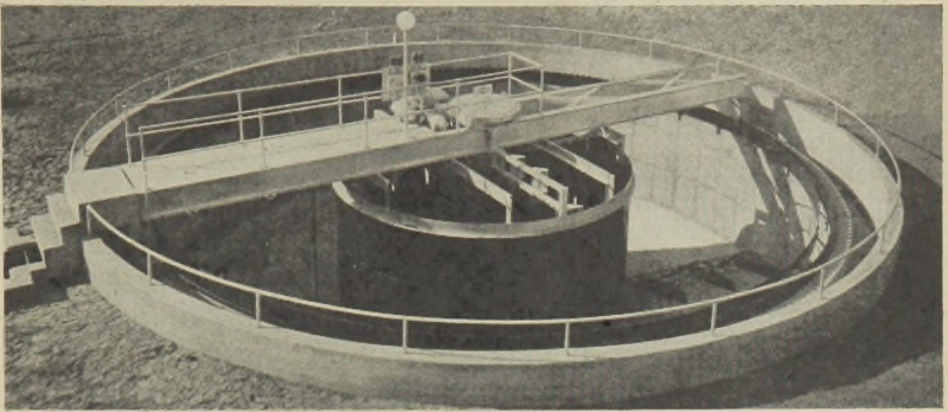

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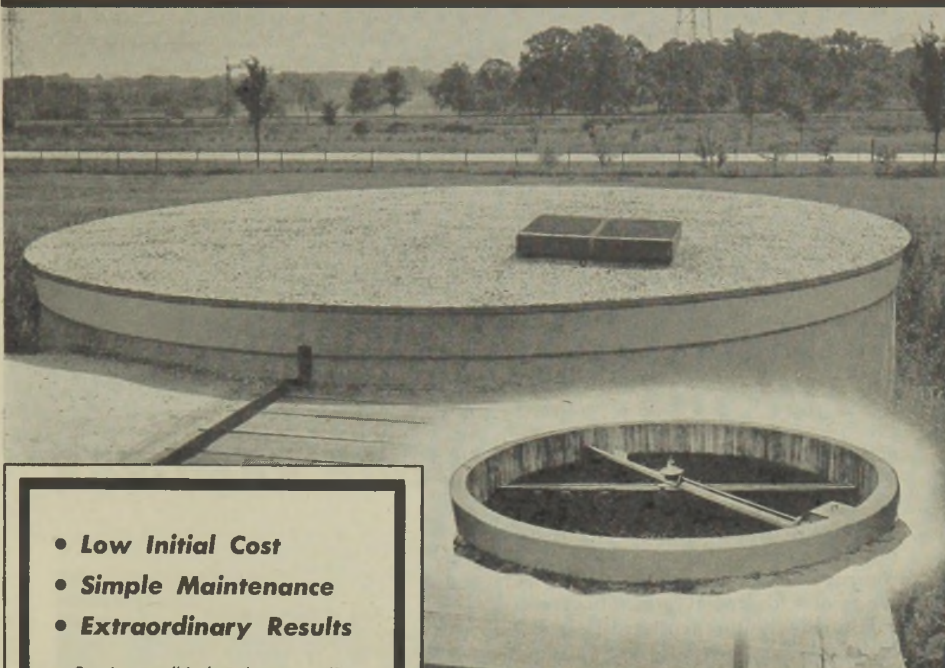

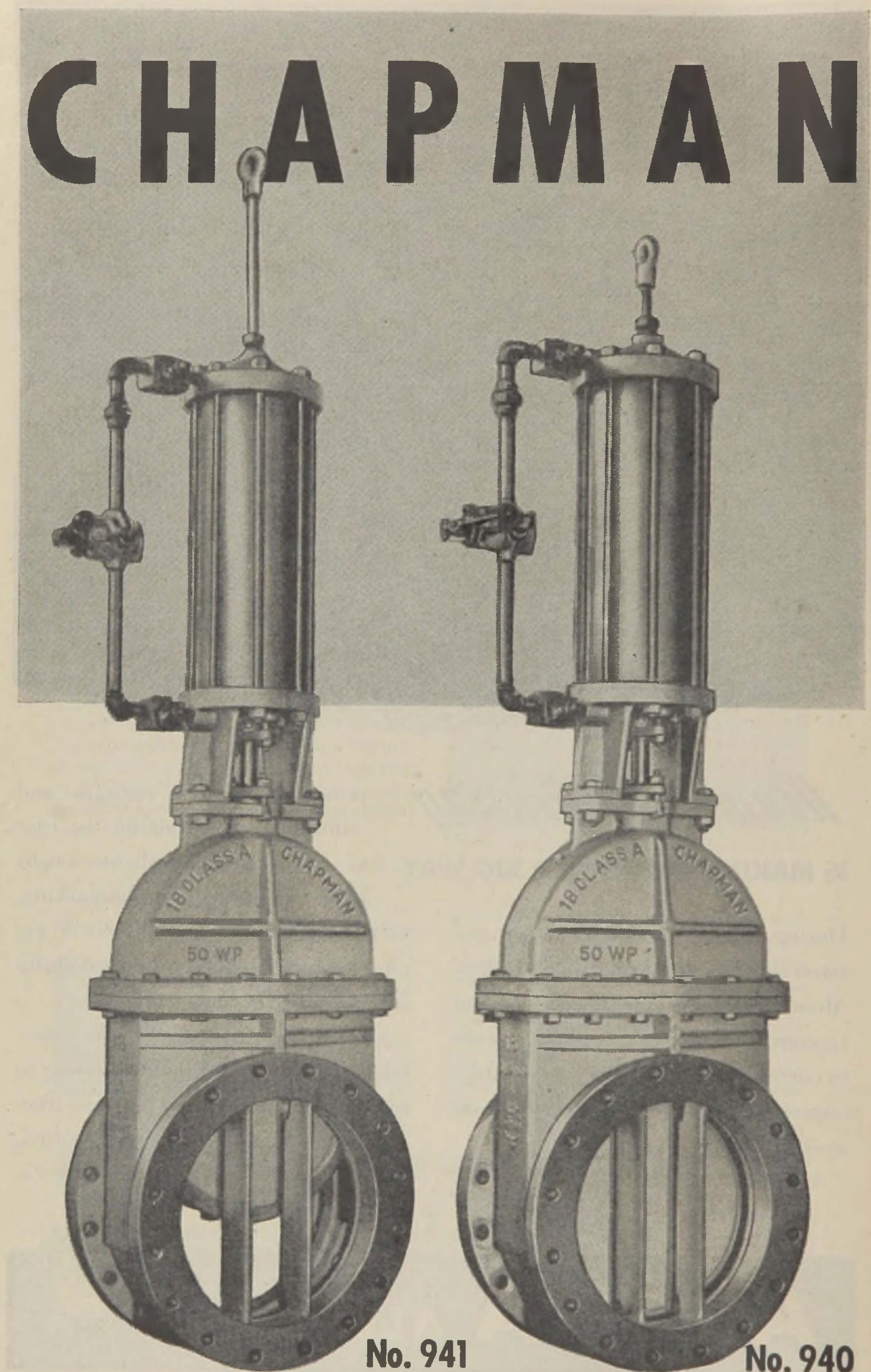
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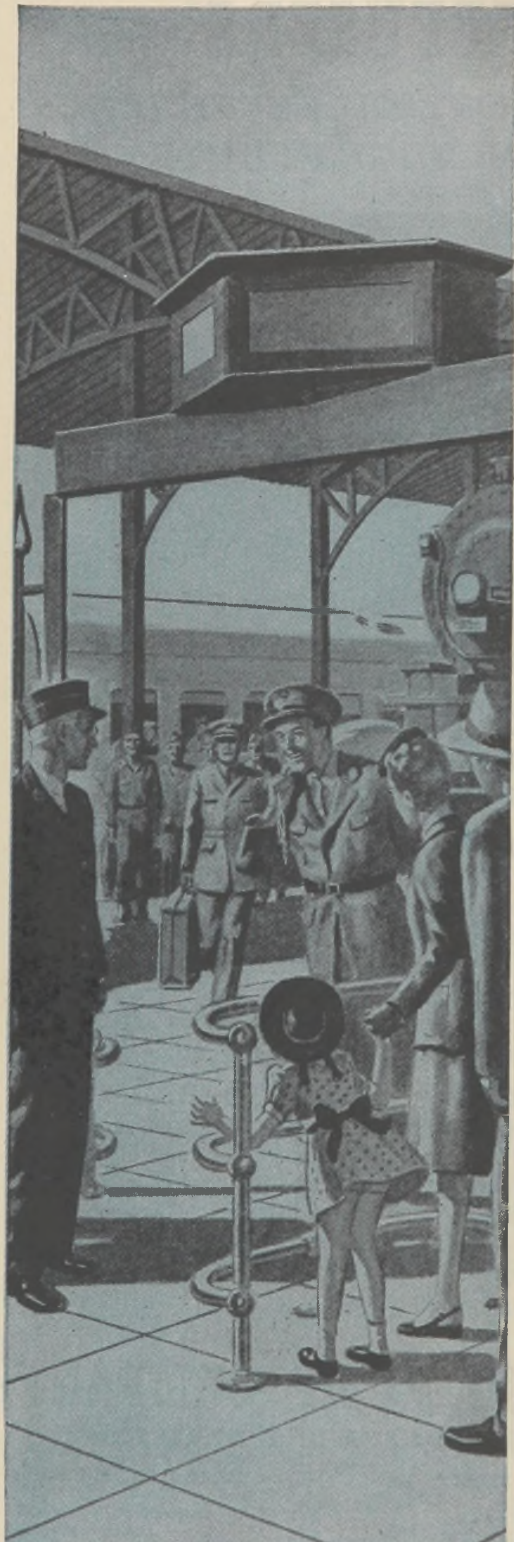

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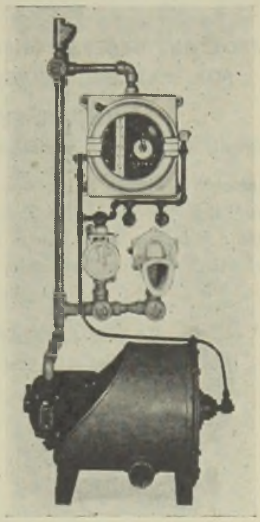

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**Plant Operation:**



**Sewage Research:**



**Industrial Wastes:**



**Sewage Works Planning:**



**Stream Pollution:**



**Contributed Discussions:**



**The Operator's Corner:**

# Plant Operation

## PRACTICAL APPLICATIONS OF PRINCIPLES OF MODIFIED SEWAGE AERATION *

By L. R. Setter, W. T. Carpenter and George C. Winslow

*Principal Sanitary Chemist, Senior Chemist and Engineer in Charge of Jamaica Sewage Treatment Plant, Respectively, Department of Public Works, City of New York*

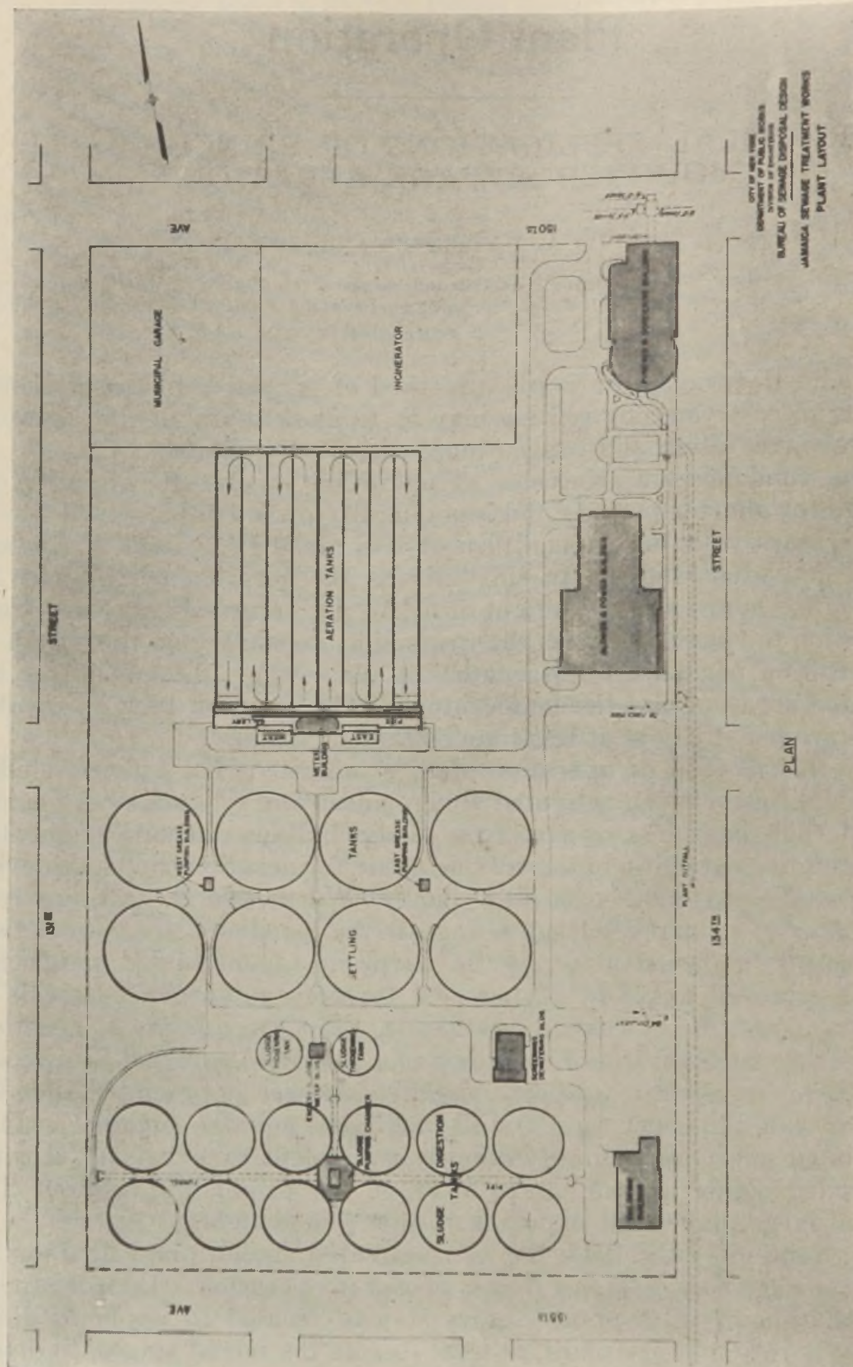
Modified sewage aeration is a method of operation of the activated sludge process whereby sewage may be treated to any degree between plain sedimentation and conventional activated sludge.

The fundamental principles of operation involve the aeration of sewage for shorter periods and less quantity of active biological floc in the aerators with the expenditure of less air than is used in conventional activated sludge. In this process the aeration period may be one to four hours and the weight of active floc returned may vary from a fraction to roughly 4 times the raw solids, depending on the length of the aeration period, the "strength" of the sewage, the amount of air used for aeration and the temperature. The aeration tank suspended solids are usually held at less than 600 to 800 p.p.m.

By this method of operation studies indicated that a dense sludge with qualities between activated sludge and primary sludge may be obtained, that the process is free from sludge bulking difficulties, and that a substantial reduction in the volume of air for aeration can be achieved. From studies (5) made of a pilot plant at Wards Island treating a constant flow of primary settled sewage it was predicted that for a two-hour aeration period at 68° F. the average of suspended solids and B.O.D. removed would be 72 per cent for aerator suspended solids of 200 p.p.m. and 80 per cent for 400 p.p.m. For three hours of aeration, the average removal would be 79 per cent for 200 p.p.m. and 85 per cent for 400 p.p.m. aerator suspended solids. It was appreciated that the aerator wall film consisting of stalked ciliates, aquatic earthworms, and associated microorganisms frequently equivalent to 100 p.p.m. aerator suspended solids accounted for part of the promising results. The need of large plant scale experimentation was evident.

On September 28, 1943, the new activated sludge plant at Jamaica with a sewage flow of 35 m.g.d. was placed in operation. In order to get confirmation of pilot plant studies it was decided to apply modified sewage aeration at the plant, at least during the initial stages, to determine treatment performance and power economies. Fortunately, the size of the units and hydraulic conditions at this plant permitted the

* Presented at 17th Annual Meeting, New York State Sewage Works Association, New York City, January 19, 1945.




Layout of Jamaica sewage treatment plant.

study of short aeration periods and low aerator solids with minor alterations.

It is the purpose of this paper to present the results of the application of modified sewage aeration at a 35 m.g.d. plant over a 14-month period and to compare the results with that of the pilot plant studies.

## Other Studies

Some practical studies on aeration approaching the principles of modified sewage aeration appear in the literature. Many of the earlier studies were incompletely reported, primarily because nitrification was considered important to purification and a crystal clear effluent was desired.

Hatfield (2) reported the experimental operation of the Decatur sewage treatment plant in 1931. The sewage was aerated for 1.85 to 2.66 or an average of 2.54 hours with a clarifier return flow of 3.9 to 22, or an average of 9 per cent of the sewage flow, to yield an aeration tank suspended solids of 190 p.p.m. Air was supplied at a rate of 0.35 to 0.85 cu. ft. per gallon. Very little sludge accumulated in the clarifier, but the moderately strong Imhoff tank effluent B.O.D. was reduced 20 to 45 or an average of 32 per cent.

Anderson (1) reported an aeration period of 4.75 hours and a yearly average aerator suspended solids of 733 to 891 p.p.m. During five years of operation prior to 1941 a reduction of 71.6 to 82.8 per cent of the primary settler effluent B.O.D. and a similar reduction of the suspended solids due to aeration and settling was achieved with the use of 1.8 to 2.1 cu. ft. of air per gallon of sewage. A thick excess sludge was produced.

Ridenour (4) reported a study of an activated sludge plant using very low aerator suspended solids of 150 p.p.m., but a long aeration period of 9 hours.

Many mechanical aerators have been found most efficient when an aerator solids well under 1,000 p.p.m. is maintained. All activated sludge plants operate in a manner similar to modified aeration for brief periods during initial operation before major accumulation of aerator solids or perhaps immediately following severe bulking troubles.

## The Jamaica Sewage Treatment Plant

At the Jamaica plant essentially domestic sewage from a combined system is aerated without presettling and, except for the last month of the study, without fine screening. Following coarse and fine racks, the sewage passes through grit chambers and the fine screens before it is pumped against a head of some 35 feet. It then flows by gravity through the aeration tanks and settling tanks and is finally discharged through a long outfall into Jamaica Bay.

There are two spiral flow aeration tanks, each consisting of four channels 320 feet long by 30 feet wide and 15 feet deep with a net volume of 4.1 m.g. Thus, for a sewage flow of 35 m.g.d. and a return sludge flow of 6 m.g.d., the theoretical aeration period is 2.4 hours with one aerator in service or 4.8 hours with both aerators in service.

Only four of the eight available settlers have been in service at a time. The settlers are 120 feet in diameter with central feed, V-notched effluent weirs, and scum and sludge removal mechanisms. Each has a volume of 1.03 m.g. Thus the volume of four settlers is equivalent to one aerator. The average detention in the settlers is 2.8 hours, the

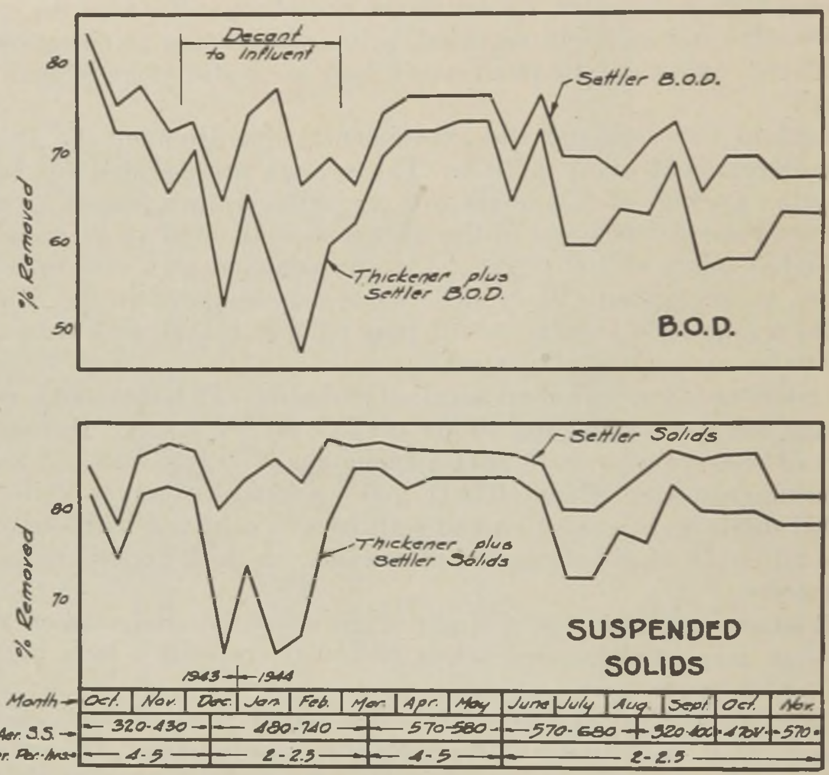



FIGURE 1.—The chronological semi-monthly suspended solids and B.O.D. removal by the settlers and the combined settler and thickener removal.

overflow rate is 850 gal. per day per sq. ft. or 24,400 gals. per day per linear foot of weir for a 35 m.g.d. sewage flow. The desludging mechanism operates at a constant speed of one revolution in 40 minutes or, theoretically, 3 hours for the mechanical transfer of sludge from the periphery to the collecting sumps at the center. In two of the settlers, excess sludge may be drawn by gravity to one or both of two sludge thickeners. Sludge is returned to the aeration tanks by air lifts. The return sludge is mixed with sewage in an aerated influent channel before entering the aerator.

The two circular sludge thickeners, which are 55 feet in diameter and 10 to 12 feet deep, have a two-armed picket fence collecting and thickening mechanism. They are centrally fed and have a smooth weir

162 feet long at the periphery. Charged at a rate of 2 m.g.d. the overflow rate is 955 gals. per day per sq. ft. or 12,300 gals. per day per linear foot of weir. The thickener effluent is discharged to the outfall. The thickened sludge is fed to the digesters.

The plant effluent is chlorinated during the bathing season.

Digester gas furnishes most of the fuel to three 1,540 h.p. gas engines, only one of which is operated at a time. The engines are used in generating the necessary electrical energy for pumping and air supply.

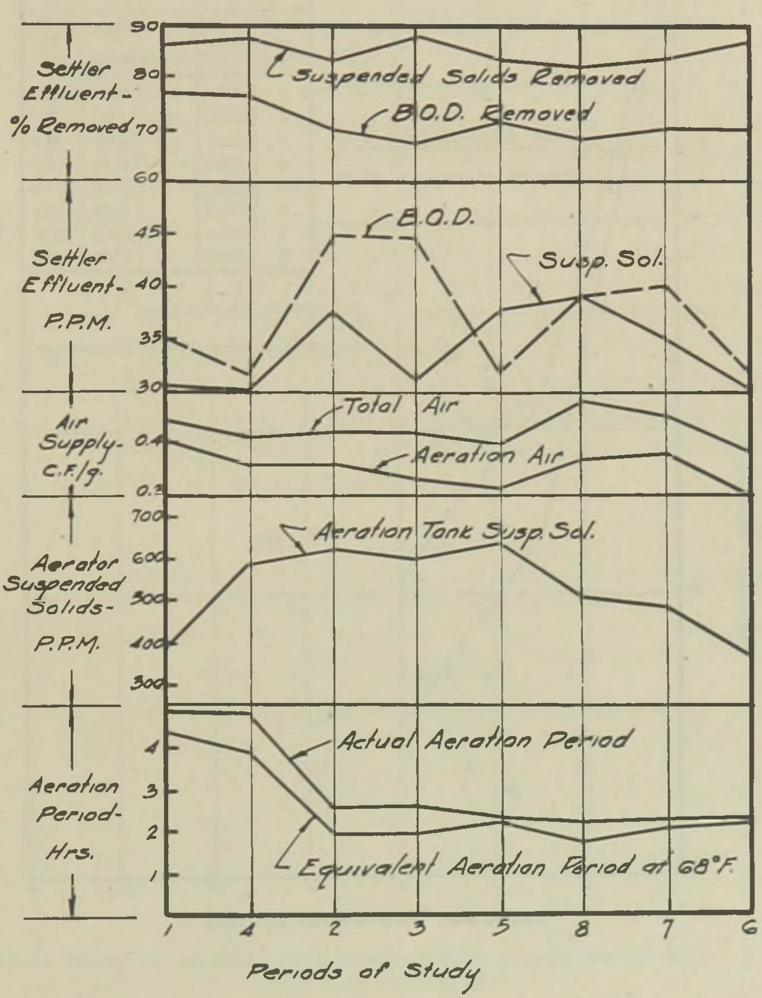



FIGURE 2.—Correlation of treatment performance with operating conditions.

## Operation by Modified Sewage Aeration

During the first 14 months of operation substantially four systems of control were investigated, namely, a short or long aeration period in combination with either a low or high aerator suspended solids content.

By short and long aeration is meant 2.0 to 2.5 hours or 4 to 5 hours aeration, respectively. With low aerator suspended solids all the sludge from two of the four settlers in service was returned and with high aerator suspended solids all the sludge from three of the four settlers in service was returned. Using this simple and positive method of control it was found that the aerator suspended solids varied from a

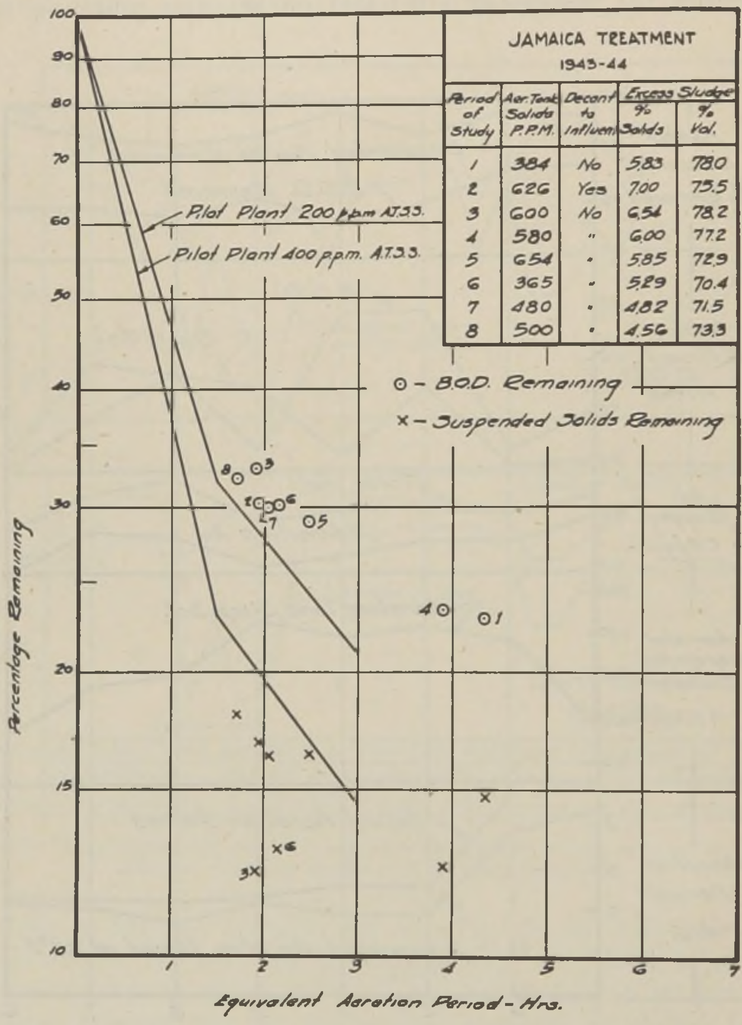



FIGURE 3.—A comparison of plant scale operation at the Jamaica sewage treatment plant with pilot plant studies.

minimum of 200 to a maximum of 500 p.p.m. for low aerator solids and from a minimum of 400 to a maximum of 1,200 p.p.m. for high aerator solids.

The flow of return sludge was of minor concern except as it decreased the effective aeration period. The air lifts were so set that a flow of 3 m.g.d. was returned from each settler. Thus, for low aerator solids the return sludge flow was 6 m.g.d. and for high aerator solids the return sludge flow was 9 m.g.d. Under these conditions the return sludge solids varied from 600 to 5,000 p.p.m. or an average of 1,600 to 2,000 p.p.m.

Except for the first 2 months of operation only one of the two thickeners has been in service. Roughly 2 m.g.d. of thin sludge containing a calculated 0.35 per cent or less solids was concentrated to 4 to 7.25 per cent solids and fed to the digesters.

## Results of Operation

The results of the first 14 months of operation are presented in Tables 1 to 8 and Figures 1 to 3 inclusive. Table 1 summarizes the use of digester and utility gas for operating the gas engines and boilers. It will be noted that almost two months were required to place the digesters in active operation while using utility gas to heat them for mesophilic digestion. The gas engines were ready for operation about the time digester gas was being produced in liberal quantities. Gas engine cooling water and exhaust heat exchangers then furnished most of the heat necessary for the digesters, buildings and hot water. During the summer months settler effluent was circulated to waste through the engine cooling water heat exchangers. Although a yearly average of only 7.2 per cent of the total gas energy was purchased from December, 1943, to December, 1944, it is anticipated a lesser amount may be necessary following minor improvements.

Table 1.—*Gas Energy Used*

| Year | Month | Thousands of Cubic Feet of Gas per Day | | | | | Percentage Utility |
|---|---|---|---|---|---|---|---|
| | | For Engines | For Aux. Heat | Utility Purchased | Digester Gas | Total Used | |
| 1943 | Oct. | 0 | 145.6 | 145.6 | 0 | 145.6 | 100.0 |
| | Nov. | 64.5 | 144.0 | 148.8 | 59.7 | 208.5 | 71.2 |
| | Dec. | 391.1 | 71.5 | 36.1 | 426.6 | 462.5 | 7.8 |
| 1944 | Jan. | 408.6 | 3.8 | 35.1 | 412.4 | 447.5 | 7.8 |
| | Feb. | 376.8 | 1.7 | 22.6 | 355.9 | 378.5 | 6.0 |
| | Mar. | 308.1 | 1.1 | 0.2 | 309.0 | 309.2 | 0.1 |
| | Apr. | 384.0 | 3.7 | 2.3 | 385.7 | 388.0 | 0.6 |
| | May | 384.0 | 0 | 5.7 | 378.7 | 384.4 | 1.5 |
| | June | 377.0 | 0 | 12.0 | 365.0 | 377.0 | 3.2 |
| | July | 381.5 | 0 | 88.3 | 293.2 | 381.5 | 23.1 |
| | Aug. | 409.0 | 0 | 47.6 | 361.4 | 409.0 | 11.6 |
| | Sept. | 428.0 | 0 | 37.4 | 390.6 | 428.0 | 8.7 |
| | Oct. | 455.2 | 0 | 65.6 | 389.6 | 455.2 | 14.4 |
| | Nov. | 458.2 | 1.3 | 24.2 | 435.1 | 459.1 | 5.3 |
| Ave. | Oct.-Oct. | 326.0 | 31.0 | 48.5 | 308.5 | 357.0 | 13.6 |
| Ave. | Dec.-Dec. | 396.8 | 6.9 | 31.4 | 403.7 | 435.1 | 7.2 |

## Electrical Energy Used

Table 2 summarizes the electrical energy generated, the utility electrical energy purchased and the breakdown of energy used for the blowers versus that used for pumping sewage and sludges, grinding screenings, auxiliary motors and lighting. Following the first two months, it will be noted that of the yearly average of 547 kw. hr. per million gallons of sewage, 6.8 per cent was purchased. Of the 547 kw. hr., 256 kw. hr. or 46.8 per cent was used by the air blowers.

Table 2.—*Electrical Energy Used*

| Year | Month | Thousands of Kw. Hr. per Day | | | | Kw. Hr. per M.G. | Percentage Utility | Percentage for Blowers |
|---|---|---|---|---|---|---|---|---|
| | | Generated | Utility | Total | For Blowers | | | |
| 1943 | Oct. | 0 | 15.93 | 15.93 | 8.58 | 455 | 100.0 | 53.8 |
| | Nov. | 1.87 | 14.58 | 16.44 | 9.04 | 470 | 88.6 | 54.9 |
| | Dec. | 13.68 | 3.38 | 17.06 | 8.38 | 590 | 19.8 | 49.1 |
| 1944 | Jan. | 15.58 | 1.65 | 17.23 | 8.42 | 574 | 9.6 | 48.8 |
| | Feb. | 16.21 | 1.31 | 17.52 | 8.45 | 600 | 7.5 | 48.1 |
| | Mar. | 16.65 | 1.20 | 17.85 | 8.16 | 584 | 6.7 | 45.7 |
| | Apr. | 16.70 | 1.06 | 17.76 | 8.41 | 534 | 6.0 | 47.4 |
| | May | 16.00 | 0.82 | 16.82 | 7.97 | 550 | 4.9 | 47.4 |
| | June | 15.67 | 1.19 | 16.86 | 7.65 | 540 | 7.0 | 45.4 |
| | July | 15.87 | 1.21 | 17.08 | 7.63 | 512 | 7.1 | 44.7 |
| | Aug. | 16.78 | 0.61 | 17.39 | 7.50 | 469 | 3.5 | 43.2 |
| | Sept. | 17.80 | 0.55 | 18.35 | 8.24 | 485 | 3.0 | 44.9 |
| | Oct. | 18.97 | 0.616 | 19.58 | 9.46 | 561 | 3.5 | 48.4 |
| | Nov. | 19.10 | 1.05 | 20.15 | 9.57 | 560 | 5.21 | 47.5 |
| Ave. | Oct.-Oct. | 13.57 | 3.62 | 17.19 | 8.20 | 530 | 21.2 | 47.7 |
| Ave. | Dec.-Dec. | 16.58 | 1.21 | 17.79 | 8.32 | 547 | 6.8 | 46.8 |

## Blower Air

Table 3 summarizes the utilization of blower air. Compressed to a pressure of 6.5 lbs. per square inch, roughly 10,000 c.f.m. of free air was supplied at the lowest and most inefficient speed of a single blower. With minor increase in power input it has been found that the blower operates more smoothly at the second of the five available speeds. At this speed roughly 12,000 c.f.m. are produced at the same pressure. During the 14 months of operation, with rare exception, the blower has been operated at one of these two speeds and process control has been adjusted to obtain near maximum utilization of this air supply. The table shows that following the first two months, a yearly average of 18 per cent of the air was used by the air lifts. Thus, a yearly average of 0.42 cubic ft. of free air per gallon of sewage was used for treatment, of which 0.34 cu. ft. was used for aeration.

TABLE 3.—*Blower Air*

| Year | Month | Million Cu. Ft. per Day | | Percentage for Air Lifts | Total Air (C.F./Gal.) | Air for Aeration (C.F./Gal.) |
|---|---|---|---|---|---|---|
| | | Produced | For Air Lifts | | | |
| 1943 | Oct. | 16.2 | 1.01 | 6.2 | 0.46 | 0.43 |
| | Nov. | 15.4 | 1.12 | 7.3 | 0.44 | 0.41 |
| | Dec. | 15.0 | 2.63 | 17.5 | 0.43 | 0.35* |
| 1944 | Jan. | 15.0 | 2.23 | 14.9 | 0.43 | 0.36* |
| | Feb. | 14.8 | 2.27 | 15.3 | 0.42 | 0.35* |
| | Mar. | 14.1 | 2.30 | 16.3 | 0.40 | 0.33* |
| | Apr. | 15.6 | 2.30 | 14.7 | 0.44 | 0.37 |
| | May | 14.3 | 2.09 | 14.6 | 0.41 | 0.35 |
| | June | 13.6 | 2.74 | 20.1 | 0.44 | 0.35 |
| | July | 13.6 | 2.88 | 21.2 | 0.41 | 0.32 |
| | Aug. | 13.7 | 2.88 | 21.0 | 0.35 | 0.28 |
| | Sept. | 13.1 | 2.88 | 22.0 | 0.38 | 0.30 |
| | Oct. | 15.85 | 2.50 | 15.8 | 0.45 | 0.38 |
| | Nov. | 17.17 | 3.80 | 22.2 | 0.48 | 0.37 |
| Ave. | Oct.-Oct. | 14.50 | 2.28 | 15.7 | 0.44 | 0.35 |
| Ave. | Dec.-Dec. | 14.65 | 2.63 | 18.0 | 0.42 | 0.34 |

* Inclusive of 5 to 20 per cent of aeration air to an idle aerator.

## MARSHALLING OF TREATMENT AND ANALYTICAL DATA

Since operation was intentionally changed from time to time, the 14-month period is divided into semi-monthly or monthly periods of operation which are then grouped into 8 periods. A weighted average was calculated for each period containing more than one set of monthly averages. This method of marshalling data is shown clearly in Tables 4 to 7. A resumé of the periods and major operating conditions is as follows:

| Period | Date of Study | Length of Study (Months) | Aeration Period (Hours) | Aerator Suspended Solids (P.P.M.) | Remarks |
|---|---|---|---|---|---|
| 1 | Oct. 1–Dec. 15 | 2.5 | 4—5 | 385 | |
| 2 | Dec. 16–Feb. 29 | 2.5 | 2—2.5 | 625 | (1) |
| 3 | Mar. 1–Mar. 15 | 0.5 | 2—2.5 | 600 | |
| 4 | Mar. 16–May 30 | 2.5 | 4—5 | 580 | |
| 5 | June 1–Aug. 24 | 2.75 | 2—2.5 | 635 | |
| 6 | Aug. 25–Sept. 30 | 1.25 | 2—2.5 | 365 | |
| 7 | Oct. 1–Oct. 31 | 1 | 2—2.5 | 480 | (2) |
| 8 | Nov. 1–Nov. 30 | 1 | 2—2.5 | 500 | |

(1) A substantial quantity of digester supernatant was returned to the head of the plant. In all succeeding periods the supernatant was drawn directly to the plant outfall (Tables 6 and 7).

(2) A variable aerator solids was maintained to compensate for diurnal fluctuations of the incoming B.O.D. load. From 8 A.M. to 12 midnight the average aerator suspended solids were 560 p.p.m. and from midnight to 8 A.M. they were 380 p.p.m.

## Flow and Loading Factors

Table 4 summarizes averages of the sewage and return sludge flows in million gallons per day, the aeration period and detention in the settling tanks in hours, the amount of rainfall or precipitation in inches for the period of study, the sewage temperature in degrees Fahrenheit, the aeration tank suspended solids in p.p.m., the temperature factor based on the Phelps' formula (4) and used to convert the actual aeration period to an equivalent aeration period at a constant sewage temperature of 68° F. and the calculated equivalent aeration period.

It is important to bear in mind the diurnal fluctuation of dry weather flows as affecting treatment. For example, an average aeration period of 2.5 hours includes a maximum aeration period of 4 hours or more from 2 A.M. to 8 A.M. and minimum aeration periods of 1.3 to 1.4 hours from 11 A.M. to late in the evening. Similarly, the average detention in the settling tanks of 3 hours includes a maximum of 6 hours or more and a minimum detention of 1.75 hours, assuming equal flow in each settler. Actually, unequal flows prevailed, so that the detention period

Table 4.—*Flow and Loading Factors*

| Period | Date | Sewage Flow (M.G.D.) | Return Flow (M.G.D.) | Aeration Period (Hrs.) | Settler Detention (Hrs.) | Rainfall (Inches) | Sewage Temp. (° F.) | Aerator Sus. S. (P.P.M.) | Temp. Factor to 68° F. | Equiv. Aeration Period 68° F. (Hrs.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| | Low Solids—Long Aeration | | | | | | | | | |
| | Oct. 1–15 | 35 | 5 | 4.9 | 2.82 | 3.19 | 66.0 | 390 | 0.95 | 4.65 |
| | 16–31 | 35 | 5 | 4.9 | 2.82 | 6.05 | 63.4 | 430 | 0.89 | 4.35 |
| | Nov. 1–15 | 35 | 6 | 4.8 | 2.82 | 1.59 | 64.1 | 320 | 0.90 | 4.30 |
| | 16–30 | 35 | 6 | 4.8 | 2.82 | 0.38 | 62.6 | 350 | 0.87 | 4.17 |
| | Dec. 1–15 | 28.5 | 6 | 5.0 | 3.47 | 0.15 | 62.5 | 430 | 0.865 | 4.32 |
| 1 | Ave. | 33.7 | 5.6 | 4.88 | 2.95 | — | 63.7 | 384 | — | 4.36 |
| | High Solids—Short Aeration—Decant | | | | | | | | | |
| | Dec. 16–31 | 29 | 9 | 2.6 | 3.41 | 1.27 | 60.6 | 570 | 0.83 | 2.16 |
| | Jan. 1–15 | 31 | 9 | 2.46 | 3.19 | 5.13 | 54.4 | 480 | 0.71 | 1.75 |
| | 16–31 | 29 | 9 | 2.60 | 3.41 | 0.19 | 57.7 | 710 | 0.77 | 2.00 |
| | Feb. 1–15 | 29.3 | 9 | 2.58 | 3.38 | 1.41 | 56.5 | 740 | 0.75 | 1.93 |
| | 16–29 | 29.3 | 9 | 2.58 | 3.38 | 0.79 | 55.7 | 630 | 0.73 | 1.88 |
| 2 | Ave. 12/16–3/1 | 29.5 | 9 | 2.56 | 3.34 | — | 57.0 | 626 | — | 1.94 |
| 3 | Mar. 1–15 | 28.9 | 9 | 2.60 | 3.42 | 3.81 | 55.8 | 600 | 0.735 | 1.91 |
| | High Solids—Long Aeration | | | | | | | | | |
| | Mar. 16–31 | 32.4 | 9 | 4.8 | 3.05 | 2.81 | 56.7 | 570 | 0.75 | 3.60 |
| | Apr. 1–30 | 33.3 | 9 | 4.7 | 2.97 | 5.05 | 59.0 | 590 | 0.795 | 3.74 |
| | May 1–30 | 30.6 | 9 | 5.0 | 3.23 | 1.54 | 61.0 | 580 | 0.835 | 4.17 |
| 4 | Ave. | 32.0 | 9 | 4.82 | 3.09 | — | 59.3 | 580 | — | 3.90 |

TABLE 4.—*Flow and Loading Factors*—Continued

| Period | Date | Sewage Flow (M.G.D.) | Return Flow (M.G.D.) | Aeration Period (Hrs.) | Settler Detention (Hrs.) | Rainfall (Inches) | Sewage Temp. (° F.) | Aerator Sus. S. (P.P.M.) | Temp. Factor to 68° F. | Equiv. Aeration Period 68° F. (Hrs.) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| | High Solids—Short Aeration | | | | | | | | | |
| | June 1–15 | 31 | 9 | 2.46 | 3.2 | 1.55 | 64.0 | 680 | 0.90 | 2.22 |
| | 16–31 | 31 | 9 | 2.46 | 3.2 | 1.83 | 66.0 | 680 | 0.95 | 2.34 |
| | July 1–31 | 32 | 9 | 2.40 | 3.1 | 2.20 | 69.0 | 640 | 1.03 | 2.47 |
| | Aug. 1–24 | 37 | 9 | 2.14 | 2.67 | 3.07 | 69.0 | 570 | 1.03 | 2.10 |
| 5 | Ave. | 33 | 9 | 2.35 | 3.0 | — | 67.5 | 634 | — | 2.24 |
| | Low Solids—Short Aeration | | | | | | | | | |
| | Aug. 25–31 | 36 | 6 | 2.35 | 2.74 | 0.01 | 67.0 | 325 | 0.975 | 2.29 |
| | Sept. 1–12 | 37 | 6 | 2.30 | 2.67 | 0.10 | 67.0 | 335 | 0.975 | 2.24 |
| | 13–30 | 38 | 6 | 2.24 | 2.60 | 8.51 | 65.0 | 400 | 0.93 | 2.08 |
| 6 | Ave. | 37.3 | 6 | 2.28 | 2.65 | — | 66.0 | 365 | — | 2.16 |
| | Compensating Low Solids—Short Aeration | | | | | | | | | |
| 7 | Oct. 1–31 | 34.8 | 8 | 2.3 | 2.84 | 3.44 | 64.0 | 480 | 0.90 | 2.06 |
| | High Solids—Short Aeration | | | | | | | | | |
| 8 | Nov. 1–30 | 36.0 | 9 | 2.2 | 2.74 | 7.14 | 58.0 | 500 | 0.775 | 1.7 |

in one settler was as high as 7 to 8 hours, and in another as low as one hour.

## Quality and Condition of Liquors

Table 5 summarizes the influent, settler effluent, thickener effluent and returned sludge suspended solids in parts per million; the concentration of excess sludge pumped to the digesters in per cent dry solids and the fraction of the dry solids which is volatile or lost on ignition; the influent, settler effluent and thickener effluent 5 day B.O.D. in parts per million; and the aeration tank effluent and settling tank effluent dissolved oxygen in parts per million.

It will be noted that the Jamaica raw sewage has an average suspended solids of 200 p.p.m. and a rather low B.O.D. of 150 p.p.m. or less, exclusive of the period December 16 to February 29, 1944, when the return of digester supernatant affected sampling. The settler effluent varied somewhat depending on the type of treatment. The daily suspended solids and B.O.D. in p.p.m. varied from the low twenties to the high forties with very few exceptions. The thickener effluent suspended solids and B.O.D. were comparable to that of raw sewage except when digester supernatant was returned to the influent. Since the thickener effluent is relatively "fresh" it should logically be returned to the aerator for further treatment. The seeding of the excess sludge by anaerobic organisms of the supernatant is definitely deleterious to sludge thickening. Any type of septicity should logically be avoided.

The excess sludge concentration varies considerably from day to day, depending more on excess sludge pumping schedules than on the condition or nature of the sludge. However, rainfall frequently brings in solids of a low volatile content which can be easily thickened to a greater degree. The results show that an average concentration of greater than 4.0 per cent could be obtained readily. The average concentration of excess sludge from October 15, 1943, to December 1, 1944, was 5.85 per cent.

The average masks a satisfactory picture of the true dissolved oxygen conditions since it includes abnormally high dissolved oxygen values following sewage dilution by rainfall and it is further an average of morning and afternoon tests. Following the long early morning aeration period, a moderately high dry weather aerator effluent dissolved oxygen of 4 to 6 p.p.m. was found. A sharp drop of 50 to 75 per cent

TABLE 5.—*Quality and Condition of Liquors*

| Period | Date | Suspended Solids (P.P.M.) | | | | Excess Sludge | | 5-Day B.O.D. (P.P.M.) | | | Diss. Oxygen (P.P.M.) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plant Inf. | Settler Eff. | Thick Eff. | Return Sludge | Total Sol. (%) | Volatile Sol. (%) | Plant Inf. | Settler Eff. | Thick Eff. | Aerator Eff. | Settler Eff. |
| | **Low Solids—Long Aeration** | | | | | | | | | | | |
| | Oct. 1–15 | — | 28 | — | 2280 | 2.3 | — | 160 | 26.3 | — | 4.6 | 1.1 |
| | 16–31 | 179 | 38 | 125 | — | 6.0 | — | 134 | 31.5 | 85 | — | — |
| | Nov. 1–15 | 212 | 28 | 125 | 1120 | 6.7 | 78 | 152 | 33.6 | 85 | 5.1 | 1.8 |
| | 16–30 | 204 | 27 | 140 | — | 5.75 | 79 | 149 | 40.6 | 117 | — | — |
| | Dec. 1–15 | 248 | 32 | 110 | 1470 | 4.85 | 77 | 167 | 43.8 | 51 | 3.5 | 1.6 |
| 1 | Ave. | 211 | 30.6 | 125 | 1654 | 5.85 | 78 | 152 | 35.2 | 85 | 4.6 | 1.5 |
| | **High Solids—Short Aeration—Decant to Plant Influent** | | | | | | | | | | | |
| | Dec. 16–31 | 260 | 46 | 625 | — | 6.28 | 77 | 165 | 56.9 | 295 | — | — |
| | Jan. 1–15 | 244 | 32 | 355 | 1420 | 7.25 | 77 | 141 | 35.6 | 192 | 3.8 | 3.1 |
| | 16–31 | 333 | 33 | 705 | — | 7.15 | 76 | 184 | 41.3 | 510 | — | — |
| | Feb. 1–15 | 328 | 43 | 900 | 2010 | 7.00 | 73.4 | 147 | 48.8 | 398 | 3.1 | 2.8 |
| | 16–29 | 250 | 33 | 350 | — | 7.30 | 76.3 | 137 | 40.7 | 185 | — | — |
| 2 | Ave. 12/16–3/1 | 283 | 37.4 | 587 | 1666 | 7.00 | 75.5 | 155 | 44.7 | 316 | 3.5 | 2.7 |
| 3 | Mar. 1–15 | 204 | 31 | 95 | 1930 | 6.54 | 78.2 | 134 | 44.7 | 65 | 4.2 | 2.5 |
| | **High Solids—Long Aeration** | | | | | | | | | | | |
| | Mar. 16–31 | 186 | 26 | 160 | — | 5.87 | 76.2 | 127 | 31.6 | 105 | — | — |
| | Apr. 1–30 | 184 | 28 | 151 | 2090 | 6.40 | 77.0 | 121 | 28.0 | 78 | 3.9 | 1.8 |
| | May 1–30 | 205 | 34 | 120 | 2110 | 5.66 | 78.6 | 156 | 36.0 | 76 | 1.8 | 0.9 |
| 4 | Ave. | 193 | 30 | 140 | 2066 | 6.00 | 77.5 | 136 | 31.9 | 83 | 3.0 | 1.6 |

TABLE 5.—*Quality and Condition of Liquors*—Continued

| Period | Date | Suspended Solids (P.P.M.) | | | | Excess Sludge | | 5-Day B.O.D. (P.P.M.) | | | Diss. Oxygen (P.P.M.) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Plant Inf. | Settler Eff. | Thick Eff. | Return Sludge | Total Sol. (%) | Volatile Sol. (%) | Plant Inf. | Settler Eff. | Thick Eff. | Aerator Eff. | Settler Eff. |
| | | | | | | High Solids—Short Aeration | | | | | | |
| | June 1–15 | 255 | 34 | 128 | 1860 | 5.70 | 74.0 | 129 | 37.0 | 82 | 1.6 | 0.8 |
| | 16–30 | 255 | 36 | 128 | — | 6.86 | 74.0 | 141 | 33.0 | 82 | — | — |
| | July 1–31 | 185 | 42 | 283 | 2050 | 5.70 | 72.5 | 109 | 33.0 | 159 | 2.5 | 0.5 |
| | Aug. 1–24 | 172 | 35 | 150 | 1640 | 5.52 | 72.3 | 85 | 27.5 | 71 | 3.5 | 0.8 |
| 5 | Ave. | 206 | 37.5 | 190 | 1630 | 5.85 | 72.9 | 111 | 32.1 | 107 | 2.5 | 0.7 |
| | | | | | | Low Solids—Short Aeration | | | | | | |
| | Aug. 25–31 | 185 | 28.5 | 171 | — | 4.34 | 74.3 | 106 | 30.0 | 78 | — | — |
| | Sept. 1–12 | 220 | 25.5 | 78 | 1540 | 4.26 | 75.0 | 118 | 31.0 | 48 | 5.2 | 0.9 |
| | 13–30 | 195 | 33.0 | 151 | — | 6.30 | 66.0 | 97 | 32.7 | 85 | — | — |
| 6 | Ave. | 202 | 29.8 | 133 | 1520 | 5.29 | 70.4 | 105 | 31.7 | 71 | 5.0 | 0.9 |
| | | | | | | Compensating Low Solids—Short Aeration | | | | | | |
| 7 | Oct. 1–31 | 209 | 35 | 264 | 1420 | 4.82 | 71.5 | 132 | 40.0 | 162 | 4.5 | 0.5 |
| | | | | | | High Solids—Short Aeration | | | | | | |
| 8 | Nov. 1–30 | 212 | 39 | 133 | 1570 | 4.56 | 73.3 | 121 | 39.0 | 87 | 3.7 | 1.4 |

in the aerator effluent dissolved oxygen occurred by 2 P.M. when the B.O.D. load was high and the aeration period short. The dissolved oxygen of the mixed liquor half way through the aerator was roughly one-half that of the aerator effluent. At least 0.5 p.p.m. dissolved oxygen in the first three channels was considered desirable. The settler effluent dissolved oxygen was invariably zero for dry weather flows following the long early morning detention. By 2 P.M. the settler effluent dissolved oxygen was near a maximum and equal to roughly one-half of the afternoon aerator effluent.

## SOLIDS BALANCE

Table 6 summarizes the average tons of dry solids entering and leaving the plant per day on a semimonthly or monthly basis. Since a substantial amount of supernatant solids was returned to the influent from December 1 to March 1, 1944, the amount appearing in column 2 has been accounted for as recirculated solids. The effluent solids consist of the thickener effluent and the settler effluent in columns 3 and 4, respectively. The total effluent solids appears in column 5. Three measurements of the captured solids were available. They are (*a*) the influent flow and suspended solids found in Tables 4 and 5 less the effluent solids;

(*b*) the daily sludge volume converted to tons of dry solids and averaged and (*c*) the volume of supernatant and digested sludge withdrawn during a period plus or minus the difference in the total volume of the digesters at the beginning and end of the period converted to dry tons by the average concentration of sludge. The volume in method (*b*) shown in column 7 consists of taking elevations of the primary digestion tanks before and after they are charged. The volume in method (*c*) shown in column 8 consists of taking elevations of the secondary or tertiary digesters before and after sludge or supernatant is withdrawn, plus the levels of all tanks at the beginning and end. The authors are of the opinion that the average of the latter two methods is more indicative of the actual conditions. Howéver, there is a minor choice of methods when the percentage removal or percentage captured solids is calculated. The percentage removal of solids by the settlers and thickeners by all three methods is presented in column 9 and the percentage re-

TABLE 6.—*Solids Balance*

| Period | Date | Solids in Dry Tons per Day | | | | | | | Per Cent Removal | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Decant to Plant Influent | Thickener Effluent | Settler Effluent | Total Effluent (Col. 3 & 4) | Plant Influent | Captured Solids: Primary Levels | Captured Solids: Secondary Levels | Settler and Thickener | Settler |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | **Low Solids—Long Aeration** | | | | | | | | | |
| | Oct. 1–15 | — | 1.00 | 4.10 | 5.10 | 26.0 | 24.7 | — | 82 | 85 |
| | 16–31 | — | 1.00 | 5.34 | 6.54 | 26.0 | 20.2 | — | 75 | 78.6 |
| | Nov. 1–15 | — | 1.53 | 4.10 | 5.63 | 30.9 | 23.8 | 26.4 | 82 | 86.2 |
| | 16–30 | — | 1.73 | 3.94 | 5.67 | 29.8 | 29.6 | 28.6 | 83 | 87.7 |
| | Dec. 1–15 | 2.03 | 0.93 | 3.80 | 4.73 | 29.6 | 23.2 | 28.4 | 82 | 87.1 |
| 1 | Ave. | — | 1.24 | 4.26 | 5.49 | 28.5 | 24.3 | 25.6 | 81.6 | 85.7 |
| | **High Solids—Short Aeration—Decant to Plant Influent** | | | | | | | | | |
| | Dec. 16–31 | 0.97 | 5.2 | 5.55 | 10.75 | 31.4 | 20.5 | 12.7 | 64 | 80.5 |
| | Jan. 1–15 | 0.67 | 3.0 | 4.13 | 7.13 | 31.5 | 18.8 | 19.9 | 74 | 83.9 |
| | 16–31 | 7.93 | 5.9 | 4.00 | 9.90 | 40.2 | 21.8 | 20.1 | 64 | 86.0 |
| | Feb. 1–15 | 9.00 | 7.5 | 5.25 | 12.75 | 40.0 | 24.2 | 24.5 | 66 | 83.8 |
| | 16–29 | 1.50 | 2.9 | 4.02 | 6.92 | 30.5 | 36.5 | 29.1 | 79 | 88.3 |
| 2 | Ave. 12/16–3/1 | 4.01 | 4.9 | 4.59 | 9.49 | 34.7 | 24.4 | 21.3 | 67.3 | 83.2 |
| 3 | Mar. 1–15 | — | 0.8 | 3.73 | 4.53 | 24.6 | 30.7 | 30.9 | 85 | 87.7 |
| | **High Solids—Long Aeration** | | | | | | | | | |
| | Mar. 16–31 | — | 1.25 | 3.50 | 4.75 | 25.1 | 30.2 | 29.4 | 85 | 87.9 |
| | Apr. 1–30 | — | 1.25 | 3.88 | 5.13 | 25.5 | 30.2 | 28.4 | 83 | 87.2 |
| | May 1–30 | — | 1.00 | 4.33 | 5.33 | 26.1 | 33.8 | 33.8 | 84 | 87.0 |
| 4 | Ave. | — | 1.15 | 3.98 | 5.13 | 25.6 | 31.6 | 30.7 | 83.9 | 87.5 |

TABLE 6.—*Solids Balance*—Continued

| Period | Date | Solids in Dry Tons per Day | | | | | | | Per Cent Removal | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Decant to Plant Influent | Thickener Effluent | Settler Effluent | Total Effluent (Col. 3 & 4) | Plant Influent | Captured Solids | | Settler and Thickener | Settler |
| | | | | | | | Primary Levels | Secondary Levels | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | High Solids—Short Aeration | | | | | | | | | |
| | June 1–15 | — | 1.07 | 4.40 | 5.47 | 33.0 | 29.7 | 28.0 | 84 | 86.7 |
| | 16–30 | — | 1.07 | 4.65 | 5.71 | 33.0 | 26.5 | 25.0 | 82 | 85.4 |
| | July 1–31 | — | 2.36 | 5.60 | 7.96 | 24.6 | 24.8 | 26.2 | 73 | 80.5 |
| | Aug. 1–24 | — | 1.25 | 5.40 | 6.65 | 26.5 | 27.5 | 27.4 | 78 | 82.3 |
| 5 | Ave. | — | 1.59 | 5.15 | 6.74 | 28.1 | 26.7 | 26.6 | 78.6 | 83.6 |
| | Low Solids—Short Aeration | | | | | | | | | |
| | Aug. 25–31 | — | 2.85 | 4.26 | 7.11 | 27.7 | 24.7 | 25.4 | 76.7 | 85.2 |
| | Sept. 1–12 | — | 1.30 | 3.93 | 5.23 | 33.9 | 23.6 | 26.3 | 83.3 | 87.1 |
| | 13–30 | — | 2.51 | 5.21 | 7.72 | 30.8 | 33.7 | 41.6 | 80.2 | 86.2 |
| 6 | Ave. | — | 2.16 | 4.62 | 6.78 | 31.3 | 28.8 | 33.8 | 80.9 | 86.5 |
| | Compensating Low Solids—Short Aeration | | | | | | | | | |
| 7 | Oct. 1–31 | — | 1.10 | 5.06 | 6.16 | 30.4 | 24.7 | 26.1 | 80.1 | 83.6 |
| | High Solids—Short Aeration | | | | | | | | | |
| 8 | Nov. 1–30 | — | 1.11 | 5.84 | 6.95 | 31.8 | 25.0 | 27.0 | 78.7 | 82.0 |

moval by the settling tanks by all three methods, assuming that the thickener solids are captured when returned to the head of the plant, is shown in column 10.

## B.O.D. Balance

Table 7 summarizes the average tons of B.O.D. entering and leaving the plant per day. The method of marshalling the data was similar to that used with the solids balance. Again the percentage removal by the settlers and thickeners and the percentage removal by the settlers, assuming the capture of thickener effluent B.O.D. by retreatment, was calculated.

## Treatment Summary

The removal of suspended solids and B.O.D. by the settlers is plotted chronologically in Figure 1. The combined settler and thickener effluent gave a removal of 78.7 per cent of the suspended solids and 65.4 per cent of the B.O.D. over the 14-month period. If the thickener effluent was returned to the plant influent without any effect on the settler effluent, the 14-month average suspended solids and B.O.D. removal would be 84.9 and 72.5 per cent, respectively.

Since operating conditions were changed, the more pertinent average results of the eight periods of similar operation in Tables 3 to 7 are recapitulated in Table 8 and Figure 2. These results are arranged according to a decreasing aeration period and from a low to high to low aerator suspended solids, irrespective of the season of the year.

Figure 2 more clearly correlates the operating conditions with the treatment results. The results may appear particularly confusing when it is noted that period 6, having nearly the shortest aeration period, the lowest aeration solids and the lowest air supply, compares very favorably in treatment performance to period 4, which has twice as long an aeration time and almost twice the aeration solids. The answer probably lies in the character or settleability of the active floc. The relatively long aeration period has processed the sewage to a degree where the active floc acquires poorer settling qualities and, although the

TABLE 7.—*B.O.D. Balance*

| Period | Date | Tons of 5-Day B.O.D. per Day | | | | | Per Cent Removal | |
|---|---|---|---|---|---|---|---|---|
| | | Decant to Raw Sewage | Thickener Effluent | Settler Effluent | Total Effluent (Col. 4 & 5) | Plant Influent | Settler and Thickener | Settler |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | **Low Solids—Long Aeration** | | | | | | | |
| | Oct. 1–15 | — | 0.67 | 3.83 | 4.50 | 23.3 | 80.7 | 84 |
| | 16–31 | — | 0.69 | 4.60 | 5.29 | 19.5 | 72.9 | 76 |
| | Nov. 1–15 | — | 1.07 | 4.90 | 5.97 | 22.2 | 73.1 | 78 |
| | 16–30 | — | 1.47 | 5.90 | 7.37 | 21.8 | 66.2 | 73 |
| | Dec. 1–15 | 0.31 | 0.43 | 5.20 | 5.63 | 19.8 | 71.2 | 73.4 |
| 1 | Ave. | — | 0.866 | 4.89 | 5.755 | 21.32 | 73.0 | 77.2 |
| | **High Solids—Short Aeration—Decant** | | | | | | | |
| | Dec. 16–31 | 0.17 | 2.44 | 6.86 | 9.30 | 19.9 | 53.0 | 65.2 |
| | Jan. 1–15 | 0.12 | 1.60 | 4.60 | 6.20 | 18.2 | 65.7 | 74.6 |
| | 16–31 | 1.40 | 4.25 | 5.00 | 9.25 | 22.2 | 55.6 | 76.0 |
| | Feb. 1–15 | 1.60 | 3.33 | 5.96 | 9.29 | 17.9 | 48.1 | 66.8 |
| | 16–29 | 0.27 | 1.57 | 4.97 | 6.54 | 16.3 | 59.8 | 69.5 |
| 2 | Ave. 12/16–3/1 | 0.71 | 2.64 | 5.48 | 8.12 | 18.9 | 55.4 | 69.8 |
| 3 | Mar. 1–15 | 0 | 0.54 | 5.37 | 5.91 | 16.1 | 63.3 | 67.0 |
| | **High Solids—Long Aeration** | | | | | | | |
| | Mar. 16–31 | — | 0.81 | 4.26 | 5.07 | 17.1 | 70.3 | 75 |
| | Apr. 1–30 | — | 0.65 | 3.88 | 4.53 | 16.8 | 73.0 | 77 |
| | May 1–30 | trace | 0.63 | 4.60 | 5.23 | 19.9 | 73.8 | 77 |
| 4 | Ave. | — | 0.674 | 4.24 | 4.92 | 18.1 | 72.8 | 76.6 |

TABLE 7.—*B.O.D. Balance*—Continued

| Period | Date | Tons of 5-Day B.O.D. per Day | | | | | Per Cent Removal | |
|---|---|---|---|---|---|---|---|---|
| | | Decant to Raw Sewage | Thickener Effluent | Settler Effluent | Total Effluent (Col. 4 & 5) | Plant Influent | Settler and Thickener | Settler |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | | | High Solids—Short Aeration | | | | | |
| | June 1–15 | — | 0.68 | 4.78 | 5.46 | 16.1 | 66.1 | 71 |
| | 16–30 | — | 0.68 | 4.26 | 4.94 | 18.2 | 72.9 | 77 |
| | July 1–31 | trace | 1.37 | 4.40 | 5.77 | 14.5 | 60.2 | 70 |
| | Aug. 1–24 | — | 0.50 | 4.23 | 4.73 | 13.1 | 63.9 | 68 |
| 5 | Ave. | — | 0.996 | 4.97 | 5.97 | 17.0 | 64.9 | 71 |
| | | | Low Solids—Short Aeration | | | | | |
| | Aug. 25–31 | — | 1.30 | 4.50 | 5.80 | 15.9 | 63.6 | 72 |
| | Sept. 1–12 | — | 0.80 | 4.77 | 5.57 | 18.2 | 69.4 | 74 |
| | 13–30 | — | 1.41 | 5.17 | 6.58 | 15.3 | 57.0 | 66 |
| 6 | Ave. | — | 1.19 | 4.93 | 6.12 | 16.35 | 62.6 | 69.9 |
| | | | Compensating Low Solids—Short Aeration | | | | | |
| 7 | Oct. 1–31 | — | 2.20 | 5.78 | 7.98 | 19.1 | 58.3 | 70.0 |
| | | | High Solids—Short Aeration | | | | | |
| | Nov. 1–30 | — | 0.72 | 5.84 | 6.56 | 18.1 | 63.8 | 67.8 |

effluent is free from sewage turbidity, it contains active floc impurities. With the short aeration and low aerator solids a higher percentage of sewage turbidity and a much smaller percentage of active floc appears in the effluent.

The inferior results in period 2 can be ascribed mainly to the return of digester supernatant to the head of the plant and should be compared with the short 15-day period 3 which followed without the return of digester supernatant. An improvement in the suspended solids is observed but no improvement in the B.O.D. periods 5 and 6 should be compared as equal time of aeration but roughly twice the amount of returned solids in period 5. The same logic as used in comparing periods 4 and 6 applies, i.e., even with an aeration period of 2.25 hours the high return of active floc at this summer temperature processed the sewage to a degree that the floc acquires poorer settling qualities and, although a low effluent B.O.D. is achieved, the suspended solids is higher than when a low aerator solids is maintained.

Periods 7 and 8 cover two months of fall operation when high solids were maintained for a short aeration period. Considering only the short aeration periods, removals of 70 to 71 per cent of the B.O.D. and

TABLE 8.—*Treatment Summary*

| Period<br>Date Begun<br>Date Ended | 1<br>Oct. 1, 1943<br>Dec. 15 | 4<br>March 16<br>May 30 | 2 (a)<br>Dec. 16<br>Feb. 29 | 3<br>March 1<br>March 15 | 5<br>June 1<br>Aug. 24 | 8<br>Nov. 1, 1944<br>Nov. 30 | 7 (b)<br>Oct. 1, 1944<br>Oct. 31 | 6<br>Aug. 25<br>Sept. 30 |
|---|---|---|---|---|---|---|---|---|
| Aeration Period (Hrs.) | 4.88 | 4.82 | 2.56 | 2.6 | 2.35 | 2.2 | 2.3 | 2.28 |
| Equiv. Aer. Period (Hrs.) | 4.36 | 3.9 | 1.94 | 1.91 | 2.24 | 1.7 | 2.06 | 2.16 |
| Aerator Solids, p.p.m. | 384 | 580 | 626 | 600 | 634 | 500 | 480 | 365 |
| Excess Sludge Solids (%) | 5.85 | 6.0 | 7.0 | 6.54 | 5.85 | 4.56 | 4.82 | 5.29 |
| Excess Sludge Vol. Solids (%) | 78.00 | 77.5 | 75.5 | 78.2 | 72.9 | 73.30 | 71.50 | 70.4 |
| Settler Effluent | | | | | | | | |
| Susp. Sol. (P.p.m.) | 30.6 | 30.0 | 37.4 | 31.0 | 37.5 | 39.0 | 35.0 | 29.8 |
| 5-Day B.O.D. (P.p.m.) | 35.2 | 31.9 | 44.7 | 44.7 | 32.1 | 39.0 | 40.0 | 31.7 |
| Removal by Settler | | | | | | | | |
| Susp. Solids (%) | 85.7 | 87.5 | 83.2 | 87.7 | 83.6 | 82.0 | 83.6 | 86.5 |
| 5-Day B.O.D. (%) | 77.2 | 76.6 | 69.8 | 67.0 | 71.0 | 67.8 | 70.0 | 69.9 |
| Removal by Settler and Thickener | | | | | | | | |
| Susp. Solids (%) | 81.6 | 83.9 | 67.3 | 85.0 | 78.6 | 78.7 | 80.1 | 80.9 |
| 5-Day B.O.D. (%) | 73.0 | 72.8 | 55.4 | 63.3 | 64.9 | 63.8 | 58.3 | 62.6 |
| Air Supply | | | | | | | | |
| Total (C.F. per Gal.) | 0.45 | 0.41 | 0.43 | 0.42 | 0.40 | 0.48 | 0.45 | 0.38 |
| For Aer. (C.F. per Gal.) | 0.41 | 0.36 | 0.36 | 0.33 | 0.32 | 0.37 | 0.38 | 0.30 |
| Dissolved Oxygen | | | | | | | | |
| Aerator Eff. (P.p.m.) | 4.6 | 3.0 | 3.5 | 4.2 | 2.5 | 3.7 | 4.5 | 5.0 |
| Settler Eff. (P.p.m.) | 1.5 | 1.6 | 2.7 | 2.5 | 0.7 | 1.4 | 0.5 | 0.9 |

(*a*) Digester supernatant returned to plant influent.
(*b*) Variable aerator solids to compensate diurnal B.O.D. load.

84 to 86 per cent of the suspended solids during the summer and removals of 68 to 70 per cent of the B.O.D. and 82 to 84 per cent of the suspended solids during the fall were obtained.

## Comparison with Pilot Plant Studies

In comparing the operation at Jamaica with the pilot plant studies, the eight periods of similar operation have been superimposed on Figure 4 of a previous paper (5), and are presented in Figure 3. Since there was a greater divergence between the removal of suspended solids and B.O.D., it was desirable not to average the two indices as had been done in the pilot plant studies but to consider each separately. The equivalent aeration period at 68° F., which permits the correlation of studies made at different temperatures, was plotted against the percentage of remaining B.O.D. and suspended solids.

Considering an average pilot plant curve it may be observed that the same trends of treatment performance were achieved at Jamaica. However, several important factors should be mentioned. First, it should be remembered that the Jamaica performance was obtained on raw sewage rather than pre-settled sewage. Secondly, in the practical studies, the diurnal flow cycles cause a daily fluctuation of from one-half to twice the average aeration period and settler detention. Thirdly, any improvement which might be expected due to a greater quantity of active floc in the aerator is offset by over processing the sewage during low flows and increased septicity in the settling tank. Both of these latter factors increase the settler effluent impurities.

## Discussion

Modified sewage aeration as practiced at Jamaica during the first year of operation has proven its predicted potentialities. With some changes in operation better performance may be expected. Some of these changes are:

(*a*) The return of thickener tank effluent to the plant influent for reprocessing.

(*b*) Better control of excess sludge pumping to the digesters to maintain maximum efficiency of the thickeners. At present the concentration of excess sludge bears no relation to the compactability of the sludge.

(*c*) The introduction of air into sections of the settler to maintain dissolved oxygen throughout the tank. The air may be supplied mechanically or by diffusion only during periods of prolonged detention to "freshen" the liquor or decrease the effective settling capacity.

(*d*) The storage of active floc during part of the day to be returned during the peak diurnal B.O.D. load to prevent under-processing of sewage during high flows or peak loads. This may be feasible at low aerator solids but not at high aerator solids without increasing the air supply.

(*e*) A better distribution of air, particularly during peak load conditions.

## Summary

The principles of modified aeration have been applied at the Jamaica sewage treatment plant since October, 1943, to a flow of 35 m.g.d. The raw sewage was aerated without pre-settling for either 2 to 2.5 or 4 to 5 hours, settled for 3 hours and all the sludge from one-half or three-fourths of the settling tanks in service was returned. Thin sludge in the remaining settling tanks was concentrated in thickening tanks and digested. The gas from the digesters was utilized for power generation and heating. Utility gas and electricity were purchased for the first two months. During the following 12 months 7.2 per cent of the gas energy and 6.8 per cent of the electrical energy was purchased; the remaining energy being supplied by digester gas.

An average of 547 kw. hr. of electrical energy was needed per million gallons of sewage, of which 46.8 per cent was for operating the blowers and 53.2 per cent for sewage and sludge pumping, lighting and auxiliary motors, etc.

Eighteen per cent of the 14.65 million cubic feet of air per day was used for the return sludge air lifts and the remainder for aeration. Thus, 0.34 cubic feet of free air per gallon of sewage treated was used for aeration, or 0.42 cubic feet per gallon of sewage for aeration and air lifts.

The return sludge from half of the settlers in service amounted to 6 m.g.d. and maintained an average aerator suspended solids of 375 p.p.m.

The return sludge from three-fourths of the settlers in service amounted to 9 m.g.d. and maintained an average aerator suspended solids of 600 p.p.m.

With 4 to 5 hours aeration, more than 75 per cent of the B.O.D. and 85 per cent of the suspended solids were removed by the settlers, irrespective of the concentration of aerator solids.

With 2 to 2.5 hours aeration, 70 per cent of the B.O.D. and 83 per cent of the suspended solids were removed by the settlers, irrespective of the concentration of aerator solids.

The excess sludge was drawn at concentrations of 4 to 7 per cent or an average of 5.85 per cent dry solids. With moderate care in sludge withdrawals, a concentration of 5 to 7 per cent may be anticipated. Digested sludge may be drawn at a concentration of 4 to 6 per cent without difficulty.

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## Discussion

By Robert Shapiro and James W. T. Hogan

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It is the purpose of this discussion to add some data to the practical experience with modified sewage aeration, in the light of operation experience at the Bowery Bay sewage treatment works, where this method is now employed.

The Bowery Bay plant includes coarse screens, a grit chamber, primary settling, aeration and final settling tanks. Excess activated sludge is thickened in separate tanks. Excess and primary sludges are digested. Digested sludge is barged to sea. The plant was designed for secondary treatment by the "step aeration" modification of the activated sludge process, which method consists of returning sludge from the final tanks to the head end of the aerators and adding the sewage at from one to four points along the flow through the aerators. The designed aeration period is 2.5 hours with 25 per cent return sludge.

The plant was placed in operation on November 20, 1939, using primary sedimentation only. Activated sludge by step aeration was started on March 12, 1942, and continued until December 20, 1943, when aerator solids were reduced and modified sewage aeration begun. With modified sewage aeration, all sewage enters the aeration tanks and is mixed with return sludge at the head end of the tanks.

The data presented in Table 1 offer a comparison between step aeration and modified aeration results. The table shows that there had been an increase in the volume of sewage treated from 1942 to 1944, but not enough to influence significantly the detention periods in the treatment works.

With modified sewage aeration in 1944 the air ratios were reduced to about ⅔ of the previous air requirements, with a 22.4 per cent reduction in volume of air required per pound of B.O.D. removed. The kw. hr. per million gallons during 1944 was 22 per cent less than for the preceding two periods.

The suspended solids load entering the plant was almost identical, as shown by the yearly average figures. The primary effluent shows a continuous improvement in the annual averages, due principally to changes made in grease removal and to improvement in the quality of decant liquor.

TABLE 1.—*Salient Data on Operation Results at the Bowery Bay Sewage Treatment Works Step Aeration Vs. Modified Aeration*

| Period | 1942 (8 months) | 1943 (12 months) | 1944 (11 months) |
|---|---|---|---|
| Aeration System | Step | Step | Modified |
| Sewage Flow—m.g.d. | 32.5 | 36.6 | 37.8 |
| Detention Periods—hrs. | | | |
| Primary | 1.15 | 1.10 | 1.05 |
| Aeration | 2.6 | 2.2 | 2.5 |
| Final | 1.8 | 1.6 | 1.7 |
| Aeration Suspended Solids—p.p.m. | 1,490 | 1,780 | 505 |
| Air Supply—cu. ft./gal. | 0.59 | 0.61 | 0.39 |
| Cu. Ft. Air per Lb. B.O.D. Removed | 760 | 760 | 590 |
| Power Used—kw. hr./m.g. | 560 | 570 | 440 |
| Suspended Solids—p.p.m. | | | |
| Raw | 193 | 192 | 194 |
| Primary | 145 | 122 | 113 |
| Final | 12 | 37 | 29 |
| B.O.D.—p.p.m. | | | |
| Raw | 145 | 189 | 174 |
| Primary | 107 | 133 | 103 |
| Final | 14 | 37 | 24 |
| Removal of Suspended Solids—per cent | | | |
| Primary | 24.9 | 36.5 | 41.7 |
| Total | 93.8 | 81.3 | 85.1 |
| Removal of B.O.D—per cent | | | |
| Primary | 26.2 | 29.6 | 40.8 |
| Total | 90.3 | 80.5 | 86.2 |
| Sludge—per cent solids | | | |
| Primary | 5.04 | 5.52 | 6.83 |
| Activated | 2.42 | 2.75 | 3.57 |
| Weighted Average | 3.78 | 4.17 | 5.50 |
| Digested | 4.48 | 3.96 | 5.26 |
| Volume of Sludge—cu. ft./day | | | |
| Primary | 10,320 | 8,460 | 6,310 |
| Activated | 10,120 | 7,990 | 5,030 |
| Total | 20,440 | 16,450 | 11,340 |
| Digested Sludge to Sea—cu. ft./month | 319,000 | 280,000 | 159,000 |

The results of 1942 show that step aeration gave better overall removals than modified sewage aeration. The impaired results for 1943 as compared with 1942 were due to a series of difficulties, such as oil wastes and very heavy decant liquors. Changes in digester operation toward the end of 1943 and the subsequent heavier sludges obtained during 1944 permitted a reduction in volume and an improvement in quality of the decant liquor. Oil wastes in noticeable quantities were no longer found to be entering the plant. However, it should be emphasized that modified sewage aeration should not be expected to give better overall removals of suspended solids and B.O.D. than step aeration, as shown by the comparison of 1942 and 1944 results.

Another important difference in the two methods of operation is evident in the concentration of excess activated sludges. The decrease in sludge volume obtained from the thickening tanks helped improve the quality of the decant liquor, which in turn improved operations in general as already stated. This smaller volume also made it easier and more economical to maintain digester temperatures. The resultant effect was a heavier digested sludge of a lower volatile content and a lesser quantity of sludge to be sent to sea.

In general, therefore, the overall purification on a plant scale was very similar to the predictions based on the pilot plant studies as previously reported by Setter in the July, 1943, and by Setter and Edwards in the March, 1944, issues of *This Journal.* The compensation for the slightly lower plant efficiencies were lower air ratios, and consequent power savings; a heavier excess sludge which improved and decreased the volume of decant liquor; higher digester temperatures; improved digested sludge concentration and a marked economy in barging the sludge to sea.

# EFFECT OF INDUSTRIAL WASTES ON THE OPERATION OF A SEWAGE TREATMENT PLANT *

By

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The effect of varying quantities of industrial wastes on the operation of a sewage treatment plant has been demonstrated during the last four years at the Rahway Valley Joint Meeting plant, New Jersey. The effect of the wastes was noticeable on (1) sedimentation, (2) sludge volume, (3) digestion, (4) gas production, and (5) sludge drying. Condensed results are presented to indicate the effects and operation difficulties.

In 1928, nine municipalities located in the Rahway Valley entered into a contract forming a joint meeting. All conditions pertaining to the participation in construction cost, allocation of space in the trunk sewer and treatment plant, and the apportionment of operating and maintenance expenses were embodied in the contract. The actual construction of the trunk sewer was begun in 1929 and completed in 1931. The entire trunk sewer flow is by gravity to the plant, at which point it is lifted 15 feet by means of pumps. Flows are measured by recorders placed near the boundaries of the municipalities and at the treatment plant. Construction of the sewage treatment plant was begun in 1935 and completed in 1937. The construction cost for trunk sewer and plant was approximately $3,000,000.

The trunk sewer ranges in graduated sizes from 36 to 72 inches in diameter and was designed for a normal average daily flow of 25 m.g.d., estimated to be sufficient to 1960.

The sewage treatment plant embodies mechanical collection of grit and screenings, pumping of raw sewage, sedimentation, separate sludge digestion, sludge drying, and chlorination. The sedimentation tanks design is based on four hours' detention at 12.5 m.g.d. Sludge digestion tanks and sludge drying beds were to serve a population of 75,000. A general layout of the plant is shown in Figure 1.

## Contributing Population and Flows

In order to determine the effect of increased sewage flows and volumes of industrial wastes discharged on the operation of the plant, the total contributing population, the number of employees in industries discharging liquid wastes, volumes of sewage, volumes of industrial

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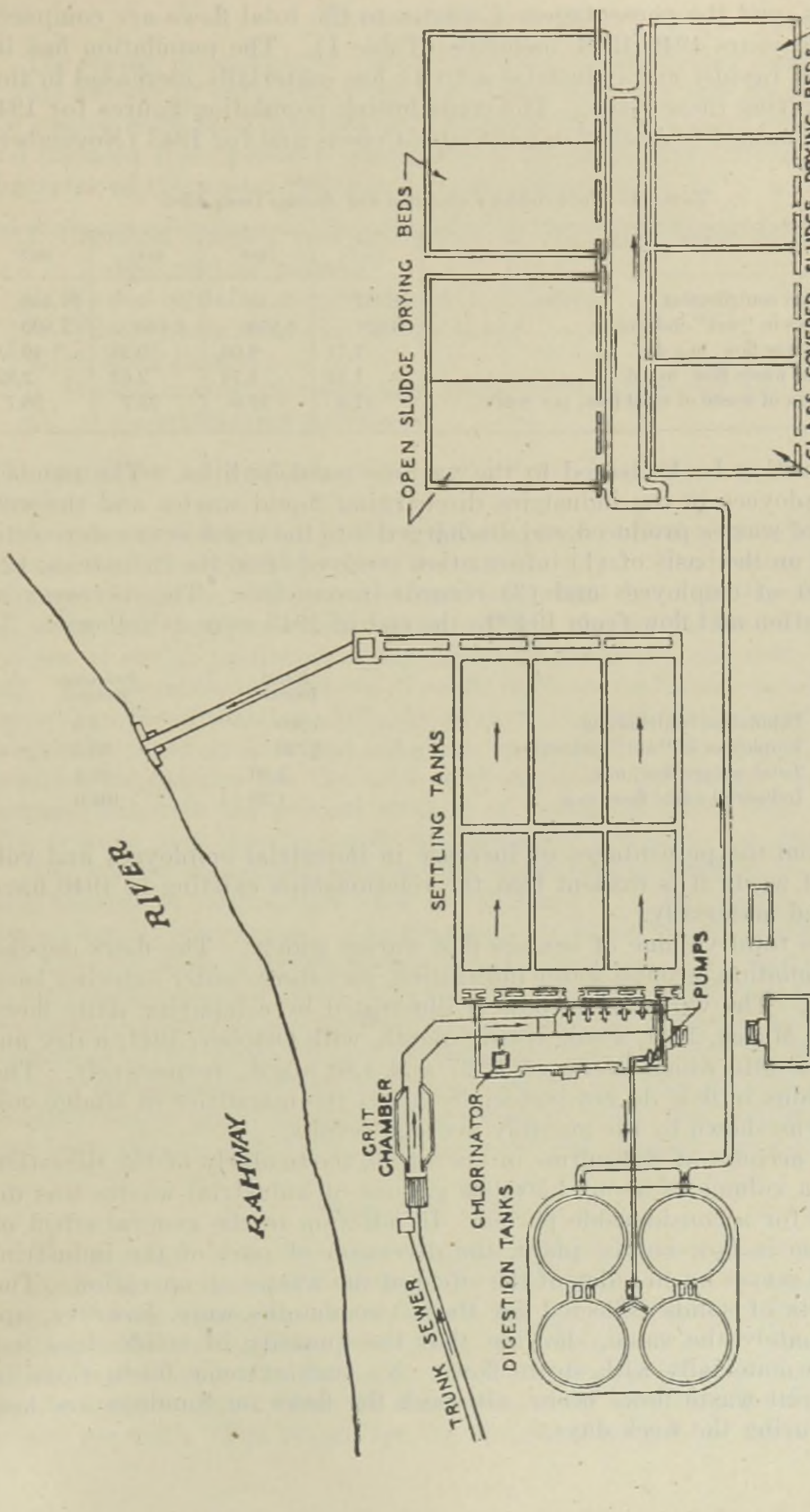


FIGURE 1.—General layout of Rahway Valley plant.

wastes, and the percentages of wastes to the total flows are compared for the years 1940–1943, inclusive (Table I). The population has increased rapidly and industrial activity has materially increased in this area during these years. The contributing population figures for 1940 were obtained from the United States Census and for 1943 (November)

TABLE I.—*Contributing Population and Average Daily Flow*

| | 1940 | 1941 | 1942 | 1943 |
|---|---|---|---|---|
| Population contributing | 68,437 | — | — | 74,346 |
| Employees in "wet" industries | 4,051 | 6,959 | 7,446 | 7,800 |
| Total sewage flow, m.g.d. | 7.71 | 8.04 | 10.28 | 10.51 |
| Industrial waste flow, m.g.d. | 1.34 | 1.74 | 2.63 | 2.82 |
| Proportion of waste of total flow, per cent | 17.3 | 21.6 | 25.7 | 28.7 |

from ration books issued in the various municipalities. The number of employees in the industries discharging liquid wastes and the volumes of wastes produced and discharged into the trunk sewer were estimated on the basis of (1) information received from the industries, (2) number of employees and (3) records in our files. The increases in population and flow from 1940 to the end of 1943 were as follows:

| | Actual Increase | Percentage Increase |
|---|---|---|
| Population contributing | 5,909 | 8.6 |
| Employees in "wet" industries | 3,750 | 93.5 |
| Total sewage flow, m.g. | 2.80 | 36.4 |
| Industrial waste flow, m.g. | 1.38 | 104.0 |

From the percentages of increase in industrial employees and volume of waste it is evident that the relationships existing in 1940 have changed materially.

The total volume of sewage flow varies widely. The flows depend on population, ground water infiltration, and storm water entering local sewers. The variation in flow is illustrated by comparing daily flows during March, 1941, a wet spring month, with October, 1941, a dry autumn month, which averaged 12.27 and 4.40 m.g.d., respectively. The variations in flow do not materially affect the quantities of sludge collected, as shown by the monthly average results.

On account of difficulties in operation, particularly of the digestion units, a volume of about 1,500,000 gallons of industrial wastes was diverted for a considerable period. In addition to the general effect of increase in flow on the plant, the diversion of part of the industrial wastes serves as an index of the effect of the wastes on operation. The amounts of solids collected for these two months were, however, approximately the same, showing that the quantity of solids does not change materially with storm flows. No such extreme fluctuations in industrial waste flows occur, although the flows on Sundays are less than during the week days.

## Types of Wastes

The wastes discharged by the 33 industries in the district come from a wide variety of industrial processes. The character and strength of the wastes have been determined by analyses for the larger industries and deduced from products produced by the smaller industries. The character of the wastes fall into five groups, namely:

1. Chemical wastes, acid or alkaline in character, some containing dyes and/or poisons;
2. Wastes containing solvents and/or soaps;
3. Wastes containing oils and greases;
4. Pickling liquors;
5. Wastes containing suspended solids from paper, rug, and similar manufacturing processes.

The quantities of wastes received are largest from the first and fifth groups.

In general, the wastes in the different groups affect sewers and the operation of the treatment plant in various ways. The wastes in the first group may be considered as most important from the standpoints of sewer and equipment corrosion, settling characteristics of solids, volume of sludge produced, sludge digestion processes, and sludge drying. The quantities of suspended solids in these wastes are usually not more than those found in domestic sewage, but material in solution is frequently much greater and influences suspended solids removal. Of greatest importance are the acids and alkalies. Dyes may color the sewage, but with the present method of treatment exert little effect. The poisons may interfere with the biological action in the digesters.

The wastes containing solvents are important in relation to explosion hazards in sewers, and some solvents are very detrimental to the sludge digestion processes. The greases and oils aid in scum formation, but have not been of great importance at this plant. The wastes containing pickling liquors have been chiefly important in relation to their precipitating action on suspended solids, resulting in increased sludge formation. The sludge formed is frequently thin and watery, affecting thereby the capacity of the digesters. Paper, rug and similar wastes produce larger quantities of sludge. These wastes may contain fiber and hair, causing difficulties with clogging and scum in the digesters.

## Operation Results

The average daily operation results for four years are summarized in Table II. Grit removal during dry weather flow has been satisfactory. During excessive storm flows some grit passes through to the settling tanks and hence to the digesters. The quantities of screenings collected per day are fairly constant with the exception of periods during January to April when the daily collections may increase as much as 400 per cent. The reason for the abnormal screenings collection is that large masses of filamentous fungus growth, occurring on the sides of sewers, slough off. This material does not drain readily and has an offensive odor. Drained grit has a moisture content of about 73 per cent and screenings about 90 per cent. Both grit and screenings collected are carted away by truck and dumped on the nearby state reformatory grounds where the materials are used for soil improvement.

Suspended solids removal is persistently high, ranging from 60 to 81 per cent with a four-year daily average of 66 per cent. This high efficiency can be attributed to the coagulating action of some of the industrial wastes. With the increased industrial activity in the area served and proportionate increase in suspended solids, plus the retarding effect on sludge digestion, it was necessary to reduce the efficiency of the settling tanks by cutting out two units and thereby decreasing the total detention period. The effluent produced with the reduced detention time was considered unsatisfactory by the State Health Department and, in order to meet the requirements, three settling tanks were replaced in operation. Attention is directed to the fact that the average daily percentage removal of suspended solids, based upon the p.p.m. suspended solids in influent and effluent, did not decrease as much as might be expected. In this respect the variation in suspended solids of the raw sewage, as well as the change in character of sewage, should be kept in mind.

TABLE II.—*Average Daily Operation Results Rahway Valley Joint Meeting Sewage Treatment Plant*

| | 1940 | 1941 | 1942 | 1943 |
|---|---|---|---|---|
| Grit removal, cu. ft. per m.g. | 7.8 | 6.1 | 5.6 | 6.9 |
| Screenings removal, cu. ft. per m.g. | 2.4 | 3.5 | 2.6 | 3.4 |
| Suspended solids in raw sewage, p.p.m. | 176 | 212 | 154 | 168 |
| Suspended solids in effluent, p.p.m. | 55 | 68 | 62 | 61 |
| Suspended solids removal, per cent | 69 | 68 | 60 | 64 |
| B.O.D. of raw sewage, p.p.m. | 171 | 182 | 143 | 198 |
| B.O.D. removal, per cent | 32 | 31 | 35 | 33 |
| Wet sludge production, cu. ft. | 2,139 | 2,561 | 2,642 | 3,100 |
| Dry total solids retained, lbs. | 10,000 | 11,510 | 10,715 | 12,840 |
| Dry total volatile solids retained, lbs. | 6,990 | 7,885 | 7,610 | 9,360 |
| Dry total volatile solids to digesters, lbs. | 6,990 | 7,885 | 6,800 | 6,670 |
| Increase in wet sludge retained, per cent | — | 11.5 | 7.1 | 12.8 |
| Increase in dry volatile solids, per cent | — | 12.8 | 11.3 | 34.0 |
| Detention time, hrs. | 6.5 | 5.4 | 2.6 | 2.9 |

Since July, 1940, there has been a gradual rise in the volume of solids arriving at the plant. This can be attributed to (1) increase in population served and (2) increase in industrial activity. Despite the fact that during part of 1942 and 1943 a considerable volume of industrial wastes was diverted before reaching the plant, the increase in the volume of sludge collected was greater in extent than the population increase over the four years under consideration. Of particular importance is the large increase in volatile solids, which were one-third greater in 1943 than in 1940. The increase in volume of wet sludge placed a burden on the digestion and sludge disposal facilities, requiring increased capacities. In effect, the large increase in volatile solids increased the load on the digesters beyond the capacity of the available facilities and it became necessary to build a large sludge storage basin to supplement the sludge drying beds. Excess digested sludge was stored in this basin during the winter and removed during the dry summer period. This method worked satisfactorily until the winter of 1942–43 when, because of the retarding effect of industrial wastes on sludge digestion, it became necessary to pump excess fresh solids into the basin daily. Since the basin was then used as an unheated digestion unit, the sludge could not be removed during the summer of 1943 and as a consequence the basin was filled by the end of August, 1943. It became necessary to construct a second basin with a capacity of 250,000 cubic feet. On August 30, 1943, the basin was completed and ready for operation. Early in September the industrial wastes received at the plant affected the digesters to such a degree that both primary digesters had to be emptied into the newly constructed basin, occupying 30 per cent of the available capacity. Shortly thereafter, three settling tanks had to be operated to maintain an effluent satisfactory to the State Health Department, causing an additional increase in volume of sludge retained. At the same time a large volume of industrial wastes was again diverted. Despite the diversion of industrial wastes, the increase in fresh solids collected made it necessary to discharge 800 cubic feet of fresh solids daily into the storage basin.

## Gas Production

The gas collected has an average heat value of 650 B.T.U. per cubic foot. It is used for heating the buildings and digestion tanks and serves as fuel for the gas engines driving the main sewage pumps, which lift the entire sewage flow into the settling tanks. With normal functioning of the sludge digestion processes the gas production ranges from 70,000 to 100,000 cubic feet a day, depending upon the quantity and character of the fresh solids placed in the digesters. The average quantities of gas collected during the 1940–43 period, together with the amounts of gas produced per pound volatile matter collected and added to the digesters, are shown in Table III. The average daily gas collection increased during the first two years under consideration, but decreased sharply during 1943. The daily loadings to the digesters, expressed in pounds volatile matter, were only 4 per cent less in 1943 than

Table III.—*Average, Maximum, and Minimum Quantities of Gas Collected in Cubic Feet*

| | 1940 | 1941 | 1942 | 1943 |
|---|---|---|---|---|
| Average daily | 67,000 | 76,500 | 68,400 | 46,400 |
| Maximum per day | 79,400 | 116,000 | 124,000 | 99,000 |
| Minimum per day | 10,000 | 53,000 | 11,000 | 0 |
| Gas per lb. volatile matter collected | 9.6 | 9.7 | 9.0 | 4.44 |
| Gas per lb. volatile matter to digesters | 9.6 | 9.7 | 10.0 | 6.85 |

in 1940, but the average daily gas production was reduced by 31 per cent. During the entire period of four years, daily gas production fluctuated greatly, as indicated by the minimum and maximum figures. These fluctuations occurred more or less in cycles, gas production gradually decreasing until a low figure was reached, when the load on the digesters would be temporarily reduced. It is clear, however, that the reduction in gas production was not the result of reduced loading. Gas production per pound of volatile matter added to the digesters in 1943 was 27.5 per cent less than in 1940. This reduction in gas production was caused by the industrial waste in the sewage. The specific effects of the wastes on the digestion process are indicated by the experiences during the four years.

During September, 1940, an abnormal reaction in the sludge digestion process was indicated by a gradual decrease in daily gas production and by the digesting sludge turning acid. Plant operating records revealed a gradual dropping in pH values of both fresh solids and raw sewage, which led to the belief that this was caused either by mineral acids in the sewage or poisonous substances affecting biological action, or by both.

Hourly determinations on sewage samples at the plant and at various points in the trunk sewer showed the presence of large quantities of acid wastes. Conferences were held which resulted in a temporary diversion of a large volume of acid wastes. After an extensive survey the wastes were neutralized at the source and again discharged into the trunk sewer. Some time after the neutralized waste was treated at the point of discharge, gas production again began to drop and the digesting sludge became acid. Investigation showed that the difficulties were not caused by either excess acidity or excessive quantities of solids placed in the digesters. The retarding action was caused by toxic or poisonous materials present in the wastes received. The poisons thought to be responsible were removed from the wastes and the digesters recovered. During January, May, July, and August, 1943, difficulties were again experienced, primarily in reduction of gas production. Finally in September, 1943, the sludge digestion process broke down completely. A large volume of wastes was again diverted from the plant.

The effect of the waste without the toxic materials is shown by the following figures comparing the average daily digester loadings and gas production over a period of eleven months with the loadings and gas production over a period of nine preceding months when all waste was diverted:

| | Sludge to Digesters | | Gas Production | |
|---|---|---|---|---|
| | Cu. Ft. | Lbs. Solids | Cu. Ft. per Day | Cu. Ft. per Lb. Solids |
| Waste Out | 2665 | 10,350 | 73,775 | 7.14 |
| Waste In | 1810 | 6,875 | 45,100 | 6.51 |
| Per Cent Less | 40.0 | 32.4 | 33.8 | 8.9 |

The results show that the waste apparently affected gas production in two ways: (1) reduction in total gas production by one-third on account of reduced dry solids loading, and (2) reduction in gas production from equal quantities of dry solids. The acid wastes were neutralized with lime at their source during the period under consideration, but contained small quantities of solvents. The results led to the conclusion that about 15 per cent of neutralized acid waste containing a few parts per million of solvents in the total flow of sewage, affected digestion to such a degree that about one-third less dry solids could be handled by the digesters and this, in turn, caused subsequent equal decrease in total gas production. In other words, the digestion capacity required was increased materially and excess sludge was stored in lagoons.

Previous to diversion, the loading on the digesters had been gradually reduced from a normal 3,000 cubic feet of sludge a day to 1,770 cubic feet, resulting in a reduction in the sludge digestion facility of 41 per cent. The relation between sewage flow, gas production, and solids collected and digested over a period of 40 months, including periods when large volumes of waste were handled and diverted, is shown graphically in Figure 2. From the plant records it appeared that a

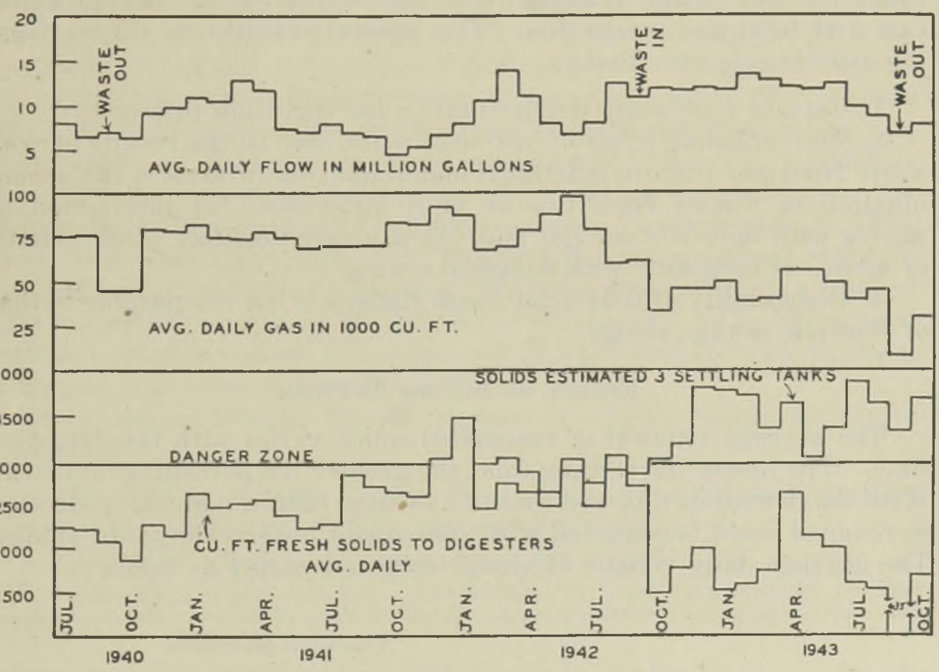


FIGURE 2.—Relation between total and volatile solids and percentage suspended solids removal, and detention time.

maximum loading of 3,000 cubic feet of sludge a day could be handled temporarily, suggesting that the "danger zone" was about 2,900 cubic feet of wet sludge a day. With the method of operation practiced the concentration of fresh solids collected is rather constant. Analysis shows the following daily averages of total solids and volatile matter:

| | Total Solids Per Cent | Volatile Matter Per Cent |
|---|---|---|
| 1940 | 7.57 | 69.7 |
| 1941 | 7.27 | 68.5 |
| 1942 | 6.50 | 71.1 |
| 1943 | 6.59 | 72.9 |

It will be noted that the sludge concentration which could be obtained decreased gradually with the increase in percentage of industrial wastes received. This placed an additional burden on the digestion and sludge drying facilities. The increase in volume of sludge has an important relation to supernatant liquor removal (see below).

## Laboratory Digestion Experiments

To confirm the plant results and to determine specifically the effects of the wastes and indicate the allowable loadings on the digesters, extensive laboratory experiments were made. Samples of sewage were obtained in the trunk sewer at various places, the solids settled and added daily to a series of digesting mixtures and the gas collected. Similarly, samples of wastes were collected and added in varying proportions to sewage solids primarily of a domestic source. It was soon found that the sludge obtained from wastes affected the rate of digestion and total gas production. The general conclusions drawn from the experiments were that:

1. Certain wastes are detrimental to the digestion processes.
2. The retarding effect of various wastes may be the results of: (*a*) waste from one or more individual manufacturing processes, (*b*) a combination of wastes from two or more processes, (*c*) interaction of wastes with domestic sewage and (*d*) a proportionately large volume of wastes as compared with domestic sewage.
3. Digestibility of industrial waste sludges is not comparable to that of domestic sewage sludge.

## Effect on Sludge Volume

The average removal of suspended solids varies with the detention time. The longer the settling time, the greater the percentage removal. With the detention time reduced to less than half, a material reduction in removal could be expected with subsequent lower volumes of sludge. The average daily volume of sludge collected varied as follows:

| Year | Detention Time (Hrs.) | Volume of Sludge Produced | | |
|---|---|---|---|---|
| | | Cu. Ft. per Day | Cu. Ft. per M.G. | With Equal Amounts of Susp. Solids Removed (Cu. Ft. per M.G.) |
| 1940 | 6.5 | 2139 | 276 | 212 |
| 1941 | 5.4 | 2561 | 319 | 239 |
| 1942 | 2.6 | 2642 | 268 | 278 |
| 1943 | 2.9 | 3100 | 294 | 267 |

The volume of sludge collected per million gallons of sewage treated did not decrease with the material reduction in detention time, although the percentage suspended solids removal based upon p.p.m. decreased. The volume of sludge for equal quantities of suspended solids removed increased. This was not caused by an increase in the strength of sewage, which on the basis of suspended solids in the raw sewage was less in the two years with low detention times than in the years with a greater detention time (Table IV). The average figures for the years

TABLE IV.—*Average Daily Sludge Removal With Different Detention Periods*

| Detention (Hrs.) | Removal (Per Cent) | Sludge Removed (Cu. Ft.) | Dry Total Solids (Lbs.) | Dry Volatile Solids (Lbs.) | Time Operation (Months) |
|---|---|---|---|---|---|
| 1.50 | 56 | 2,165 | 9,413 | 6,646 | 5 |
| 4.12 | 60 | 2,655 | 10,450 | 7,430 | 19 |
| 6.30 | 67 | 2,860 | 12,460 | 8,775 | 13 |

do not accurately show the increase in solids volume, because of diversion of large volumes of industrial flow during part of some years. For this reason, two periods were selected when the detention time was approximately the same but the volume of industrial wastes was different. From April 1 to August 31, 1940, which is the period selected as being representative of plant operation before abnormal increases in industrial activity caused a large increase in industrial waste, the average daily volume of solids collected amounted to 2,450 cubic feet a day. If this quantity of sludge is taken as normal and industrial activity is assumed to have increased proportionally to the rise in population, the daily amount of sludge for the period November 1 to December 31, 1943, should have been 2,800 cubic feet. In effect, the actual amount collected was 3,600 cubic feet a day plus about 600 cubic feet diverted, a total of 4,200 cubic feet per day, or an increase of 50 per cent. The 50 per cent increase in sludge volume compares with 11.9 per cent increase in population and 26.6 per cent increase in flow.

The principal reasons for the increase in sludge volume appear to be threefold:

1. Coagulation of finely divided suspended solids which, incidentally, increased the percentage volatile matter in the sludge,
2. Quantities of sludge present in certain wastes,
3. Chemicals which retard compaction or cause expansion of the sludge.

## Relation Between Detention Time and Quantity of Sludge

The relation between the detention time in the settling tanks and the volume of sludge, as well as the dry solids and volatile matter retained, is of general interest. By segregating the results obtained during periods when 1, 2, or 3 settling tanks were in operation, some facts become apparent which are not readily appreciated when only the difference in the percentage removal is taken into consideration. In Table IV the average results are compared with varying detention periods. The theoretical detention periods were calculated from the actual flow measured and averaged for monthly periods; the results on the volume of sludge removed are based on daily measurements, and the total dry solids and volatile matter removed are based on daily analyses made on composites of samples taken at 10-minute intervals during pumping.

The percentage removal with more than double the detention period indicates only a 4 per cent increase on the basis of p.p.m. suspended solids removal, whereas the increase in volume of the sludge removed daily amounted to 23 per cent. The increase in suspended solids as ordinarily recorded and the volume of sludge and the quantity of solids over the 1.5-hour detention time were as follows:

| | | |
|---|---|---|
| Detention time, hrs. | 4.12 | 6.30 |
| Per cent increase detention time | 275 | 420 |
| Per cent increase volume of sludge | 23 | 31 |
| Per cent increase total dry solids | 11 | 31 |
| Per cent increase dry volatile matter | 12 | 31 |
| Per cent increase removal suspended solids | 4 | 11 |

It is evident that the increase in sludge volume and solids removed was appreciably greater than that indicated by the percentage removals of suspended solids, based on p.p.m. There was, however, no direct relationship between the time required to produce the greater removals and the actual quantities of sludge. In other words, the causes which exerted the effect were not operative at a constant rate. The general relationship between total and volatile solids removal, percentage suspended solids removal, and detention time is illustrated in Figure 3.

The effect of the industrial wastes may overbalance the effect of the detention time. This is indicated by results obtained during a six-month period when about 83 per cent of all the industrial waste was by-passed as compared with a period of seven months when all industrial waste was handled. During both periods the detention time was practically the same, hence, the volume of sewage received was the same, but of a different character. The average daily results for these two periods were as follows:

| Waste | Detention Time (Hrs.) | Sludge Volume (Cu. Ft.) | Dry Solids (Lbs.) | Volatile Solids (Lbs.) |
|---|---|---|---|---|
| Out | 2.97 | 2,325 | 7,584 | 6,494 |
| In | 2.92 | 2,516 | 10,299 | 7,380 |
| Per Cent Increase | —— | 9.5 | 26.4 | 12.0 |

With the same detention time the handling of industrial wastes resulted into 9.5 per cent more sludge by volume and 26 per cent more dry solids. In view of the fact that the wastes contained about the same amounts of suspended solids as the domestic sewage, it is clear that the wastes caused considerable precipitation of the more finely divided material and probably some dissolved substances. It is of interest that these acid wastes, pretreated by lime for neutralization, caused precipitation of solids which carried down the inert materials as well as the volatile solids in suspension which ordinarily would not settle. These solids required space in the digesters and reduced the digestion capacity in addition to the larger quantities of volatile solids removed from the sewage. With increased detention time, more of the flocculated material settles, hence larger volumes of sludge and greater amounts of dry solids are retained. The wastes effected the removal of solids primarily by: (1) coagulation of finely divided suspended solids, and (2) precipitation of soluble material.

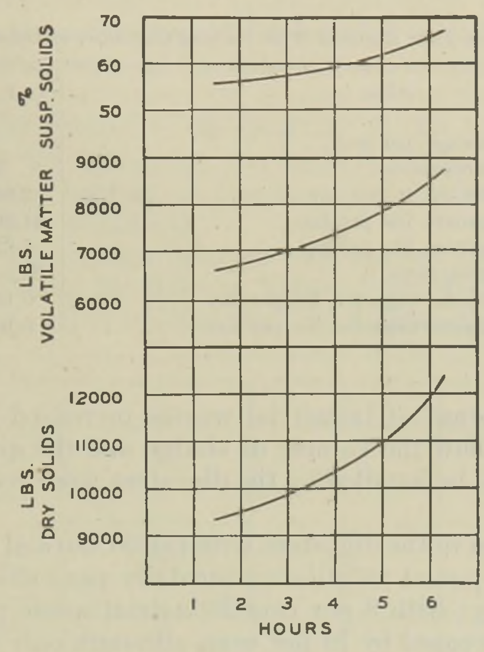


FIGURE 3.—Relation between flow, solids retained, and gas production during two periods when large volumes of trade wastes were treated and diverted.

## EFFECT ON DIGESTION TIME

The effect of the wastes on the digestion process has been briefly discussed above but the actual effect on the time required for the digestion of equal quantities of sludge deserves further consideration. For comparison, three periods were chosen, as follows: (1) 20 months when relatively small quantities of industrial wastes were present (about 8 per cent of total flow), (2) 13 months when all wastes were handled (about 18 per cent of the total flow), and (3) 10 months when nearly all of the wastes were diverted and a fairly normal domestic sewage was treated with small quantities (about 3 per cent) of diversified industrial wastes.

The system of sludge digestion tanks, consisting of two primary and two secondary tanks, has been operated by the usual method of charging the primary tanks with raw sludge. The quantities of raw sludge added daily were averaged for the three different periods, and the results, together with other pertinent calculations, are shown in Table V. When only a small amount of industrial waste was present the volume of sludge handled in the primary tanks averaged about 2,800 cubic feet per day or about 8,168 pounds of dry volatile matter. These amounts allowed an average detention period in the primary tanks of slightly more than 23 days. When the industrial waste percentage present in the sewage increased to 8 per cent, the volume of sludge and quantities of volatile solids handled in the digesters decreased only 4 to 5 per cent,

TABLE V.—*Digestion Time Required With Varying Quantities of Industrial Waste Present*

| Period | 1 | 2 | 3 |
|---|---|---|---|
| Amounts of wastes in sewage, per cent | 8 | 18 | 3 |
| Length of time, months operation | 20 | 13 | 10 |
| Sludge added to digesters, cu. ft. per day | 2,628 | 1,260 | 2,812 |
| Dry solids added to digesters, lbs. per day | 11,265 | 5,220 | 10,996 |
| Vol. solids added to digesters, lbs. per day | 7,837 | 3,710 | 8.168 |
| Ave. detention in digesters, days | 28.5 | 60.0 | 23.1 |
| Dry solids per cu. ft. digester capacity, lbs. per day | 0.151 | 0.70 | 0.147 |
| Vol. solids per cu. ft. digester capacity, lbs. per day | 0.104 | 0.49 | 0.109 |

but when the amount of industrial wastes increased to 18 per cent of the total sewage flow the volume of sludge and the quantity of volatile solids which could be handled by the digesters were reduced to less than half.

The load added to the digesters with rather normal sewage amounted to more than 0.1 pound volatile matter daily per cubic foot of primary digestion capacity; with 8 per cent industrial waste present the digestion time was increased by 19 per cent, although only slightly less volatile matter was added, but with an average of 18 per cent industrial waste in the sewage the digestion time was increased 260 per cent. Under normal conditions the raw sludge was kept in the primary digesters an average of 23.1 days, but with larger volumes of industrial wastes the retention time had to be increased to 60 days. Even after 60 days' retention, the sludge was not digested and the secondary tanks had to be converted into primary digesters.

The effect of increased quantities of industrial waste in prolonging digestion time was primarily due to:

*a*. Retardation of biological activities,
*b*. Deterioration of seed sludge,
*c*. Poor separation of liquor.

## Effect on Supernatant Liquor

Proper separation of sludge from the liquid is an important factor in separate sludge digestion practice. This phase of operation has received some attention from a research standpoint, and is frequently referred to by operators. Failure to attain proper separation of sludge and liquor leads to decreased available digestion capacities and subsequent difficulties in operation. From an operator's standpoint separate sludge digestion should be considered from two angles:

1. Maximum safe loading of the digesters to insure rapid digestion and the greatest possible liquid separation,
2. Load to be placed upon final sludge disposal facilities.

Liquid separation in digesters operated at fairly constant temperatures varies with the quantities of fresh solids added to the digesters, the rate of digestion accomplished and the capacity of the tanks. Under normal digestion conditions the amount of supernatant that can be obtained is directly related to the quantity of raw solids added to the digesters, because the tank space available is fixed. In another paper the relation between loading of digesters and supernatant production is discussd in greater detail (1).

The general relationship between supernatant liquor removal and raw sludge additions at the Rahway Valley Joint Meeting plant is illustrated in Figure 4. It is evident that the volume of a relatively clear

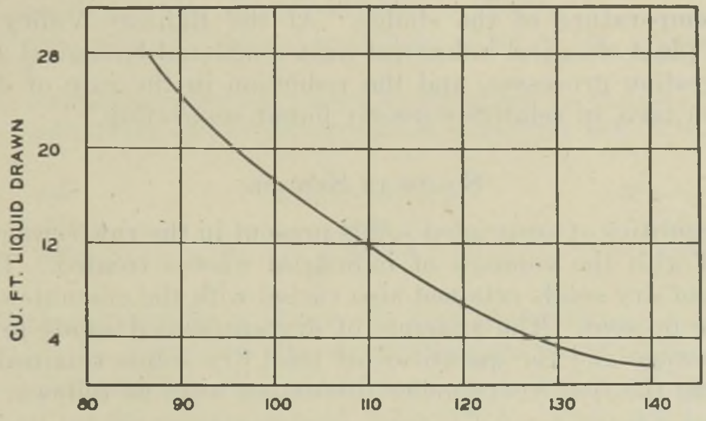


FIGURE 4.—General relation between supernatant removal and solids additions.

supernatant (average suspended solids 2,000 p.p.m.) decreases rapidly with increased loading of fixed capacity digesters. When the biological activities in the digesters are affected by industrial wastes, or the quantity of solids in such wastes increases the total volume of sludge to be handled, the volume of supernatant liquor decreases. On the other hand, when the volume of sludge added to the digesters decreases because of its effect on the digestion processes the material must be kept longer in the tanks and the volume of supernatant liquor increases because less disturbance takes place and a longer time is allowed for separation of solids and liquid. At the Rahway Valley sewage treatment plant, with careful operation and optimum loading, as much as 50 per cent of the volume of fresh solids added can be removed as clear supernatant liquor. To have sufficient room for fresh solids to be added, the maximum loading may be considered to have been reached when about 40 per cent of the volume added can be withdrawn as supernatant liquor. Calculating the percentage supernatant drawn during the three periods under consideration for equal primary digestion times, we find:

| Waste Present (Per Cent) | Supernatant Drawn (Per Cent) | Ave. Supernatant Removed (Cu. Ft.) |
|---|---|---|
| 3 | 50.6 | 1423 |
| 8 | 37.0 | 1205 |
| 18 | 21.0 | 847 |

Since the loadings were not constant, the actual volumes of supernatant removed do not present an accurate picture, hence the removals were calculated on an equal digestion time basis, using the sewage with the least amount of industrial waste as a basis. It is evident from the figures that increased amounts of waste exerted a material effect upon liquor separation.

The factors affecting liquor separation are primarily: (1) the initial concentration of raw sludge added, (2) the time of storage in the tanks, (3) the temperature of the sludge. At the Rahway Valley sewage treatment plant chemical industrial wastes affected biological activities in the digestion processes, and the reduction in the rate of digestion resulted, in turn, in relatively poorer liquor separation.

## Solids in Sewage

The quantities of suspended solids present in the raw sewage varied in general with the volumes of industrial wastes treated. The total quantities of dry solids retained also varied with the amounts of industrial waste present. The amounts of dry suspended solids present in the raw sewage and the quantities of total dry solids retained by settling during the four years under discussion were as follows:

| Year | Suspended Solids in Raw Sewage (Tons) | Total Solids Retained (Tons) |
|---|---|---|
| 1940 | 2020 | 1840 |
| 1941 | 2600 | 2100 |
| 1942 | 2405 | 1955 |
| 1943 | 2720 | 2325 |

The dry suspended solids cannot be directly compared with the total dry solids retained, because the wastes precipitate some finely divided and soluble substances and considerable quantities of lime were added for neutralization. We are, however, primarily interested in the increase in suspended solids produced by the contributing population and the quantities of total solids retained for further treatment. We do not have available accurate population figures for the years 1941 and 1942, but do have the 1940 United States Census figures and the number of ration books issued during November, 1943. On the basis of these figures the average suspended solids present in the raw sewage in pounds per day and the total solids retained per day were as follows:

| Year | Suspended Solids | Total Solids Retained |
|---|---|---|
| 1940 | 11,300 | 10,000 |
| 1943 | 14,700 | 12,840 |
| Per Cent Increase | 30.0 | 28.4 |

The increase in population between January, 1940, and November, 1943, amounted to 8.6 per cent, whereas the average suspended solids in the raw sewage increased 30 per cent and the total solids retained showed about the same percentage increase as the suspended solids in the raw sewage. The increase in population was caused principally by an increase in industrial activity. It is evident that the increases in suspended solids present and the total solids retained were not proportional to the increase in population. The increase in suspended solids in the sewage as well as the increase in total solids retained appears to be caused by:

1. Expansion of the wet industries,
2. Solids retained by the coagulating effect of the wastes received.

These conclusions are supported by the amounts of suspended solids and total solids retained when expressed in pounds per capita per day:

| Year | Susp. Solids in Sewage | Total Solids Retained |
|---|---|---|
| 1940 | 0.166 | 0.146 |
| 1943 | 0.214 | 0.173 |

Operation results have shown (1) that the optimum loading of the digesters at the Rahway Valley plant amounts to 0.1 pound solids per cubic foot primary digestion capacity or 0.05 pound dry solids per cubic foot, based on the total digestion capacity, to insure adequate supernatant liquor withdrawal and concentrated, well digested sludge. The amount of dry solids retained amounted in 1940 to 0.146 pound per capita, therefore, the digestion capacity required was nearly 3 cubic feet per capita. With the increase in industrial activity the digestion capacity required increased to nearly 3.5 cubic feet per capita, whereas the digesters retained their fixed digestion capacity of 2 cubic feet per capita; based on a population of 75,000. It is evident that the increased industrial activities resulted in insufficient capacity which was made more acute by the type of industrial wastes received.

## Effect on Sludge Drying

Digested sludge is dewatered on six open sand beds with an area of 37,500 square feet and four glass covered sand beds with an area of 19,800 square feet. The design population capacity is 77,100. Our experiences have not justified the drying areas provided of 1 square foot per capita for open beds and 0.5 square foot for glass covered beds, particularly during the winter months. Drying and removal of sludge from the beds can generally be scheduled from April to November, but from December through March removals are unpredictable. Freezing of the sludge and sand when temperatures are low and thawing of the sludge to a molasses state when temperatures rise do not permit proper drying or removal of sludge during this period.

With the increase in sludge volume an attempt was made to reduce the drying time by the addition of alum. Addition of alum aided drying and enabled the handling of more sludge, but the volumes of sludge continued to increase.

The dried sludge is disposed of by use for agricultural purposes at a nearby reformatory. Since the sludge drying facilities were inadequate, the Joint Meeting purchased a 1,000 gallon tank to cart liquid digested sludge to the farmland. This procedure helped to relieve the conditions, but soon a large storage basin had to be constructed, which was later followed by a still larger basin.

The effect of the industrial waste on sludge drying is primarily indirect and caused by:

1. Retarding the digestion of sludge and thereby reducing the degree of digestion and consequently reducing the drainability of the sludge.
2. Decreasing the density of the sludge in the digesters and thereby increasing the volume of sludge to be handled, resulting in further reducing the sludge digestion capacity available and subsequent larger volumes of sludge.
3. Dispersion of fine sludge particles and making supernatant liquor separation more difficult.
4. Resettling of poor supernatant liquor resulting in rehandling of sludge and larger volumes of sludge.

## Summary and Conclusions

The Rahway Valley Joint Meeting sewage treatment plant, which receives the sewage of nine municipalities, has experienced the effect of varying quantities of industrial wastes during the last several years. The types of wastes as well as the quantities treated varied materially and could be divided into five general groups. The wastes noticeably affected sedimentation, sludge volumes, digestion, gas production, and sludge drying.

Extensive laboratory experiments made to check plant operation showed that the digestion processes were retarded because of the quantity of waste, toxic substances, combinations of various wastes, and interaction of domestic sewage with waste. The digestibility of industrial waste sludge was not comparable to domestic sewage sludge.

Plant results showed that the industrial wastes affected:

1. The sludge volume, because of (*a*) coagulation of finely divided material, (*b*) quantities of sludge present in the wastes and (*c*) retardation of compaction on expansion of the sludge.
2. The sedimentation detention time, by coagulation of suspended solids and precipitation of soluble materials.
3. The digestion time, because of (*a*) retardation of biological activities, (*b*) deterioration of seed sludge and (*c*) poor separation of liquor.
4. The supernatant liquor separation, which decreased with increasing quantities of wastes.
5. The total solids, which increased markedly with the increase in industrial flow and the coagulation effect of the wastes on the sewage solids.
6. Gas production, by toxic substances, and after their removal, by neutralized acid wastes containing small quantities of solvents.
7. Sludge drying, because of (*a*) the retarding effect of the wastes on digestion, (*b*) reduction of the drainability of the sludge, (*c*) decrease in density of the sludge and (d) dispersion of fine sludge particles.
8. The most important effect of the wastes was on sludge digestion with subsequent lower digester loadings and loss of gas.

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# SOME EARLY STEPS IN SEWAGE TREATMENT *

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It is fitting occasionally to consider origins and to review progress. This paper, accordingly, seeks to outline the beginnings and the growth of sewage treatment in the United States—its extent and the direction which it has taken.

At the present time there are about 6,000 sewage treatment plants in the United States, serving some 40,000,000 of our people, but the records indicate that in 1885, only sixty short years ago—a date within the life span of many in this room—there was not in operation anywhere in this country a single municipal sewage treatment plant which had been constructed primarily for protection of the public health.

The few plants existing at that time were either small sewage farms at scattered state institutions or absorption fields located in arid sections of the West where the sewage was used for irrigation purposes.

This was in direct contrast to conditions in England, where governmental agencies had been active for thirty years, and through establishment of permissible limits for stream pollution and issuance of uniform regulations had brought about the installation of over 200 sewage farms and some 50 chemical precipitation plants.

Our apparent lag in sewage treatment plant construction was not so strange as it appeared on the surface. Conditions here differed greatly from those in England; our population was not so dense and our rivers were larger. Concept prevailed that sewage treatment was primarily for the purpose of elimination of nuisance and it was but natural that leading engineers should endeavor to ascertain and develop the possibilities of our rivers for inoffensive assimilation of sewage by dilution—a method of abatement which apparently had received little or no attention abroad.

However, not all of our centers of population were located on large rivers where adequate dilution was available. In many areas, such as in southern New England, relatively small rivers received disproportionately large volumes of sewage and putrescible trade wastes from numerous cities and towns, textile mills, tanneries and other industries, with the result that stream conditions became intolerable.

Typhoid fever was generally prevalent. While the germ theory of disease had recently been clearly substantiated, it was not fully appreciated nor understood and many still adhered to the popular fallacy that running water of a stream would purify itself in some seven miles of travel over a sandy or rocky stream bed. There was unrest among politicians and indecision among men of science.

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While the results of some notable investigations as to the cause of epidemics had been published in official reports, there were no general American treatises on water pollution or sewage treatment. Only a few had access to the several reports of the British Royal Commissions on Sewage Disposal, or had been fortunate enough to visit Europe and obtain a clearer knowledge of sanitation developments abroad.

In the midst of these chaotic conditions, the Massachusetts Legislature of 1886, under urge of the earnest recommendation of a special investigating committee, enacted a law placing the general control of inland waters of the Commonwealth under jurisdiction of the State Board of Health, and making an appropriation for the employment of engineers and others to conduct experiments to determine the best practicable methods for purification of drainage and sewage.

Pursuant to the provisions of this act, an experiment station, containing some 20 experimental filters and equipped with chemical and bacteriological laboratories, was established at Lawrence and placed in operation in 1887.

The importance of this step should not be overlooked. It was the first time in the history of sewage treatment that engineers, chemists and biologists were given opportunity to work together under expert leadership with one end in view—the promotion of the public health.

Immediately, there was instituted a series of investigations of the true nature and the mechanics of sewage filtration; investigations which, during the next 20 years, accomplished more than any other studies, either here or abroad, to place sewage treatment on a sound, scientific basis. Experiments undertaken, almost at the start, paved the way for development in later years of the contact bed, the sprinkling filter and, perhaps, the activated sludge process. Important as were these developments, the greatest contribution to the art of sewage treatment was the clear and forceful demonstration of the basic fact that sewage filtration is not merely a mechanical straining but a biological and chemical process of delicacy, involving the gradual transformation of dead organic matter by living organisms working in the presence of oxygen.

Lawrence Experiment Station did more than provide answers to certain specific problems which were then pressing for solution. It definitely demonstrated the value of the coordinated effort of men trained in kindred branches of science and it set a precedent which during the next few decades resulted in establishment of sewage testing stations throughout the country to investigate and report on the applicability of certain processes to local conditions, in order that the municipal officials might have reliable data on which to base designs.

## Milestones of Progress

The development of the art of sewage treatment has been so rapid and complex and has been furthered by so many workers that to attempt even the barest outline, in the short time available, manifestly would be impossible, but we may be helped by passing note of some of the milestones along the route.

*Intermittent Sand Filtration*

Earlier investigators on the Continent and in England had grasped the basic fact that micro-organisms played some part in sand filtration. However, the Lawrence demonstration that controlled application of sewage in intermittent doses on prepared, underdrained beds of sand would accomplish the continuous purification of municipal sewage was so convincing, and so definitely explained the biological processes which were involved, that intermittent sand filtration has since been accepted as an American development.

Practical results were forthcoming. Framingham soon completed a plant containing approximately 12 acres of filters and Brockton followed shortly after with a somewhat larger plant. Within a few years there were over 30 plants in New England and as many more elsewhere in the United States. Even today, the process merits regard as a finishing process, provided the filters are not overloaded and necessary labor can be furnished for cleaning the beds.

*Chemical Precipitation*

Today, we are accustomed to think of chemical precipitation as a highly specialized method for treatment of industrial wastes or for occasional use where it is desired to provide a degree of purification between plain sedimentation and complete biological treatment.

Such was not always the case, for at the height of its popularity in England and Scotland, during the last decades of the past century, some 200 chemical precipitation plants were in operation, treating upwards of 700 million U. S. gallons of sewage daily. The wide adoption of chemical precipitation abroad was due largely to government requirements that industrial wastes, as well as sanitary sewage, be treated before discharge into the streams, and to definite recommendation favoring this mode of treatment as a preliminary to land filtration.

This latter stimulus was lacking in this country, and chemical precipitation was adopted by only a few summer resort communities, the Village of East Orange, N. J., the 1893 World's Fair in Chicago, and two large cities where special conditions prevailed—Worcester, Mass., where the sewage contained acid-iron wastes from pickling processes in the wire mills, and Providence, R. I., where the sewage contained wool grease and dye wastes from the textile mills.

Both of these latter plants were patterned after British designs, and consisted of a screen chamber, baffled chemical mixing flume, series operated settling tanks and sludge presses. The effluents were of satisfactory clarity, but only modest reduction of dissolved organic matter was obtained. At Providence, where discharge was in tidal water, the treatment was sufficient, but at Worcester sand filters were added in order to maintain inoffensive conditions during periods of low flow in the Blackstone River.

Although all these early plants have been replaced by new installations employing other methods of treatment, they must be remembered in our annals as signalizing development of special processes of sewage treatment which could be made applicable to particular needs. Furthermore, data relative to the value of different precipitants and methods of conditioning sludge for dewatering, which were painstakingly collected at Worcester and Providence during their many years of service, still have value.

It is worthy of particular note that, from the start, both of these plants were under charge of full time graduate engineers and chemists, thus constituting our first recorded service by technical sewage treatment plant operators.

*Preliminary Treatment*

In the earliest filter plants, there were no preliminary treatment facilities other than rack screens and small grit chambers. The solids removed from the raw sewage by filtration necessitated frequent cleanings of the beds and investigators in France, England and this country, impressed by the liquefaction of sewage solids in the ordinary household cesspool, were experimenting with a variety of sealed tanks.

Success rewarded the efforts of Donald Cameron of Exeter, England, and in 1896 he introduced the septic tank for scientific control of anaerobic putrefaction of sewage solids.

While the end results of septic tank treatment frequently were unsatisfactory, both as concerns quality of effluent and of sludge, the process had merit and was widely adopted in this country.

Then came the Saratoga Springs law suits for recovery of royalties—suits which, after extended litigation, were terminated in January, 1908, by a U. S. Circuit Court of Appeals' decision in favor of the Cameron Company, American patentees.

It is a matter of speculation whether progress in the art of sewage treatment was fostered or hindered by the decision of this high tribunal. Certain it is that American engineers had little sympathy with the large royalties demanded by the patentees and they set about to circumvent such of the process and apparatus claims as had been upheld. One of these innovations was embodied in the Baltimore sewage treatment plant and consisted of three separate, uncovered tanks 105 feet square and 14 feet water depth, into which sludge deposited in the nearby settling tanks was pumped by centrifugal pumps for digestion. These were truly separate sludge digestion tanks. While after-search reveals that the method had been recommended for installation elsewhere at an earlier date, it is believed that the Baltimore tanks, which went into service in 1912, constituted the first actual full size installation of separate sludge digestion tanks in this and, perhaps, in other countries.

Meanwhile, experiments were everywhere underway. In rapid succession we were introduced to the Hampton or Travis tank, the Imhoff tank and finally were led back to the single story settling tank. Each of these, as we know, offered relief from some faults of its predecessor but the road ahead still is not entirely clear.

*Trickling Filters*

The step from sand filters and contact beds to trickling filters was undoubtedly one of the most important advances in the art of sewage treatment.

While this country can lay claim to the initial investigations of coarse grained filter media at Lawrence in 1898, and to establishment of the essential importance of the "slow movement of the sewage in thin films over the surface of the stones, with air in contact," credit must again be given to British investigators for development of the modern, underdrained trickling filter, having stationary nozzles, rotating arms or reciprocating type distributors.

The American adaptation of the British installations, and particularly the solution of problems as to economic depth of stone, ability to withstand our northern winters, permissible loading and proper rates of operation were carefully developed in testing stations operated by Columbus, Ohio, and following cities during the first decade of this century, and by research sponsored by our universities, particularly that at the Sewage Testing Station of the Massachusetts Institute of Technology.

The year 1908 witnessed the start of operation of our first three modern municipal trickling filters, sizable plants at Reading, and Washington, Pa., and a large ten-acre plant at Columbus, Ohio. The next large installation was at Baltimore where the first 12-acre unit was completed in 1912. Others, large and small, followed in rapid succession until at the close of 1940, the U. S. Public Health Service Reports show that nearly 1,600 trickling filters were in operation, equivalent to 58 per cent of all the plants in this country providing secondary treatment.

That is, indeed, a rapid survey of the very real accomplishments attained during 60 years. It omits much—activated sludge, of course, contact beds, the developments in high rate filtration, sludge disposal, the utilization of gas, disinfection, special work in industrial wastes, and many other significant phases of the art and science of sewage treatment. Most of these can, however, be ascribed to recent days and can be viewed as the logical extension of the "early steps" which I have sought to place in perspective.

Rather than to attempt to gauge the true worth of any of the newer methods, however, let us take a backward look over the road we have traveled.

While we may agree that England has truly and properly been designated as the birthplace of modern sewage treatment, we should recognize that European developments would have benefited us but little if they had been transplanted bodily without due regard for differences in climate, soil, economic conditions and standards to be met in this country.

Realization thus comes that our early progress in sewage treatment and stream sanitation and likewise the impetus to sound methods of investigation was due to the unusual foresight, keen judgment and technical skill of a mere handful of chemists, biologists and engineers who labored unceasingly for accomplishment of the purpose to which they had dedicated themselves—the promotion of the public health. In peril of some embarrassing omissions, I would, from the past, include among these:

William T. Sedgwick of the Massachusetts Institute of Technology, biologist, epidemiologist, inspired teacher and lecturer on sanitary science.

Leonard P. Kinnicut of Worcester Polytechnic and A. N. Talbot of the University of Illinois, professors of sanitary chemistry, authors and research workers.

Col. George E. Waring, civil engineer, proponent of the "separate system," pioneer in the development of sanitary sewage disposal for isolated homes, and, in later years, the organizer of New York City's "White Wings."

Rudolph Hering, internationally famous civil engineer and hydraulician, courageous advocate of the Chicago Drainage Canal and other great projects for disposal of sewage by dilution. More than any other man, he seemed to possess unusual ability for assessing new developments in Europe and adapting them for use in this country.

Allen Hazen, in charge of the Lawrence Experiment Station during its initial years, who by virtue of deep study, marked ability for clear thinking and a dominating personality, attained international fame as a hydraulician and hydrographer.

George W. Fuller, who succeeded in charge at Lawrence and then undertook the important studies at Louisville which demonstrated the value of downdraft filtration, soon was embarked on his distinguished career as sanitary engineer and consultant. His sound judgment, great energy and pleasing personality carried him far. As author, consultant and friend he will long be held in reverent memory by many.

Harrison P. Eddy, his keen ability for analysis of technical problems, well ordered mind and talent for clear expression in speech and writings, characterized his long, distinguished and useful career in the sanitary engineering field. His unfailing courtesy and pleasant manner endeared him to all.

George C. Whipple, the eminent sanitarian and authority on aquatic microscopy, author and teacher, was respected and admired by those who were privileged to know him.

F. Herbert Snow, designer of the Brockton plant and the first to apply the principles embodied in our present systems of sewer rentals, followed his early work with an honored career as a state sanitarian.

T. Chalkley Hatton, who contributed so largely to the development of the activated sludge process of sewage treatment, through preliminary investigations and experiments followed by courageous design and skillful operation of the Milwaukee sewage treatment works—the first large installation of this process in the United States.

Kenneth Allen, whom we delight to honor, served his profession well in studies of pollution of tidal waters and in the development of the base plan for sewage disposal of this great City of New York.

Robert Spur Weston, widely known for his successful solution of many industrial wastes pollution problems, will long be remembered.

Frederick P. Stearns of Boston, Samuel M. Gray of Providence, John H. Gregory of Baltimore, James H. Fuertes of New York, R. Winthrop Pratt of Cleveland, John W. Alvord of Chicago, civil engineers and hydraulicians whose unusual abilities in preliminary investigation and design, contributed greatly to development of the art.

Gentlemen, such is our heritage. Well may we be proud of those who have preceded us. Our opportunity is just as great as theirs and the need as pressing. May we measure up to the tasks which are before us in this our chosen field of sanitation.

Note: Factual material concerning early plants and processes was obtained in part from "Sewage Disposal in the United States," Rafter & Baker, 1894; "British Sewage Works," M. N. Baker, 1904; early issues of *Engineering News*; Annual Reports of Massachusetts State Board of Health and early text books. Characterizations have been adjusted to published memoirs in some cases.

## Discussion

By William R. Copeland

*Formerly Chemist on Original Staff at Lawrence Experiment Station*

In Mr. Emerson's interesting article, he has emphasized the various phases of sewage disposal prevailing between 1885 and 1945. He presents a partial list of the men who have been leaders in the field. To his roster should be added the following names:

Dr. Wolcott, Chairman of the Massachusetts State Board of Health, who was mainly responsible for raising the funds to finance the Lawrence Experiment Station;

Hiram F. Mills, the engineer who directed the type and scope of the experiments carried out at the Station;

Dr. Drown, Professor of Chemistry at M. I. T., who supervised the details of chemical analyses and biological research conducted at the laboratory; and Harry W. Clark, who as Chief Chemist and later Director, supervised the daily work performed at the Station.

In 1895 the farmer's practice of composting stable manure to make fertilizer for growing plants, the decay of meat, and the rotting of leaves in the forest were familiar to all. But just why these changes took place was an enigma. Louis Pasteur had pointed out that such fermentation processes are brought about by hosts of minute living organisms feeding upon the organic matter. It was due to the foresight and exact scientific training of such men as the author refers to that these vague ideas of "Nature's methods" of destroying organic matter were reduced to formulae capable of control by man.

Experiment at the Lawrence Station had much to do with solving these problems. For example, the researches there explained how complex organic compounds of nitrogen are broken down first into free ammonia and gaseous nitrogen, and then how these are later oxidized into nitrite and finally into nitrate. Mrs. Helen Richards, Assistant Professor of Chemistry at M. I. T. and noted expert upon foodstuffs and nutrition, and Mr. George Whipple were among the first to isolate the living organisms that carry out this oxidizing process. The complete cycle starts off with a period of fermentation, or rotting and decomposition of organic matter by which the elements of oxygen, carbon, etc., are plucked out from the organic matter. These processes were employed by Cameron in his septic tanks, and are active in the farmer's compost heaps.

The farmer spreads this compost upon his fields or buries it in the top soil. There, groups of bacteria taking oxygen, etc., out of the air, oxidize the ammonia and nitrogen into nitrites and nitrates. To employ this principle and at the same time multiply its effectiveness, experiments were made at Lawrence with many kinds of sands, gravels, coke, stones, slates, etc., through which air was forced by various methods. It was while carrying out such tests that Clark developed the fundamental principle of activated sludge for purifying sewage.

The farmer's idea and activated sludge have one principle in common. It is to carry oxygen to the oxidizing bacteria. The ideas differ, however, in that the former feeds the water to the bacteria stationary in the soil, whereas in the activated sludge process the finely divided sewage solids, coated by immense numbers of bacteria, are swept back and forth through the sewage in the presence of great quantities of air. Consequently, a sewage farm can handle only 100,000 gallons of water on an acre of ground, whereas an activated sludge plant can handle from 15 to 20 million gallons on an acre. Power motors, air blowers, pumps and machinery of many kinds have thus become the handmaidens of Nature's methods of sewage disposal but, as great industries are built, new problems constantly arise.

Therefore, research, experiment, and ingenuity upon the part of biologists, chemists, engineers and sewage plant operators must in the future build new and greater works upon the background so well established years ago by the pioneers in the field of sewage and trade waste disposal.

# Sewage Research

## PLANT SCALE TESTS ON THERMOPHILIC DIGESTION *

By A. J. Fischer and R. A. Greene

*Development Dept., The Dorr Co., New York City, and Chemist, Sewage Treatment Plant, Jackson, Mich., Respectively*

The rapid digestion of sewage sludge and trade wastes in the thermophilic range has been amply demonstrated in the laboratory and in pilot plant tests. Favorable results have been reported with digestion periods ranging from two to twelve days as against ten to twenty-one days for mesophilic digestion at 85°–95° F.

Besides smaller digester volume requirements, it was claimed that thermophilic digestion gave a greater production of gas. Disadvantages cited were the difficulties in obtaining and maintaining thermophilic temperatures; the production of a poor quality supernatant liquor; and the production of an odorous digested sludge that was difficult to dewater.

### Aurora Tests

In order to determine whether these benefits and disadvantages would be realized in full plant scale operation, tests were conducted at Aurora, Ill., in 1931. In these tests a comparison was made of single stage mesophilic vs. thermophilic digestion of raw sludge at approximately a twelve-day digestion period. In order to reduce the digestion period to this figure—measured on the basis of solids detention—it is necessary to carry relatively low sludge levels in the digestion tanks, which were 50 ft. square by 17 ft. in water depth. This necessitated accurate checks on the total solids content in each unit. Depth samples were collected daily at one- to three-inch intervals in the sludge blanket and immediately above it, for solids and volatile matter determinations. In order to keep the solids and ash content in the digesters approximately constant, digested sludge was withdrawn daily in amount equal to the daily raw sludge additions, taking into account the reduction in solids due to digestion.

The Aurora test results are summarized in Table 1. These results cover a period of sixty-two days after stable conditions were established. They indicate that slightly greater solids and volatile matter reductions were obtained with thermophilic digestion. Gas production figures and overflow liquor analyses indicate, however, that the apparent increased digestion is due to greater liquefaction and a higher volatile matter content in the overflow rather than to greater gasification.

* Presented at Seventeenth Annual Meeting, New York State Sewage Works Association, New York City, January 19, 1945.

TABLE 1.—*Mesophilic vs. Thermophilic Digestion*
*Aurora, Ill., Tests*

| | 90° | 130° |
|---|---|---|
| *Raw Sludge:* | | |
| Total Dry Solids Added per Day—Lbs. | 1,725 | 1,725 |
| Per Cent Solids | 6.1 | 6.1 |
| Per Cent Volatile Matter | 69.8 | 69.8 |
| *Digested Sludge:* | | |
| Per Cent Solids | 5.90 | 8.65 |
| Per Cent Volatile Matter | 53.3 | 50.9 |
| *Sludge in Digester:* | | |
| Total Dry Solids—Lbs. | 21,020 | 21,590 |
| Per Cent Solids | 0.79 | 0.81 |
| Per Cent Volatile Matter | 54.9 | 55.8 |
| *Sludge Blanket:* | | |
| Depth—Inches | 23 | 16 |
| Per Cent Solids | 4.6 | 8.2 |
| Per Cent Volatile Matter | 53.5 | 50.9 |
| *Gas:* | | |
| Daily Production—Cu. Ft. | 12,990 | 13,220 |
| Daily Production at 90° F.—Cu. Ft. | 12,990 | 12,350 |
| Per Cent $CO_2$ | 29.4 | 29.7 |
| Per Cent Solids Production (calc.) | 35.3 | 39.4 |
| Per Cent Volatile Matter Reduction (calc.) | 50.5 | 56.4 |
| Gas—Cu. Ft. at 90° F. per Lb. Vol. Matter Added | 10.8 | 10.3 |
| Gas—Cu. Ft. at 90° F. per Lb. Vol. Matter Destroyed | 21.3 | 18.2 |
| Ratio of Digested to Raw Solids Added Daily | 12.2 | 12.5 |
| Ratio of Digested to Raw Vol. Matter Added Daily | 9.6 | 10.0 |
| Digester Loading—Lbs. Solids Added per Cu. Ft. per Month | 1.22 | 1.22 |
| Digester Loading—Vol. Matter Digested per Cu. Ft. per Month | 0.43 | 0.48 |
| Digestion Period—Days | 12.5 | 12.9 |

The digested sludge obtained from the thermophilic tank was similar to that from the mesophilic unit in that it was black in color and comparatively inodorous. Of significant advantage was the higher solids content of the former. It was, however, more difficult to dewater. Neither sludge dried as rapidly as that resulting from digestion at 90° F. for long periods.

Figure 1 shows the results of Büchner funnel tests of both sludges under vacuum using $FeCl_3$ as a coagulant. These curves show that the 90° sludge dewatered more rapidly. The cake moisture at 130°, however, was lower by about 5 per cent, indicating that the heated sludge would give a drier cake on vacuum filters.

The overflow liquor at 130° was black in color and was high in colloidal and non-settleable solids that could not be removed even with high

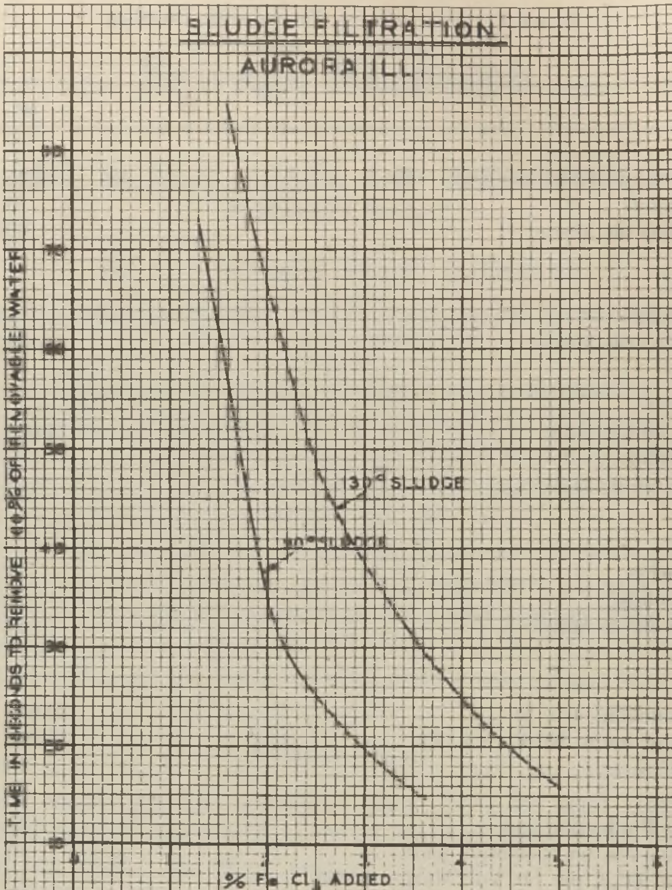


FIGURE 1.—Büchner funnel tests on mesophilic and thermophilic sludges at Aurora, Ill.

coagulation doses of lime and ferric chloride. Average analyses of both overflows are given in Table 2.

During these tests, both the mesophilic and the thermophilic tanks were heated by conventional hot water heating coils arranged around the tank walls. With the thermophilic tank the ingoing heating water was maintained at about 180° F. After the tests were concluded the

TABLE 2.—*Mesophilic vs. Thermophilic Digestion*
*Overflow Liquor—Aurora Tests*

| | 90° | 130° |
|---|---|---|
| Total Solids—p.p.m. | 2,310 | 3,090 |
| Dissolved Solids—p.p.m. | 1,537 | 1,600 |
| Suspended Solids—p.p.m. | 773 | 1,490 |
| Non-Settleable Susp. Solids—p.p.m. | 107 | 451 |
| Settleable Susp. Solids—p.p.m. | 666 | 1,049 |
| Settleable Solids—cc. per liter | 12.0 | 17.2 |

tank was drained and it was found that a very heavy sludge cake and scale had formed on the coils.

Summarizing the results of the Aurora tests, it was apparent that a significant advantage of thermophilic digestion was that it gave a thicker sludge, but that its disadvantages were that it produced a poorer quality overflow liquor and a digested sludge more difficult to dewater. It was also clear that heating methods other than by conventional hot water heating coils would be required to maintain thermophilic temperatures.

## Jackson Tests

In view of the advances in sludge digestion practice during the 1930's, it appeared reasonable that the disadvantages brought out in the Aurora tests might be readily overcome by the use of stage digestion. This belief was strengthened by the favorable indications reported in the Los Angeles pilot plant studies of Smith and Studley. Accordingly, a new series of plant studies was initiated at Jackson, Mich., in January, 1942, and continued to November, 1944.

The Jackson plant is of the activated sludge type, the raw sludge consisting of approximately one part primary to three parts activated sludge. The waste activated sludge is returned to the raw sewage, and the combined raw sludges pumped to six digestion units; four 50 ft. in diameter by 22 ft. s.w.d., having a capacity of 47,000 cu. ft. each; and two 60 ft. in diameter by 22 ft. s.w.d., having a capacity of 69,300 cu. ft. each.

Parallel tests were first run at equal loadings, the tanks being arranged in two batteries with two 50-ft. tanks and one 60-ft. tank operated in series in each battery. The primary unit of one set was held at 84° F., while that of the other was maintained at 125° F. The daily production of raw sludge was fed to alternate batteries every other day, an equal volume of primary digester sludge being displaced to the secondary unit and from there to the tertiary tank. Supernatant liquor and digested sludge were periodically withdrawn from the tertiary tanks, the supernatant being returned to the raw sewage.

The results of a comparative period covering six months' operation after conditions were stabilized are given in Table 3. These results show that greater gas production and higher volatile matter reduction were obtained by thermophilic digestion. Also, slightly more overflow liquor of a better quality was obtained at 125°. In either case the overflow was of such a quality that it did not interfere with the treatment process when returned to the system.

Scum blankets were present in both primary digesters at all times during the tests. These scum blankets varied in depth, greater depth and higher solids and volatile matter content being present in the thermophilic unit as shown in Table 4. The scum in the thermophilic tank, however, was always soft. In the mesophilic unit the scum was invariably hard even at higher moisture content. The presence of large

TABLE 3.—*Mesophilic vs. Thermophilic Digestion Jackson, Mich., Tests*

| | Mesophilic | Thermophilic | |
|---|---|---|---|
| | Period 1 | Period 1 | Period 2 |
| *Temperature:* | | | |
| Primary—° F. | 84 | 125 | 133 |
| Secondary | 86 | 111 | 121 |
| Tertiary | 73 | 78 | 114 |
| *Raw Sludge:* | | | |
| Dry Solids Added per Day—Lbs | 5,740 | 5,900 | 13,930 |
| Per Cent Solids | 5.23 | 5.25 | 5.3 |
| Per Cent Volatile Matter | 64.0 | 63.9 | 62.8 |
| *Digested Sludge:* | | | |
| Per Cent Solids | 8.7 | 8.9 | 7.0 |
| Per Cent Volatile Matter | 47.7 | 44.8 | 45.9 |
| *Sludge from No. 1 Digester:* | | | |
| Per Cent Solids | 3.7 | 3.1 | 3.3 |
| Per Cent Volatile Matter | 52.4 | 49.7 | 49.8 |
| *Sludge from No. 2 Digester:* | | | |
| Per Cent Solids | 5.8 | 5.4 | 4.7 |
| Per Cent Volatile Matter | 47.8 | 46.1 | 48.0 |
| *Sludge in Primary Digester:* | | | |
| Total Dry Solids—Lbs. | 86,130 | 92,450 | 87,530 |
| Per Cent Solids | 3.28 | 3.80 | 4.08 |
| Per Cent Volatile Matter | 55.8 | 52.8 | 52.1 |
| *Gas:* | | | |
| Primary Unit—Cu. Ft. per Day | 23,400 | 32,700 | 59,000(est.) |
| Primary Unit—Cu. Ft. per Day at 84° F. | 23,400 | 30,400 | 54,100(est.) |
| Prim. + Sec. Unit—Cu. Ft. per Day | 26,000 | 35,500 | 64,000 |
| Prim. + Sec. Unit—Cu. Ft. per Day at 84° F. | 26,000 | 33,070 | 58,860 |
| Per Cent Gas Obtained in Primary | 90.0 | 91.8 | 92.0 |
| Per Cent $CO_2$—Primary | 30.0 | 31.9 | 31.0 |
| Per Cent $CO_2$—Secondary | 32.4 | 29.7 | 28.0 |
| *Supernatant:* | | | |
| Gallons per Day | 9,385 | 10,590 | 21,650 |
| Gallons per Gallon of Raw Sludge | 0.73 | 0.81 | 0.71 |
| B.O.D.—P.P.M. | 597 | 405 | 796 |
| Total Solids—P.P.M. | 4,920 | 3,983 | 9,620 |
| Suspended Solids—P.P.M. | 3,002 | 1,933 | 7,596 |
| Dissolved Solids—P.P.M. | 1,918 | 2,050 | 2,024 |
| Ratio of Primary Dig. Sludge to Raw Solids—Added Daily | 16.0 | 15.7 | 6.3 |
| Ratio of Primary Vol. Matter to Raw Vol. Matter—Added Daily | 13.4 | 13.0 | 5.2 |
| Per Cent Solids Reduction—Primary | 24.3 | 28.2 | 25.9 |
| Per Cent Solids Reduction—Primary + Secondary | 31.0 | 33.0 | 28.5 |
| Per Cent Solids Reduction—Pri. + Sec. + Tert. | 31.2 | 34.7 | 31.2 |
| Per Cent Vol. Matter Reduction—Primary | 38.0 | 44.2 | 39.6 |
| Per Cent Vol. Matter Reduction—Pri. + Sec. | 48.3 | 51.6 | 45.3 |
| Per Cent Vol. Matter Reduction—Pri. + Sec. + Tert. | 48.7 | 54.3 | 49.8 |
| Gas—Cu. Ft. at 84° per Lb. Vol. Matter Added—Pri. | 6.38 | 8.01 | 6.18(est.) |
| Gas—Cu. Ft. at 84° per Lb. Vol. Matter Added—Pri. + Sec. | 7.05 | 9.03 | 6.74 |
| Gas—Cu. Ft. at 84° per Lb. Vol. Matter Digested—Pri. | 16.8 | 18.1 | 15.6 (est). |
| Gas—Cu. Ft. at 84° per Lb. Vol. Matter Digested—Pri. + Sec. | 14.3 | 17.5 | 14.9 |
| Digester Loading—Lbs. Solids Added per Cu. Ft. per Mo.—Pri. | 3.67 | 3.77 | 8.90 |
| Digester Loading—Lbs. Solids Added per Cu. Ft. per Mo.—Pri. + Sec. | 1.84 | 1.89 | 4.45 |
| Digester Loading—Lbs. Solids Added per Cu. Ft. per Mo.—Pri. + Sec. + Tert. | 1.06 | 1.09 | 2.56 |
| Digester Loading—Lbs. Vol. Matter Dig. per Cu. Ft. per Mo.—Pri. | 0.89 | 1.07 | 2.22 |
| Digester Loading—Lbs. Vol. Matter Dig. per Cu. Ft. per Mo.—Pri. + Sec. | 0.57 | 0.62 | 1.39 |
| Digester Loading—Lbs. Vol. Matter Dig. per Cu. Ft. per Mo.—Pri. + Sec. + Tert. | 0.33 | 0.38 | 0.80 |
| Primary Digestion Period—Days | 27.3 | 26.7 | 11.7 |

quantities of oil in the sewage contributed greatly to the depth of the scum blankets.

It would appear from the percentage solids in the sludge transferred from the secondary digesters that the mesophilic sludge tended to thicken better than the thermophilic sludge. Such, however, was not the case. The slight difference in solids may be accounted for by the

TABLE 4.—*Scum Blankets—Jackson Tests*

| | Mesophilic | Thermophilic | |
|---|---|---|---|
| | Period 1 | Period 1 | Period 2 |
| Temperature—° F. | 84 | 125 | 133 |
| Average Scum Depth—ft. | 2.3 | 4 | 7 |
| Per Cent Moisture—Top 2-ft. layer | 79 | 56 | 39 |
| Per Cent Volatile Matter—Top 2-ft. layer | 74 | 89 | 87 |

greater reduction in solids in the thermophilic battery. Also, monthly inventories invariably showed the presence of more supernatant liquor in the thermophilic secondary unit.

Results covering a four-month period at the end of the test run are also given in Tables 3 and 4. Here the entire plant raw sludge production was pumped to the thermophilic battery. During this comparatively high solids loading period there was never any evidence of tank foaming, and volatile matter reductions were slightly better than those obtained at half loadings with mesophilic digestion. The solids in the digested sludge withdrawn from the tertiary tank, however, showed a definite drop in solids content. The sludge, as before, was comparatively inodorous and exhibited all the characteristics of a well digested sludge as regards color, drainability, etc. It did not, however, dry as readily as did the sludge obtained at lower tank loadings during the first period.

## HEATING EXPERIENCES

Of particular interest in these tests were our experiences in digester heating. During the initial period, when parallel tests were run at equal loadings, the thermophilic tank was maintained at the required temperature by means of conventional hot water heating coils. In August, 1942, an attempt was made to increase the load to the thermophilic battery by 25 per cent. It was soon found, however, that it was impossible to maintain this higher loading as the tank temperature dropped off, even though we carried ingoing heating water temperatures as high as 195° F. The loads were again equalized until January, 1943, when a new auxiliary heater was installed.

The new heater is shown in Figures 2 and 2 (a) and had for its principle the aspiration of hot gases directly into the sludge as it was recirculated through an injector. The sludge, after passing through the injector, discharged to a vented storage tank for the purpose of releasing $CO_2$, and then passed back to the digester. This heating unit was designed to burn 25 c.f.m. of digester gas with a circulation of 600 g.p.m. of sludge through the injector at a pressure drop of 10 pounds. It was felt that the high temperature of the sludge as it passed through the injector would not be detrimental to digestion as the contact period between the sludge and hot gases was very short. It was also felt that even if the organisms were killed, the sludge would be immediately re-

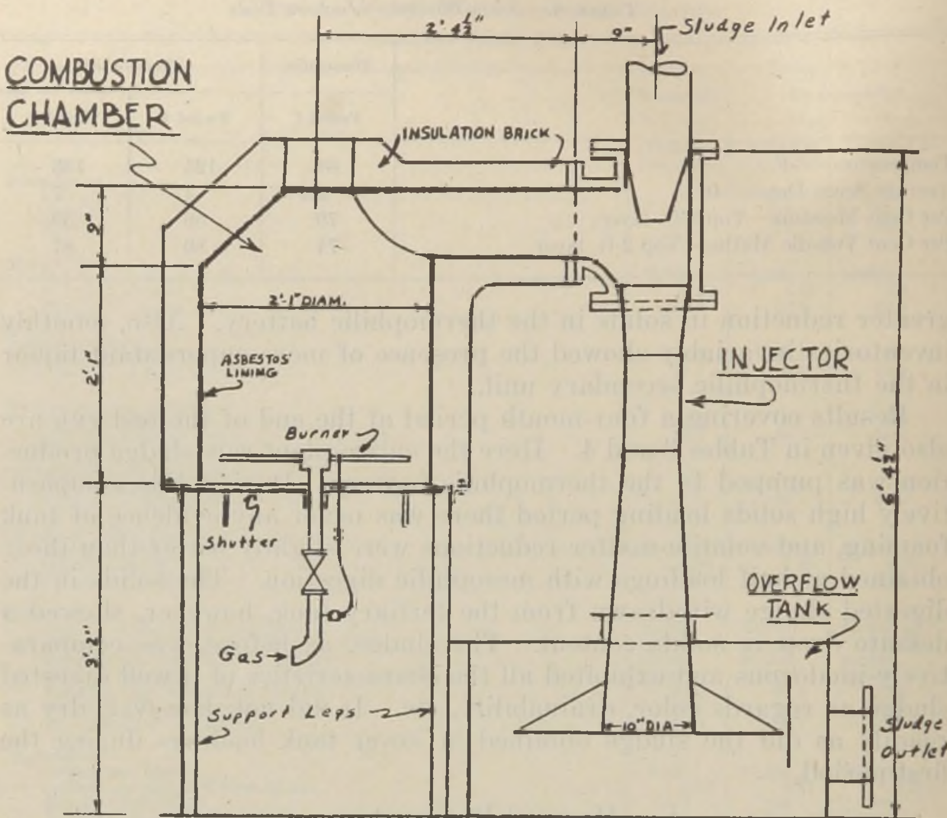


FIGURE 2.—Auxiliary contact type heater—Jackson tests.

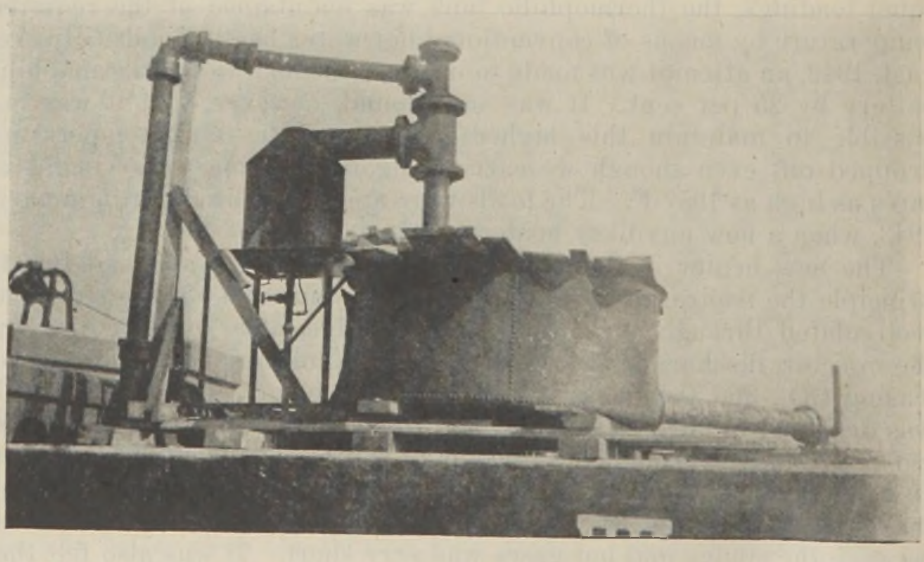

FIGURE 2 (a).—Auxiliary contact type heater—Jackson tests.

seeded when it again came into contact with the large volume of active material in the digester.

Twenty-two hours after the new heater was started up, however, the gas production from the thermophilic tank dropped from 30,000 c.f.d. down to 1,600 c.f.d. Sludge additions were then halted and the tank temperature raised by means of the internal heating coils. Sludge additions were resumed and the heater again started up. Again the gas production fell off sharply. For a second time raw sludge additions were interrupted. Then, when the temperature was brought up to the thermophilic range again, operation of the new heater was resumed at a 10 c.f.m. gas burning rate. This time digestion proceeded satisfactorily and the gas rate was increased gradually to a maximum of 25 c.f.m. with no ill effects as far as digestion was concerned. Apparently the difficulty encountered in the first two starts of the new heater was caused by too rapid a rise or drop in the digester temperature and not to the heater itself. A rise or drop of 5° F. or more during a relatively short period appeared to affect greatly the digestion process in the temperature range of 115–125°. This variation is far more serious in the range of 115–120° and may cause a temporary complete cessation in digestion activity.

It soon developed that the combustion chamber of the new heater was very inefficient because of high radiation losses. Also, the release of vapors in the $CO_2$ release tank gave rise to considerable aerial nuisance. In order to reduce heat losses and odors, a combustion chamber as shown in Figures 3 and 3 (a) was constructed, and the injector arranged to discharge directly into the digester manhole as indicated diagrammatically in Figure 4. This arrangement had a higher gas burning capacity (2,000 c.f. per hr.) and greatly improved the thermal efficiency but was still inefficient because of the inability of the injector to draw in all the hot gases produced in the combustion chamber. Also, some odors were still present, due to the release of hot vapors from the digester manhole, which acted as a $CO_2$ gas release vent.

The method of heating next tried was the injection of steam directly into the digester. For this purpose a Bryant 12–S–63 boiler, rated at 31.8 boiler horsepower and having a B.T.U. output of 1,065,000 B.T.U. per hr., was employed. Feed water consisting of city water softened from 17 gr. per gal. as $CaCO_3$ down to 2.5 gr. per gal. by base exchange softeners, was fed to the unit at a 2 g.p.m. rate. At the start the steam was fed by a 3-inch pipe 10 feet below the tank surface, the pressure at the boiler being 4.5 to 5.0 lbs. A slight vibration was felt at this pressure when one stood on the tank roof. Also, poor distribution of heat was obtained, necessitating almost continuous recirculation of the bottom sludge. Ten extra feet of pipe were then added, raising the pressure at the boiler to 10 lbs. This caused the vibration to disappear and improved the heat distribution but did not entirely eliminate the need for recirculation. Other than the care required to regenerate the softeners daily and the blowing down of the boiler once each shift, the

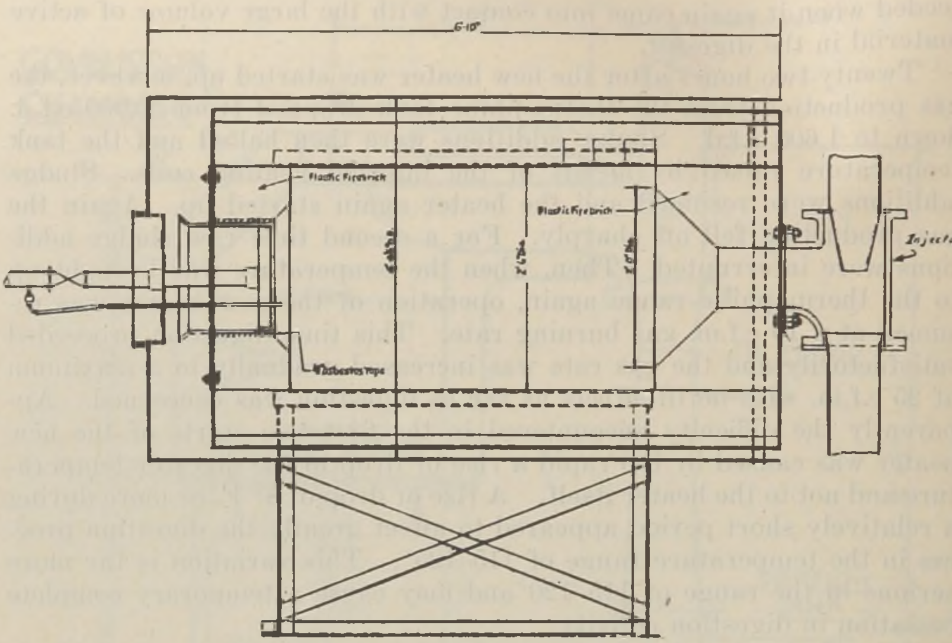


FIGURE 3.—Enlarged contact type heater—Jackson tests.

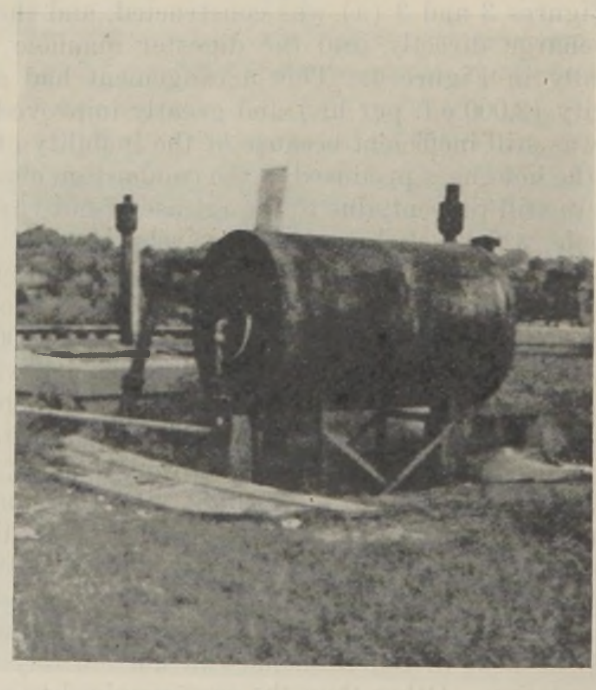

FIGURE 3 (a).—Enlarged contact type heater—Jackson tests.

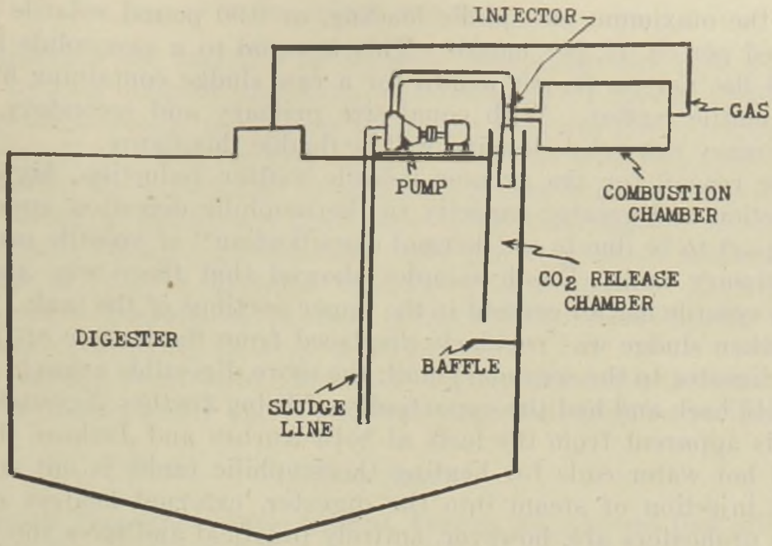


FIGURE 4.—Arrangement of contact type heater—Jackson tests.

steam heating system required very little attention and operated in a very satisfactory manner.

## General Discussion

The prime functions of a digester are to stabilize and concentrate the sludge so that it may be readily dewatered on sand beds or other drying devices without odor nuisance. Incidental to stabilization is the production of a maximum quantity of gas and maximum volatile matter reduction. Incidental to concentration is the production of an overflow liquor low in solids so that its return to the raw sewage will not upset clarification or secondary oxidation.

Long time experiences at Jackson have shown that although good stabilization may be obtained at relatively high loadings in the mesophilic range, satisfactory concentration will not occur if the weight of volatile matter digested per cu. ft. of total digester capacity per month exceeds 0.5 to 0.6 pound. By "satisfactory concentration" is meant the production of a digested sludge of at least the same moisture content as that of the raw sludge.

The results at 84° in Period 1 show that this result is attained by using only the primary and the secondary digester. Tank soundings also showed that it was possible to obtain a fair quality supernatant liquor at this loading. These results were also attained by thermophilic digestion at the 0.62 pound loading. The same solids concentration, however, was not realized when all the sludge was put through the thermophilic battery and when the primary plus secondary loading was 1.39 pounds of volatile matter digested per cu. ft. per month. A study of the records did show that approximately the same density of digested sludge was obtained with the thermophilic digestion at about 1.6

times the maximum mesophilic loading, or 0.90 pound volatile matter digested per cu. ft. per month. This is equal to a raw solids loading of 2.74 lbs. per cu. ft. per month for a raw sludge containing 62.8 per cent volatile matter. With equal size primary and secondary tanks, the primary raw solids loading will be double this figure.

The reason for the greater volatile matter reduction, higher gas production and greater capacity in thermophilic digestion appears in great part to be due to a "thermal classification" of volatile matter in the primary tank. Depth samples showed that there was always a higher volatile matter content in the upper portions of the tank. Therefore, when sludge was regularly displaced from the bottom of the primary digester to the secondary unit, the more digestible organic matter was held back and had the opportunity of being further digested.

It is apparent from the tests at both Aurora and Jackson that the use of hot water coils for heating thermophilic tanks is not suitable. Direct injection of steam into the digester, external heaters or raw sludge preheaters are, however, entirely practical and have the advantage that the boilers or heaters are always accessible for inspection and cleaning. In the case of steam heating, it is necessary to soften the boiler feed water in hard water areas. External heaters would have to be totally enclosed to prevent odor nuisances.

The most satisfactory range for a primary thermophilic tank appears to be 125°–130° F. At 142° F. the overflow becomes odorous, while if the temperature falls below 115° F., the digestion process will be seriously upset.

At Jackson, the total amount of water used per month for the production of steam, boiler blow-down and softener regeneration was roughly 100,000 gals. per month. At the prevailing water rates the cost of this water was about $10 per month. Salt for regeneration of the base exchange units cost an additional $2 per month. The boiler required very little maintenance.

The heat requirements for thermophilic digestion are about twice those for operation in the mesophilic range. Although the radiation losses at Jackson were about 50 B.T.U. per sq. ft. of tank surface per hr. as against 6 to 8 B.T.U. per sq. ft. per hr. for 80°–90° operation, the tanks at Jackson were admittedly not designed for high temperatures and, consequently, heat losses through the tank walls and roof were very high. Proper insulation would greatly reduce the radiation losses at very little additional cost. The secondary unit of a thermophilic system need not be heated at all, even during the coldest months.

The amount of water vapor in the gas at thermophilic temperatures was quite high. Adequate provisions to remove this moisture ahead of metering would be required in a regular installation, otherwise the maintenance costs on meters and other gas collection equipment would be excessive.

## Practical Aspects

Considering the increase in capacity obtainable per unit of tank volume by thermophilic digestion, economically the thermophilic two-stage system appears to be attractive where sufficient gas or waste heat is available for heating the raw sludge. There is, however, some doubt as to whether the system can be justified for new small or medium size plants. Here a temporary upset due to an interruption in heating would greatly retard digestion, and upset plant operation unless duplicate units or reserve digestion capacity were available. Such provisions would be impractical for small plants but entirely within the realm of economic possibility in large installations.

For existing overloaded plants, the system has much to recommend it, and by its use, costly digestion plant extensions may be avoided.

## Conclusions

1. Single stage plant scale tests at Aurora, Ill., showed that although the sludge digested rapidly at thermophilic temperatures, a poor quality overflow liquor and a digested sludge difficult to dewater were produced. A more concentrated sludge, however, was obtained.
2. Full plant scale tests at Jackson, Mich., showed that the disadvantages as found at Aurora were entirely overcome by the use of multi-stage digestion.
3. With two-stage thermophilic-mesophilic digestion, 60–75 per cent more sludge can be digested than in a two-stage mesophilic system of equal size.
4. Conventional hot water heating coils are not satisfactory for maintaining thermophilic temperatures. Direct injection of steam into the digesting sludge gave good results.
5. Direct heating of sludge by hot combustion gases, though feasible, does not appear economically attractive; also serious odor nuisances result.
6. The higher loadings obtainable by thermophilic stage digestion should make the process especially attractive for existing overloaded plants.

## Acknowledgment

The tests at Aurora and Jackson were carried out through the co-operation of Mr. W. A. Sperry and Mr. A. B. Cameron, superintendents of these respective plants. The test data at Aurora were collected by the staff of The Dorr Co., and at Jackson by the junior author. Both programs were carried out under the supervision of the senior author. The co-operation of the operating staffs at both plants made this work possible and is gratefully appreciated. The assistance of Mr. R. B. Jackson, Plant Engineer at Jackson, was particularly helpful in studying the various sludge heating methods tried at this plant.

# EXPLORING THE EFFECT OF HEAVY DOSES OF CHLORINE IN SEWAGE *

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The experimental work for this paper was undertaken, as the title implies, to explore the effect of greater than normal additions of chlorine to sewage. At the outset this was believed to have been virgin territory but a search of the literature revealed that at least two workers, Frank E. Hale and L. H. Enslow, had already done work along similar lines in 1927.

Hale (1) reported in 1927 that, unexpectedly, chlorination had definitely reduced the free ammonia content of the effluent from two sewage plants on the New York City watershed. Although such a phenomenon appeared to have little sanitary significance at the time, Hale was interested enough to examine the data carefully and to record the findings in a public document.

Enslow (2), during the same year, as recorded in the *Proceedings* of the Ninth Texas Water Works Short School, reported that up to 62 per cent B.O.D. reductions could be expected with chlorination alone and that the greater the initial B.O.D., the greater would be the removal. This is in line with work hereinafter reported to the effect that greatest B.O.D. removals per pound of chlorine added is obtained in the strongest sewages.

The reactions between chlorine and nitrogenous compounds, including some of the albuminoid types, have also been studied to a limited extent by a few experimenters, such as Calvert (3), Rudolfs and Gehm (4), without conclusive results from a practical point of view. This subject is discussed to a limited degree in the current paper.

Concerning the effect of nominal doses of chlorine on B.O.D. removal, it has become well established, both experimentally and through practical application, that chlorination to a first chlorine residual will result in the greatest reduction in B.O.D. This paper carries the subject a step further and contains data relating to the effect of heavy doses of chlorine on B.O.D., doses amounting in some cases to as much as 400 p.p.m. to and beyond the "break-point."

The present work is confined entirely to laboratory experiments, and is presented for record purposes only. No attempt is made to draw definite conclusions and all figures are subject to revision as new data on other type and strength sewages are collected. Many other tests and comparisons could and should be made to complete the picture. It is believed, however, that the material presented is basic and will form a pattern for chlorination.

* Presented at Seventeenth Annual Meeting, New York State Sewage Works Association, New York City, January 19, 1945.

All samples were collected from a plant where raw, settled, aerated and activated sludge effluents were available. Chlorine was applied to all samples immediately after collection. All samples for ammonia nitrogen, albuminoid nitrogen, and B.O.D. determinations were dechlorinated with sodium sulphite. Sodium sulphite was used instead of sodium thiosulphate in order to reduce the chloramines quantitatively, *i.e.,* to insure complete dechlorination of all samples. Such a procedure also avoided false B.O.D. readings that result when thiosulphate is employed. The ammonia and albuminoid nitrogen in the samples dechlorinated in this manner were determined by distillation and nesslerization, a deviation from *Standard Methods* procedure.

## Chlorine Residuals

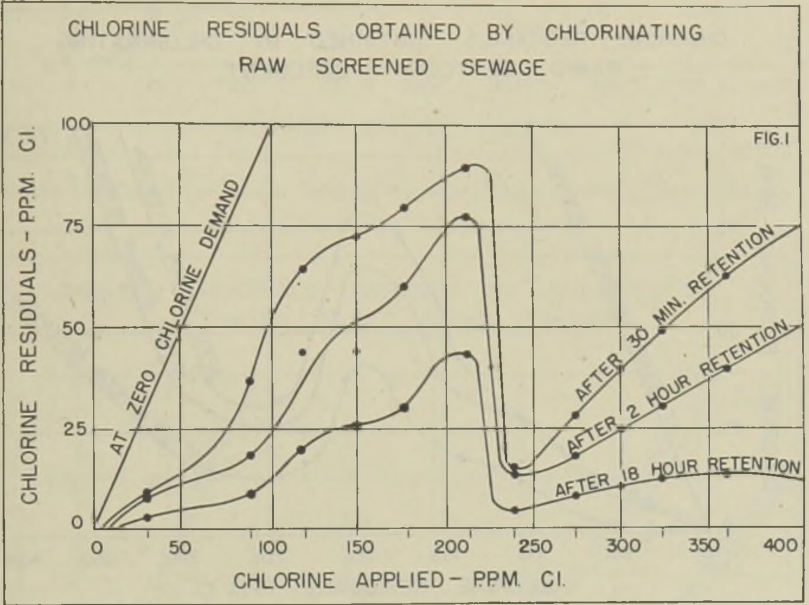



FIGURE 1.—Chlorine residuals obtained by chlorinating raw screened sewage.

The residual curves shown in Figure 1 demonstrate that when chlorine is added to sewage in sufficient quantities, a typical break-point chlorine residual curve results. The residuals in the "hump" area, after completion of the break-point reaction, are composed of chloramine while those beyond the "break" are composed of free available chlorine.

It is interesting to note, as will be explained further on, that the peak of the "hump" is somewhat flatter than would have been expected in a potable water where the pollution would have been less pronounced. Had the chlorine demand of the raw screened sewage been fully satisfied, the residual curve beyond the "break" would have been parallel to the zero chlorine demand line. In this case, however, the curve drops away from the zero line. This is particularly emphasized after 18 hours' retention where it becomes almost parallel to the chlorine application. This is due, no doubt, to the large amount of suspended solids in the raw screened sewage under test and is typical of heavily polluted waters.

When chlorine is added in increments up to 400 p.p.m. to the effluent from the primary settling basins the "break" takes place at approximately the same point as in the raw sewage (Figure 2). The "hump," however, is less pronounced and the 30-minute retention curve is parallel to the zero chlorine demand line. As the retention time increases up to 18 hours, the curve becomes progressively flatter but does not reach the extremes encountered in Figure 1. This is indicative of a lesser amount of suspended material.

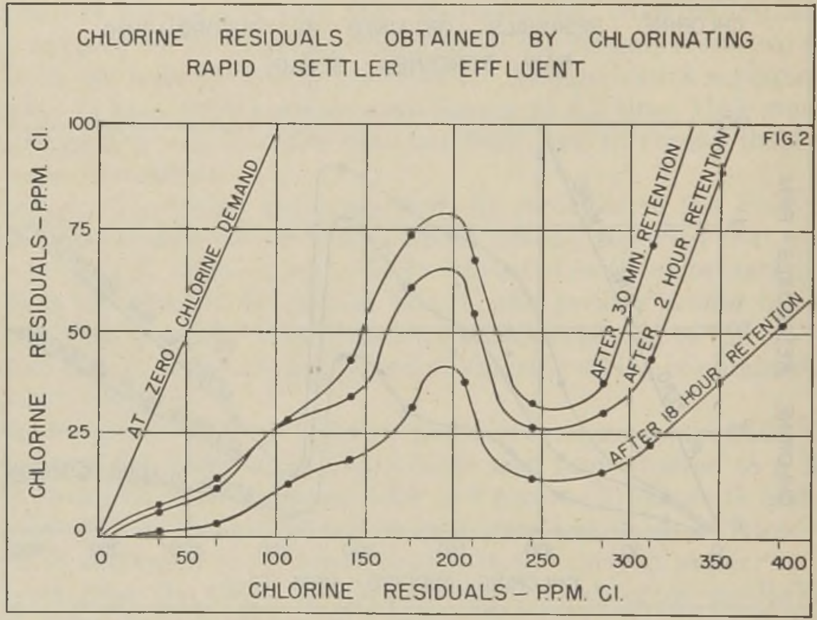



FIGURE 2.—Chlorine residuals obtained by chlorinating rapid settler effluent.

The results plotted in Figure 3 were obtained by applying chlorine in increments up to 200 p.p.m. to a partially oxidized effluent. Although these curves are essentially the same as in Figure 2 their magnitude is much lower. The residual at the "hump," for instance, has dropped from about 75 p.p.m. to about 30 p.p.m. and the "break" has retreated from a chlorine application of 250 p.p.m. to 125 p.p.m. This indicates that the combined effluents contain considerably less organic matter and ammonia than the settled sewage. This is not an unexpected result because the effluent from an aeration unit should be in better condition than plain settled sewage.

It is the general expectation that activated sludge process effluent should be relatively free of suspended material and relatively low in

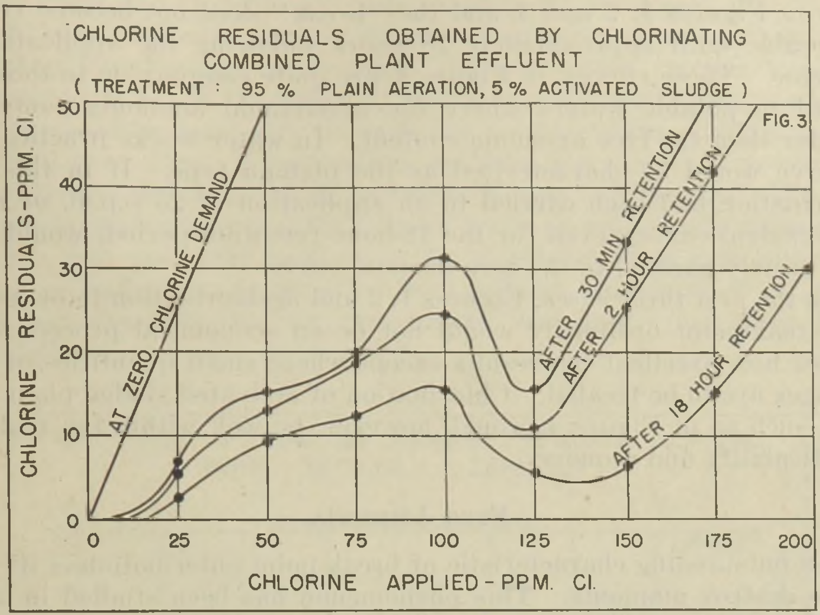



FIGURE 3.—Chlorine residuals obtained by chlorinating combined plant effluent.

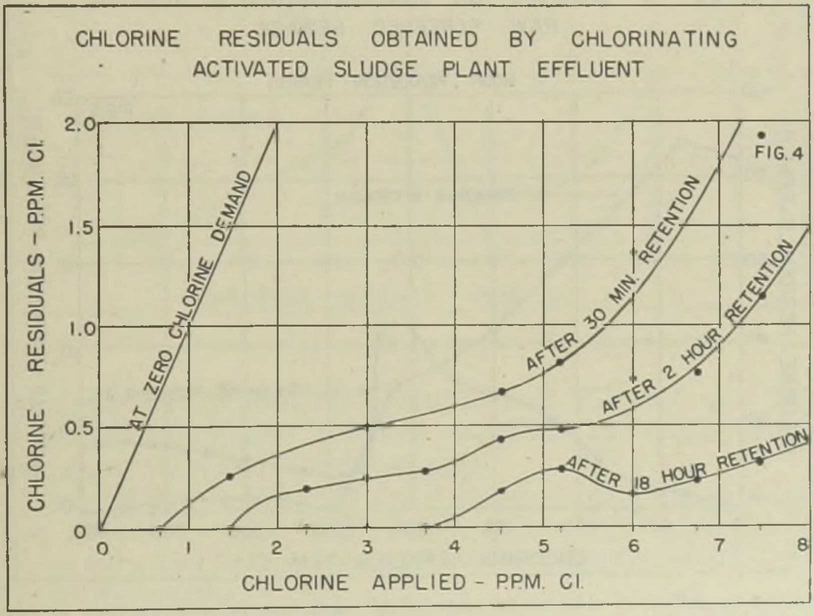



FIGURE 4.—Chlorine residuals obtained by chlorinating activated sludge plant effluent.

ammonia content, although at the present time there is a tendency to maintain a higher ammonia residual in the final effluent than heretofore.

The residual curves on the activated sludge process effluent, Figure 4, substantiate such reasoning. Here the residuals are much lower than in Figures 1, 2 and 3, and the "break" does not become readily noticeable until approximately 18 hours following the application of chlorine. These curves, in Figure 4, are quite comparable to those obtained in potable waters where the albuminoid ammonia content is greater than the free ammonia content. In water works practice such a curve would be characterized as the plateau type. If in this case chlorination had been carried to an application of 25 p.p.m. or more, the residual curves, even for the 18-hour retention period, would have been nearly parallel to the zero demand curve.

In the first three cases, Figures 1, 2 and 3, chlorination to or beyond the break-point ordinarily would not be an economical procedure, no matter how excellent the results except where small quantities of such sewages are to be treated. Chlorination of activated sludge plant effluents, such as in Figure 4, would, however, be well within the realm of practicability and economy.

### Free Ammonia

An outstanding characteristic of break-point chlorination is its ability to destroy ammonia. This phenomenon has been studied in detail in relation to potable water supplies but very little has been done in

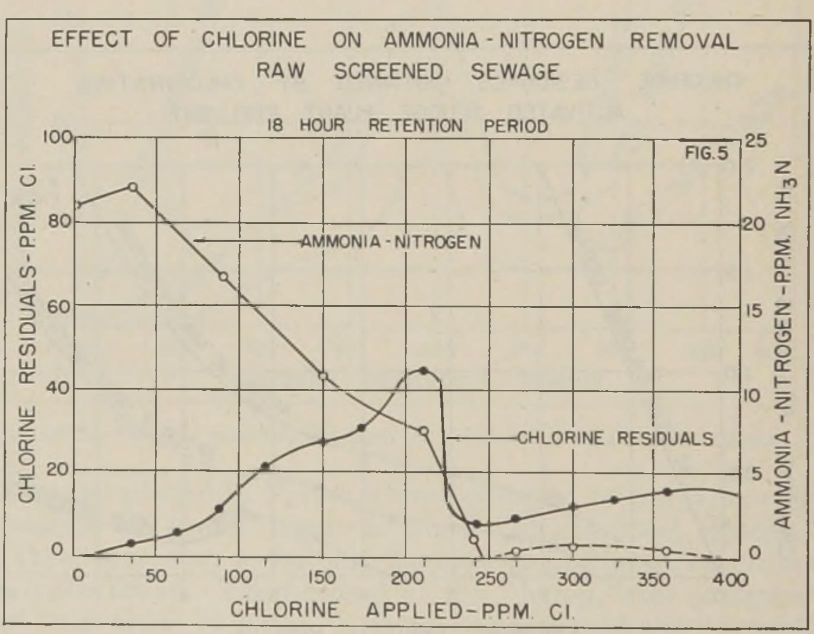



Figure 5.—Effect of chlorine on ammonia-nitrogen removal raw screened sewage.

connection with sewage. Figures 5, 6, 7 and 8 relate to the destruction of ammonia in sewage by chlorination.

The data in Figure 5 show how ammonia is destroyed progressively from the first appearance of a residual until the "break" is reached, where ammonia disappears completely.

The small and variable amounts of ammonia recovered beyond the "break" are attributed to the presence of nitrogen trichloride, an end-product of the break-point reaction. The ammonia existing as chloramines to the left of the "break" had to be determined quantitatively and this could be done only through the use of sodium sulphite in the analytical procedure. Since sodium sulphite was employed as part of the analytical technique in all samples, it was only natural that any nitrogen trichloride beyond the "break" was quantitatively reduced to ammonia and appeared as such in the analysis. Had sufficient time elapsed or had vigorous aeration been applied, this form of nitrogen would have escaped to the atmosphere and would not have been recovered.

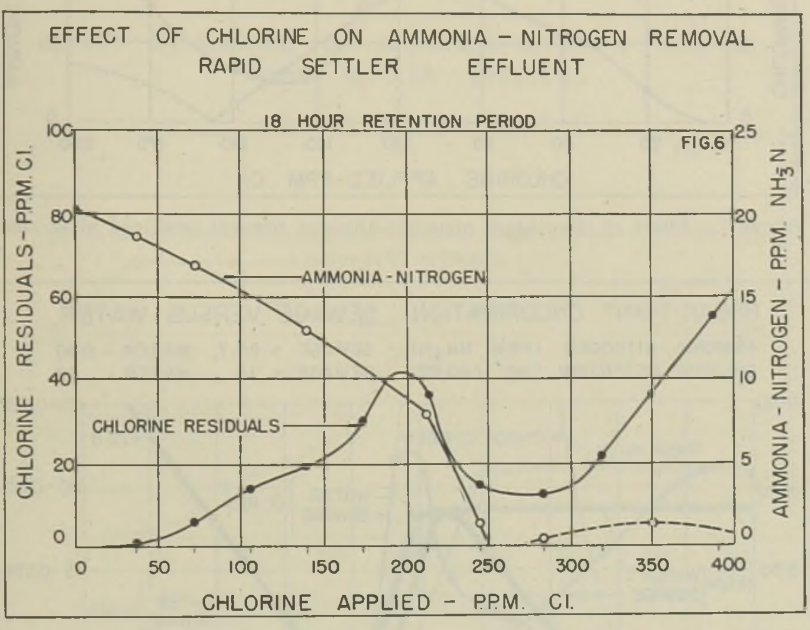



FIGURE 6.—Effect of chlorine on ammonia-nitrogen removal rapid settler effluent.

Ammonia removals from the settled effluent, Figure 6, and the combined plant effluent, Figure 7, follow essentially the same patterns as in Figure 5 and need no further comment.

The data plotted on Figure 8 are designed to show the difference in ammonia removal in water and sewage, and to show what the curves would have been had the sewage reactions been exactly parallel to those in water works practice.

The heavy black line, hollow circles, represents a water break-point curve and residual ammonia curve. It is to be noted that there is little drop in ammonia content until the residual reaches its maximum in the "hump" area. From that point on, it falls rapidly, reaching zero at the "break."

The sewage curves are shown in light black lines. Here the am-

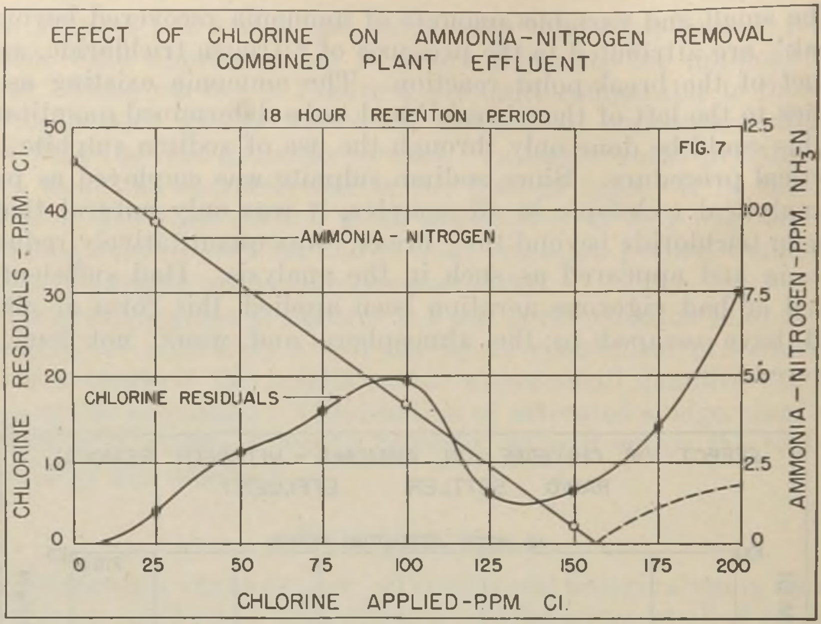



FIGURE 7.—Effect of chlorine on ammonia-nitrogen removal combined plant effluent.

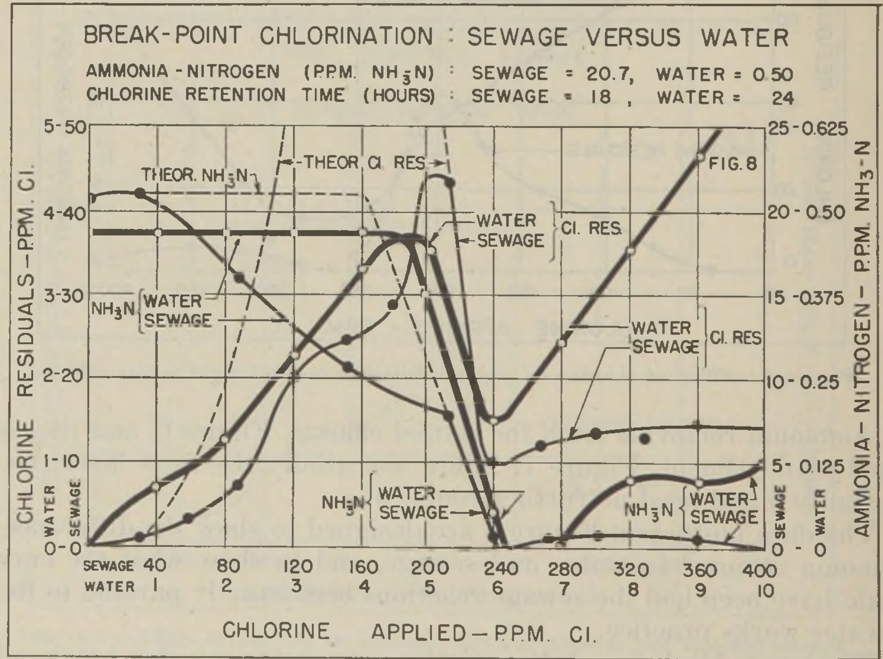



FIGURE 8.—Break-Point chlorination: sewage versus water.

monia content begins to decline immediately following the appearance of a residual whereas in the case of water the ammonia remains undiminished to the top of the hump.

Had the reaction proceeded exactly as it does in water, the sewage curves would have followed the dashed line, designated as theoretical ammonia nitrogen ($NH_3$–N) and chlorine residual in Figure 8.

## Albuminoid Ammonia

Very little is known regarding the effect of chlorine on albuminoid nitrogen. The general assumption is that in the presence of free ammonia it will have little influence on the position of the "break" or the magnitude of the residual at the top of the "hump." It is known, however, that chlorine will occasionally release some free ammonia from albuminoid nitrogen but usually not enough to be of real significance.

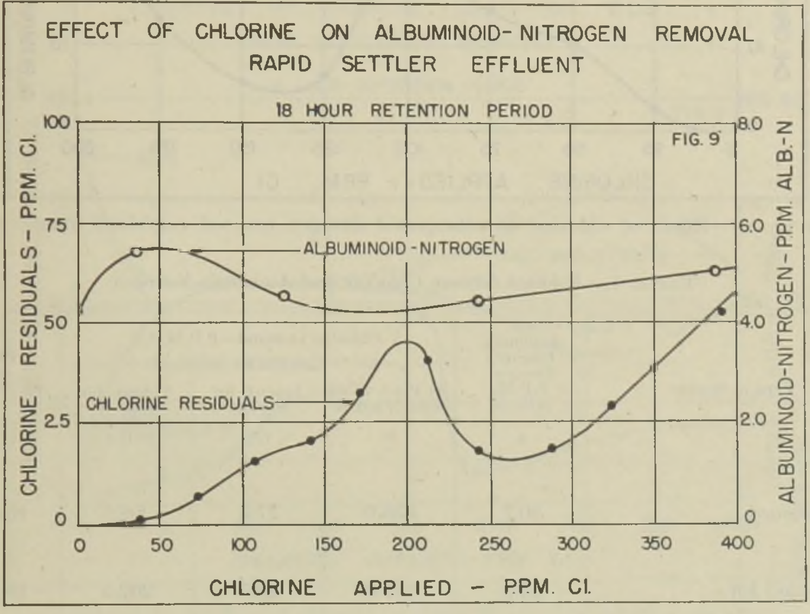



Figure 9.—Effect of chlorine on albuminoid-nitrogen removal rapid settler effluent.

The data contained in Figures 9 and 10 tend to affirm this assumption. Although there is a slight difference in the albuminoid nitrogen content at the various points tested, certainly the results do not indicate a removal of albuminoid nitrogen, neither do they indicate any great increase. This leads to the generalized conclusion that the nitrogen compounds of the albuminoid type are, from a practical point of view, unaffected by chlorine up to 400 p.p.m.

## Ratio of Chlorine to Ammonia

Much data (5) have been presented indicating the ratio of chlorine to ammonia at the "break-point" is on the order of 10:1, or more. The presentation of the ratio in sewage is summarized in the following table.

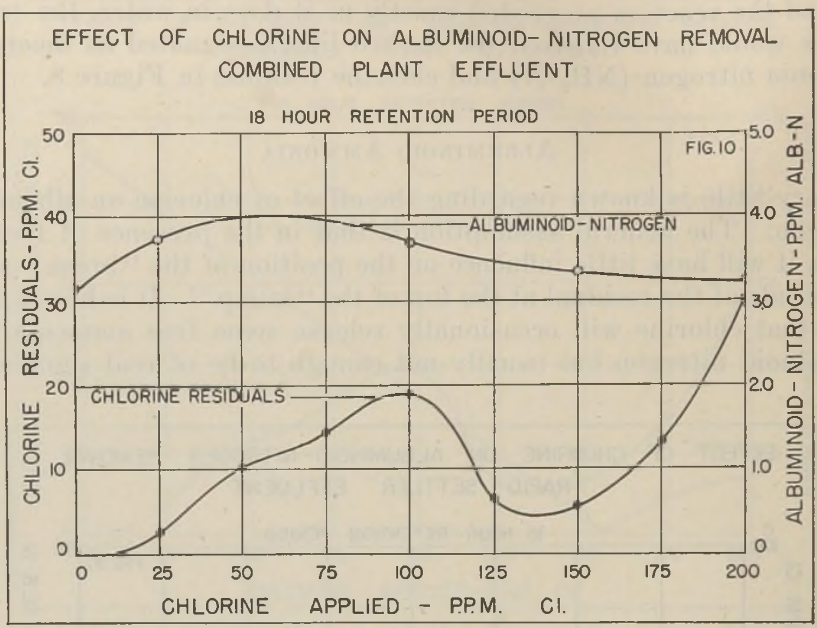



FIGURE 10.—Effect of chlorine on albuminoid-nitrogen removal combined plant effluent.

TABLE 1.—*Relation between Chlorine and Ammonia-Nitrogen*

| Type of Sewage | Ammonia-Nitrogen Content P.P.M. $NH_3$–N | Chlorine Demand—P.P.M. Cl | | | Ratio of Cl : $NH_3$–N |
|---|---|---|---|---|---|
| | | At Point where $NH_3$–N is 0.00 | Approx. for Sewage | Approx. for $NH_3$–N | |
| | A | B | C* | D (B–C) | D : A |
| Raw Screened | 20.7 | 236.0 | 27.5 | 208.5 | 10.07:1 |
| Rapid Settled Eff. | 20.2 | 237.0 | 29.5 | 207.5 | 10.27:1 |
| Combined Plant Eff. | 11.2 | 148.0 | 22.0 | 126.0 | 11.25:1 |

* The figures in Column "C" represent the chlorine demand at the lowest chlorine application of the test at the 18-hour contact period.

Hale (1), Moore (6), Harvill (7), Levine (8) and others do not quite agree with this ratio. Hale, Harvill and Levine think it should be nearer 7.5:1 while Moore has reasoned from experimental work that it should be somewhat higher, perhaps about 9.0:1. Hale concluded in 1927 that since the chlorine consumed was reduced to chlorides, any increase in chloride content following chlorination would represent the amount of chlorine required to remove the ammonia. Future work will decide which figure is correct. Meanwhile, in practice, the ratio of 10:1 appears to coincide with the greatest number of field experiences and seems to suffice for estimating purposes.

## B.O.D. Removal

Literature is replete with data pertaining to the effect of chlorine on B.O.D. reductions, but deals with reductions obtained by applications of chlorine to sub-residuals or low residuals (0.1 and 1.0 p.p.m.). The chlorine residuals, regardless of their magnitude, in previous studies, generally have been chloramines or related compounds. In this study sufficient chlorine is used to remove the ammonia and to produce residuals consisting of free available chlorine.

Little attention is given to the magnitude of the residuals produced because the purpose is to determine the effect of high doses of chlorine, to and beyond the break-point, on B.O.D.

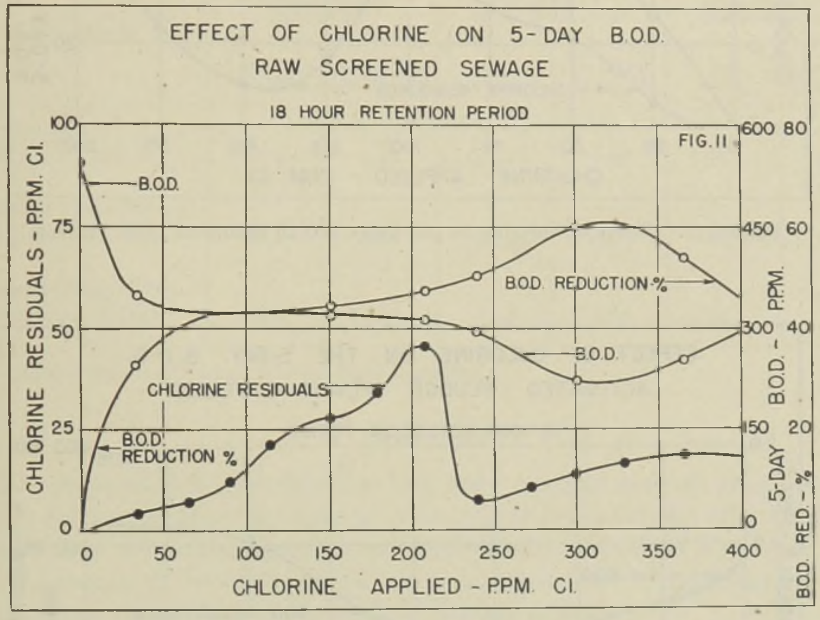
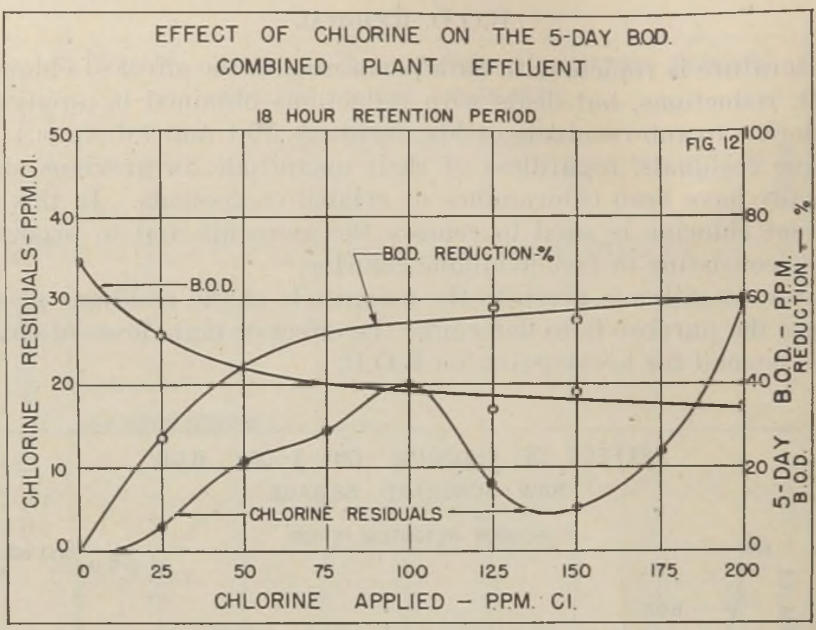



Figure 11.—Effect of chlorine on 5-day B.O.D. raw screened sewage.

Previously it has been stated that experience has shown the greatest B.O.D. reduction can be expected following the first appearance of a residual. The data in Figure 11 are not contrary to such an opinion, for the initial B.O.D. reduction amounts to approximately 30 per cent. Although at chlorine dosages beyond the break-point there seems to be a tendency toward further reductions, the amounts are relatively insignificant and could scarcely be called of economic importance. The reductions in B.O.D. in Figure 12 are essentially the same as in Figure 11, and yield to the same comment.

B.O.D. reductions, in the case of highly purified effluents, are somewhat different than in raw or settled sewage where suspended solids are present. In Figure 13, for instance, the B.O.D. reductions seems to be a straight line function up to the break-point where the maximum re-




- FIGURE 12.—Effect of chlorine on the 5-day B.O.D. combined plant effluent.

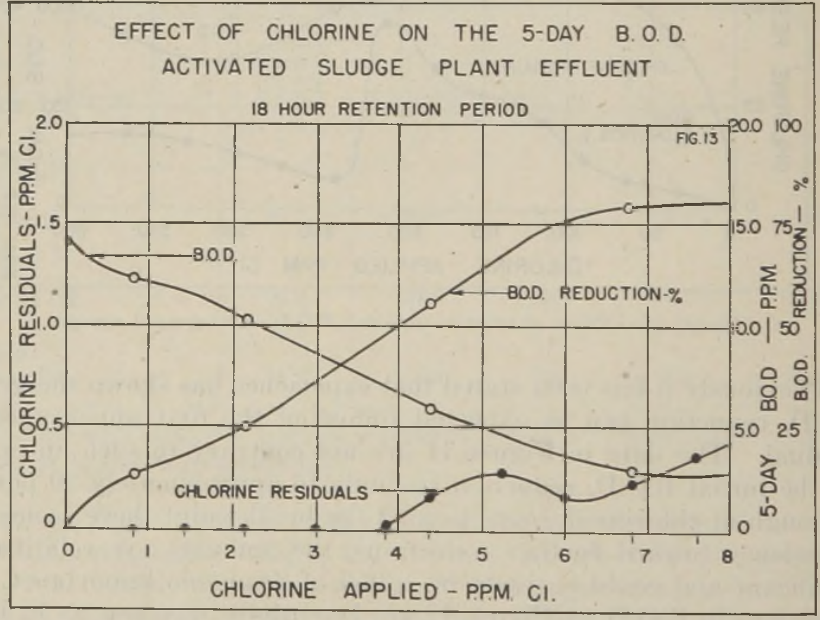



FIGURE 13.—Effect of chlorine on the 5-day B.O.D. activated sludge plant effluent.

duction is obtained and beyond this point little or no further reduction appears to take place. In fact, in none of the cases studied was there evidence of a noticeable change in the B.O.D. beyond the break-point.

It is often advantageous to report B.O.D. removals in percentages as well as in relation to the pounds removed per pound of chlorine added, as in Table 2. It is significant to note here that the greatest B.O.D. removal was obtained in the treated sewage but the greatest removal per pound of chlorine added initially occurred in the strongest sewage. Economically, the addition of chlorine beyond the initial dose does not appear practical for B.O.D. removals alone, except in the case of highly purified sewages. This was mentioned before and is reaffirmed here.

TABLE 2.—*B.O.D. Removal by Chlorination after 18 Hour Retention Period*

| Type of Sewage | * Removal at Initial Chlorine Application | | Removal by Chlorination to the Break-Point | | Removal at Maximum Chlorine Application (Overall) | |
|---|---|---|---|---|---|---|
| | Per Cent | Lbs. B.O.D. per Lb. Cl | Per Cent | Lbs. B.O.D. per Lb. Cl | Per Cent | Lbs. B.O.D. per Lb. Cl |
| Raw Screened (546 p.p.m. B.O.D.) . . . | 35.3 | 6.43 | 45.1 | 1.02 | 53.1 | 0.80 |
| Combined Plant Effluent (70 p.p.m. B.O.D.) . . . . | 27.1 | 0.76 | 58.6 | 0.33 | 61.4 | 0.19 |
| Activated Sludge Effluent (13.6 p.p.m. B.O.D.) . . . | 54.8 | 1.67 | 74.3 | 1.68 | 83.4 | 1.26 |

* With a chlorine residual after 18-hour retention.

## SUMMARY

It can be stated that chlorine has been used in sewage treatment for nearly half a century but due to economical reasons, the effects of chlorine beyond the amounts required to produce a residual up to 1.0 p.p.m. after a nominal contact period of approximately 10 minutes to a few hours have been studied to a very limited degree.

In this work heavy doses of chlorine, to and beyond the break-point, were added to sewage taken from four points within the same plant. These included raw screened sewage, settled sewage, a combination of aerated (95 per cent) and activated sludge process (5 per cent) effluents, and activated sludge process effluent alone. The effect on the ammonia nitrogen, albuminoid nitrogen, B.O.D. and chlorine residuals, were noted and plotted.

Our analysis of the data presented indicates that: (1) Typical break-point chlorine residual curves are produced when sufficient chlorine is added to sewage. (2) The "hump" area of chlorine residual curves for sewage are somewhat lower than in water, particularly on the ascending side of the hump. (3) Ammonia is destroyed progressively from the first appearance of a chlorine residual until the "break" is reached, where it completely disappears. (4) The ratio of chlorine to ammonia at the break-point in sewage appears on the same order as

that found in water works practice, *i.e.*, 10 : 1. (5) Albuminoid nitrogen is not appreciably affected by the amounts of chlorine used in the work, *i.e.*, up to 400 p.p.m. (6) All appreciable B.O.D. reductions take place ahead of the break-point. There is no evidence of increased application of chlorine adversely affecting B.O.D. removal. (7) The greatest B.O.D. reduction per pound of chlorine applied, in sewage of all strengths, occurs at the first appearance of a chlorine residual. (8) The greatest B.O.D. reduction per pound of chlorine applied, up to the first appearance of a chlorine residual, occurs in the strongest sewages. (9) The greatest B.O.D. reduction in per cent, up to the first appearance of a chlorine residual, occurs in the most highly purified sewages. (10) The greatest overall B.O.D. reduction in pounds of chlorine applied and in per cent occurs in the most highly purified sewages. (11) Up to approximately eighty per cent removals can be expected by chlorination of highly purified sewages.

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# THE RELATIONSHIP BETWEEN ACCUMULATION, BIOCHEMICAL CHARACTERISTICS OF FILM AND PURIFICATION CAPACITY OF A BIOFILTER AND STANDARD FILTER

## Part IV. Purification Capacity *

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In the previous papers of this series (3, 4) the quantity and the biochemical characteristics of the film in the biofilter and standard filter were discussed. Before any relationship between these characteristics and purification can be established, it is necessary to present the results produced by these plants. Catch samples of the primary and final tank effluents were taken on days when the beds were sampled for film. It was realized, however, that such samples did not represent truly the action of the film. The character and the efficiency of the film are influenced by the application of sewage over a considerable period. In order to obtain a more definite correlation between the film, loading, and performance, the full plant records from the biofilter plant were made available through the courtesy of Major R. Eliassen and Mr. C. Shephard. Such complete records are not available, however, from the standard filter plant. Analytical results obtained on the catch samples are given in order to establish a relationship with the complete daily records based on composites. These daily records, however, constitute the basis of the discussion.

The discussion deals with the performance of the plants as a whole, and an attempt is made to assess the different units individually.

### Plant Purification

The B.O.D. and suspended solids in the raw sewage and final effluent of the biofilter are given in Tables I, II, and III. In Table I are shown the monthly averages of the daily plant records, and in Table II, catch samples taken on film sampling days are compared with the corresponding values of daily composites. The average monthly B.O.D. of the raw sewage varied from 164 to 288 p.p.m., the two lowest values occurring in June and July (Table I). The average monthly B.O.D. values in the final effluent varied from 14 to 53 p.p.m. The lowest value was obtained in May and the highest in February, 1943. The overall reduction varied from a minimum of 75 per cent in February, 1943, to a maximum of 93 per cent in May. The suspended solids values in the raw sewage and in the final effluent followed generally the B.O.D. results. The

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TABLE I.—*Monthly Averages of Daily Composite B.O.D. and Suspended Solids Values of Raw Sewage and Final Effluent in Biofilter Plant*

| Date | B.O.D. | | | Suspended Solids | | |
|---|---|---|---|---|---|---|
| | R.S. (P.P.M.) | Final Effluent (P.P.M.) | Reduction (Per Cent) | R.S. (P.P.M.) | Final Effluent (P.P.M.) | Reduction (Per Cent) |
| Jan. | 215 | 45 | 79 | 200 | 37 | 82 |
| Feb. | 215 | 53 | 75 | 211 | 53 | 75 |
| March | 218 | 39 | 82 | 227 | 37 | 84 |
| April | 216 | 30 | 86 | 238 | 32 | 86 |
| May | 200 | 14 | 93 | 200 | 14 | 93 |
| June | 166 | 18 | 89 | 194 | 16 | 92 |
| July | 164 | 17 | 89 | 183 | 13 | 93 |
| Aug. | 225 | 20 | 91 | 238 | 24 | 90 |
| Sept. | 226 | 18 | 92 | 273 | 23 | 91 |
| Oct. | 204 | 30 | 85 | 244 | 31 | 87 |
| Nov. | 188 | 32 | 83 | 210 | 22 | 90 |
| Dec. | 288 | 48 | 83 | 338 | 45 | 87 |
| Jan. | 246 | 34 | 86 | 235 | 47 | 80 |
| Feb. | 215 | 26 | 88 | 228 | 45 | 80 |

minimum reduction in suspended solids of 75 per cent took place in February, 1943, and a maximum of 93 per cent in May and July.

The 24-hour composite B.O.D. and suspended solids values of the raw sewage and final effluent showed greater fluctuations than the average monthly values (Table II). A minimum of 13 and a maximum of 85 p.p.m. B.O.D. in the final effluent were obtained during the film sampling days, whereas the suspended solids values varied from a minimum of 7 to a maximum of 83 p.p.m. The reduction of B.O.D. varied during the individual sampling days from a minimum of 50 to a maximum of 93 per cent. The suspended solids reduction varied from a minimum of 65 to a maximum of 93 per cent. The comparison of B.O.D. values in the effluent of the catch samples and the 24-hour composites on corresponding days show that in 10 out of 16 samples the values were considerably higher in the catch samples. This may be expected, since the catch samples were taken during the daytime.

The reduction of B.O.D. and suspended solids on the basis of monthly average and sampling day results are given in Figure 1. High average reductions of B.O.D., in the order of 90 per cent, were obtained from May to September. During the rest of the period the reductions ranged from 75 to 85 per cent. The average values for the entire period and for the summer and winter are given in Table III. The B.O.D. of the raw sewage during the entire period averaged 212 p.p.m. It was 196 p.p.m. in summer and 230 p.p.m. in winter. The daily composite B.O.D. in the final effluent was 30 p.p.m. during the entire period and 34 p.p.m. during the sampling days. The corresponding suspended solids values were 31 and 36 p.p.m. The composite daily B.O.D. in the final effluent was 21 p.p.m. in the summer and 39 p.p.m. in winter, and the suspended solids 26 and 45 p.p.m., respectively.

TABLE II.—*B.O.D. and Suspended Solids of Raw Sewage and Final Effluent in Biofilter Plant on Film Sampling Days*

| Date | B.O.D. | | | | Suspended Solids | | |
|---|---|---|---|---|---|---|---|
| | 24-Hour Comp. | | Catch Sample | Reduction of Comp. Samples (Per Cent) | 24-Hour Composite | | |
| | R.S. (P.P.M.) | Final Effluent (P.P.M.) | Final Effluent (P.P.M.) | | R.S. (P.P.M.) | Final Effluent (P.P.M.) | Reduction (Per Cent) |
| Jan. 6 | 165 | 55 | — | 67 | 196 | 52 | 73 |
| Jan. 19 | 110 | 29 | — | 74 | 112 | 38 | 75 |
| Feb. 3 | 170 | 85 | — | 50 | 228 | 35 | 84 |
| Feb. 24 | 255 | 65 | — | 74 | 258 | 60 | 77 |
| Mar. 18 | 160 | 20 | 20 | 88 | 214 | 35 | 84 |
| April 7 | 230 | 33 | 40 | 86 | 206 | 36 | 82 |
| April 28 | 215 | 23 | 40 | 89 | 215 | 23 | 89 |
| May 19 | 186 | 13 | 10 | 93 | 186 | 13 | 93 |
| June 10 | 175 | 23 | 26 | 87 | 176 | 17 | 90 |
| June 23 | 160 | 16 | 48 | 90 | 160 | 16 | 90 |
| July 21 | 170 | 15 | 29 | 91 | 196 | 7 | 96 |
| Aug. 4 | 165 | 15 | 13 | 91 | 184 | 19 | 90 |
| Aug. 18 | 275 | 51 | 27 | 81 | 236 | 45 | 81 |
| Sept. 9 | 160 | 19 | 31 | 88 | 328 | 33 | 90 |
| Sept. 29 | 315 | 30 | 90 | 90 | 260 | 40 | 85 |
| Oct. 13 | 200 | 35 | 105 | 82 | 314 | 64 | 80 |
| Oct. 15 | — | — | — | — | — | — | — |
| Nov. 3 | 50 | 13 | 14 | 74 | 56 | 12 | 79 |
| Nov. 12 | — | — | 33 | — | — | — | — |
| Dec. 1 | 270 | 63 | 73 | 77 | 462 | 54 | 88 |
| Jan. 5 | 130 | 25 | 35 | 81 | 194 | 38 | 80 |
| Feb. 8 | 200 | 57 | 70 | 72 | 237 | 83 | 65 |

TABLE III.—*Average B.O.D. and Suspended Solids in Raw and Final Effluent in Biofilter*

| | Entire Period | Summer | Winter 1943 and 1944 | Winter 1943 | Winter 1944 |
|---|---|---|---|---|---|
| B.O.D.—daily composites: | | | | | |
| Raw, p.p.m. | 212 | 196 | 230 | 216 | 250 |
| Final, p.p.m. | 30 | 21 | 39 | 42 | 36 |
| Per Cent Reduction | 83 | 89 | 83 | 81 | 86 |
| B.O.D.—film sampling days (catch samples): | | | | | |
| Raw, p.p.m. | 182 | 185 | 190 | 186 | 200 |
| Final, p.p.m. | 34 | 23 | 45 | 24 | 48 |
| Per Cent Reduction | 81 | 88 | 76 | 87 | 76 |
| Suspended solids—daily composites: | | | | | |
| Raw, p.p.m. | 230 | 220 | 240 | 219 | 266 |
| Final, p.p.m. | 31 | 20 | 42 | 40 | 46 |
| Per Cent Reduction | 86 | 91 | 82 | 82 | 83 |
| Suspended solids—film sampling days (catch samples): | | | | | |
| Raw, p.p.m. | 221 | 209 | 232 | 204 | 298 |
| Final, p.p.m. | 36 | 26 | 45 | 40 | 58 |
| Per Cent Reduction | 84 | 88 | 81 | 80 | 81 |

During ten months the average B.O.D. values in the effluent were less than 35 p.p.m. and during the remaining four months the values were above 35 p.p.m. Values in excess of 30 p.p.m. did not occur between April and October.

The B.O.D. load in the raw sewage and the quantity of B.O.D. removed by the plant are presented in Figure 2. During January the

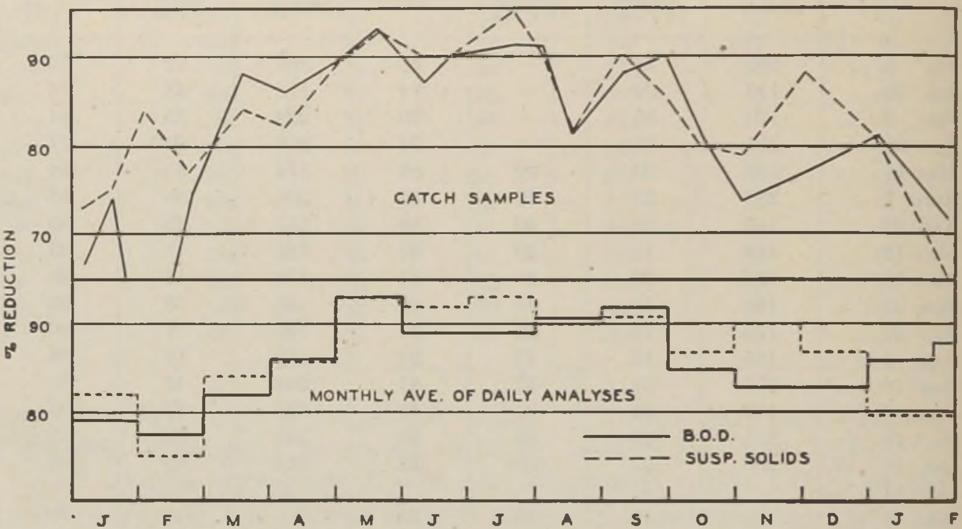


FIGURE 1.—B.O.D. and suspended solids reductions by the biofilter plant.

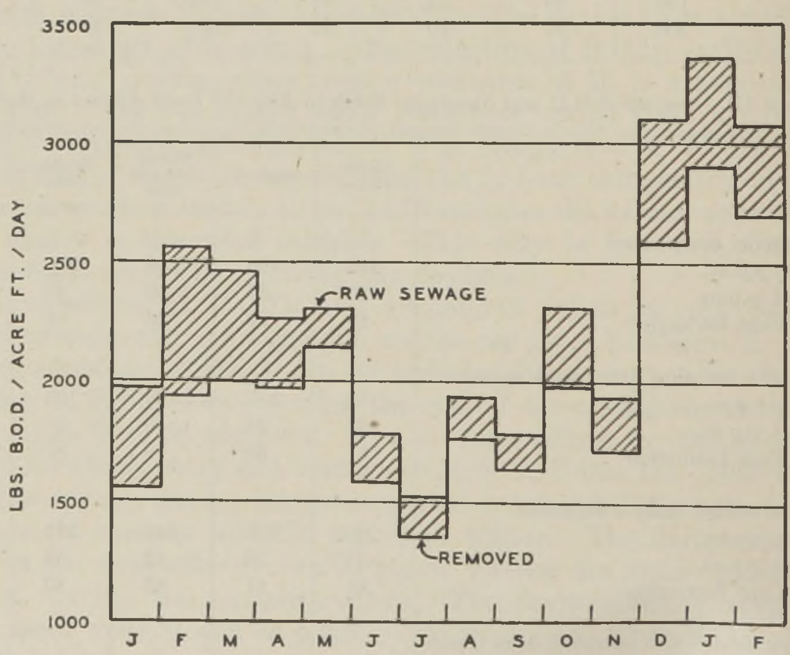


FIGURE 2.—Relationship between the quantity of B.O.D. in the raw sewage and quantity of B.O.D. removed by the biofilter plant.

quantity of B.O.D. removed was low with relatively high B.O.D. load in the raw sewage. During February, March and April the load as well as the removals increased, but the quantity of B.O.D. in the final effluent as represented by the area between the two curves was also high. During this period the plant had not attained maximum efficiency because of the handicap of cold weather during the maturing period of the beds. In May the removals increased without an increase in load. In June, July, August and September the removals decreased simultaneously with a decrease in the load. In October the load increased without a corresponding increase in removals, followed by a decrease in load in November. In December, January and February the load increased to maximum values recorded of over 3,000 pounds of B.O.D. per acre foot per day, accompanied by high removals.

The quantities of suspended solids present in the raw sewage and those removed by the plant are illustrated in Figure 3. The suspended

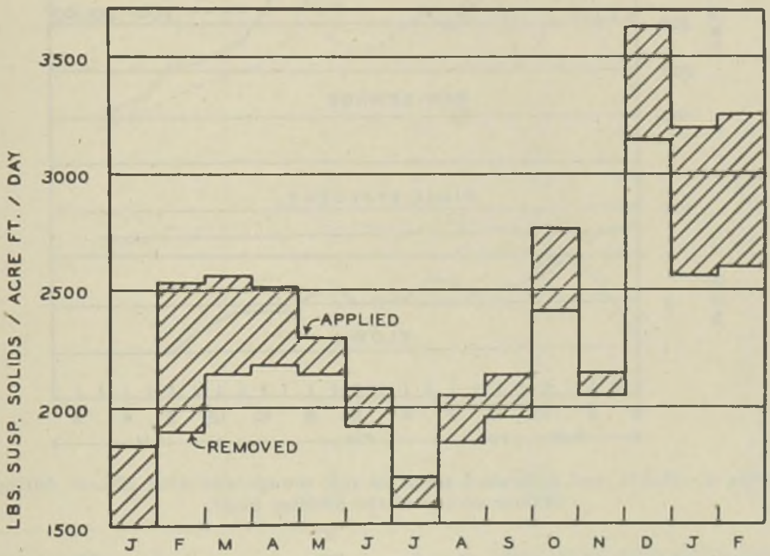


FIGURE 3.—Relationship between the quantity of suspended solids in the raw sewage and quantity removed by the biofilter plant.

solids applied were low in January, increased in February, March and April, decreased thereafter gradually until July when they reached a low value of 1,700 pounds per acre foot per day. The load increased to about 2,000 pounds per acre foot per day in August and September. In October another increase took place, followed by a decrease in November. In December the load increased to a maximum of over 3,600 pounds, and in January and February of 1943 it was about 3,200 pounds. The removals followed closely the fluctuations in the load. The area between the two curves represents the pounds of suspended solids in the final effluent.

On February 11, 1944, a 24-hour survey was made of the B.O.D.

and suspended solids of the raw sewage and final effluent of the biofilter plant for the purpose of determining the hourly variations in the incoming sewage and the effect of such variations on the effluent from the plant.

Hourly composites were made from 15-minute samples from 6 A.M. to 12 midnight, and thereafter hourly catch samples were taken. The average flow for the day was 2.0 m.g. and varied from a minimum rate of 1.0 to a maximum of 3.0 m.g.d. The results are plotted in Figure 4. A B.O.D. above 300 p.p.m. was obtained in the raw sewage for a period of 16 hours. The average B.O.D. for the day was 338 p.p.m. The B.O.D. in the final effluent remained very uniform during the 24 hours with an average of 48 p.p.m. An average of 86 per cent reduction of

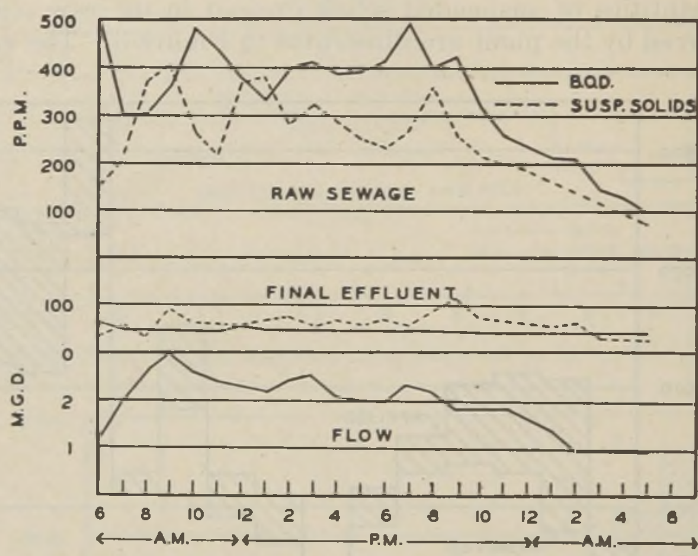


FIGURE 4.—B.O.D. and suspended solids in raw sewage and final effluent during a 24-hour survey of the biofilter plant.

B.O.D. was obtained during the day. The suspended solids in the raw sewage fluctuated somewhat more than the B.O.D. The average suspended solids was 241 p.p.m. in the raw sewage and 62 p.p.m. in the final effluent, giving a reduction of 74 per cent. The solids in the effluent fluctuated more than the B.O.D.

There are three definite peaks in the suspended solids of the raw sewage: at 8 to 9 A.M., at 12 to 1 P.M. and at 8 P.M. The time of flow from the most remote point in the camp to the sewage plant is a little over an hour at the 2.0 m.g.d. rate. The peaks in suspended solids correspond with the kitchen activities during mealtime. The peaks in B.O.D. do not correspond with the suspended solids but come either before or after suspended solids peaks, probably coinciding with the flushing of the urinals. The peaks in the suspended solids of the effluent correspond to the high suspended solids content of the raw sewage.

The B.O.D. values of the raw sewage of the standard filter plant are not available. The B.O.D. results of the final effluent based on catch samples taken on film sampling days are given in Table IV. The B.O.D. in the final effluent was consistently low, with a maximum of 14 p.p.m. and a minimum of 4 p.p.m. Generally, the lower values were obtained during the summer. The actual B.O.D. in the effluent is probably lower on the basis of 24-hour composites, since the values given were obtained from catch samples during the day. The suspended solids results of the raw sewage and of the final effluent are on the basis of 8-hour composites during the day and are, therefore, higher than on

TABLE IV.—*B.O.D. in the Final Effluent and Suspended Solids in the Raw Sewage and Final Effluent in the Standard Filter Plant*

| | B.O.D.* | Suspended Solids † | |
|---|---|---|---|
| | Final Effluent (P.P.M.) | Raw (P.P.M.) | Final Effluent (P.P.M.) |
| Jan. 6 | — | — | — |
| Jan. 19 | — | — | — |
| Feb. 3 | — | 162 | 5 |
| Feb. 24 | — | 126 | 8 |
| Mar. 18 | — | 152 | 8 |
| April 7 | 7 | 190 | 14 |
| April 28 | 13 | 154 | 7 |
| May 19 | 4 | 146 | 10 |
| June 10 | 6 | 168 | 14 |
| June 23 | 7 | 174 | 16 |
| July 21 | 4 | 202 | 8 |
| Aug. 4 | 5 | 164 | 12 |
| Aug. 18 | 7 | 178 | 11 |
| Sept. 9 | 8 | 170 | 7 |
| Sept. 29 | — | — | — |
| Oct. 13 | 14 | 156 | 5 |
| Nov. 3 | 12 | 190 | 3 |
| Dec. 1 | 12 | 190 | 6 |

* Catch samples. † Eight-hour daily composites.

the basis of 24-hour composites. The sewage should be regarded as weak. The daily average suspended solids for the entire year on the basis of 8-hour composites gave a value of 173 p.p.m. The average for the catch samples on days when stone samples were taken was 168 p.p.m. The average suspended solids in the effluent from the plant on the basis of daily 8-hour composites throughout the year was 8 p.p.m. and for catch samples on stone sampling days 9 p.p.m.

### Performance of the Primary Clarifier in the Biofilter Plant

When the performance of the primary clarifier in the biofilter plant is assessed on the basis of p.p.m. B.O.D. in the raw sewage and primary clarifier effluent, high reductions are obtained because of the dilution by the recirculated filter effluent, as is indicated by the values given below:

| | B.O.D. Reduction (Per Cent) | Recirculation Ratio | | B.O.D. Reduction (Per Cent) | Recirculation Ratio |
|---|---|---|---|---|---|
| Jan. | 52 | 1.6 | Aug. | 77 | 1.5 |
| Feb. | 54 | 1.2 | Sept. | 77 | 1.4 |
| March | 64 | 1.2 | Oct. | 66 | 1.1 |
| April | 61 | 1.0 | Nov. | 64 | 1.1 |
| May | 67 | 0.9 | Dec. | 53 | 0.9 |
| June | 66 | 0.9 | Jan. | 53 | 0.5 |
| July | 73 | 1.3 | Feb. | 54 | 0.4 |

The results indicate an increased efficiency of the clarifier during the warmer months which cannot be directly attributed to the higher recirculation ratios during this period.

More accurate performance values may be obtained on the basis of the quantity of B.O.D. entering and leaving the tank. There are two alternative methods: (1) By adding the pounds of B.O.D. in the raw sewage to that in the recirculated water and subtracting from this the pounds of B.O.D. leaving the tank (see sample calculations in appendix). This method is based on the assumption that the primary clarifier is serving the function of the secondary clarifier in removing the impurities from the recirculated water. (2) By subtracting the B.O.D. contributed by the recirculated water from the total B.O.D. leaving the primary tank and then by subtracting this value from the pounds of B.O.D. in the raw sewage. This method gives values of performance as if the filter effluent was not recirculated. The percentages of removal calculated on the basis of both methods are presented in Figure 5.

The reductions calculated by excluding the load contributed by the recirculation water are higher than the reductions obtained by total B.O.D. entering and leaving the primary tank including the recirculation water. By disregarding the removal of the portion of the B.O.D. contributed by the recirculation it is assumed that effluent from the primary clarifier still contained the same quantity of B.O.D. contributed by the recirculation, which is obviously not true. A considerable portion of B.O.D. of the filter effluent is actually removed by the secondary clarifier. Hence by assuming that none of this B.O.D. was removed by the primary clarifier, a greater credit is given to the removal from the raw sewage component than is actually the case. By including the recirculation in determining the B.O.D. reductions, values corresponding more nearly to actual operating conditions are obtained. Selecting the proper method of determining the efficiency is difficult, but there is no question that the trends obtained by either method are similar. The efficiency is low during the winter and increases to a peak during the summer, decreasing again to a low value in the winter. Over 40 per cent reductions are obtained during the period between May and October by including the B.O.D. contributed by the recirculation. A peak value of 53 per cent was obtained in August. These values are higher than are generally obtained in plain sedimentation tanks.

These trends in the removal of B.O.D. by the primary clarifier are not affected by the strength of sewage, as indicated by the p.p.m. B.O.D. shown in Figure 5. Neither are the high removals correlated with increased detention time due to variations in the flow of sewage and of the recirculated water. With the exception of the first winter's operation,

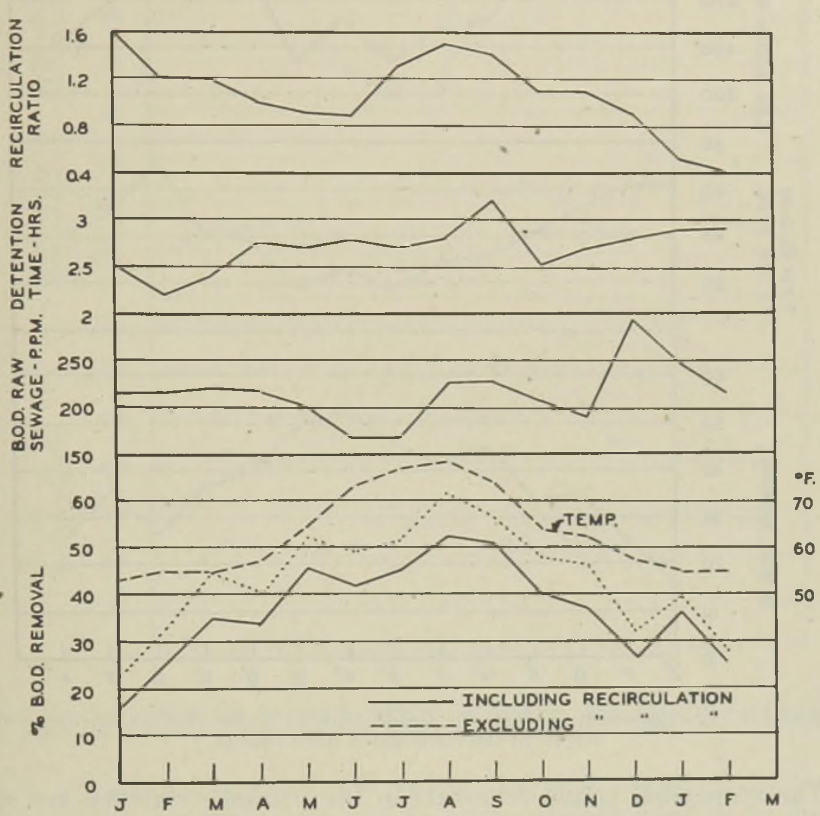


FIGURE 5.—Relationships between the B.O.D. removal by the primary clarifier and the B.O.D. in raw sewage, detention time, recirculation ratio, and temperature of the sewage.

there is a correlation between recirculation ratios and percentage reductions. A more positive relationship is obtained with the temperature.

It is of interest to point out that the higher reductions during the warmer months were obtained despite the decrease in the quantity of B.O.D. in the recirculated effluent (Figure 6). This fact alone would tend to decrease the percentage reductions. During the winter months when the total B.O.D. load entering the primary tank was high, the reductions were low. Normally, percentage removals increase as the concentration increases. Concentrations of both sewage and the recirculated effluent were low during the period of high removals.

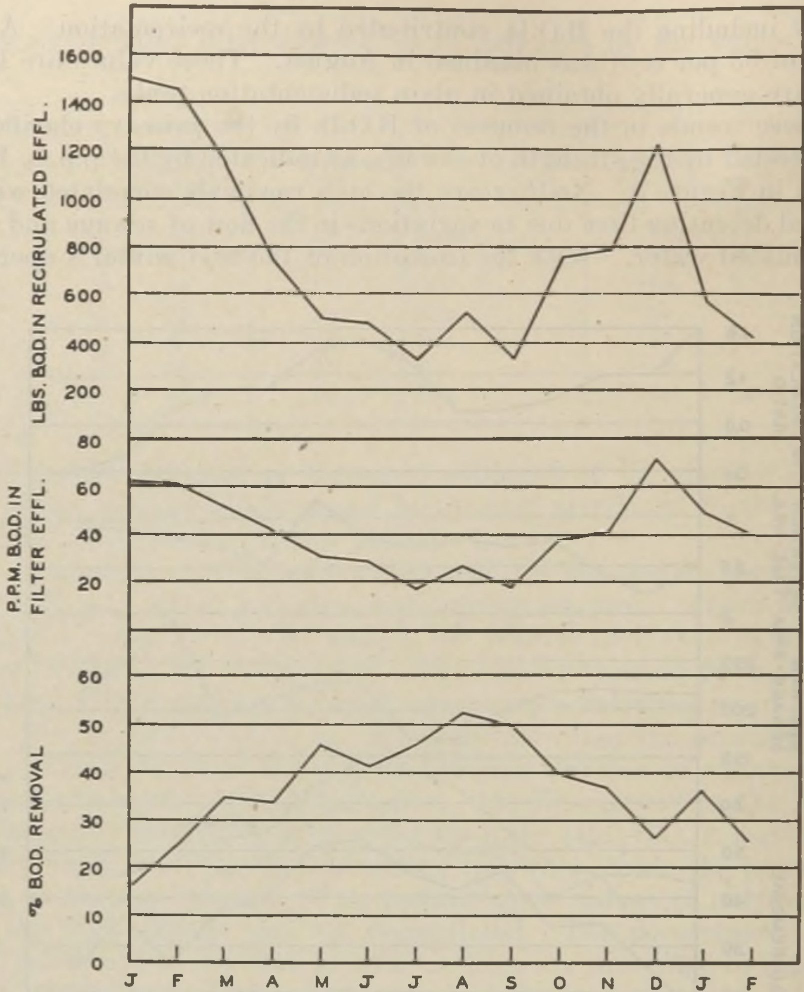


FIGURE 6.—The relationship between the B.O.D. removal in the primary clarifier and the B.O.D. in the recirculated filter effluent.

The suspended solids removals in the primary clarifier are shown in Figure 7. The results were calculated by including and excluding the recirculated water similar to the method used with B.O.D. removals. The reductions obtained by disregarding the suspended solids contributed by the recirculated water are higher than those obtained by taking the total suspended solids entering and leaving the tank. The removals were generally lower in winter than in summer, but the maximum difference between these two seasons was not so great as it was in B.O.D. reduction. The suspended solids removals can be considered as average for plain sedimentation tanks. The relatively higher B.O.D. reductions were obtained without an accompanying increase in suspended solids removals. In fact, at times, the reductions of B.O.D. were nearly equal to the suspended solids reductions. The latter seem to be more directly related to the strength of sewage than are the

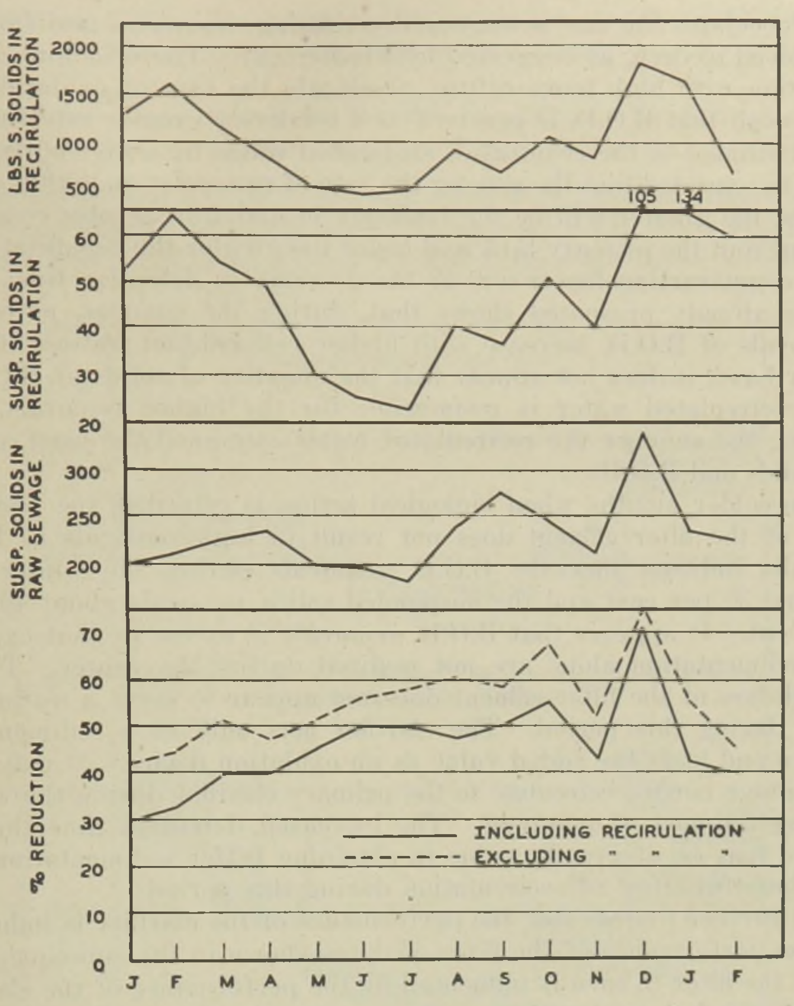


FIGURE 7.—The relationship between suspended solids removal by the primary clarifier and the suspended solids in raw sewage and suspended solids in the recirculated filter effluent.

B.O.D. reductions, particularly during December when exceptionally high removals were accompanied by high suspended solids in the sewage. In addition, the removals seem to be generally influenced by the concentration and total amount of suspended solids in the recirculated water (Figure 6).

If the higher B.O.D. removals in summer were due to more efficient sedimentation as a result of lower density and viscosity of the sewage, suspended solids removals should be affected similarly. However, suspended solids removals during this period are either equal to or only slightly higher than B.O.D. removals. The high summer removals of B.O.D. were not due to an increase in the strength of sewage or an increase in detention time. It appears, therefore, that factors other than those influencing sedimentation are responsible. The temperature relationship suggests a biological factor. Recirculation of the filter effluent inoculates the raw sewage with oxidizing organisms and furnishes dissolved oxygen, as suggested by Fischer (2). These factors, in conjunction with high temperature, accelerate the rate of oxidation with the result that B.O.D. is removed at a relatively greater rate than can be attributed to the removal of suspended solids by sedimentation. It is to be expected that the greater the rate of recirculation within certain limits, the greater will be the tendency to maintain aerobic conditions throughout the primary tank and hence the greater the beneficial effect. The counteracting factor will be the decrease in detention time. Evidence already presented shows that, during the summer, percentage removals of B.O.D. increase with higher recirculation ratios. On the other hand, it does not appear that the quantity of solids or B.O.D. in the recirculated water is responsible for the higher removals, since during the summer the recirculated water contained the least amount of solids and B.O.D.

In colder months when biological action is retarded, the recirculation of the filter effluent does not result in high removals of B.O.D. Results indicate that the B.O.D. removals during the winter were around 30 per cent and the suspended solids removals about 40 to 50 per cent. It appears that B.O.D. removals in excess of that expected by sedimentation alone are not realized during the winter. The recirculation of the filter effluent does not appear to serve a useful purpose during this period. The clarifier acts only as a sedimentation device and loses the added value as an oxidation device. It may be of advantage not to recirculate to the primary clarifier during the winter, saving the cost of pumping. The increased detention time thus obtained may be of greater value in obtaining better sedimentation than the doubtful effect of recirculation during this period.

It further follows that the performance of the clarifier is influenced by the performance of the filter, and (as shown in the subsequent section) the filter in turn is influenced by the performance of the clarifier. Both are influenced by the same factors, namely, the temperature of the sewage and the load. When the clarifier is operating under the handicap of lower temperature the return of the filter effluent with high solids and B.O.D. does not help removals in the clarifier.

The removals of B.O.D. and suspended solids may also be influenced by the difference in the relative rates of settling of particles in sewage and in the recirculated water. Only the coarser and settleable portion of sewage solids contribute to the removals. In the recirculated water the solids are more uniform and also in a finer state of dispersion than in the raw sewage. Hence, the greater the quantity of solids and B.O.D. contributed by the recirculated water, the less the percentage removals will be. The recirculation of filter effluent may thus have an adverse or a beneficial influence, depending on the interplay of temperature and the quantity of material in the recirculated liquid. In the winter the recirculated effluent contains more material which is difficult to remove by sedimentation and the temperature is not favorable for biological oxidation; hence, the net effect on the clarifier performance may be worse than if no recirculation was practiced.

### Performance of the Filter and Secondary Clarifier of the Biofilter Plant

The performance of the filter and secondary clarifier cannot be assessed on the basis of p.p.m. of B.O.D. or suspended solids applied to the filter and in the final effluent because it does not take into account

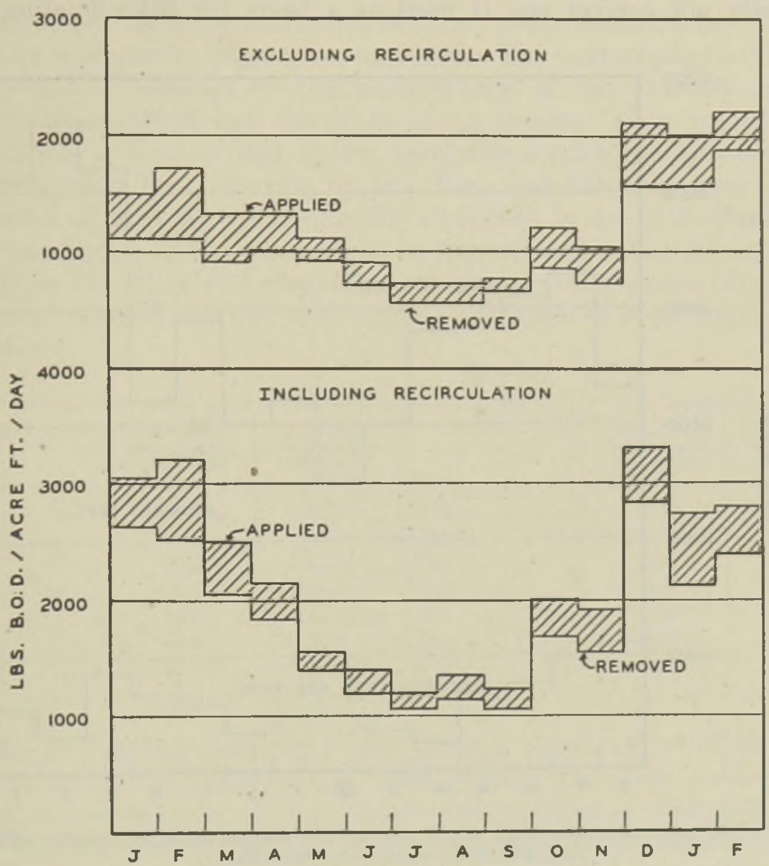


Figure 8.—The relationship between the quantity of B.O.D. applied and removed by the filter and secondary clarifier of the biofilter plant.

the variations in the flow or the p.p.m. B.O.D. and suspended solids in the recirculated effluent from the secondary clarifier to the filter. Should the load contributed by the recirculated water coming from the primary clarifier be excluded or included in determining the load applied to the filter? If it is to be included, then it seems logical to include also the load contributed by the recirculation from the secondary clarifier to the filter. This method would include the maximum load derived from the non-settled portion of the sewage and the recirculated flow. On the other hand, it may be argued that the load contributed by recirculation does not represent the true load and should be excluded. It then becomes difficult to approximate the portion of the sewage B.O.D. which passed through the clarifier in the presence of recirculation. In other words, what portion of the B.O.D. in the primary effluent is represented by sewage and what portion by the recirculated water? The assumption can be made that none of the B.O.D. contributed by the recirculation water is removed in the primary clarifier, as was done in assessing the efficiency of the primary clarifier. This assumption is obviously not correct and if used as a basis for filter loading would

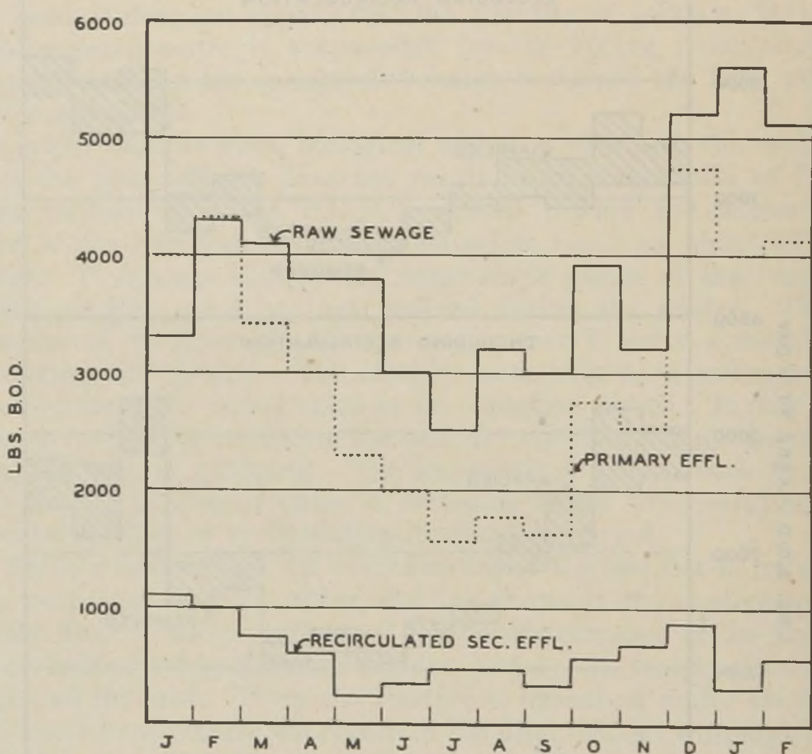


FIGURE 9.—The relationship between the B.O.D. in raw sewage, primary clarifier effluent and recirculated secondary clarifier effluent.

tend to make the values lower. Both methods of expressing filter loadings are used in this paper, the limitations of both methods being borne in mind. Obviously, in assessing the performance of the filter the load cannot be expressed on the basis of raw sewage.

The pounds B.O.D. applied per acre foot per day on the basis of primary tank effluent plus the recirculation to the filter, and also on the basis of the exclusion of all recirculation, are given in Figure 8 in conjunction with the removals accomplished by the filter and secondary clarifier. As was to be expected, the load applications excluding the recirculation are lower than the load applications including the recirculation but follow the same general trend. They are high during the first and second winters and low during the summer. The filter loading expression including the recirculation is influenced by the (1) sewage flow and strength, (2) performance of the primary clarifier, and (3) volume and strength of recirculated final effluent. The quantity of B.O.D. in the raw sewage, primary effluent, and recirculated final effluent, showed the same seasonal trend (Figure 9). They all decreased during the summer and increased in the winter. There was, therefore, a greater difference between the maximum loading in the winter and minimum loading in the summer when the results included the recirculation than when recirculation was excluded. The load applied to the filter was greatly influenced by the performance of the primary clarifier. The combined effect was such that in the summer when the filter was able to take a greater load, it was receiving a minimum quantity, with the result that the removals by the filter and the secondary clarifier decreased (Figure 8). The quantity of B.O.D. in the final effluent, however, was higher in the winter than in the summer. The percentage removals by the filter and secondary clarifier, calculated on the bases of total load applied and the load applied exclusive of recirculation, were as follows:

| | Including Recirculation (Per Cent) | Excluding Recirculation (Per Cent) | | Including Recirculation (Per Cent) | Excluding Recirculation (Per Cent) |
|---|---|---|---|---|---|
| Jan. | 86.5 | 73.0 | Aug. | 87.0 | 76.5 |
| Feb. | 80.0 | 63.5 | Sept. | 88.0 | 81.5 |
| March | 82.5 | 67.5 | Oct. | 83.0 | 71.5 |
| April | 85.5 | 76.5 | Nov. | 83.0 | 68.5 |
| May | 90.0 | 85.5 | Dec. | 85.0 | 75.5 |
| June | 87.0 | 78.5 | Jan. | 82.0 | 77.0 |
| July | 86.5 | 78.0 | Feb. | 86.5 | 83.5 |

The percentage removals varied from a minimum of 82 to a maximum of 90 on the basis of total load applied and from a minimum of 63.5 to a maximum of 85.5 when the recirculation is excluded. There is no marked tendency toward greater efficiency in the summer as there was in the primary clarifier. The primary clarifier was performing the maximum amount of work, thus creating an underloaded condition in the filter. The filter, however, was removing the greater portion of the load during the winter when clarifier performance dropped off.

These statements are borne out by the following results in which the B.O.D. removed by the plant is apportioned between the primary clarifier and filtration and sedimentation.

The results are based on the difference in pounds of B.O.D. in the raw sewage and final effluent, the difference being taken as 100 per cent. The portion removed by the primary clarifier is calculated on the basis of B.O.D. leaving the tank, exclusive of the recirculation.

| | Primary Clarifier (Per Cent) | Filter + Sec. Clarifier (Per Cent) | | Primary Clarifier (Per Cent) | Filter + Sec. Clarifier (Per Cent) |
|---|---|---|---|---|---|
| Jan. | 29.5 | 70.5 | Aug. | 61.5 | 38.5 |
| Feb. | 43.5 | 56.5 | Sept. | 61.0 | 39.0 |
| March | 54.5 | 45.5 | Oct. | 56.5 | 43.5 |
| April | 47.0 | 53.0 | Nov. | 55.0 | 45.0 |
| May | 56.0 | 44.0 | Dec. | 38.5 | 61.5 |
| June | 55.0 | 45.0 | Jan. | 46.0 | 54.0 |
| July | 57.5 | 42.5 | Feb. | 41.5 | 58.5 |

The scatter diagrams of the pounds of B.O.D. applied to the filter by including and excluding recirculation, and the quantities removed by the filter and secondary clarifier, are given in Figure 10. The removals increase with loading, as has been shown by earlier investigations. The increase may be presented by a straight line.

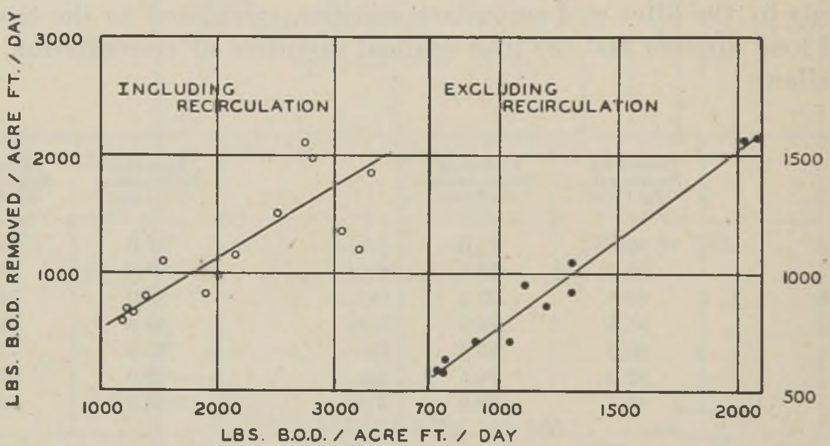


FIGURE 10.—Relationship between B.O.D. applied and removed by the filter and secondary clarifier.

An attempt was made to evaluate the relative B.O.D. removals accomplished by the filter in relation with the secondary clarifier. It was necessary to exclude the B.O.D. contributed by recirculation. The load applied to the filter was calculated as previously, namely, by subtracting from the pounds of B.O.D. of raw sewage the pounds of B.O.D. in the primary effluent minus the B.O.D. of the recirculated filter effluent. From the amount of B.O.D. in the filter effluent, the quantity contributed by the recirculation from the final effluent to the filter was also subtracted. The difference between the values thus calculated was taken to represent the removal by the filter itself. The additional removal accomplished by the secondary clarifier was similarly calculated. The results expressed as percentage of B.O.D. load removed, exclusive of recirculation by each unit, were as follows:

| | Removed by Filter (Per Cent) | Removed by Sec. Clar. (Per Cent) | | Removed by Filter (Per Cent) | Removed by Sec. Clar. (Per Cent) |
|---|---|---|---|---|---|
| Jan. | +12.5 | 85.0 | Aug. | 20.3 | 56.5 |
| Feb. | 1.6 | 61.5 | Sept. | 57.0 | 24.6 |
| March | + 5.0 | 72.5 | Oct. | 21.0 | 50.5 |
| April | 27.0 | 50.0 | Nov. | 9.3 | 59.5 |
| May | 15.1 | 59.5 | Dec. | 18.3 | 57.0 |
| June | 23.6 | 55.0 | Jan. | 35.0 | 42.4 |
| July | 51.5 | 27.0 | Feb. | 55.0 | 28.0 |

It will be seen that the percentage removals by the filter varied greatly but were, with a few exceptions, very substantial. There are no marked seasonal trends in the relative percentage of B.O.D. removed by the filter. The secondary clarifier removed additional B.O.D., the magnitude of which depended on the efficiency of the filter. When the filter removed a small percentage of B.O.D. the bulk of the removal was accomplished by the secondary clarifier and vice versa. Thus, the two units supplement each other and assure a consistently high removal.

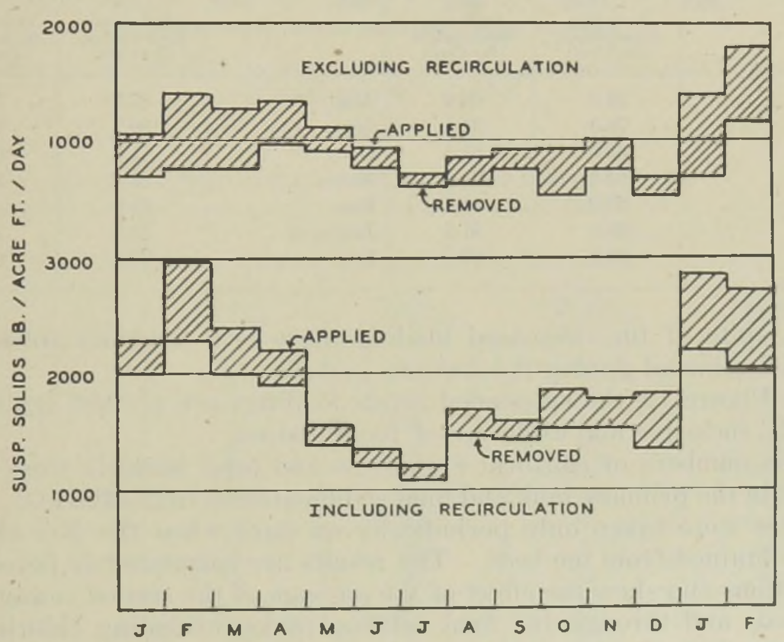


FIGURE 11.—Relationship between suspended solids applied and removed by the filter and secondary clarifier.

The substantial reductions of the B.O.D. of the sewage in passage through the filter support the view advanced in the previous papers of this series that the biofilter is not a mere "colloider." If the biofilter were only a "colloider," a relatively small portion of the B.O.D. would be removed by the filter itself and the effluent from this unit would contain substantially the same quantity of oxidizable material as the applied sewage, except that it would be changed to an agglomerated form. The removal by the secondary clarifier would be the result of sedimentation of the agglomerated particles. Undoubtedly, sedimentation in the secondary clarifier still plays the major role in B.O.D. removals. The removal in the filter itself may be the result of oxidation or the adsorption of the impurities by the film. It appears that at times oxidation and adsorption more than counterbalance the discharge of solids from the film. When the removal by the filter is low, either the impurities are not oxidized or removed by adsorption or the rate of discharge of solids from the film is accelerated and outweighs the removals.

Suspended solids applied to and removed by the filter and secondary clarifier including and excluding recirculation are presented in Figure 11. When the recirculation is included, the values for the applied load and removals are higher than when recirculation is excluded. As in the case of the B.O.D. results, however, load applications were lower during the summer. The percentages of suspended solids removed were as follows:

| | Including Recirculation (Per Cent) | Excluding Recirculation (Per Cent) | | Including Recirculation (Per Cent) | Excluding Recirculation (Per Cent) |
|---|---|---|---|---|---|
| Jan. | 86.0 | 68.0 | Aug. | 87.5 | 75.0 |
| Feb. | 78.5 | 55.5 | Sept. | 89.5 | 80.0 |
| March | 83.5 | 61.5 | Oct. | 81.5 | 60.5 |
| April | 84.5 | 74.0 | Nov. | 87.0 | 77.0 |
| May | 90.0 | 85.5 | Dec. | 74.0 | — |
| June | 87.5 | 81.5 | Jan. | 78.0 | 50.5 |
| July | 90.0 | 83.0 | Feb. | 76.0 | 64.0 |

In spite of the decreased loading there is a tendency toward increased removal during the warmer period.

In Figure 12, the suspended solids loadings are plotted against removals, inclusive and exclusive of recirculation.

The numbers of coliform organisms and total bacteria were determined in the primary tank and final sedimentation tank effluents. These samples were taken only periodically on days when the film samples were obtained from the beds. The results are calculated as percentage reductions and show the effect of the passage of the settled sewage over the beds and through the final settling tanks, excluding chlorination. A comparison of the percentage reductions obtained by the biofilter and standard filter is given in Table V. During the first three months reductions of coliform organisms varying from 0 to 77 per cent were obtained in the biofilter; these reductions increased to 88 per cent in April. From the end of May until the beginning of August, reductions varied from 90 to 99.9 per cent. Thereafter, the reductions decreased and fluctuated. Again the response of the filter to higher temperature is shown. The primary function of a filter is not the reduction of the

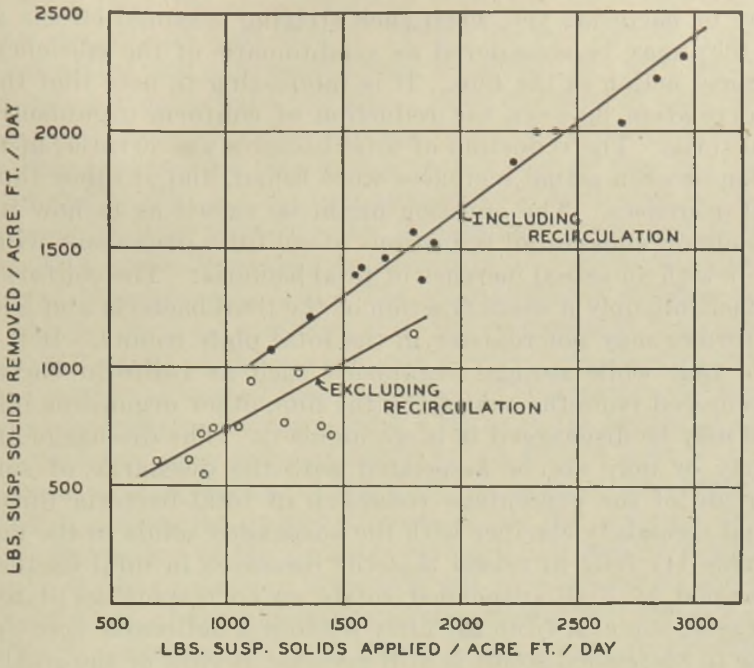


FIGURE 12.—Relationship between suspended solids applied and removed by the filter and secondary clarifier.

TABLE V.—*Bacterial Reductions in the Biofilter and Standard Filter*

| | Biofilter | | Standard Filter | |
|---|---|---|---|---|
| | Coliform Organisms (Per Cent) | Total Bacteria (Per Cent) | Coliform Organisms (Per Cent) | Total Bacteria (Per Cent) |
| Jan. 6 | 64 | — | 90 | — |
| Jan. 19 | 77 | 45 | 58 | — |
| Feb. 3 | 0 | +19 | 96 | 92 |
| Feb. 24 | 50 | 0 | 96 | 93 |
| Mar. 18 | 74 | +66.5 | 99 | 90 |
| April 7 | 88 | 10 | 96 | 95 |
| April 28 | 99 | 24 | 76 | 48 |
| May 19 | 99 | 21 | 96 | 96 |
| June 10 | 99 | 82 | 90 | 96 |
| June 23 | 90 | 44 | 90 | 90 |
| July 21 | 99.9 | 54 | 90 | 93 |
| Aug. 4 | 99.9 | 99 | 96 | 81 |
| Aug. 18 | 76 | +63 | 99.6 | 90 |
| Sept. 9 | 88 | 85 | 96 | 93 |
| Oct. 13 | 58 | 0 | 99 | 90 |
| Nov. 3 | 99 | 49 | 76 | 87 |
| Nov. 12 | 54 | 0 | — | — |
| Dec. 1 | 0 | 6 | 96 | 93 |
| Jan. 5 | 58 | 70 | — | — |

numbers of bacteria; yet, when such striking seasonal effects are produced, they may be considered as symptomatic of the efficiency of the biochemical action in the film. It is interesting to note that there was little correlation between the reduction of coliform organisms and of total bacteria. The reduction of total bacteria was erratic; at times no reduction or even actual increases were found, and at other times, substantial decreases. The question might be raised as to how it is possible to obtain substantial reductions of coliform organisms with no decrease or with an actual increase of total bacteria. The coliform organisms constitute only a small fraction of the total bacteria and a decrease in the former may not register in the total plate counts. It is further possible that while sewage organisms such as coliform bacteria are being removed from the sewage by the film, other organisms inhabiting the film may be discharged in large numbers. The discharge of organisms may or may not be associated with the discharge of solids. A comparison of the percentage reduction of total bacteria through the filter and secondary clarifier with the suspended solids in the final effluent (Table II) fails to reveal that the increases in total bacteria were accompanied by high suspended solids on corresponding dates. The discharge of bacteria from the filter without a noticeable accompanying increase in suspended solids is still possible in view of the small size of the organisms.

The relationship between temperature and reduction in the number of total bacteria is not so definite as in the case of coliform organism, but greater and more consistent total bacterial reductions are obtained in summer than in winter. Allen, Tomlinson and Norton (1) have also obtained an increase in plate counts in the effluent of a primary filter of alternating double filters during the colder period, and substantial decreases during the warmer period. They failed to find a relationship between the chemical quality (B.O.D. and oxygen consumed) and the bacterial quality of the effluents.

The reductions of coliform organisms in the standard filter were 90 per cent or higher with three exceptions throughout the period of study. Similarly, the reductions of total organisms were uniformly high. The reductions of coliform and total organisms were about in the same order of magnitude, and a drop in the reduction in one was registered also in the other. In these respects the standard filter offers a contrast to the biofilter. Like the evidence obtained from chemical results, the performance of the standard filter is more uniform seasonally. It should be remembered that this plant was underloaded. The *B. coli* reductions obtained in this filter during the warmer months were no higher than those obtained in the biofilter, but in the latter the bacterial reductions as well as the chemical quality of the effluent were affected by the lower temperatures.

## Discussion

The evalution of overall filter plant loadings and removals with or without recirculation offers no difficulties. Removals can be determined simply from the concentrations of B.O.D. and suspended solids in the raw sewage and final effluent. From the flow figures the loadings may be calculated and expressed either as pounds per acre foot per day or as pounds per cubic yard per day. Both methods of expression are based on unit volume of media and are free from the objections of surface loading expressions (lbs. per acre per day or lbs. per sq. ft. or sq. yd. per day). The volume unit acre foot has been used in this paper in preference to cubic yard in order to eliminate fractional figures.

Difficulties arise, however, in assessing the different plant units when recirculation is practiced. The main difficulty consists in determining whether the load contributed by the recirculated liquid should be considered as a part of the sewage load or should be disregarded. The argument may be advanced that recirculation is a feature of the process to bring about certain desired results, similar to the return of activated sludge, and hence does not constitute an additional load to the units. This may be a valid argument but does not resolve the difficulties encountered in making the proper corrections for the recirculation.

The performance of the primary clarifier unit and of the filter and secondary clarifier units can obviously not be assessed on the basis of the concentration of the impurities in the influent and effluent when recirculation is practiced. In the plant under study, recirculation was practiced from the filter effluent to the primary clarifier and from the secondary clarifier to the filter. The quantity of the impurities (B.O.D. and suspended solids) in the raw sewage, in the recirculated water and in the effluents must be known. Then certain assumptions have to be made. For instance, in the case of the primary clarifier, it can be assumed that all of the impurities contributed by the recirculation are removed or that none of them are removed. Neither assumption is correct, and the truth lies somewhere in between.

The removal of the impurities contributed by the recirculation in the primary clarifier is not known. It may be assumed that approximately the same percentage removal is obtained in the primary clarifier from the recirculated portion of the filter effluent as in the secondary clarifier. If the latter information is available, then a correction can be introduced to permit estimation of the removal of impurities in the primary clarifier contributed by the recirculation, and the removal of impurities from the sewage can be determined.

In this paper calculations of performance have been made by completely excluding and by including the materials contributed by recirculating liquids. Although the magnitude of the values obtained by these two methods is different, the values indicate the same general trend. In the case of filter and secondary clarifier a second correction must be made if it is desired to exclude the materials contributed by recirculation from the secondary clarifier to the filter.

It might be said that any attempt to segregate and evaluate the role played by each unit of a plant employing recirculation in the purification of sewage will lead to an artificial, forced, awkward and not necessarily accurate method of expressing results. The results presented have demonstrated the interdependence of units and the relation of the whole process to recirculation. A biofilter plant without recirculation would lose its most essential feature, and once the recirculated water is mixed with the sewage it is difficult to unscramble the two.

The performance of the biofilter plant as a whole was affected by: (1) the load variations and (2) the temperature. There were substantial load variations in the incoming sewage. The B.O.D. and suspended solids in the incoming sewage varied from a maximum of 3,300 pounds to a minimum of 1,500 pounds per acre foot per day. In addition to the magnitude of variation, the distribution of load variation is also important from the standpoint of plant performance. The maximum load received by the plant occurred during the colder months; thus during the summer months when the plant was able to take a greater load, it received actually less than during the winter, making it difficult to assess what the plant could do under optimum temperature conditions at maximum load.

The plant removals followed very closely the load received, with increases and decreases in the load registered on the removals. The efficiency of removals as measured by the percentage reduction of B.O.D. ranged from 75 to 93 per cent and of suspended solids from 80 to 93 per cent. The average B.O.D. reduction during the summer was 89 and during the winter 83 per cent, with corresponding values for suspended solids of 91 and 82 per cent. Notwithstanding the lower loads during the summer, a greater efficiency of removal was obtained. It is reasonable to expect that even greater reductions could have been obtained if the maximum loads had occurred during this period.

The performance of the different units was also affected by the load and the temperature of the sewage. It is natural to expect that the filter itself, which is dependent for its performance on biological activities, should be affected by the temperature. However, results presented indicate that the performance of the primary clarifier is also similarly affected by the temperature. The latter generalization is particularly true of B.O.D. removal. While suspended solids removal in the primary clarifier was affected directly by the suspended solids concentration of the raw sewage, without definite seasonal trends, the B.O.D. removals were highest during the summer when the B.O.D. in the raw sewage was at a minimum. It is significant that during this period B.O.D. reductions (50 to 60 per cent) were at least equal to suspended solids reductions, whereas in winter the more normal relationship prevailed, with suspended solids reductions higher than B.O.D. reductions. The results, therefore, do not indicate more efficient sedimentation during the summer as an explanation of this phenomenon. The high B.O.D. removals in the primary clarifier during the summer were obtained despite the low B.O.D. in the raw sewage as well as in the recirculated water. The role played by recirculation appears to offer an explanation. Under its influence dissolved oxygen is maintained in the clarifier and the sewage is seeded with aerobic organisms. Under favorable temperature conditions recirculation results in oxidation, yielding B.O.D. removals higher than would be expected by plain sedimentation. In the winter this favorable influence is not exerted and the B.O.D. removals are primarily due to sedimentation only. Since recirculation does not serve a useful purpose in the winter, it could safely be eliminated under prevailing conditions. Increased detention time and saving in power cost would result.

The implications of the seasonal performance of the primary clarifier are also important. With a greater portion of the B.O.D. removed by the clarifier, the filter receives less B.O.D. in the summer when it is able to handle more. In the winter when the biological activities in the filter are retarded, it receives a greater load even if the sewage flow and strength remain constant. In the plant under study, the load in the raw sewage was also lower during the summer and these two factors made the divergence between summer and winter loadings greater. Of the total B.O.D. load received by the plant a greater percentage was removed by the primary clarifier during the summer, but in the winter a greater percentage was removed by the filter. On the basis of the load applied, the percentage B.O.D. reduction through the filter and secondary clarifier did not show a definite summer maximum, as was true for plant removals as a whole or primary clarifier performance. Other implications of this phenomenon as they affect the quantity and the characteristics of the film have been pointed out in the previous papers of this series. The quantity and the state of oxidation of the film as revealed by ash content, B.O.D., etc. have been shown to be affected by temperature and load.

In respect to the relative removals by the filter and secondary clarifier it is noteworthy that substantial reductions of B.O.D. are obtained in the filter itself before sedimentation. If the filter was acting as a mere "colloider" the removal of finely divided material from the sewage and the discharge of the flocculated material from the film would keep apace. A short period of storage in the filter itself would not materially decrease the B.O.D. of the filter effluent over the influent. The secondary clarifier would be the last safeguard to remove these flocculated materials. In general, this is true, yet the B.O.D. reductions through the filter indicate storage and at times considerable oxidation before discharge, corroborating by a different approach the evidence derived from the study dealing with the biochemical characteristics of the film.

The quantity of material discharged in the filter effluent also has an influence on the primary clarifier, since part of the filter effluent is recirculated through the clarifier. The concentration and the quantity of B.O.D. in the filter effluent recirculated through the primary clarifier decrease during the summer; nevertheless better performance results are obtained in the primary clarifier during the warmer months. It is, therefore, not the quantity of materials recirculated through the clarifier that effect a greater B.O.D. reduction. Seeding of the sewage with aerobic organisms from the filter is only one of the factors influencing the biochemical oxidation in the clarifier, the others being temperature and dissolved oxygen. The nature of the flora may change and a smaller quantity of materials in the recirculated water may be more effective under optimum conditions than a larger quantity which remains inactive under unfavorable conditions.

Bacterial reductions through the filter and secondary clarifier corroborate the evidence obtained by the B.O.D. and suspended solids criteria discussed above. A substantial reduction of coliform organisms was obtained during the summer as contrasted with small erratic reductions during the winter. The percentages of total bacteria reduction were not so great as the percentages of reduction of coliform organisms and at times there was an actual numerical increase in the final effluent.

The limited results available on the standard filter indicate a uniformly low suspended solids and B.O.D. in the final effluent not subject to seasonal variations. The strength of the sewage, however, was medium to weak. The average yearly suspended solids in the raw sewage was 173 p.p.m. on the basis of 8-hour daily composites. The B.O.D. in the final effluent varied from 4 to 14 p.p.m. and the suspended solids from 3 to 16 p.p.m. The percentage reductions of coliform organisms and total bacteria were uniformly high and not influenced by seasonal variations.

## Summary and Conclusions

The performance of the bio filter plant as a whole and of the individual units during a 14-month period is evaluated. The study is based on the results obtained from catch samples of primary tank and final effluents during the film sampling days and on the complete plant records, during the same period, on the basis of daily composites. The evaluation of the standard filter plant is made on the basis of B.O.D. values from catch samples of primary tank and final effluents and suspended solids values derived from daily plant records from 8-hour daily composites.

The average B.O.D. in the raw sewage during the entire period was 212 p.p.m. and suspended solids 230 p.p.m. In the final effluent the average B.O.D. was 30 p.p.m. and suspended solids 36 p.p.m. The plant loading during this period varied from 3,300 to 1,500 pounds of B.O.D. and suspended solids per acre ft. per day. An average reduction of 86 per cent of B.O.D. and suspended solids was obtained through the plant.

The plant reductions were higher in summer than in winter, whereas the B.O.D. load in the raw sewage was low in summer and high in winter.

Calculations in evaluating the performance and loadings of the individual units of the biofilter plant by including and excluding the recirculation are given. The merits and drawbacks of each method of calculation are discussed. The values obtained by each method, though varying in magnitude, give the same general trends.

The performance of the primary clarifier is greatly influenced by the temperature of the liquid, especially in respect to B.O.D. removals. The B.O.D. removals increase to a maximum of 50 to 60 per cent during the summer with suspended solids removals of nearly the same magnitude. In the winter suspended solids removals are higher than B.O.D. removals. The high B.O.D. removals during the summer are obtained in conjunction with lower B.O.D. in the raw sewage and the recirculated water. These observations confirm previous claims that where recirculation is practiced the primary clarifier performs a double function, namely, sedimentation and oxidation, and is somewhat comparable to the aeration tank of an activated sludge plant. The dissolved oxygen and the organisms furnished by the recirculation are responsible for oxidation and for B.O.D. removals greater than can be expected by plain sedimentation. However, such oxidation is dependent on favorable temperature and is negligible during the winter.

The greater B.O.D. removals by the primary clarifier during the summer result in a lower load on the filter when it is capable of handling a greater load. In the plant under study there was, in addition, a decrease in the raw sewage load during the summer. The result of these contributing factors was that the efficiency of the secondary treatment did not show a marked increase in the summer, although the quantity of impurities in the final effluent was lower. Thus the primary clarifier and the filter supplement each other, the latter removing the greater percentage of impurities in winter and the former effecting most of the removal in summer.

In assessing the relative removals by the filter and the secondary clarifier, it was found that although the major portion of the load applied to the secondary treatment is removed by the secondary clarifier, the filter itself is not a mere "colloider" but at times removes a considerable portion of the B.O.D.

Substantial reductions in the numbers of coliform organisms take place during passage of the sewage through the filter and secondary clarifier. These reductions are also affected by the temperature, being higher in summer (90 to 99.9 per cent) than in winter. The numbers of total bacteria were at times higher in the final effluent than in the influent to the filter, and at other times there was little or no reduction, particularly during the winter.

The standard filter produced uniform effluents with low B.O.D. and suspended solids values throughout the period (5 to 15 p.p.m.) and was not subject to seasonal variations. However, this plant received weak to medium strength sewage (average suspended solids of 173 p.p.m. in 8-hour daily composites). The reductions of coliform and total organisms were uniformly high during the different seasons.

## APPENDIX

*Sample Calculation No. 1*

Removal in the Primary Clarifier

| | |
|---|---|
| 1. Sewage flow, m.g.d. | 1.85 |
| 2. Sewage B.O.D., p.p.m. | 215 |
| 3. Sewage B.O.D., lb. | 3,310 |
| 4. Recirculation, m.g.d. | 2.92 |
| 5. B.O.D. in recirculation, p.p.m. | 62 |
| 6. B.O.D. in recirculation, lb. | 1,505 |
| 7. Flow in primary clarifier | 4.77 |
| 8. B.O.D. in primary clarifier effluent, p.p.m. | 102 |
| 9. B.O.D. in primary clarifier effluent, lb. | 4,050 |

*By Including the Recirculation*

$$(3310 + 1505) - 4050 = 765 \text{ lb. removed}$$

$$\frac{765}{3310 + 1505} \times 100 = 15.8 \text{ per cent removed}$$

*By Excluding Recirculation*

$$3310 - (4050 - 1505) = 765 \text{ lb. removed}$$

$$\frac{765}{3310} \times 100 = 23.1 \text{ per cent removal}$$

*Sample Calculation No. 2*

Removal in Filter and Secondary Clarifier

| | |
|---|---|
| 1. Sewage flow, m.g.d. | 1.85 |
| 2. Recirculation from filter effluent to primary m.g.d. | 2.92 |
| 3. Recirculation from secondary clarifier to filter, p.p.m. | 2.88 |
| 4. B.O.D. in recirculation from secondary clarifier to filter, p.p.m. | 45 |
| 5. B.O.D. in final effluent, p.p.m. | 37 |

All other data as given above

*By Including Recirculation*

| | |
|---|---|
| B.O.D. in primary clarifier effluent, lb. | 4,050 |
| B.O.D. in recirculation from secondary clarifier to filter, lb. | 1,080 |
| B.O.D. in final effluent 1.85 × 37 × 8.34, lb. | 695 |

$$(4050 + 1080) - 695 = 4435 \text{ lb. removed}$$

$$\frac{4435}{4050 + 1080} \times 100 = 86.5$$

*By Excluding Recirculation*

Lb. B.O.D. applied = lb. B.O.D. in primary effluent − lb. B.O.D. in recirculation from filter effluent to primary

Lb. B.O.D. applied = 4050 − 1505 = 2545

Lb. B.O.D. in final effluent = 695

2545 − 695 = 1850 lb. removed

$$\frac{1850}{2545} \times 100 = 73.0 \text{ per cent removed}$$

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# SURVEY OF RESEARCH PROJECTS UNDER INVESTIGATION AND REQUIRING STUDY—1945

## Research Committee, Section B

## Federation of Sewage Works Associations

By H. Heukelekian, *Chairman,* B. H. Barton, A. E. Berry, F. J. Brinley, C. H. Coberly, H. Ell, V. P. Enloe, A. L. Genter, G. J. Hopkins, W. P. Hughes, W. Q. Kehr, K. C. Lauster, G. Martin, G. W. Marx, L. J. Murphy, R. S. Phillips, R. Pomeroy, M. E. Rogers, R. J. Smith, Geo. E. Symons, F. S. Taylor, S. R. Weibel, J. Williamson, Jr., W. S. Wise, C. H. Young

Representatives of all the Member Associations were requested to furnish all of the information they could obtain from the members of their respective organizations regarding research and problems requiring investigation. Replies were received from eight groups. An attempt was made this year to bring the listings up to date by eliminating those projects which have been completed and temporarily or permanently discontinued. Thus, the present report includes only new projects or old projects which are still active.

### I. Problems Under Investigation

Eighty-two projects are reported this year in comparison with 94 reported in 1944. The breakdown under the various headings for 1944 and 1945 is as follows:

| | 1944 | 1945 |
|---|---|---|
| Sewage | 35 | 21 |
| Industrial waste | 49 | 46 |
| Stream pollution | 5 | 7 |
| Analytical methods | 5 | 8 |
| | 94 | 82 |

The decrease in the total number of projects under investigation during the present year is caused by a decrease in the number of problems dealing with sewage. The number of problems dealing with industrial wastes held firm and represents at present over twice the number of sewage problems. The breakdown of industrial waste projects for the past two years is as follows:

| | 1944 | 1945 |
|---|---|---|
| Sugars and fermentation | 2 | 3 |
| Paper wastes | 6 | 14 |
| Textile and dyes | 7 | 4 |
| Pickling liquors | 5 | 3 |
| Acid wastes | 4 | — |
| Laundry wastes | 1 | 1 |
| Oil wastes | 5 | 3 |
| Rubber wastes | 6 | 4 |
| Food, canning, tannery | 10 | 5 |
| Explosives | — | 4 |
| Miscellaneous | — | 5 |

The most important change in trend of research in industrial waste has been in a striking increase in problems under investigation in the paper waste field. This tendency has been catalyzed by the organization of this industry into the National Council for Stream Improvement.

The prominence displayed by the industrial waste research in general has led to the recognition of the need for more adequate methods for evaluation of the character and effects of these wastes on streams. The adaptation of established methods such as the B.O.D. and the development of newer methods are awaited before great advances can be made in this field.

## II. Problems Requiring Investigation

Thirty-five problems were submitted for which investigators are needed as compared with 41 problems suggested last year. Fifteen of the problems requiring investigation deal with industrial waste. Despite the amount of work done with the treatment of textile wastes, it appears that there are some unsolved problems still requiring attention in this field.

It is not claimed that the report includes a complete list of all the problems both under investigation and requiring investigation. It probably represents a fair cross-section of the trends and tendencies in research activities at this time. There are undoubtedly a number of problems the committee was unable to list because of restrictions in travel and pressure of time. Research activities in general have naturally been curtailed considerably during the war, but there has been a stimulation of research in connection with wastes produced in certain wartime industrial activities, such as in the manufacture of synthetic rubber, explosives and paper. With the cessation of hostilities and a greater availability of manpower, many ideas that have been dormant or placed in the background by other preoccupations will find expression.

The yearly publication of the report serves a useful purpose in giving an advance notice of the problems that are under investigation in different organizations. It may happen, as it has in several instances in projects listed in the present report, that several similar problems are being worked on simultaneously and independently by different investigators. This is only natural and not necessarily objectionable if

TABLE I.—*Problems Under Investigation*

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| | | *A. Survey of Sewage Research Problems* | |
| 1 | Inventory of sewage works. | Continuing inventory and statistical study of sewage works in the U. S. | U.S.P.H.S., Sanitary Engineering Division, Water and Sanit. Investigations Sta., Cincinnati, O. |
| 2 | Septic tanks. | Comparison of usefulness of various detention periods. | Mass. Dept. of Pub. Health, Lawrence, Mass.; Mass. State College; Mass. Agr. Exp. Sta. |
| 3 | Disposal of septic tank effluents. | Determination of saturation points of fine soils. | Mass. Dept. of Pub. Health, Lawrence Exp. Sta.. Lawrence, Mass.; Mass, State College; Mass. Agr. Exp. Station. |
| 4 | Incineration of sewage and garbage from rural homes. | Injecting wastes into the feed screw of a standard furnace stoker. | W. E. Howland and Don E. Bloodgood, Purdue University, Lafayette, Ind. |
| 5 | Institutions. | Basic principles involved in the treatment of sewage and waste in institutions. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research, Rutgers University, New Brunswick, N. J. |
| 6 | Rainfall, flow, and purification. | Effect of rainfall and flow variation on suspended solids and B.O.D. removal by primary treatment. | N. J. Agr. Exp. Sta., Dept. of Water and Sew. Research, Rutgers Univ., New Brunswick, N. J. |
| 7 | High daily rate filter study. | Study to determine advantages accruing to practically instantaneous rain-like distribution over the surface of high daily rate sewage filters. | Upper Mississippi Board of Engineers aided by U.S.P. H.S. at Neosho, Missouri. |
| 8 | High-rate trickling filters. | Determination of maximum possible B.O.D. loading; ratio of loading of B.O.D. to removal; comparison of recirculation with further treatment on secondary filter. | Mass. Dept. of Pub. Health, Lawrence Exp. Sta., Lawrence, Mass. |
| 9 | High-rate secondary sand filtration of trickling filter effluents. | Sand filtration of trickling filter effluents at high rates to find saturation points with (*a*) continuous rate and (*b*) periodic increases and decreases in rates. | Mass. Dept. of Pub. Health, Lawrence Exp. Sta., Lawrence, Mass. |
| 10 | Filter fly control. | The control of filter flies with DDT. | Don E. Bloodgood and G. Erganian at Purdue University. |
| 11 | Activated sludge. | Research on causes and cures of bulking at Sioux Falls, South Dakota, plant due to the presence of packing-house waste. | C. N. Sawyer, F. W. Mohlman and K. V. Hill. |
| 12 | Rate of solubility of oxygen from air bubbles. | Work directed toward increasing the efficiency of air application to activated sludge. | W. C. Killin, Purdue Univ., Lafayette, Ind. |
| 13 | Vertical aeration plate holders. | Study of efficiency, distribution and clogging. | L. E. Langdon (Pacific Flush Tank Co.) at Sanitary District of Chicago, Southwest plant. |

TABLE I.—*Continued*

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 14 | Activity of activated sludge. | A study of utilization of activated sludge as relates to its rising time. | Univ. of Wisconsin, Sanitary Engineering Dept. |
| 15 | Sludge digestion | Preliminary study on Metropolitan (Boston) sludge, for proposed disposal works. | Mass. Dept. of Pub. Health, Lawrence Exp. Sta., Lawrence, Mass. |
| 16 | Supernatant liquor treatment. | Chemical treatment and thermophilic digestion together with other possible methods of treatment. | H. E. Babbitt and Ming Lee, Eng'g. Exp. Sta., Univ. of Illinois, Urbana. |
| 17 | Supernatant liquor treatment. | Study of treatment by vacuum aeration of digester supernatant liquor. | C. V. Erickson (Pacific Flush Tank Co.) at Cleveland, Ohio, and Ann Arbor, Michigan. |
| 18 | Digester preheaters. | Study of capacities and efficiencies. | C. B. Cox (Pacific Flush Tank Co.) at Crystal Lake, Ill., and Urbana–Champaign, Illinois. |
| 19 | Digestion of garbage. | To determine by pilot plant tests the volume of gas production per pound of volatile garbage material when digested with sewage solids. | David P. Backmeyer, Marion, Indiana, sewage treatment plant. |
| 20 | Sludge. | Absorption capacity and removal of water from different types of sludges. | N. J. Agr. Exp. Sta., Dept. Water and Sew. Research, Rutgers Univ., New Brunswick, N. J. |
| 21 | Sludge. | Effect of phosphates on coagulation, settling, digestion and dewatering of sewage solids. | N. J. Agr. Exp. Sta., Dept. Water and Sew. Research, Rutgers Univ., New Brunswick, N. J. |
| | *B. Survey of Industrial Wastes Research Problems* | | |
| 22 | Settling anthracite coal dust. | Study on separation and removal of fine coal dust and solids from breaker wash waters produced in preparation of coal. | Pennsylvania Dept. of Health, J. R. Hoffert, and Anthracite Coal Committee. |
| 23 | Waste problems of the iron and steel industry. | Study to develop and improve practical and economical method for treatment of spent pickle liquors primarily for reduction of stream pollution. | Mellon Inst. of Ind. Research, Pittsburgh, Pa.; W. W. Hodge for American Iron and Steel Industry. |
| 24 | Study of alpha TNT wastes. | A study of the changes in alpha TNT wastes resulting in the production of highly colored waters and the possible treatment procedures for such waters. | U.S.P.H.S., Sanitary Engineering Division, Water and Sanit. Investigations Sta., Cincinnati, O. |
| 25 | Effects of TNT and synthetic rubber wastes on streams. | To determine what effects TNT and synthetic rubber wastes and derivatives exert upon various organisms in streams. | U.S.P.H.S., Sanitary Engineering Division, Water and Sanit. Investigations Sta., Cincinnati, O. |
| 26 | Treatment of artillery shell manufacturing wastes. | To establish methods of treatment and to reduce pollution. | W. H. and L. D. Betz, Philadelphia, Pa. |

TABLE I.—*Continued*

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 27 | Synthetic rubber wastes. | Pilot plant studies on the treatment of synthetic rubber wastes. | U.S.P.H.S., Sanitary Engineering Division, Water and Sanit. Investigations Sta., Cincinnati, O. |
| 28 | Synthetic rubber. | Treatment of wastes from the manufacture of butadiene and styrene, used in the manufacture of synthetic rubber. | Metcalf and Eddy, Consulting Engineers, Boston, Mass. |
| 29 | Treatment of waste waters from synthetic rubber manufacturing. | Development of satisfactory treatment of butadiene and styrene waste waters through removal of oil, reduction of B.O.D. and taste and odors. | Koppers United Co., Pittsburgh, Pa., and Metcalf and Eddy, Consulting Engineers, Boston, Mass. |
| 30 | Koroseal and Neoprene wastes. | Determination of quantities, characteristics and methods of treatment of Koroseal and Neoprene wastes. | U.S.P.H.S., Sanitary Engineering Division, Water and Sanit. Investigations Sta., Cincinnati, O. |
| 31 | Effects of DDT on fresh water. | To determine the effects of various forms and concentrations of DDT dosages upon fresh water flora and fauna other than mosquito larvae. | U.S.P.H.S., Sanitary Engineering Division, Water and Sanit. Investigations Sta., Cincinnati, O. |
| 32 | Cyanide wastes. | Treatment of plating wastes containing cyanides by means of chlorine. | Conn. State Water Commission, Hartford, Conn., Wesleyan Univ., Middletown, Conn. |
| 33 | Treatment of cyanide waste waters from electroplating. | Removal of toxic constituents. | M. M. Braidech and G. E. Barnes, Cleveland, O. |
| 34 | Oil field brines. | Pilot plant studies on the recovery and utilization of oil field brines. | L. Schmidt, Bureau of Mines, Petroleum Exp. Sta., Bartlesville, Okla., in cooperation with Kansas State Bd. of Health. |
| 35 | Treatment of oily wastes. | Means of controlling the discharge of oily wastes, thereby reducing stream pollution. | W. H. and L. D. Betz, Philadelphia, Pa. |
| 36 | Filtration research. | To reduce oil attached to suspended matter. | Laboratory of the Atlantic Refining Co., Philadelphia, Pa. |
| 37 | Laundry wastes. | Treatment of laundry wastes by high-rate trickling filters. | Mass. Dept. of Pub. Health, Lawrence Exp. Sta., Lawrence, Mass. |
| 38 | Paper pulp. | Basic research dealing with wood chemistry and lignin. | D. M. Ritter, Univ. of Washington, Seattle. |
| 39 | Paper pulp. | Utilization studies of pulp and paper mill wastes. | J. L. McCarthy, Univ. of Washington, Seattle. |
| 40 | Paper pulp. | Disposal studies of pulp and paper mill wastes. | R. G. Tyler, Univ. of Washington, Seattle. |
| 41 | Waste problems of the pulp, paper, and paperboard industries. | Reduction of stream pollution and recovery of wastes. | Mellon Inst. of Ind. Research and Nat. Council of Stream Impr. of the Paper, Pulp and Paperboard Industries, New York City. |

TABLE I.—*Continued*

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 42 | Aerobic production of yeast from sulfite waste liquor. | Study includes removal of B.O.D. from sulfite waste liquor through production of yeast protein from the sugars and other fermentable compounds. | A. J. Wiley, Sulfite Pulp Mfgr's. Comm. on Waste Disposal. At the Inst. of Paper Chemistry, Appleton, Wisconsin. |
| 43 | Production of yeast from sulfite paper mill waste. | Study of means for producing emulsions. | H. Beddoes (Pacific Flush Tank Co.) at P.F.T. Testing Lab., Chicago, Ill., and Neenah, Wisc. |
| 44 | Paper pulp. | Basic studies of fundamental factors involved in white water treatment. | N. J. Agr. Exp. Sta., Dept. of Water and Sew. Research, Rutgers Univ., New Brunswick, N. J. |
| 45 | De-inking paper mill wastes. | Treatment of paper mill wastes from de-inking processes for discharge into waterways. | Conn. State Water Commission, Hartford, Conn.; Wesleyan Univ., Middletown, Conn. |
| 46 | Treatment of de-inking wastes. | A study of methods for the treatment of de-inking waste from pulp and paper mills. | Gladys Swope, Mellon Inst. of Ind. Research, Pittsburgh, Pa., under auspices of Nat. Council for Stream Improvement of the Pulp, Paper and Paperboard Inds., Inc. |
| 47 | Paperboard mill wastes. | Treatment of wastes from paperboard mills by flocculation and sedimentation with and without chemicals. | Conn. State Water Commission, Hartford, Conn.; Wesleyan Univ., Middletown, Conn. |
| 48 | Trickling filter treatment of waste sulfite liquor. | Five years of study on trickling filter methods of treating sulfite waste liquors are being followed up and further developed with existing pilot plants. | J. M. Holderby, A. J. Wiley and H. W. Gehm. The Sulfite Pulp Mfgr's. Comm. on Waste Disposal and the Nat'l. Council for Stream Improvement at Inst. of Paper Chemistry, Appleton, Wisconsin. |
| 49 | Studies on the treatment of paper mill wastes. | Recovery of stock and reduction of pollution load. | Albright and Friel, Consulting Engineers, Philadelphia, Pa. |
| 50 | Treatment of rag cooker wastes from paper mills. | Reduction in stream pollution. | W. H. and L. D. Betz, Chem. Engs., Philadelphia, Pa. |
| 51 | Recovery and disposal of sulfite pulp liquors. | Continuing study to improve methods of reclaiming and eliminating objectionable pollutional characteristics in waste sulfite liquors, soda liquors, de-inking waters and white water, including effects of pollution on the Clarion River. | Joseph P. Gray, Castanea Paper Co., Johnsburg, Pa. |
| 52 | Treatment of corn canning wastes. | Continuing study on corn canning waste treatment works, consisting of screens, mechanical treatment, sedimentation, high capacity trickling filter, storage lagoon and regulated discharge. | Blue Mountain Canneries, Martinsburg, Pa. |

TABLE I.—*Continued*

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 53 | Sodium nitrate treatment of cannery lagoons. | Study of effectiveness of sodium nitrate and other chemicals in odor control and reduction of pollutional strength in waste storage in lagoons. | Wisconsin State Bd. of Health, and Nat'l. Canners Assn., L. F. Warrick, T. F. Wisniewski and N. H. Sanborn at canning plants in Wisconsin. |
| 54 | Penicillin waste. | Development of physical, chemical and biological methods of treatment for the disposal of spent ferment liquor. | N. J. Agr. Exp. Sta., Dept. of Water and Sew. Research, Rutgers Univ., New Brunswick, N. J. |
| 55 | Digestion of yeast plant and malt house wastes. | Study of volatile acids balance. | H. E. Schlenz (Pacific Flush Tank Co.) at Crystal Lake, Ill., and Jefferson Junction, Wis. |
| 56 | Yeast waste. | Digestion and biological filtration of spent ferment liquor. | N. J. Agr. Exp. Sta., Dept. of Water and Sew. Research, Rutgers Univ., New Brunswick, N. J. |
| 57 | Food dehydrating plant waste studies. | Determination of pollutional characteristics and unit loadings on treatment systems. | Upper Mississippi Board of Engineers aided by U.S.P.H.S. at plants in Minnesota and Wisconsin. |
| 58 | Tannery wastes. | Treatment of tannery wastes more expecially for the reduction of sulfides in the final effluent. | Mass. Dept. of Pub. Health, Lawrence Exp. Sta., Lawrence, Mass. |
| 59 | Tannery wastes. | Treatment of calfskin tannery wastes to meet certain requirements for disposal. | Metcalf and Eddy, Consulting Engineers, Boston, Mass. |
| 60 | Treatment of mercerizer wastes. | For caustic recovery. | W. H. and L. D. Betz, Philadelphia, Pa. |
| 61 | Textile wastes. | Treatment of textile wastes to meet certain requirements for disposal. | Metcalf and Eddy, Cons. Engs., Boston, Mass. |
| 62 | Textile wastes. | Treatment by chemical precipitation of wastes from cotton or wool dyeing and finishing and cotton printing processes. | Conn. State Water Commission, Hartford, Conn.; Wesleyan Univ., Middletown, Conn. |
| 63 | Wool scouring. | Treatment of wastes from wool-scouring liquors, with recovery of grease. Treatment to prevent stream pollution. | Metcalf and Eddy, Consulting Engineers, Boston, Mass. |
| 64 | Chlorine. | Use of chlorine for the treatment of certain industrial wastes. | N. J. Agr. Exp. Sta., Dept. of Water and Sew. Research, Rutgers Univ., New Brunswick, N. J. |
| 65 | Lime. | Fundamental factors in the use of lime for the treatment of certain industrial wastes. | N. J. Agr. Exp. Sta., Dept. of Water and Sew. Research, Rutgers Univ., New Brunswick, N. J. |
| 66 | Biochemical oxygen demands of industrial wastes. | A study of the natural rates of biochemical oxidation of some of the new industrial wastes. | U.S.P.H.S., Sanitary Engineering Division, Water and Sanitation Investigations Sta., Cincinnati, O. |

TABLE I.—*Continued*

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 67 | B.O.D. | Utilization of B.O.D. determination for the detection of inhibiting substances in industrial wastes and the dilutions necessary to overcome such inhibiting effects. | N. J. Agr. Exp. Sta., Dept. of Water and Sew. Research, Rutgers Univ., New Brunswick, N. J. |
| | *C. Survey of Stream Pollution Research Problems* | | |
| 68 | Experimental reaeration of the Flambeau River. | A river popular with sportsmen but now heavily polluted with sulfite waste liquor is being mechanically aerated on a commercial scale to accelerate natural removal of B.O.D. and to increase the D.O. level above the critical point for normal existence of aerobic biological stream flora and especially of game fish. | A. J. Wiley, H. W. Gehm, L. F. Warrick, H. H. Coolidge, and R. G. Tyler, The Sulfite Pulp Mfgr's. Comm. on Waste Disposal. The Nat'l. Council for Stream Impr., Wis. State Board of Health, and the Flambeau Paper Co. at Park Falls, Wisconsin. |
| 69 | Reservoir operation. | Effect of low flow augmentation and other changes resulting from reservoir operation on pollution problems. | U.S.P.H.S., Sanitary Engineering Division, Water and Sanitation Investigations Sta., Cincinnati, O. |
| 70 | Stream pollution. | Sources of pollution and conditions of the major tributaries of the Tennessee River system. | G. R. Scott, Tenn. Valley Authority, Knoxville, Tenn. |
| 71 | Fish life. | Effect of phosphorus on fish. | G. R. Scott, Tenn. Valley Authority, Knoxville, Tenn. |
| 72 | Toxic effects of various wastes on plankton forms. | Method for evaluation of toxicity effect on plankton forms. | Lab. of Atlantic Refining Co., Philadelphia, Pa. |
| 73 | Influence of pH and temperature on the survival of coliform and enteric pathogens when exposed to chloramines. | Studies have been completed on efficiency of chloramines in water disinfection. Report in preparation. | U.S.P.H.S., Sanitary Engineering Division, Water and Sanitation Investigations Sta., Cincinnati, O. |
| 74 | Relative resistance of *Escherichia Coli* and *Eberthella Typhosa* to chlorine and chloramines. | Study completed and published, *Public Health Reports*, 59: 1661 (Dec. 29, 1944). | U.S.P.H.S., Sanitary Engineering Division, Water and Sanitation Investigations Sta., Cincinnati, O. |
| | *D. Survey of Research on Analytical Methods* | | |
| 75 | Bromination. | Development of a reliable method for the determination of small amounts of bromine. | U.S.P.H.S., Sanitary Engineering Division, Water and Sanitation Investigations Sta., Cincinnati, O. |
| 76 | Studies on detergency. | Determination of the physical and chemical properties necessary for detergency, the minimum values of these that will produce a good detergent and simple tests for these properties. | U.S.P.H.S., Sanitary Engineering Division, Water and Sanitation Investigations Sta., Cincinnati, O. |

TABLE I.—*Continued*

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 77 | Determination of dissolved oxygen. | A comparison of analytical procedures for the determination of D.O. in the presence of interfering substances. | U.S.P.H.S., Sanitary Engineering Division, Water and Sanitation Investigations Sta., Cincinnati, O. |
| 78 | Dissolved oxygen methods. | Effect of industrial wastes on dissolved oxygen determination. | N. J. Agr. Exp. Sta., Dept. of Water and Sew. Research, Rutgers Univ., New Brunswick, N. J. |
| 79 | Accelerating the B.O.D. test. | An attempt to shorten the incubation period by the addition of active biologic material. | D. E. Bloodgood and G. Erganian, Purdue University, Lafayette, Ind. |
| 80 | B.O.D. determination. | Development of a technique for the B.O.D. determination suitable to measure the effect of concentrated wastes upon a stream. | G. R. Scott, Tenn. Valley Authority, Knoxville, Tenn. |
| 81 | Organic industrial wastes. | Determination of the rates of oxidation of various wastes. | G. R. Scott, Tenn. Valley Authority, Knoxville, Tenn. |
| 82 | B.O.D. | Effect of certain chemicals found in industrial wastes on the B.O.D. | N. J. Agr. Exp. Sta., Dept. of Water and Sew. Research, Rutgers Univ., New Brunswick, N. J. |

TABLE II.—*Problems Requiring Investigation*

| No. | Title of Project | Description | Suggested by |
|---|---|---|---|
| | | *A. Sewage* | |
| 1 | Sedimentation. | Efficiencies of various types of sedimentation units. | P. W. Ridesel, Minn. Dept. of Health, Minneapolis. |
| 2 | Sedimentation of sewage. | Effect of temperature variations in influents upon the efficiency of settling. | H. T. Ell, N. J. State Dept. of Health, Trenton. |
| 3 | Detention periods of tanks. | Development of a simple field method to determine the actual detention period of settling tanks. | E. M. App, N. J. State Dept. of Health, Trenton. |
| 4 | Sedimentation of sewage. | Study of actual against theoretical detention periods for various types of settling tanks and correlation with settling tank efficiencies. | E. M. App, N. J. State Dept. of Health, Trenton. |
| 5 | Characteristics of a well digested sludge. | Derivation of definite standards for a well digested sewage sludge based on the characteristics of the digested sludge and not on the relationship of composition of the raw sludge and the digested. | D. M. Ditmars, N. J. State Dept. of Health, Trenton. |
| 6 | Filter efficiency. | The effect of temperature, recirculation and type of sewage on filter efficiency. | P. W. Ridesel, Minn. Dept. of Health, Minneapolis. |

TABLE II.—*Continued*

| No. | Title of Project | Description | Suggested by |
|---|---|---|---|
| 7 | Critical trickling filter rates. | Determination of the critical application rates between the standard filter rates and high capacity filter rates at which neither the orthodox nor the high capacity filters function. | D. M. Ditmars, N. J. State Dept. of Health, Trenton. |
| 8 | Retardation of biological treatment processes in sewage treatment. | What are the retarding or limiting factors in biological sewage or waste treatment processes? Are they possibly toxins or other chemical compounds which can be eliminated or counteracted? | H. T. Ell, N. J. State Dept. of Health, Trenton. |
| 9 | Filter fly control. | The possible use and effectiveness of DDT in the control of filter flies. | D. E. Dreier, Sr. San. Eng'r., Illinois State Sanitary Water Board, also D. M. Ditmars, N. J. State Dept. of Health. |
| 10 | Sand filters. | How will some of the weed killers work on intermittent sand filters; will they affect the efficiency of treatment? What is the economy of their application? | D. M. Ditmars, N. J. State Dept. of Health, Trenton. |
| 11 | After-flocculation in sand filter effluents. | What is the cause of after-flocculation in sand filter effluents after chemical treatment with alum and how can it be remedied? | D. M. Ditmars, N. J. State Dept. of Health, Trenton. |
| 12 | Application of chemicals to sewage. | Development of improved solutionizing equipment for application of lime and other chemicals to sewage. | E. M. App, N. J. State Dept. of Health, Trenton. |
| 13 | Purification organisms in biological treatment of sewage and industrial wastes. | Effect of waste composition and application rates upon the types or combination of types of purification organisms developed. | H. T. Ell, N. J. State Dept. of Health, Trenton. |
| 14 | Effective disinfection of sewage. | Effective chlorination of sewage along South Jersey Coast is counteracted by high $H_2S$ concentration. (Possibly caused by long lines, flat grades and in some cases allegedly by infiltration from sulfide bearing muds.) | D. M. Ditmars, N. J. State Dept. of Health, Trenton. |
| 15 | Automatic disinfection of sewage. | Study of full automatic control of chlorine disinfection of sewage with variable chlorine demand and variable flows. | H. T. Ell, N. J. State Dept. of Health, Trenton. |
| 16 | Disinfection of sewage. | Merits of breakpoint chlorination of sewage for effective disinfection. | H. T. Ell, N. J. State Dept. of Health, Trenton. |
| 17 | Recovery of bacteria and parasitic organisms from soil. | Recovery of pathogenic bacteria or parasitic organisms or eggs from agricultural soil treated with digested sewage sludge. | Conn. St. Dept. of Health, Hartford, Conn., Bureau of Sanitary Engineering. |

*B. Industrial Wastes*

| No. | Title of Project | Description | Suggested by |
|---|---|---|---|
| 18 | Abattoirs waste treatment. | Practical method for treating waste waters from small and medium size abattoirs. | H. E. Moses, Pa. Dept. of Health, Harrisburg, Pa. |

TABLE II.—*Continued*

| No. | Title of Project | Description | Suggested by |
|---|---|---|---|
| 19 | Acid mine drainage. | Methods of control and/or treatment of acid mine drainage. | H. E. Moses, Pa. Dept. of Health, Harrisburg, Pa. |
| 20 | Treatment of brewery wastes by activated sludge. | The modification of the activated sludge process to handle brewery wastes. | R. I. Dept. of Health, Div. of Sanitary Engineering, Providence. |
| 21 | Textile wastes. | Satisfactory treatment of textile wastes for discharge to streams or sewage treatment plants. | N. H. Dept. of Health, Div. of Chemistry and Sanitation, Concord. |
| 22 | Textile wastes. | Development of a higher degree of treatment of textile wastes. | C. L. Siebert, Consulting Sanitary Engineer, Camp Hill, Harrisburg, Pa. |
| 23 | Treatment of sewage and cotton finishing plant wastes. | Treatment of combined sewage and cotton finishing plant wastes. | R. I. Dept. of Health, Div. of San. Eng., Providence. |
| 24 | Cotton finishing plant wastes. | Treatment of cotton finishing plant wastes containing kier liquors on high-rate trickling filters. | R. I. Dept. of Health, Div. of San. Eng., Providence. |
| 25 | Dye house wastes. | Development of an economical and effective treatment of dye house wastes. | H. T. Ell, N. J. State Dept. of Health, Trenton. |
| 26 | Wool wastes. | Treatment of partially degreased wool scouring wastes. | R. I. Dept. of Health, Div. of San. Eng., Providence. |
| 27 | Tannery wastes. | Determination of results of various methods of treating tannery wastes to a degree satisfactory for discharge to streams. | Weston and Sampson, Consulting Engineers, Boston, Mass. |
| 28 | Paper mill wastes. | Treatment of paper mill wastes from the manufacture of cigarette paper from flax straw. | Mass. Dept. of Pub. Health, Lawrence Exp. Sta., Lawrence, Mass. |
| 29 | Paper mill white water. | Comparative study of efficiencies of various types of white water save-alls (plain sedimentation, chemical coagulation, atmospheric flotation, vacuum flotation and tray clarifier) to determine the efficiencies of removal of solids to permit maximum re-use of effluent and use of removed solids. | Pennsylvania Dept. of Health, Harrisburg, Pa. |
| 30 | Paper mill wastes. | Development of means to overcome the objections to complete re-use of all water at box board plants. | D. M. Ditmars, N. J. Dept. of Health, Trenton. |
| 31 | Disposal of industrial wastes treatment sludges. | Dewatering of sludges on drying beds, vacuum filtration, etc., produced on chemical treatment of various industrial wastes such as iron, textile, copper and brass. | Conn. State Water Commission, Hartford, Conn. |
| 32 | Stabilization by lagooning. | Minimum storage periods, and B.O.D. and solids reductions effected by the several processes acting upon wastes stored in impounding areas (lagoons) for stabilization. | P. W. Ridesel, Minn. Dept. of Health, Minneapolis. |

TABLE II.—*Continued*

*C. Stream Pollution*

| No. | Title of Project | Description | Suggested by |
|---|---|---|---|
| | | No problems reported. | |

*D. Analytical Methods*

| No. | Title of Project | Description | Suggested by |
|---|---|---|---|
| 33 | Determination of suspended solids in sewage effluents. | Filtration method based on difference between total solids and dissolved solids as compared to other methods such as Gooch crucible, etc. | Conn. State Dept. of Health, Hartford, Conn., Bureau of Sanitary Engineering. |
| 34 | B.O.D. of industrial wastes. | B.O.D. of distillery, pulpmill, cannery wastes, etc. have long been of questionable accuracy, and further work should be done to develop, evaluate and standardize procedures. | A. J. Wiley, Sulfite Pulp Mfgr's. Comm. on Waste Disposal. |
| 35 | B.O.D. of pure organic substances. | Determination of the B.O.D. of pure organic substances and establishment of time-demand relationships for variation of solution strength. | H. T. Ell, N. J. State Dept. of Health, Trenton. |

the magnitude of the problem warrants it. Inherently different individual methods of approach may lead to corroboration or to entirely different results. At the same time, by giving such advance notice, unnecessary duplication may be avoided when a project is contemplated and attention may be diverted to other problems, equally pressing. It should also help to put the different investigators working on similar problems in closer contact with each other for the exchange of mutually profitable ideas. Furthermore, the report furnishes an opportunity to others confronted with practical problems in the field to communicate and obtain such information as may be immediately available and useful for the solution of their problems. The results of investigations are often either not published or are published a year or more after the completion of the project.

By compiling a list of projects upon which investigation is needed, the committee hopes to serve as a clearing house and an intermediary between the person making the suggestion and the available investigator. Such an arrangement can be made either through the committee or by the interested parties directly.

# Industrial Wastes

## COORDINATED INDUSTRIAL WASTE RESEARCH *

By Harry W. Gehm

*Technical Advisor, National Council for Stream Improvement, Pulp, Paper and Paperboard Industries, Inc., New York, N. Y.*

In passing from individualized and small group research on manufacturing wastes and stream pollution to an integrated national program, the pulp, paper and paperboard industries have embarked upon a pioneering experiment, which, if successful, may well become the model for other industries. The National Council for Stream Improvement which will undertake this work is at present supported by 75 per cent of this industry and is rapidly expanding. As the name implies, this organization is concerned with stream improvement and, while research will be one of its important functions, it is a means to an end and not the end itself. Hence, provision has been made to implement the assembly of problems, institute research and apply the fruits thereof to the solution of immediate pollution problems. Agreements whereby existing knowledge and successful methods of waste handling will be shared and applied have been instigated. Adequate financing is provided by an annual budget of $150,000 to which might be added an equivalent sum now expended in existing regional projects. These sums are exclusive of expenditures for work carried on by individual mills concerning problems peculiar to their plants.

Those of us concerned with organizing and getting the Council functioning have found this an involved and fascinating task. It has been our job to think out and execute a coordinated plan of action which would be acceptable to all responsible bodies concerned and show reasonable promise of successful development. We believe that it would be of interest to this group to review in general the plans worked out and now being executed by the Council.

Perhaps the most important consideration involved in this program was to bring together the technically qualified groups involved and interested in stream pollution, and to have them agree on courses of action whereby they would work together toward solutions to these problems to mutual advantage. Despite the existence of some conflicting interests, we were firmly of the belief that these were overshadowed by common interests. This thesis has appeared more and more reasonable as relationships have developed. Groups, which were of necessity included, were as follows:

* Presented at 17th Annual Meeting, New York State Sewage Works Association, New York City, January 19, 1945.

(1) Pulp, paper and paperboard industries.
(2) Pollution control agencies.
(3) Resources, conservation and development agencies.
(4) Research organizations.
(5) Other industries.
(6) Water control bodies.

The method devised to bring these agencies together throughout the areas of the country where the industry is located involves seven regional committees, consisting of representatives of executive and technical capacity empowered to speak for their companies. These men were selected in such a manner that all products manufactured in the region are represented, as well as each watershed area containing this industry. Through meetings of these committees, together with the Council's staff and interested agencies, a firm foundation for cooperation has already been established and it appears that, in the future, decisions involving procedure leading to stream improvement will be worked out to mutual advantage.

It is the function of the regional committees to assemble, with the aid of the Council's technical staff, research and experience of individual companies in waste treatment, recovery and utilization. This material will provide data helpful to some mills where immediate application of such information can be made. It will also prevent duplication of effort and investment in unsuccessful devices, as well as provide the background for the third committee function, which is the assembly of problems for the research groups and the designation of priorities for them.. Assistance in the latter function will be obtained from stream control agencies. When decisions are reached, it then becomes the duty of the Council's staff to provide ways and means of gettting the work done.

The multiplicity of waste and stream problems and the geographical distribution of the industry demanded that research projects be spread throughout the country. It was immediately evident, however, that the services of a major, centralized research organization were necessary, which organization would pursue problems of wide interest to the industry and serve as a contact group with other industries, wherein the use of certain waste material might be involved. This organization would also serve as an advisory agent and assist in assembling problems.

The Council was fortunate in obtaining the services of the Mellon Institute of Industrial Research to act in this capacity. A multiple fellowship was established at this institution under the direction of Dr. George Beal. Here a well-rounded technical staff is being developed which is equipped with chemical and engineering laboratories. This unit will be able to handle a wide variety of problems, as experts in organic, physical, sanitary and engineering chemistry will be included. The first assignment of this group has been to review published literature, prior art on the treatment, recovery and utilization of pulp, paper and paperboard wastes, with regard to modern technology, and to submit a series of reports containing summaries of such work for each class of wastes, including recommendations as to lines of further study. These reports will, together with the industry experience and problem assembly, serve as a basis for decisions relating to other research projects.

The Council has entered into an agreement with the Institute of Paper Chemistry regarding maintenance of a complete bibliography on pulp and paper wastes, whereby all such information published will be available to research groups on a current basis.

It is now well recognized that one important function of a stream is the purification of wastes. Streams are, and will always be, employed for this purpose, but it is necessary in so using a stream not to overtax its ability to do this or destroy the water for the uses to which it is normally put. Upon this basis, the waste loading must be predicated. As much data concerning the character of streams and the discharge of wastes are available and more are forthcoming, the Council has established a project at Manhattan College under Professor C. J. Velz, Head of the Civil Engineering Department, under which such data will be assembled and analyzed for the purpose of determining the relative responsibility for pollution of the pulp and paper industry, municipalities and other industries on the watersheds concerned. What degree of abatement the mills must provide to put these waters in satisfactory condition for the uses to which they are to be put, if others concerned do their share, will be determined. The information provided by this work will also assist the research and technical staffs in evaluating the magnitude of usefulness of processes under development.

Regional projects supported by the Council will be placed on the basis of four considerations, which are as follows:

1. Concentration of particular product production.
2. Severity of the stream problems.
3. Facilities of research organizations in the region.
4. Facilities of the regional mills for assisting in the work.

In some cases these will be placed at university and research laboratories and in others at mills. Particular attention will be paid to adapting processes to actual mill conditions and to the improvement of unit processes and sewering within the mills to reduce waste discharge.

Many of the larger mills have stream, waste and by-product research laboratories. In several instances, groups of the industry concerned with common problems have supported research projects directed toward finding a solution to these. Government laboratories have also embarked on research along related lines. To date, the Council has established close working relations with these organizations, which will undoubtedly go far toward rapidly increasing our knowledge of the subject.

As research becomes productive, provision must be made for its direct application. Prosecution of this function is the responsibility of the technical staff. It is planned that further development of processes forthcoming from the various laboratories will be carried through the pilot, demonstration or full-scale plant development, as indicated at the mills themselves. Where necessary, assistance will be provided by research organizations employed by the Council; general supervision coming under the technical advisor's office. Offers to finance construction of such units have been received from a number of member companies. The development departments of several equipment companies have expressed interest in assisting in these projects and will, undoubtedly, give valuable aid in the future.

The findings of the various research, development and survey groups will be made available to all member industry, through the Council's office, and the adoption of particular processes to individual mills will be a function of the staff and research personnel. General advice and information regarding waste problems will also be provided as well as mill survey services.

During the six months of its activity, the Council has moved steadily toward the development of this program and the next year should see it well under way.

# Sewage Works Planning

## SANITATION AND TOWN PLANNING*

By James F. MacLaren

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Town planning is among the major subjects receiving consideration for postwar construction. Many municipalities and communities are giving serious consideration to such projects and some are preparing plans for work to be undertaken as circumstances warrant after the war. Town planning is a popular subject, for naturally we like to think of the elimination of slum areas and poor housing conditions and we look forward to making our towns and cities, and countryside generally, more attractive and better places in which to live and work.

It seems though, that to be sound in our planning, we must maintain a proper perspective, and undertake only those works that are logical and justifiable steps, having in mind that Rome wasn't built in a day and that we should proceed by putting first things first.

There is nothing of more importance to the essential life of a community than an abundant supply of good water and adequate sanitation. It is now realized that the good health of the community is dependent on these and that among the numerous public works that we have come to associate with modern urban development, none is of more benefit to the prosperity and growth of a municipality than a good water works system and a good sewerage system with adequate sewage disposal. It would seem then that the establishment of adequate sanitation should be one of our first considerations in town planning. In addition to water works and sewerage, good municipal housekeeping and the protection of health involve refuse collection and dispōsal, including street cleaning and general cleanliness.

### Progress in Sanitation—Control

In reviewing the development that has taken place in Canada in the field of public sanitation in the past it is clear that in more recent years the demand for an abundant supply of "safe" water and for better sewage treatment and disposal has increased. Today the importance of securing and protecting sources of surface and ground water supplies by legislation and/or by purchase to insure an adequate supply of water is realized. In more recent years the realization that good sanitation is a valuable asset to the good health of the community has brought about a different attitude towards the unchecked contamination

* Presented at Eleventh Annual Meeting, Canadian Institute on Sewage and Sanitation, Toronto, November 2–3, 1944.

of streams, lakes and shore waters, and against other insanitary practices. It is realized that the health of the region outside the community and in neighboring municipalities is as important as the health within the community itself. Also, it is realized that the recreational facilities afforded by our beaches, lakes and rivers, and the fish life contained in these waters, are valuable assets to the health and livelihood of many communities and that these benefits are depreciated and have in many cases been destroyed by pollution from sewage and trade wastes.

The realization that our natural waters must be shared by the community has quite logically been a contributing factor to the establishment, in some instances, of water and drainage boards or other authorities whose duty it is to administer and control the supply of water and disposal of sewage and waste in the community. It is to be hoped that this tendency will increase as it is a more effective way of safeguarding the health and interests of the community than is likely to result from independent action by the municipalities; also, in many instances joint action will provide better administration and technical direction, and will prove more economical.

Among our most notable achievements in this field in Canada has been the creation of the Vancouver and Districts Joint Sewerage and Drainage Board established in 1914 and the Greater Vancouver Water District established in 1924. Again in the city of Winnipeg and its suburban area, primary water supply and sewage disposal are respectively under the jurisdiction of the Greater Winnipeg Water District established in 1913 and the Greater Winnipeg Sanitary District established in 1935; these districts being administered by boards for the benefit of the several municipalities all with common interests. In this province the Windsor Public Utilities Commission supplies water to the city of Windsor and several suburban municipalities, and also has under its administration the matter of sewage disposal. In the Toronto area we have the Mimico-New Toronto Joint Sewerage Commission under whose administration sewage from these municipalities, and from a portion of the township of Etobicoke, is treated and disposed of.

A notable instance in this province of co-operation between municipalities worthy of mention is the arrangement between the municipalities of West Lorne, Rodney and Dutton whereby the former supplies or is about to supply filtered water to the other two municipalities. These municipalities are small but by working together have been able to overcome, or at least lessen, the financial obstacle that stood in the way of otherwise obtaining an adequate water supply.

There appears to be a growing feeling among sanitary engineers and health authorities that in many instances sanitation and the abatement of pollution can be more logically and effectively controlled by applying the control to a catchment basin or drainage area, as has been the case in some instances when dealing with flood control and conservation. The Grand River Conservation Commission is an instance in this province of such authority. The Commission, in addition to administering and operating the works for controlling flood waters in the Grand

River, controls the release of water from the impounding reservoirs thoughout the year as circumstances warrant and thus the situation in respect to dilution of the effluents from several sewage treatment plants along the river is much improved.

Also worthy of mention as contributing to our thinking in these matters is the very excellent report recently issued dealing with flood control and conservation in the Ganaraska River watershed.

The creation of these authorities whether they be for water supply, sewerage, flood control or conservation is tangible evidence that we are able to see beyond the narrow limits of municipal boundaries and are able to enact legislation for the benefit of the community. It is to be hoped that we will continue to make progress in this field because it is a good foundation on which to build sound sanitary practice in a community. We should continue our efforts to improve legislation in this direction. For instance, under Section 101 of the Ontario Public Health Act and subject to the approval of the Provincial Department of Health, an urban municipality may construct an intercepting sewer through, and a sewage disposal plant in, an adjoining township municipality and if such a system is established then the township has the right to enter into an agreement with the urban municipality to connect to the sewerage system and have the sewage treated at the disposal plant, from any area adjoining the sewage disposal plant or intercepting sewer in connection therewith in the township. It would seem reasonable to suggest that the Public Health Act should be amended to permit of two or more municipalities amalgamating in a joint scheme for the installation and operation of a sewage disposal plant. At the present time this can only be done by a private bill. Such an amendment to the Act would have a tendency to reduce the number of sewage disposal plants and with the larger plants it is generally found that the efficiency of the treatment processes is better than in the smaller plants.

## Sewerage Planning

Today a good sewerage system is a recognized necessity. A sane consciousness that good health is a valuable municipal asset and depends to a large extent upon good sanitation has been a leading cause of the willingness of taxpayers to indorse extensive sewerage undertakings. However, it would seem that there is no branch of municipal engineering in which there has been so much confusion in the minds of some people as has been the case when considering and discussing proposals for sewerage systems and for sewage treatment undertakings. This is due largely to the numerous factors that can influence the adoption of a sewage plan and the failure on the part of many to appreciate that some local condition may be a powerful determinant in one case and of little importance in another. In some cases the course to pursue will be evident and the plan a simple one, but in others the complexities of the problems will require prolonged and thorough study and sane thinking before the best plan can be adopted.

In some cases it will be difficult to determine how far a plan should be carried beyond immediate requirements to allow for extension and to care for the greater volume of sewage and storm water that will be contributed in the future. This problem generally resolves itself into one of determining how much the present should be taxed for the benefit of the future. In some cases it will be a simple matter to extend a sewage scheme as future growth demands, in others it will be obvious that to care for future growth will be an expensive matter and it is in such situations that the decisions will be difficult. Generally speaking the engineer is not justified in being swayed too far in making allowances for requirements of the future where to do so will place too heavy a burden on the taxpayer.

It is expected that in this country there will be few opportunities to plan a whole new city or town in the postwar period. We can assume that most of our planning will be confined to schemes within our present cities and towns, the purpose of which will be to correct obvious errors of the past or to modernize conditions now existing. Other schemes, and probably these will be in the majority, will be for the development of suburban areas. All such schemes will involve water works and sewerage systems and in a great many cases sewage disposal plants. When we consider that in Canada today there are only about 500 municipalities with sewerage systems in contrast to about 1,300 with water works systems, and of the former only about 115 have sewage treatment plants, it will be seen that there is ample opportunity ahead for sewerage planning.

Regardless of whether we are planning a new sewerage system or a water works system or whether we are dealing with the extension and correction of systems and plants already in use, our planning must be based on a thorough study of certain important features and requirements that will be found necessary in any case. These include topography, methods of disposal of sewage, sources of water supply, rainfall and run-off, population—present and probable, nature and extent of industries, street plan, geology, suburban areas and region. These items are all important determinants in the design of sewerage and water works systems and all must be thoroughly studied and considered before basic design data can be adopted with confidence.

*Topography*

The topography of an area is an important feature in any town planning study. In the matter of drainage and in the design and planning of sewerage systems topography is of the greatest importance. A prerequisite to the serious study of any sewerage system is an accurate contour plan of the area under consideration. Such plans should not only embrace the area within the existing limits of the municipality concerned but must be carried sufficiently beyond to determine accurately the extent of the drainage area. Neglect to take into account the expanse and nature of areas tributary, in a drainage sense, to the local area under consideration at the time, will generally result in an improper and uneconomic solution of a drainage problem or sewerage system, as has been the case in many instances in the past.

In a few of our cities and in fewer towns reliable contour maps are available but even where these exist it will generally be found that they must be extended. It must always be borne in mind that surface runoff has no respect for municipal or political boundaries and while a town planning scheme can be confined to an arbitrary area the volume of drainage for which storm drains or combined sewers may have to be designed, at the time or ultimately, will be influenced by the drainage basin and the physical features of the area contained therein.

*Rainfall—Runoff*

An important matter for study is that of rainfall and runoff. The rate of rainfall and the available slopes for the sewers are the factors that primarily determine the sizes of storm water drains and combined sewers. Unfortunately, many records of precipitation are of little value because they do not show maximum rate of rainfall in relation to time. Such information can only be obtained from recording rain gauges and gauges of this type are limited to those larger cities where runoff is studied in detail.

The city of Toronto maintains a number of these gauges from which a valuable record of the frequency of downpours of various intensities is available over a period of years. Based on a close study of these records the general practice in this locality is to design the local sewers for a maximum rainfall rate of 2 inches an hour, applying thereto a runoff coefficient based on the degree of imperviousness of the surface within the areas under consideration. This coefficient may be as low as 0.2 for park areas, increasing to 0.85 or 0.90 for closely built areas such as in the downtown sections of the city. A recent investigation of residential areas containing moderately sized detached dwellings on lots with frontages of 35 to 40 feet indicated that a coefficient of 0.45 to 0.50 was justified.

It is desirable to make up plans of each area showing thereon the calculated areas tributary to each street and the volume of runoff contributed.

*Separate and Combined Sewers*

Many views have been expressed concerning the relative merits of separate and combined sewer systems, but a decision in this respect is only warranted after having completed a thorough study of the local conditions. In the majority of situations the adoption of the combined system will prove the least costly to construct and for this reason such systems are more general, particularly in the larger centers. In some municipalities both combined and separate sewers have been used where extensive low lying areas have to be dealt with. In such cases it is common practice to confine the combined sewers to areas that are sufficiently high to allow discharge of storm flow without causing cellars to be flooded, separate sewers for sanitary sewage being confined to the lower elevations from which the sewage can be pumped into the interceptors or directly to the disposal works. In situations where suitable storm water outlets are conveniently close and where slopes are favorable to rapid runoff a separate system has the advantage and will in all probability cost less. From the standpoint of sewage treatment and particularly in situations where complete treatment of the sewage is required it seems logical to favor the separate system and unquestionably there appears to be a growing feeling that in the future the separate system should be adopted in such situations unless the construction costs of the sewers substantially outweigh other considerations.

Unfortunately there have been a number of cases where sewers that were obviously intended to carry only sanitary sewage have become overloaded by the addition of roof water and also by the addition of water from surface drains. If a sewer is designed only for sanitary sewage, then connections thereto from roof drains and surface drains should be prohibited and the ordinance in respect thereto should be rigidly enforced, otherwise flooding of cellars and basements may occur with resultant damage for which the municipality may be liable. In constructing new systems, particularly in the smaller municipalities, it may be found expedient on account of cost to adopt the separate system, constructing the sanitary sewers initially and leaving to some future date the construction of storm sewers.

In some town planning schemes the tendency seems to be to favor wider streets and boulevards and it is conceivable that such situations will influence the selection of the type of sewer.

### *Other Influences Affecting the Sewerage System*

In addition to the factors already dealt with, consideration must be given to the layout of streets and to the existing main sewers, as these may warrant modification of the general plan. Geology is another factor that may influence and require modification of a sewer plan in the interests of economy. These and other local conditions are worthy of study. In some instances provision will have to be made for receiving and treating the sewage from a suburban municipality, or municipalities, in order to obtain a satisfactory sewerage plan for the whole area.

### *Sewage Treatment and Sludge Disposal*

Today there are numerous processes and types of plants in use in the treatment of sewage ranging in effectiveness from coarse screening and plain sedimentation to the complicated and elaborate plants capable of producing highly purified effluents.

It must be recognized that a sewage treatment problem presents two separate phases, one the treatment of the sewage to produce an effluent suitable for the point of disposal, and the other the handling and disposal of the solids removed from the sewage. Both phases will be influenced greatly by local conditions. In evaluating degrees of treatment of sewage the accepted yardsticks are the B.O.D. test and the removal of suspended solids. By weighing these against the volume of dilution water and studying the oxygen balance, the sanitary engineer can determine how far treatment must be carried to insure meeting the standards of control required for the receiving water. Having decided upon the degree of treatment to be attained, consideration of the processes to be employed and the type of plant best suited to the local conditions should be a matter of serious study.

The use of chlorine in connection with sewage treatment has gained in favor in recent years; it is used extensively for disinfection of effluents. Other uses are for the control of odors, sludge bulking, filter pooling and as an aid in grease removal. In addition to those mentioned other special applications are reported and there appears to be a great deal of interest in research work generally having to do with the use of chlorine. Even in the case of complete treatment there are plants where the effluent is chlorinated during the summer months to reduce bacterial contamination as a safeguard to bathing beaches. It is expected that chlorination will continue to be an integral part of sewage treatment.

The handling and final disposal of the solids removed from sewage has presented many problems that have been the subject of much study and research in recent years. One of the most notable advances has been that of sludge digestion by means of which the solids removed from the sewage by sedimentation are digested in separate tanks under controlled temperature conditions. The digested sludge can be readily dried on sand beds or mechanically dewatered on filters without giving rise to the offensive conditions that made the handling and disposal of sludge so difficult in the earlier plants. The gas evolved in the digestion process is used for heating the sludge, for heating structures and in a number of cases is utilized to develop power. In addition to overcoming the offensive characteristics of raw sludge, sludge digestion will be warranted in the majority of cases on economic grounds.

Much progress has been made in mechanical dewatering although in the smaller plants drying on sand beds will generally be more economical. Elutriation of the digested sludge prior to mechanical dewatering has come into favor as by this means the amount of chemical required to condition the sludge is substantially reduced.

In respect to final disposal of the sludge the general practice is to haul the dried sludge from sand beds or mechanical filters to areas where it can be used for filling or where it can be taken for use on the land.

There have been many views expressed concerning the final disposal of sludge on the land and whether or not this practice is consistent with modern public health standards. The consensus of opinion, however, seems to recognize the use of digested air-dried sludge or heat-dried activated sludge on crop lands. In the case of gardens the feeling is that the sludge should be spread and spaded in, and should not be used where raw-edible vegetables are to be grown.

More recently there has been some attention to the disposal of digested sludge in the liquid state, hauling it in tank trucks to farms. On economic grounds disposal in this manner may be attractive in some instances but it is a method that offers likelihood of objectionable odor and public health hazard. It is not felt that the practice will become established except in the case of some small municipalities where suitable crop lands or remote disposal areas are available.

Incineration is a recent contribution to final sludge disposal and in a number of cases consideration of its adoption will be justified. Such cases for the most part will be confined to the larger centers where the great volume of sludge that must be disposed of presents many problems in transportation, disposal areas and handling that can be eliminated by incineration or by heat-drying. Some advocates of incineration claim that its adoption removes the necessity for sludge digestion. Incineration of sewage sludge along with garbage has attracted attention in some places. Also, digestion of garbage along with sewage has received some attention. These different processes and combinations are mentioned because of their importance to sludge disposal and to emphasize the necessity for studying thoroughly each particular problem in the light of the local conditions and prevailing practices in order to insure a proper solution of the problem and the adoption of the best plan in all the circumstances.

In the matter of sewage treatment there appears to be plenty of opportunity for a large development in this country. As previously mentioned, only 115 municipalities have treatment plants in operation at present and of these about 40 afford primary treatment only.

The selection of the type of treatment plant and the devices and processes to be employed for treating the sewage and disposing of the sludge are matters for considerable study. It is increasingly evident that there will be greater insistence on the part of the health authorities for complete treatment and that lesser degrees of treatment will only be approved in situations where the receiving water affords a large measure of dilution and where neighboring municipalities are not dependent on the body of water or stream for their water supply or for bathing.

### *Trade Wastes*

Of the many problems in sanitation with which we must deal, none is so perplexing as that presented by trade wastes. The solution demands close co-operation between sanitary authorities, municipalities and industry itself. To the credit of many industries let it be said that large sums of money have been spent in research and in efforts for the recovery and utilization of waste, but despite accomplishments in this direction much remains to be done and the problem has recently been accentuated by new processes developed to meet demands of war. In many cases much can be accomplished by treating these wastes at the source. In some municipalities the authorities have hesitated to impose restrictions on local industry but where by screening and settling wastes from canneries, meat packing plants, tanneries and others at the plants will prevent nuisance in the sewers and will overcome offensive and costly operation of the municipal sewage treatment plant, it is logical and reasonable to do so.

## Postwar Construction

Many of our present towns and cities have grown up on coastal waters and on the shores of lakes and along rivers that offer natural advantages for recreational pursuits, for parks and landscaping but in so many cases the advantages afforded by such blessings have been lost as these waters have become polluted. In this province and elsewhere in Canada we have instances where cities, towns and industries continue to defile and pollute streams, lakes and bordering waters to the great detriment not only of the immediate communities but also to regions bordering these waters and particularly neighboring municipalities situated downstream.

It was only natural that our pioneer industries, saw mills, grist mills, tanneries, woolen mills and pulp mills, sought sites on the banks of rivers and consequently communities grew up around them. Sanitation in those days had not become a municipal problem, or at least not recognized as such, and as communities grew and populations became more concentrated drains and sewers were constructed here and there to suit some local need and generally such outlets were carried to the nearest watercourse. However, in the light of our knowledge of the art of sanitation and sewage disposal today, there is little justification for such practices or for withholding remedial measures to correct them. The situations in some municipalities can be rectified at moderate expense, in others the expense will be considerable, and possibly in some instances beyond the capacity of the municipality or community to undertake alone. It is to be hoped that in the financial arrangements for postwar construction the necessity for carrying out these works will be recognized.

So long as many municipalities lack adequate water and sewerage systems and so long as the present filthy and insanitary conditions of many of our natural waters remain, it will be difficult to justify expenditure of public funds on some of the dubious schemes and fantastic projects proposed for postwar construction.

# PLANKTON PRODUCTIVITY OF CERTAIN SOUTH-EASTERN WISCONSIN LAKES AS RELATED TO FERTILIZATION

## II. Productivity

By James B. Lackey

*Senior Biologist, United States Public Health Service, Cincinnati, Ohio*

Those unused plants we term weeds, growing on a tennis court or in a cotton field, have a high, easily recognized nuisance quality. The surface waters of lakes frequently support a huge crop of floating or suspended microscopic plants, along with occasional minute animals. These may be weeds as far as their nuisance quality is concerned. By definition such floating or suspended forms are termed plankton; there is a standing crop of plankton in lake waters at all times, and local or short-lived dense aggregates are usually referred to as blooms. Some plankton is desirable; some blooms are highly objectionable. Blooms usually occur in lakes that are relatively small, moderately hard and shallow. There is some evidence that blooming is rare except in temperate zone lakes. Because of the ability to reproduce quickly, plankton may develop into a bloom within a few hours from a practically invisible standing crop. Blooms usually consist of a single species.

Plankton plants and animals lead three types of existence. If colorless, such as animals, bacteria or other fungi, they may be holozoic (ingest solid food) or saprophytic or saprozoic (absorb dissolved food, either organic or inorganic). If green, blue-green, brown, yellow, olive green, red or purple, they practically always contain chlorophyll and are holophytic in habit, capable of living on inorganic food. Among these lower plants and animals the exact nutritional requirements are very imperfectly known. We are also ignorant of the precise nature of many associations which occur too frequently to be without significance.

Such imperfect knowledge explains why plankton blooms have so long been a puzzle. It is unnecessary to cite the abundant literature dealing with it. Welch (1) sums up the matter by saying there is no single index of productivity for lakes, and Hutchinson (2) concluded that "in general, clear-cut correlations between chemical conditions and the qualitative composition of the plankton are not to be expected. . . ." Under these conditions, and with findings showing the cosmopolitan distribution of microscopic plants and animals, it is easy to conclude that almost any large body of water contains all the necessary materials to support some of practically every plankton species. Therefore, it may be expected that, if sufficient nutrient material be present, large growths will occur. The correctness of this is seen in the use of sewage in Germany to fertilize fish ponds, in the enrichment of plankton for shell-fish by the use of commercial fertilizer (3), in the large plankton increase reported by Juday (4) in Weber Lake, Wisconsin, following the application of soy bean and cotton seed meal, in the great increases of river plankton (5) below cities whose treated or untreated sewage enters the rivers.

Since the obnoxious blooms in the Madison lakes consist of chlorophyll-containing plants it might be inferred that they are at least partly due to fertilization with N–K–P compounds, much as commercial fertilizer of this type is used for a successful cotton crop. Sawyer has shown in the first section of this paper that such fertilization is indeed a fact.

TABLE 1.—*Physical and Chemical Characteristics of Certain Southeastern Wisconsin Lakes*

| Lake | Direct Drainage Area (sq. mi.) | Lake Area (sq. mi.) | Mean Depth (feet) | Alkalinity (Range) (p.p.m.) | Inorganic Nitrogen | | Inorganic Phosphorus | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Summer Minimum (p.p.m.) | Winter Maximum (p.p.m.) | Summer Minimum (p.p.m.) | Winter Maximum (p.p.m.) |
| *Mendota | 264 | 15.20 | 39.7 | 145–180 | 0.06 | 0.36 | 0.01 | 0.03 |
| *Wingra | 6 | 0.75 | 8.9 | 144–250 | 0.07 | 0.53 | 0.01 | 0.02 |
| *Monona | 32 | 5.44 | 27.5 | 155–194 | 0.07 | 0.91 | 0.01 | 0.10 |
| *Waubesa | 46 | 3.18 | 16.1 | 150–230 | 0.19 | 2.49 | 0.24 | 0.57 |
| *Kegonsa | 71 | 4.91 | 15.1 | 150–236 | 0.07 | 2.03 | 0.16 | 0.35 |
| Como | 9 | 1.45 | 6.5 | 178–261 | 0.09 | 0.19 | 0.01 | 0.01 |
| Delavan | 35 | 2.83 | 26.2 | 126–182 | 0.06 | 0.87 | 0.01 | 0.07 |
| Geneva | 36 | 8.76 | 64.7 | 118–182 | 0.05 | 0.14 | 0.01 | 0.01 |
| Koshkonong | 2,533 | 14.80 | — | 119–292 | 0.12 | 1.32 | 0.01 | 0.06 |
| La Belle | 14 | 1.77 | 10.8 | 168–203 | 0.07 | 0.26 | 0.01 | 0.01 |
| Lauderdale (Mill) | 12 | 0.46 | 8.2 | 150–212 | 0.06 | 0.20 | 0.01 | 0.01 |
| Nagawicka | 46 | 1.43 | 36.1 | 144–218 | 0.08 | 0.88 | 0.01 | 0.03 |
| Nemahbin (Upper) | — | 0.42 | 39.5 | 160–199 | 0.05 | 0.65 | 0.01 | 0.02 |
| Oconomowoc | 3 | 1.27 | 29.8 | 161–196 | 0.04 | 0.15 | 0.01 | 0.01 |
| Okauchee | 10 | 1.65 | 39.6 | 143–206 | 0.05 | 0.21 | 0.01 | 0.01 |
| Pewaukee | 20 | 3.59 | 12.8 | 165–215 | 0.06 | 0.21 | 0.01 | 0.01 |
| Rock | 11 | 1.91 | 20.0 | 151–182 | 0.07 | 0.11 | 0.01 | 0.01 |

* Madison, Wisconsin, lakes.

## Investigation and Findings

Five lakes at Madison and eleven in Southeastern Wisconsin were studied. Table 1 gives certain physical and chemical characteristics for these lakes and for three rivers used for comparison. Koshkonong Lake is considered as a river for it is virtually an enlargement of the Rock River. All of them are of moderate hardness, all are small, and only Geneva exceeds 40 feet in mean depth. Mendota alone has a large drainage area. Only three of them, Monona, Waubesa and Kegonsa, receive large urban drainages, and these last two are the indirect, but quick recipients of urban drainage from Monona, the distance between the three being very short. The Madison lakes were studied intensively, but samples from the other lakes were taken once monthly, or less. Therefore, only six sets of samples from each lake are herein considered. For the Crawfish River only three were available. These were taken in April, May, July, August, October and November. Chemical analyses at these times showed enough nitrogen and phosphorus to support some plankton.

Figure 1 shows the number of plankton species present in each of the lakes and rivers. It varies from 75 in Lakes Mendota and Nemahbin to 146 in Rock Lake, and 158 in the Rock River. The largest and the smallest lakes have the least variety of species. Rock Lake with a

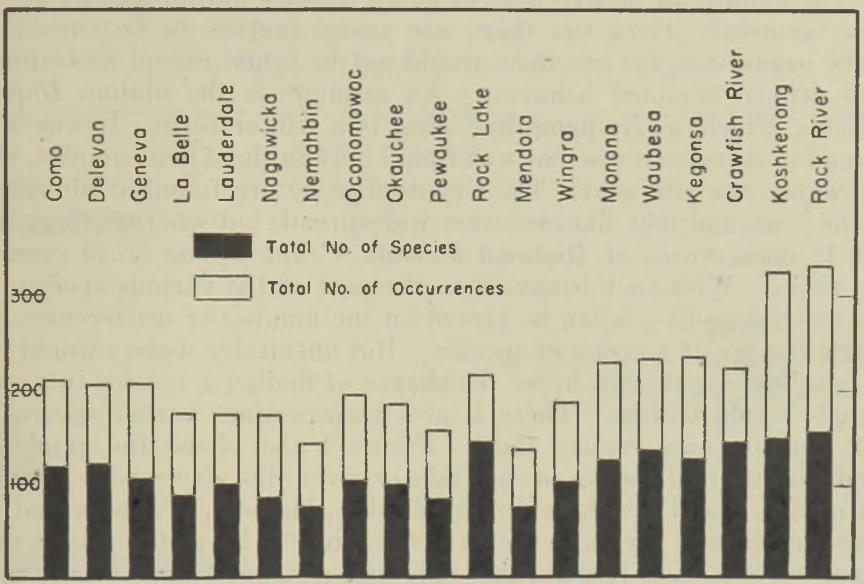


FIGURE 1.—The total number of species and the total number of occurrences of all species in 16 Wisconsin lakes and three rivers. For each station, 6 samples, taken from April to November, are plotted, except that there are only 3 for the Crawfish River.

drainage area of 11 sq. mi. (only three of the lakes have smaller ones), and exceeded in size by seven other lakes, has the largest number of species. Little if any significance can be attached to the number of species present, and it is highly probable that, if a larger number of samples had been examined, as many as 90 per cent of the species would have been found in each lake. The greater number for the rivers is largely due to the current; some species which in lakes would normally be found on the bottom are swept into suspension by the current in rivers, and appear in the samples. This is not invariably true; a few species seem to be characteristic of rivers, while a few lake species have not thus far been encountered in rivers. Due to the small number of samples considered herein, it is easy to note certain species which occurred in only one of the lakes or rivers. This was true for the following groups:

| | |
|---|---|
| Blue-green Algae | 4 species |
| Bacillarieae | 2 species |
| Heterokontae | 2 species |
| Cryptophyceae | 2 species |
| Chrysophyceae | 4 species |
| Euglenophyceae | 12 species |
| Volvocales | 15 species |
| Green Algae | 10 species |
| Rhizopoda | 6 species |
| Flagellata | 4 species |
| Ciliata | 12 species |

A few of these may be termed rare organisms, but the greater part of them are common, and would eventually have been found in most if not all of the waters under study. Some, however, are probably peculiar to the situation where found. Thus *Diplostauron pentagonum* has never been seen by the writer except in the waters of Monona, Waubesa and Kegonsa, although other workers have recorded it elsewhere. To summarize, however, the list of species is large and does not indicate marked differences between the several lakes examined.

The number of occurrences of single species and of all species was also recorded. Here too there are many factors to be considered. Some organisms, for example, would not be found except according to well defined seasonal behavior. An example is the diatom *Diatoma hiemale,* which, as its name indicates, is a winter form. It was widespread in its occurrence, but was found only in the April samples, when the water was still cold. The Cryptophyceae are found at all seasons of the year, and they likewise were widespread; but whereas there were but 12 occurrences of *Diatoma hiemale, Cryptomonas erosa* occurred 100 times. With such behavior on the part of the various species, not too much dependence can be placed on the number of occurrences of a single species or a group of species. But unsuitable waters would tend to have less organisms, hence the chance of finding a species in a small sample would be less. There is also a succession; winter species die out, but new ones replace them. Figure 1 also shows the number of occurrences of all species in each lake or river; the rivers have the highest numbers, and the three fertilized lakes, Monona, Waubesa and Kegonsa, are next. Actually the Crawfish River is lower than these three lakes, but it is to be recalled that only half as many samples were taken from it.

If fertilization is successful for all or certain species, then the numbers of individuals for all or certain species should increase in Lakes Monona, Waubesa and Kegonsa. This constitutes the real test of the question. There are available four different checks on this statement, as follows:

(*a*) Total number of all organisms counted.
(*b*) Total volume of all organisms counted.
(*c*) The number of blooms occurring in the various situations.
(*d*) The comparative numbers of certain species.

The total number of all organisms will not alone suffice, because of the great divergence in size of various ones. *Chrysococcus rufescens,* for example, is a sphere 5 microns in diameter, while certain Strombidia may be thought of roughly as spheres 50 microns in diameter. The volume of the former would be about 65 cubic microns, of the latter about 65,000 cubic microns, or a thousand times greater. Even greater discrepancies occur in regard to the amounts of *Microcystis aeruginosa* which may be present. This organism forms irregular clumps which may vary from a mass of ten or twenty cells, each about 5 microns (2.5

microns to 6.0 microns variation) in diameter, to masses three or four millimeters in diameter.

Figure 2 shows the total numbers of all plankton organisms counted. Monona and Waubesa exceed all other lakes and rivers, although Koshkonong (Rock River) virtually equals Waubesa. Kegonsa is lower, being exceeded by the river stations and by Wingra. However, in April there was a bloom of the diatom *Fragilaria capuchina,* a chain-forming type, in Kegonsa, and because of the numbers of this the sample was set aside to count this one species later. This sample was lost before the count was ever made, but this single bloom would have brought the total numbers in Kegonsa up to a considerably higher figure.

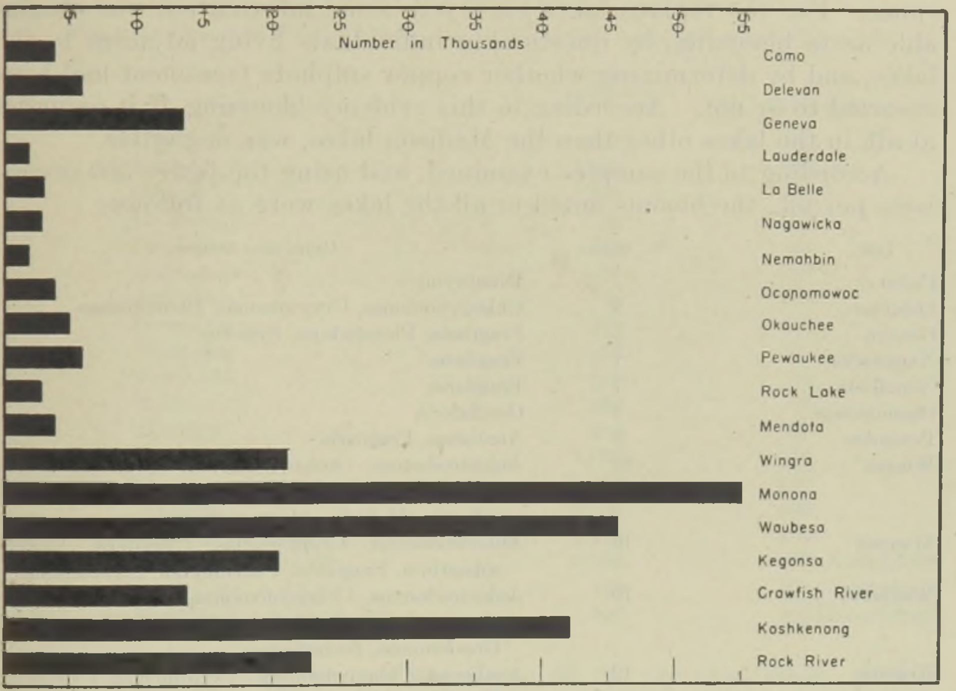


FIGURE 2.—The total number of organisms in samples examined from Wisconsin lakes and rivers. For each station, except the Crawfish River, 6 samples taken from April to November are represented.

The total volume of the organisms tabulated has not been fully worked out, as it is a long and laborious process. Monona, Waubesa and Kegonsa seem to have more of the larger organisms than the other lakes: such large forms as the diatom *Stephanodiscus astraea,* the blue-green algae *Anabaena spiroides* and *Microcystis aeruginosa,* the Volvocale *Pandorina morum,* and the large olive green flagellate *Cryptomonas ovata* were more abundant in the samples from these lakes than the others. Preliminary figures indicate for Monona a volume of about five times the highest figure for any other lake except Wingra. Waubesa and Kegonsa seem to have about four times as great a volume of plankton as any other lake except Wingra. These are rough figures, but will not be subject to much modification.

The third consideration, the number of blooms occurring in the lakes, is also difficult to evaluate critically. There is no definite criterion as to what actually constitutes a bloom, and it is easily possible for blooms to be missed when they last only a day or so. For purposes of this work, it was decided that, when an organism reached or exceeded 500 per ml. of raw water, it would be termed a bloom. For very small organisms, as *Chlorella* sp., this might not be noticeable in the water, but for organisms such as *Ceratium hirundinella* or *Pandorina morum* vivid discolorations of the water would be evident. Neither would blooms be noticeable to the layman if they did not produce some nuisance. For the various lakes surveyed, some information was obtainable as to blooming, by questioning individuals living adjacent to the lakes, and by determining whether copper sulphate treatment had been resorted to or not. According to this evidence blooming, if it occurred at all, in the lakes other than the Madison lakes, was negligible.

According to the samples examined, and using the figure 500 organisms per ml., the blooms noted in all the lakes were as follows:

| Lake | No. Blooms | Constituent Genera |
|---|---|---|
| Como | 1 | Dinobryon |
| Delavan | 3 | Chlamydomonas, Cryptomonas, Rhodomonas |
| Geneva | 5 | Fragilaria, Phormidium, Synedra |
| Nagawicka | 1 | Fragilaria |
| Nemahbin | 1 | Fragilaria |
| Oconomowoc | 1 | Oscillatoria |
| Pewaukee | 2 | Anabaena, Fragilaria |
| Wingra | 14 | Ankistrodesmus, Aphanizomenon, Chlamydomonas, Cryptomonas, Dinobryon, Fragilaria, Gomphosphaeria, Melosira, Microcystis |
| Monona | 10 | Ankistrodesmus, Cryptomonas, Cyclotella, Dictyosphaerium, Fragilaria, Phormidium, Scenedesmus |
| Waubesa | 19 | Ankistrodesmus, Chlamydomonas, Cryptomonas, Cyclotella, Fragilaria Melosira, Navicula Phormidium, Rhodomonas, Scenedesmus |
| Kegonsa | 12 | Anabaena, Chlamydomonas, Cryptomonas Cyclotella, Fragilaria, Melosira, Microcystis, Rhodomonas |

This list is very instructive. Each of the three fertilized lakes showed a variety of organisms attaining high numbers in the course of the study, whereas the remaining lakes, except Wingra, did not remotely approach these three. Six of them, including Mendota, did not have a single genus which showed 500 individuals per ml. in the samples examined, although in all of the samples from Mendota, which includes many more than those reported in this paper, there were four genera which attained or exceeded 500 per ml. on 8 occasions. Wingra is somewhat of an enigma in its productiveness; there is no satisfactory accounting for it thus far.

In addition to the tendency noted above, it should be mentioned that Monona, Waubesa and Kegonsa each had a bloom of *Microcystis aeru-*

*ginosa* during the study. This is not shown, because the clumps of Microcystis were relatively few in number, but their large size more than compensated for counts below 500.

Finally, the evidence for high production in Monona, Waubesa and Kegonsa is found in the numbers of *Cryptomonas erosa.* This olive green flagellate is common, and occurred in all of the lakes and rivers. In addition it occurs during most of the year. It is found in clean water, but highly polluted waters are unfavorable to it. Present data indicate that its maximum occurrence is in the zone downstream from sewage treatment plants, where mineralization is practically complete, but where some traces of organic matter may still be found and where there is a B.O.D. range between 1.0 and 4.0 parts per million. Table 2

TABLE 2.—*Numbers of Cryptomonas erosa in Each of the Lakes and Rivers Examined*

| Lake or River | Total Cryptomonas Count | Per Cent Occurrence |
|---|---|---|
| Como | 898 | 100 |
| Delavan | 1,788 | 100 |
| Geneva | 351 | 100 |
| La Belle | 370 | 100 |
| Lauderdale | 528 | 83 |
| Nagawicka | 161 | 100 |
| Nemahbin | 156 | 100 |
| Oconomowoc | 268 | 100 |
| Okauchee | 264 | 100 |
| Pewaukee | 146 | 83 |
| Rock | 384 | 67 |
| Mendota | 251 | 100 |
| Wingra | 1,696 | 100 |
| Monona | 3,113 | 100 |
| Waubesa | 4,852 | 100 |
| Kegonsa | 3,266 | 100 |
| Koshkonong (River) | 5,700 | 100 (7 samplings) |
| Rock River | 928 | 100 (7 samplings) |
| Crawfish River (3 samples) | 402 | 100 (3 samplings) |

shows the numbers of this one species in all the samples taken. It is a suitable organism since its occurrence was 100 per cent in all but three of the lakes. The high numbers in Monona, Waubesa and Kegonsa indicate the fertility of these three lakes, there being almost two or three times as many of these flagellates in these three lakes as in Delavan while Waubesa had about 33 times as many as Pewaukee. Since Monona, Waubesa and Kegonsa are the highest lakes as to inorganic nitrogen and inorganic phosphorus content, any comment seems unnecessary. It might be noted, however, that Koshkonong and Delavan, also high in numbers of this flagellate, are correspondingly high in inorganic nitrogen and phosphorus. Wingra is a warning against pursuing this reasoning too far, and indicates there are other factors which should be considered.

## Summary

The facts cited tend to support certain general views. 1. All of the lakes contain about the same species of plankton algae and protozoa, hence all contain the minimal necessary fertilizing elements. 2. Even using samples as small as half a liter or less, the frequency of occurrence of each species is great for each lake. 3. The actual numbers of all organisms in any lake is a poor criterion of production because of the great discrepancy of organism size. 4. The number of blooms, or of high peaks of production, for any or all species, appears to coincide with the amounts of plant nutrient material available. 5. Those lakes receiving the greatest amounts of nitrogen and phosphorus, and by inference other plant nutrients as well, tend to show the greatest total number of organisms, the largest number of blooms, the greatest volume of animals and plants, and the greatest number of any particular species.

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# Contributed Discussions

Contributed discussions of papers presented in *This Journal* are invited. Such discussions will be considered for publication if submitted to the Editor within six months of the distribution of the issue containing the original article.

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## DESIGN OF FINAL SETTLING TANKS FOR ACTIVATED SLUDGE*

### A DISCUSSION

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Test results reported by Mr. Anderson in the January, 1945, issue of *This Journal,* and which in part reflect findings and observations of early investigators relative to sludge floc behavior in final settling tanks, have been examined with interest by the writer. As a former wet nurse to the aerobes at Milwaukee during the infancy and growing pang period of activated sludge process development there, the writer, feeling that he may be able to offer something constructive, wishes to comment somewhat generally upon the author's interesting narration of his recent observations.

That activated sludge settling characteristics differ materially from those of the more ordinary sludges of which we have knowledge, is fairly well recognized not alone by engineers who participated in pioneering work, but also by those who subsequently engaged in design and operation phases of the process.

The fact that some settling tanks perform more efficiently than others, a fact which by certain of the author's implications appears to elicit an element of speculation as to reasons why, is no doubt due in large part to personal equation factors involving the degree of conception and interpretation displayed by the designer, in relation to basically indicated necessities, non-essentials, and "must nots."

If a group appraisal of currently employed designs of all types were attempted, it might well incorporate the following categories: (*a*) designs which over-emphasize structural economy and under-emphasize adaptation, (*b*) those which emphasize neither of the foregoing, and (*c*) designs reflecting attempts to reconcile basic necessities and structural economies, and the broader phase of over-all plant operating efficiency.

Early investigators at Milwaukee were vitally concerned relative to settling and concentrating tendencies of aerated sludge floc, and also

* Original paper by Norval E. Anderson published in *This Journal,* 17, 1, 50 (January, 1945).

with the intimately related problems of how best to conform designs to characteristic settling patterns observed and studied continuously over a period of years.

During those years many forms of sizeable scale tank units were conceived, constructed and operated, and early in the work, the definite conclusion became apparent that designs heretofore adapted to other treatment processes were not adaptable to the practice of activated sludge.

Settling currents observed by Mr. Anderson, particularly the up-turn and counter variety, dictated to the Milwaukee engineers the wisdom of developing designs calculated to avoid creating such currents. It is unfortunate, perhaps, that negative findings have been so consistently perpetuated and magnified through intervening years.

A round concrete tank, 30 feet in diameter with center inflow and peripheral outflow, was constructed at Milwaukee in 1916 and was referred to as the "demonstration" tank. That the name was well chosen was proven in subsequent operation; the demonstration having left little doubt in the minds of the designers on the question of erroneously conceived adaptations. In retrospect, it was an amazing demonstration of how not to attempt to harness and confine current-conscious floc, frantically but hopelessly seeking a favorable opportunity to rest and concentrate (we had hoped), while at the same time unerringly over-populating the outgoing effluent at an alarming rate.

This experience was among the first of many surprising introductions to sludge floc current phenomena, and it is vividly recalled that personal reactions thereto were not strictly of the "hail-fellow-well-met" variety. It did, however, serve the very useful purpose of indicating the necessity for a more compatible degree of understanding between the two major elements involved, namely, the human and the inanimate.

If a "rose (I use the term loosely) by another name smells just the same," the sludge floc density currents observed and studied by Mr. Anderson, and earlier by investigators at Milwaukee, would, through the similarity of their "wanderlust" tendencies, appear to be reasonable facsimiles of one and the same thing. Continued exploratory work with the 30-foot diameter experimental tank, and other trial units, some of which were of partial glass construction and illuminated from within, disclosed certain facts which our forethought had failed either to anticipate or appraise adequately. For example, the cross, up-turn, and counter currents observed, all of which are functions of velocity and related to elementary hydraulic phenomena, could have been anticipated without trial, but a trial was obviously justified to disclose the extent to which those currents retarded settling and reduced tank efficiency. While reduced rates of inflow reduced disturbances, because of reduced velocities, the currents were not eliminated nor even sufficiently minimized to rate the favor of the designers toward the principles which the tank design incorporated.

Gravity displacement of sludge floc attributable to density, when uninfluenced by externally applied flow velocities, occurs in an essentially vertically downward direction, as will be shown later. Such lateral floc movement as invariably occurs in the presence of the applied flow velocities of continuous settling, responds to rate increase or decrease as flows admitted are augmented or diminished.

The writer has no personal knowledge of any natural tendencies inherent in concentrating sludge when floc dispersion appears to be uniform, which could cause it to flow laterally of its own accord. Unbalanced concentrations of solids, however, function differently, and have frequently been observed to cause lateral movement as the concentrate levels off and expands laterally into adjacent zones of lesser density, due to the momentum imparted by its greater density. These observations indicated to the Milwaukee engineers, as they may also indicate to Mr. Anderson through his similar observations, that a central heavily concentrated point of inlet tending to pyramid solids is far less desirable than several inlets of combined greater area which accomplish a wider and less concentrated degree of dispersion, and minimize pyramiding and its effect in creating density currents. In the design of the Milwaukee tanks, the North side tanks, and, in subsequent designs by the writer, the latter of these two methods has been preferred and employed.

It may be deduced that the concentrated inlet method may produce undesirable disturbances in any tank, varying in degree with the shape of a tank, but, whether the shape be round, rectangular, octagonal, or square, multiple points of inlet can be adapted. The form of tank used may be at the discretion of the designer and depend upon his evaluation of structural factors, space and other economies.

The writer is definitely apprehensive of results obtainable in tanks which fail to take the foregoing indicated essentials into account. Figures 1 and 2 show diagrammatic adaptations of round, square, and rectangular tanks, all of which, in the writer's judgment, could be conformed reasonably well to good practice, and any one of which, for a given sewage, could be expected to produce a good standard of effluent and a fresh sludge of at least 1 per cent solids concentration or higher.

The most outstanding example of a design which would appear to violate nearly all of the basic essentials, in the writer's judgment, is a rectangular tank to which the flow is admitted at one end and the effluent is taken off at the other and, to further add to the chaos, the sludge, if it could qualify as such, being calculated to move throughout the length of the tank to a single point of discharge.

Tank depth necessary appears in the light of present knowledge, to depend mainly upon the factors of sludge settleability (Index), and upwardly expanding floc dispersion in the settling and concentrating zones, the extent of the latter depending in turn upon degree of disturbance due mainly to the higher velocities prevailing at maximum peak rates of flow. Observations of the maximum extent of likely sludge blanket depth increase at Milwaukee led to the adoption of a 15-foot liquid depth for the tanks, and, except for infrequent instances of "bulking," it has been possible to maintain clear zones sufficient in depth to consistently assure a good quality of effluent.

In some of the writer's later designs, where the ratio of peak to average rates of flow was less than at Milwaukee, a depth of 12 feet has been used successfully.

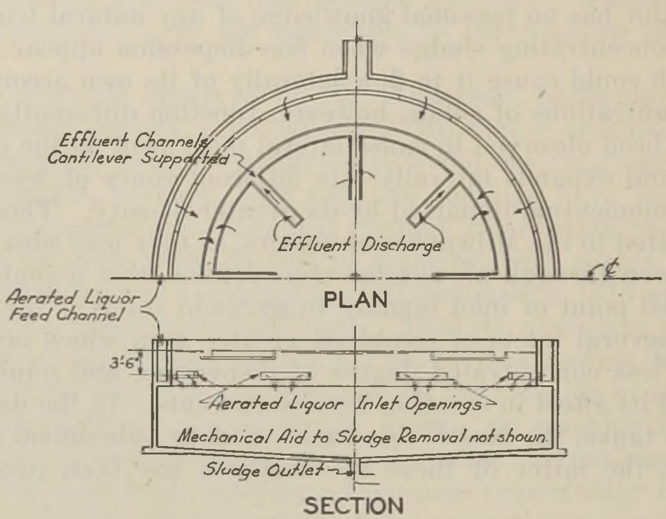


FIGURE 1.—Circular tank.

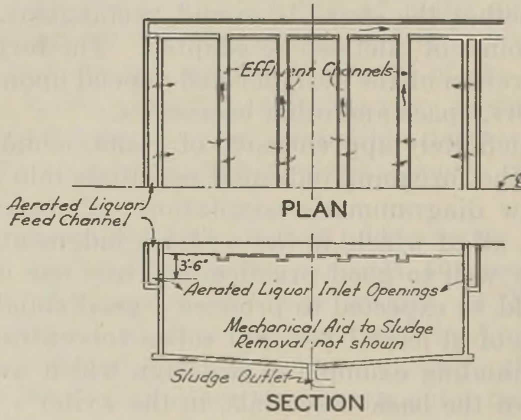


FIGURE 2.—Square or rectangular tank.

Regarding the question of optimum tank size, it is the writer's thought that practical considerations relative to the number of units desirable for a given plant layout may outweigh those of a strictly technical character. Flexibility of operation is important and in a large plant the units may be so sized that with one or more down for repair simultaneously, an unduly heavy load will not be placed upon those remaining in service. The writer is of the further opinion—again referring to the largest plants—that facilities such as are advised frequently herein for inletting aerated liquor, and for outletting effluent and sludge, are practicable and economically feasible without regard necessarily to tank area.

Mr. Anderson's inwardly positioned concentric effluent channel design for a round tank appears to be a proper adaptation and should justify his conception of its desirability. The cause of the up-turn and counter currents, however, still remains and may be expected to continue to function as a retarding factor to settling, so long as center feed is employed. In this connection, the writer wonders whether Mr. Anderson, who appears to prefer round tanks to square or rectangular forms, has given thought to interval submerged peripheral inflow as a further means of obtaining improved tank performance.

Conclusions of the writer favor designs which eliminate vertical walls so positioned as to offer surface against which currents of floc might impinge and be deflected upward and counterwise into clear zones. They likewise favor low velocity inletting in the interest of minimizing cross currents.

Again referring to Mr. Anderson's channel design, it occurs to the writer that increased overflow rates, reduced rates of overflow per unit of channel, or reduced velocity of approach to the channel could be obtained if cantilever supported connecting lengths of reduced cross section channel were to be extended radially inward at intervals, from the concentric channel toward the center of the tank. At intervals where such radial channels might occur, the cantilever main channel supports could be designed as suitable extensions for supporting the branch channels. The permissible length of branch channels would be limited, probably by the diameter assumed for the floc dispersion area of disturbance at the center of the tank.

Being duly mindful of the fact that for a similar degree of concentration obtainable in 30 minutes in undisturbed settling, the detention time required in a continuous displacement tank may range from 4 to 5 times that long, affords a reminder to emphasize the magnitude of the extent to which settling and concentrating processes are retarded by multi-directional currents present within the tank, the extent of concentration within the unit being measured by the yardstick of the moisture content of the sludge withdrawn.

The sensitivity and mobile potentialities of sludge floc, both concentrated and unconcentrated, as a result of its low specific gravity and relatively low static resistance, are such as to render it delicately susceptible to motion induced by currents, even those of a surprisingly low order. Possibly the following may serve to further illustrate this point.

Following the initial floc dispersion and velocity reducing stages prevailing upon inletting aerated liquor into a container, the phenomena of coagulation and gravity precipitation begin and the following activities have frequently been observed: As the downward velocity of floc accelerates due to its increasing size as a result of coagulation, the trailing reverse direction displacement currents induced, are, while of a necessarily low order, sufficient in magnitude to cause immediately adjacent floc of lesser specific gravity to rise vertically through substantial distances. Such rise continues at progressively decreasing rates until the initially imparted momentum is dissipated and a state of momentary equilibrium prevails, after which a secondary stage of coagulation and precipitation takes place. As reported by the writer in "Settling Characteristics of Activated Sludge," *Proceedings*, American Society of Municipal Engineers (1931), three clearly defined stages of floc precipitation have been observed to occur.

The concentration stages of bottom sludge deposit proceed in accord with logical expectations and known laws, the floc of greater densities moving into the lower zones, thus creating a stratified composite. In continuous settling, as practiced and as differentiated from that above described, the velocities of the various multi-directional currents resulting from aerated liquor inletting, and effluent and sludge outletting, plus secondary velocities attributable to density currents, introduce a complexity of settling retardation velocity factors which obviously are not susceptible to elimination. The velocities, however, are susceptible to control by designers if they become "low velocity" minded, and incline toward the selection of shorter travel distances for the essential aerated liquor and sludge flows, rather than toward longer ones.

The foregoing suggests multiple appropriately located effluent take-off channels instead of the single ones frequently and ofttimes erroneously used, and it suggests also the importance of using more than one point of removal for settled sludge. Further desirable velocity correction is obtainable by using larger aerated liquor submerged inlet openings, appropriately positioned horizontally and vertically.

The reasons for the designs as developed at Milwaukee became known to the designers prior to the time of design, and in much the same manner as they have since become apparent to Mr. Anderson through his observations of the activities occurring within the inner sanctum regions of settling tanks. It is hoped that continued exploratory work may tend to stimulate appreciation and more adequate recognition of fundamentals, which in the past appear to have been notably inconspicuous, in many instances, because of their all too frequent absence.

Verification, in part, of earlier findings afforded by Mr. Anderson's work, is of pronounced interest, and the writer commends the content of his paper to the attention of designers of activated sludge works. The methods described by the author for locating and studying density currents are unique, and to the best of the writer's knowledge similar ones have not been employed elsewhere previously. Continued investigational work, it is hoped, may indicate to Mr. Anderson, as it has previously indicated to others, that the currents with which he is concerned may assume a minor role in tank efficiency, as improved means for minimizing their importance are developed.

In closing, occasion is taken to reiterate the following which appears in a former paper by the writer.

"It would obviously be difficult to set up definite settling tank design factors applicable to all sewages and the sludge resulting therefrom, and conservative design assumptions must be made in the instance of each specific sewage."

# THE OPERATOR'S CORNER

## OPERATION INFORMATION EXCHANGE

Nothing gives us greater pleasure than to see the facilities of the Federation used to advantage. Consequently, we derived considerable satisfaction from the exchange of letters which took place between Superintendents Walter Sperry of Aurora, Ill., and Ted Lovell of Marshalltown, Iowa, after this office had brought them together for a mutual pooling of experiences in regard to metallic corrosion (*see "Tips and Quips" column, this issue*). Much of the content of the letters exchanged is believed to be of sufficient general interest to warrant publication.

"The advancement of fundamental and practical knowledge . . ." is a primary function of the Federation, and is so stated in its Constitution. To accomplish this objective for the benefit of those engaged in plant operation, we must first be advised of the nature of specific problems and, second, we must have knowledge of instances in which similar problems were met and solved, wholly or in part. The first requirement is easy to fulfill—inquiries regarding troublesome operation problems are welcome at the headquarters of your Federation and will receive careful attention. The second requirement, the availability of information leading to the solutions of these problems, is more difficult but would be less so if those operators who are successful in effecting solutions would let us hear about them! Yes, the latter statement is just a roundabout way of asking again for letters, notes or articles describing practical operation procedures, whether the problem involved is major or minor.

When an inquiry is received, a search is made for any answers which may be contained in the published literature. Then, an effort is made to recall individuals whose experience might have included the same problem and the inquiry is passed along. If no immediate solution or assistance can be suggested, the matter might be publicized in the *Journal* with a plea for aid or, if of sufficient general interest, it might be referred to a Federation committee for study. Furthermore, when adequate immediate advice cannot be offered, the problem is kept "on tap" for later attention in case something pertinent to it should be encountered.

Our headquarter facilities are modest but a real effort is made to help. The "Service" file now receives about 250 items each year, the inquiries covering such matters as technical problems, priorities, administrative matters, personnel placement and other things. Some measure of assistance has been given in nearly every case.

Let there be no hesitancy about using the central office of the Federation as an operation information exchange! There is much to gain and nothing to lose by such participation. Please keep in mind, however, that the exchange operates in both directions—that it is a "give and take" proposition. Everything possible will be done here to see that the answers get to the places at which they will do the most good!

W. H. W.

# W. P. B. RELAXES CONSTRUCTION RESTRICTIONS

## Order P–141 Revised

By amendments effective May 29, 1945, Order P–141 covering maintenance, repair and operation of sewage works now permits increased construction of facilities under simplified conditions. In announcing the amendments, M. D. Sullivan, Chief of the Sewerage and Sanitation Section of the Government Division of W. P. B., summarizes the revisions as follows (see *This Journal,* **16**, 6, 1250 (November, 1944) for Order P–141 as previously in force):

"The principal change in the Order relates to the increase from $1,500 to $25,000 in the net material cost of sewerage jobs, *including buildings,* which can be built without War Production Board authorization. An AA–3 rating and the allotment symbol MRO–P–141 is assigned for materials for such construction. Buildings for sewerage systems were formerly controlled by Order L–41. A revision of that Order eliminates any reference to buildings so that such construction can be incorporated under P–141.

"The AA–1 rating for materials and equipment for MRO purposes remains the same.

"Another important change relates to the exclusion from the definition of inventory, paragraph (a)(11), of materials to be used for plant additions. On the basis of this change, we thought it unnecessary to raise the $5,000 inventory limit now in the Order.

"In view of the increase to $25,000, Form WPB–3445 formerly required under paragraph (g)(2)(v) is no longer necessary for the types of projects described under paragraph (g)(2).

"There are a few other minor changes such as the omission of the provision in paragraph (g)(1) restricting the use of iron or steel pipe in house connections, and the omission in paragraph (f)(3)(iii) of the report when deliveries and withdrawals exceed the base period limits due to the maintenance and repair occasioned by acts of public enemy, sabotage, explosion or by fire or flood."

All inquiries and other correspondence pertinent to sewage works priorities should be directed to the attention of Mr. Sullivan in the War Production Board, Washington 25, D. C.

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# OPERATION OF SCREENS, GRIT CHAMBERS AND SEDIMENTATION TANKS *

By R. C. Merz

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## Screens

First of all, let us consider the function of a bar screen. The primary purpose of mechanically cleaned bar screens, or hand cleaned bar screens, is to protect the equipment which follows the screen in the treatment process and for that reason it should always precede all other equipment, including the grit chamber. Screens are necessary to protect pumps from injury, grit collector equipment from being fouled with

* Presented at Illinois Sewage Works Short Course, University of Illinois, Urbana, March 29, 1945.

rags, and to prevent clogging of gates, siphons, trickling filter nozzles and other plant items. The removal of screenings will reduce the volume of unsightly scum at settling tanks and minimize the formation of heavy scum layers in digestion tanks. In cases where prechlorination is practiced, it is essential that the large solid matter be removed by a screen since such materials are not readily penetrated by chlorine. In a few instances, it may be that a screen is the only treatment unit required. Where considerable dilution is available and it is possible to discharge the raw sewage directly into the receiving stream, screening should still be resorted to in order that the large solids will be removed and formation of unsightly scum blankets lessened. A third reason for using the screen is that it may be a substitute for sedimentation. In such cases, a fine screen is used, or one having openings of generally ¼-inch or less. At the Milwaukee activated sludge plant, for instance, a battery of fine screens takes the place of the usual primary sedimentation tanks. These are drum screens having slotted openings $\frac{3}{32}$-inch wide $\times$ 2 inches long. Although their use is not common at present, fine screens are being used to some extent instead of primary tanks preceding certain high rate filter processes.

Now a word about the hydraulic considerations at a screen chamber. A screen should be so designed that it will have ample capacity to pass the maximum flow, with the velocity through the bars not exceeding 2 feet per second. If a combined flow is being handled, where the peak storm flow greatly exceeds the peak domestic flow, it is safe to design on the basis of a velocity of 3 feet per second. As soon as velocities rise above these figures, several things happen almost simultaneously which can only result in trouble. Materials which may clog the pumps or cause some other damage will be forced through the bars; the screen will begin to plug rapidly; and the head loss will immediately begin to rise with equal rapidity. High head loss may put an undue strain on the equipment and will be directly responsible for an unwelcome plant surge as soon as the rack is cleaned. For those who have been experiencing any screening difficulties, or any plant operation difficulties traceable to the screening equipment, an investigation of the velocities in the screen chamber would be time well spent. If velocities are too high, they can be controlled through the use of weirs or baffles, whichever may be necessary. The minimum velocity obtaining ahead of a bar rack is also important. The screen channels should be of such size that the velocity in the channel does not drop below 1 foot per second at any time and cause deposition of grit or of organic solids. If velocities are known to be too low, it is comparatively easy to narrow the channel.

If the plant is served by a hand cleaned bar rack, and flows have increased to the point where an unreasonable amount of attention must be given the rack to keep it clean, the situation can be relieved by installing a mechanically cleaned bar screen which will give greater capacity. This piece of equipment is readily adaptable to an existing channel with practically no changes in the existing structure.

The approach to the bar rack is worthy of careful consideration. Too often the sewage is brought into the screen chamber from one side after which it is supposed to change course by 90° and flow through the rack. The result is a piling up of the debris on one side of the bar rack, resulting in an unbalanced load on the rack itself as well as the cleaning rake. The disadvantage is purely a mechanical one, but nevertheless of the type that gives the operator the most trouble. Where this condition exists, the design of a suitable baffle arrangement is suggested, with the aim of directing the flow along a desired course and causing it to reach the rack with reasonable distribution of the load it is carrying.

The bar rack, of course, performs the actual screening operation, and the bar spacing is of prime importance. Those who have a mechanically cleaned bar screen, or a hand cleaned rack, very probably have wished for a different one at one time or another. Those who contemplate the installation of a screen would do well to pay particular attention to the selection of the rack.

In the case of mechanically cleaned bar screens, a clear opening of 1 inch has been generally used and found to be quite satisfactory. There is, however, no reason why a smaller opening may not be used if deemed necessary due to any unusual conditions. A clear opening of ½-inch is the narrowest that is practical from a hydraulic standpoint, since the efficiency of that type of bar rack is very low. Bar spacing should be as large as practical and the thickness of the bar as small as practical in order to keep the efficiency as high as possible. For instance, a rack formed of ⅜-inch bars with ½-inch clear opening has an efficiency of only 57 per cent. A rack formed of 5⁄16-inch bars with a clear opening of 1 inch has an efficiency of 77 per cent. Although it is important to remove all of the large solids which would be injurious to the equipment or to plant operation, it is equally important to select a bar spacing which will keep the amount of screenings to be handled to a minimum, and permit the debris of smaller size to pass through for treatment in the normal plant process. A 1-inch clear opening adequately meets these requirements. The smaller the opening between bars, the greater will be the amount of screenings accumulated, and the greater will be the disposal problem.

Grand Island, Nebraska, for example, originally used a screen having ½-inch clear openings. This rack removed from 6 to 8 cubic feet per day of a very offensive, slow-draining material that far exceeded the capacity of the incinerator and created a definite nuisance. A new rack having clear openings of 1¼-inch was installed and the screenings volume immediately dropped to some 3 cubic feet per day. The material drained readily and was easily incinerated. No trouble with subsequent units resulted from this change, and the 3 to 5 cubic feet of screenings which then passed through the rack were handled much more readily as sludge than as screenings.

The disposal problem is not great for those who have screenings grinders, but if that arrangement does not exist, the screenings must be either buried or incinerated, and either method will require a great deal of manual labor.

A survey of sewage screen installations indicates that 42 per cent of all installations checked were using a rack having 1-inch openings. With a 1-inch opening between bars, an accumulation of about 3 to 5 cubic feet of screenings per million gallons can be expected. If the opening is narrowed down to approximately ½-inch the quantity accumulated jumps immediately to about 11 cubic feet per million gallons. If this reduction of clear opening is carried still further down to 3/32-inch, which is in the range of the fine screen, the accumulation increases to 20 cubic feet per million gallons.

Those who are operating large plants in all probability have some sort of protection for mechanically cleaned screens. If not, it is recommended that such protection be provided, for it will greatly lessen the possibility of damage to the screen. The protection is in the form of a coarse bar rack having openings of from 2 to 4 inches. The amount of debris accumulated on such a rack is not great, but it does serve to keep such materials as brickbats, large heavy sticks, and baling wire off the mechanically cleaned screen rack and to save wear and tear, or possible breakdown of the unit. A coarse rack with 2-inch openings will not accumulate more than ½ cubic foot of debris per million gallons of sewage screened, and the cost of the manual labor incurred by its use more than pays for the benefit received. The Milwaukee bar screen is well protected with a coarse rack. In its early stages of operation, the Akron, Ohio, screen was not protected with a rack and the operator soon found the necessity for providing such protection. This screen handles a combined flow that reaches a maximum of 130 million gallons per day. During storm flows the screen has been hopelessly jammed by such unusual objects brought to it as a fence post, an automobile seat, and a police dog of tremendous size. At such times it was necessary to shut down the screen and remove the material from the rack by hand.

The angle of inclination is another design factor which should be considered by those who may be contemplating the installation of a screen. Many years of experience have taught that the most desirable angle for a mechanically cleaned screen is 60° with the horizontal. An angle of inclination of 75° is not too bad, but as soon as anything steeper than this is used, operating difficulties may be anticipated.

The inclination of a hand cleaned bar rack should not exceed 45°. By keeping the angle at 45° or less, a greater rack area will be exposed to the flow and less frequent cleaning will be required. Further, the action of the flow itself will tend to push the accumulated debris up the bars rather than through them.

In most cases, much of the foregoing will have been considered by the consulting engineer, the manufacturer, or both. It is up to the operator, however, to take the installation as it is and to make the most of it through judicious operation. Many operators do not give sufficient consideration to the cleaning cycle and to the effect of proper cleaning on both the treatment plant itself and what may lay ahead of the treatment plant. For those who have racks requiring manual cleaning, it is particularly important that a definite routine be established. Bar screens which are manually cleaned are often spasmodically cleaned inasmuch as the operator is not in constant attendance at the screen and usually cleans it only two or three times a day, whenever he has the opportunity. Because the cleaning of the bars by hand is not a very desirable job, it is often neglected and the operation of the plant is thereby materially affected. If the bars are allowed to remain uncleaned for a considerable length of time, the sewage is likely to back up in the sewers and cause the deposition of grit which may give serious trouble. Then, when the screen finally is cleaned, there is a noticeable surge through the plant, and this spasmodic surge through the various units of the plant is very likely to disturb their normal, smooth operation. If the sewage enters the plant from a force main the situation is not as bad, for under such a condition it would not be possible to back the sewage up in the sewers by reason of inadequate attention to cleaning. Unless there is sufficient freeboard available, however, there is danger that an overflow of the screen chamber may occur, causing considerable unsightliness and possible damage.

In contrast with the operation of manually cleaned screens, the mechanically cleaned bar screen can be regulated by automatic control to give accurate, periodic cleaning and prevent any of the troubles that would be caused by manually cleaned screens. After lengthy experimentation with various types of controls, the time clock control has been adopted as being the most economical and the most practical. Dual clocks are furnished, one to provide operation of the screen every 10 or 15 minutes during the day and the other every 30 or 45 minutes during the night when the flows are lower. In combination with the clocks, an emergency float switch is furnished so that if the sewage should rise to a predetermined maximum level, by reason of a flash storm or some other unusual occurrence, the float would rise and start the screen in operation regardless of the position of the time clocks in their operating cycle. After a few days of operation of the mechanically cleaned screen, it is possible to establish a cleaning cycle which will keep the screen clean at all times, using a minimum of power. It should, of course, be borne in mind that the season of the year greatly influences the sewage flow, particularly if a combined sewage is being handled. In other words, the time clock setting decided upon by the cut and try method during some months of the year will not at all be correct for other months.

Those who have duplicate units are indeed fortunate, even though the second unit is nothing more than a hand cleaned rack. Where such a condition exists, it is very important to have knowledge of the limiting capacities and to know when to place the second unit in operation. By knowing the basis of design the operator can always adapt his equipment to optimum conditions and get the best out of it. Determine when to throw the second unit into operation and, even more important, know when to take one of the units out of operation so as to avoid unnecessary wear of chains, sprockets, and other moving parts.

Screenings disposal is a subject in itself, but is certainly worthy of mention here. Those who do not have grinding equipment must resort to either burial or incineration. Either method requires extensive handling and hauling of the screenings, both of which are very distasteful operations. Labor expense is also a factor of no little importance. There are now two types of screenings grinders on the market, the hammermill and the Triturator. A third unit should also be mentioned, and that is the Comminutor. That unit, however, is designed for operation while submerged in the flow of sewage and is theoretically a combined screen and grinder. The first two are strictly screenings grinders which may be combined with existing equipment or used equally successfully with a hand cleaned rack. No matter which of the three may be in use, it is important to check the teeth regularly and keep them sharp. Cutting efficiency falls off rapidly as the teeth become dull, with the result that the material may not be ground fine enough to prevent clogging of pump valves, impellers, filter nozzles, etc. Always have a spare set of teeth on hand and make the change whenever the teeth show the first sign of dullness. The teeth that accomplish the reduction of the solids by actual cutting are of exceptionally high quality material, and it will be found much more economical to have them sharpened often than to use them to the point where they become so blunt that they must be thrown away.

Cleanliness is a subject which has been emphasized so much that there is little need to dwell upon it here. The handling and disposal of screenings is one of the most unpleasant tasks incidental to plant operation and unless great care is exercised, unsightliness of both equipment and room will arise. The clean and bright looking screen room is the exception. The screen room is not usually given the extra effort necessary to impart an air of neatness to the place and this is lamentable, particularly when it would take so little time each day. Get in the habit of flushing down the floor and the equipment daily, particularly the rakes, dead plate, and other portions of the screen in direct contact with the screenings. Most of the manufacturers have done what they can to help this matter of cleanliness along by designing full housings for the screen, which hide all screenings from view.

The screen room is generally the point at which the sewage is first released from the sewers. It is here that any gases are released to the atmosphere, including the corrosive hydrogen sulphide. Make certain that the room is well ventilated, and that painting is done regularly, using paints which are suited to the environment.

One of the chief contributors to a messy screen room is the poorly designed screenings can. Very often the screenings can is anything that may be available around the plant. There is no drainage, no means of handling, and no thought given to size or weight. Design a container that meets the needs of the screen installation.

## Grit Chambers

A grit chamber is a tank or chamber so designed hydraulically that heavy, inorganic solids settle to the bottom and light, organic solids do not settle, but flow on through. This might be an acceptable definition of an ideal grit chamber. Unfortunately, it is impossible or impractical to construct this ideal grit chamber, so established practice is to compromise between the ideal and the practical in grit chamber design. It is customary to design the grit chamber to work within reasonable variations of range in flow and velocities so that all objectionable grit is removed from the flow and the amount of organic material removed with the grit kept to a minimum. Certain organic materials have settling characteristics similar to grit, and fine grit has settling characteristics similar to organic materials, with the result that a sharp separation of organic and inorganic solids is not possible.

It is evident from the foregoing that the hydraulic efficiency of a grit chamber is of prime importance. It is, therefore, worth while to discuss those factors which affect its hydraulic design.

Most modern grit chambers have a velocity controlling device, and it is important that the operator be familiar with them and their design. Those who are at present operating grit chambers without means of velocity control should give thought to such devices for improvement of existing facilities.

What part does the grit chamber play in the sewage treatment plant? A grit chamber is used for two reasons, to protect the equipment which follows and to improve plant operation. Grit is particularly abrasive and unless it is removed from the flow, subsequent plant units will deteriorate much more rapidly. The presence of grit in sewage will soon be reflected by the rapid wearing out of pump valves, impellers, and other parts, the wearing out of the shoes on the conveyor flights, and faulty digester operation.

Those who have old plants, and who are not handling a combined flow, probably have no grit chambers. Most of these operators have probably wished for a grit chamber and are looking forward to the time when such a unit can be installed. Present day practice is to include a grit chamber in the plant design, whether or not the flow is to be combined sewage. Grit is certain to be present in sewage, the amount of it depending upon the type of sewage system, the condition of the system, type of soil, the types of street surfacing, the efficiency and methods employed in cleaning the streets, and the violence of storms. For a plant treating a normal domestic sewage, the above factors can be narrowed down to the condition of the sewer system, and the type of soil. Infiltration is always a source of grit, as are the wastes from many commercial houses and industrial concerns.

As has been indicated, a grit chamber is essentially a hydraulic device that must be very carefully controlled. The settling out of the grit in the chamber is dependent entirely upon reducing the velocity to a value such that the grit will settle out, while the organics will remain in suspension. Past experience indicates that velocities must be maintained between 0.75 and 1.25 feet per second. Velocities higher than 1.25 feet per second will cause grit to carry on through the channel. Velocities lower than 0.75 feet per second will permit the settling out of too much organic material. Were it not for the fact that a considerable variation in flow is bound to be experienced during the course of the day, the design problem would be exceedingly simple. The variation in flow does exist, however, and particular precautions must be taken to provide a unit or units that will operate as efficiently as possible over the entire range in flow.

There is a very definite relationship between the effective water depth in a grit chamber, the length of the chamber, and the velocity of the sewage. No longer is a grit chamber designed on the theory that a one-minute detention period is desirable, and the length therefore made 60 feet because the velocity is 1 foot per second. All of the mentioned factors are now taken into consideration, and they are mentioned here with the thought that they might help the operator to investigate grit removal facilities in case they are known to be inefficient.

In the first place, it is necessary to decide just how fine a grit particle is to be removed. Most grit chamber designs are based on the removal of all grit to 50 to 60 mesh, or particles not less than 0.25 millimeter in diameter. Experience has been that grit finer than this does no particular harm when it is permitted to go on into the treatment plant proper. The finer the particle to be removed, the larger will be the grit chamber, and the greater will be the investment. All grit particles have a definite subsiding velocity and it is on the basis of this velocity, and the predetermined required sewage depth, that the length of a grit chamber is based.

A grit chamber is thus theoretically designed to remove certain size particles of grit for a certain sewage depth and velocity. While it is not possible to maintain a constant flow, a velocity reasonably close to the desired value of 1 foot per second can be maintained. Even doing that will give no assurance that only grit will settle out and that organics will carry through the chamber. As the sewage flow drops below normal, it is obvious that the sewage depth will decrease. As the sewage depth decreases, the grit channel then becomes actually too long and considerable material will settle out that would otherwise reach the end of the grit chamber before it was ready to settle to the bottom. Such material will consist almost entirely of lighter organics as well as finer grit particles of the same settling characteristics.

It has been pointed out that the velocity can be controlled near the desired limit of 1 foot per second. There are three such controlling devices in general use: (1) the proportional weir, (2) the Parshall flume, and (3) the Camp regulator. Where grit chamber operation is known to be inefficient, it may be possible to control the velocity through the use of one of these devices after the previously suggested investigation of hydraulic characteristics has been made. In other words, the operator should first determine the actual range in flows, the maximum effective water depth in the channel, the length of the grit chamber, etc. It may then be found entirely possible to improve operation through the use of a velocity controlling device.

A proportional weir is actually a combination weir and orifice, designed to keep the discharge proportional to the head. This is accomplished by constructing the weir with curved sides. Many authorities have advanced formulae for computing the rate of flow through a proportional weir, all derived by calculus and all giving essentially the same answer. The design and placing of the weir is usually supervised by the consulting engineer of the municipality.

The Parshall flume is another device which might be used for the control of grit chamber velocity within moderate limits and with a moderate range in flow. This device also affords a very simple means of measuring the flow with an accuracy comparable to any of the standard forms of weirs. Although it takes up very much more room than does the proportional weir, it has the advantage that it will withstand a high degree of submergence without affecting the rate of free-flow discharge.

This means that there is not as much head loss required when using the Parshall flume as when using the proportional weir. The proportional weir must have free discharge, that is, no submergence, at all times, which means that the total head loss to be provided must be equal to the effective water depth of the grit chamber. In actual practice, free-flow is provided between the minimum and maximum ranges, and there is not much concern about lack of submergence at flows below the average minimum when hydraulic conditions are usually upset. It should be remembered that this type of control section cannot maintain a uniform velocity over a wide range in flow. For instance, with a range in flow of 5:1, the minimum velocity will be approximately 60 per cent of the maximum.

The third device is the Camp regulator, a patented controller offered by one of the manufacturers in this field. Its use is based on the construction of a channel cross section approximating as closely as possible a true parabolic shape as determined by formulae derived by Mr. Thomas Camp. The principle is hydraulically sound and excellent results should be obtained with proper use. However, it is not a device that can be adapted to all existing chambers.

Multiple channels also enter this picture, for they, too, can be used to control velocity. Almost all plants, except the very small ones, in which combined flows are treated, are designed with duplicate channels, or even a greater number. A much greater range can then be successfully handled, for additional chambers can be cut in as the load increases, and cut out as the flow subsides. The operator must, of course, know the capacity of the grit chambers, be familiar with their hydraulic characteristics, and know when to put them in and take them out of service.

Another important factor in the successful operation of a grit chamber is the method by which the sewage is brought in. A straight sweep into the grit chamber is a prerequisite to good operation. If the sewage is brought into the chamber around a bend, the sewage will pile up along one wall and short-circuiting is sure to result. In addition to that, there will be a zone of quiescence along the opposite wall for a large percentage of the length, and considerable organics will settle out over the area. In the case of a curved approach channel, a simple dividing baffle wall will cause a marked improvement in tank performance.

Even if the sewage is brought into the channel in the proper manner, and distributed equally across the entire width, operating difficulties are almost certain to be encountered during peak flows where there is the type of equipment that collects the grit and then elevates it up and out of the sewage to the point of discharge. The trouble generally arises from the fact that the sewage actually dips into the buckets as they break the surface, washing the grit out and back into the channel. This can be effectively combatted by the use of suitably designed inlet baffles. A typical method of control involves the use of an equilateral baffle installed with one side parallel to the upcoming bucket. Its length should be about ⅔ of the bucket length. The grit thus actually leaves the sewage at a quiescent zone. The baffle diverts the sewage around the ends of the bucket at higher velocity. Although there is still some washing out at the very ends of the buckets, the amount lost is not appreciable, and is picked up by subsequent buckets.

The need for establishing a satisfactory cleaning cycle is just as important in connection with the grit chamber as it was with the bar screen. Operation is almost always done manually, for this is not a piece of equipment that can be run by float control or by time clocks because conditions change so much from day to day. It takes intelligent operation to produce a grit that is satisfactory for disposal on the plant grounds and about the only way to determine a satisfactory routine is by the cut and try method. Grit equipment should be operated regularly, and just as infrequently as possible so as to obtain the desired results. Bear in mind that grit is very abrasive, and that grit handling equipment has probably the shortest life of any piece of equipment in the plant. The best grit collectors on the market are built so that those parts which do wear out rapidly are readily renewable at low cost, but even so there is no point in wearing them out sooner than is necessary. It will pay to keep a close watch on all parts that are renewable and replace them as soon as they have outlived their usefulness and before any of the non-renewable parts begin to take the wear intended for the renewable parts. In many cases such renewable parts, particularly if they are wearing shoes, are reversible. It will be found that the grit chamber can be operated intermittently during normal flow conditions, but that they should be operated continuously during storm flows if the sewers are combined. It is essential to be familiar enough with the characteristics of the grit chambers to know when to begin continuous operation of the equipment, and to anticipate operating difficulties. Grit chamber equipment should always be placed in continuous operation in plants handling combined flows whenever a rain commences. One of the plants at Atlanta, Ga., is so sensitive to climatic conditions that the equipment is now placed in continuous operation if the sky just begins to cloud over, to say nothing of any actual rain coming down. The operators there have gotten into such difficulties by reason of not starting the equipment soon enough that they just cannot afford to take any chances.

It is very difficult to obtain good performance with manually cleaned channels. They must be taken out of service for cleaning, which means that the units remaining in service may be overloaded. The grit piles up unevenly in the channel with resultant short-circuiting and poor hydraulic conditions. Organics settle out during low flows and there is no way of separating them from the grit, once they have settled. About all that can be done is to clean them often enough so that the flowing through area is not reduced enough to speed up velocities and cause the carry over of grit. Controlling devices can, of course, be installed at these chambers the same as at mechanically cleaned chambers, and some benefit is certain to result.

Hand cleaned grit chambers are of simple design and lend themselves well to the installation of modern, mechanical grit removal equipment. There is a wide selection of makes and types to choose from, and budget money could not be put to better use. Any manufacturer will be more than willing to help study the problem and make a sound recommendation.

On the subject of grit washing, there is not much to say, at least from the operational standpoint. Grit washing, and by that is meant washing by a separate piece of equipment, has never been very popular. It is the writer's opinion that there is no basic need for such a procedure except in rare cases. It appears that engineers are specifying grit washing equipment less and less and that the trend is toward the use of a design which permits the cleaning of grit within the grit chamber itself.

Even among engineers, there is wide disagreement as to what the quality of a washed grit should be. Some engineers have considered a putrescibility of five per cent to be acceptable, whereas others have insisted that anything over one per cent would be unsatisfactory. The putrescibility determination on grit itself has little rhyme or reason to it and there has been no effort on the part of anyone over the past four or five years to do anything with the test which would increase its value. Under the conditions of the test, a washed grit containing a large amount of coffee grounds, fruit pits, and grain would almost certainly have a putrescible matter value of less than one per cent. If that particular grit were allowed to decompose in a damp place, however, where it would not dry out readily, there is little doubt but that it would be very obnoxious and probably cause just as much complaint as would a grit of four or five per cent putrescibility.

It is the writer's opinion that just as much can be accomplished by designing a grit chamber as hydraulically efficient as possible, and accepting the product from the grit chamber as a material which is not beach sand and which must be disposed of by burning, burying, or spreading on the land where it can dry out without causing offense, as by using a haphazard design with a separate washer. Experience has indicated that a grit washer can be successfully eliminated ninety per cent of the time by using a channel designed correctly and by properly controlling the velocity.

## Sedimentation Tanks

Any discussion of the operation of sedimentation units must, of necessity, include both primary and secondary tanks since the proper operation and control of both types of basins is so similar, with the exception of the scum removal problem. These remarks are limited entirely to modern, mechanized tanks.

The purpose of sedimentation is to remove as much as possible of the solid material carried by the sewage, especially that which will float or will settle to the tank bottom. In the case of primary tanks, this removal of suspended and settleable solids is done for the purpose of providing preliminary clarification preceding chemical or oxidation processes, or it may be for the purpose of providing partial clarification preceding disposal without further treatment. Secondary tanks have the duplicate function of completing the removal, insofar as possible, of the suspended solids, and of serving as a functional part of the secondary treatment process.

While removal of the floating materials, or scum, is essentially a function of the primary tank, it must also be considered in connection with certain secondary tanks, such as those which receive the flow directly from high rate filters. Filters of this nature will, at times, produce a foam and also slough *Psychoda* larvae which will float on the surface of the final tank and which must be skimmed off if the final tank is to have good appearance and if the plant effluent is to be the best obtainable.

There are several important design factors which influence sedimentation tank performance. These factors include the volumetric capacity or detention period, the settling rate, velocity, the method of inlet distribution, the arrangement of effluent take-off, and the sludge removal facilities. These factors are usually given careful consideration by the engineers who design the plant, and the operator need give no further thought to them. Where such consideration was not given, there is likely to be a settling tank that is inefficient, and it is up to the operator to make the modifications necessary to bring the tank into balance. With some of the items enumerated there is considerable latitude, whereas with others there is nothing to be done except to make the best of them.

The first item mentioned was the volumetric capacity, or detention period. For best efficiency, the detention period of a settling tank should be maintained within a definite range. If the detention period is too low, insufficient removals will be obtained, resulting in a load increase on either the subsequent oxidation process or the receiving water; if too high, septicity may develop within the tank.

As a general rule, a detention period of more than two hours is not justified. The slight additional removals obtained for periods longer than two hours do not warrant the expense incurred in the construction and operation of the oversize tank.

Various state authorities and manufacturers have different ideas as to the minimum allowable detention periods for any particular application. Reasonable minimum detention periods for various applications would be:

| | |
|---|---|
| Primary treatment only | 2 hours |
| Primary tank to be followed by trickling filter | 2 hours |
| Primary tank to be followed by activated sludge | 1.5 hours |
| Final tank following trickling filter | 1.5 hours |
| Final tank following activated sludge | 2 to 2.5 hours |

Obviously, the detention period of a tank is a fixed value and cannot be altered by the plant operator. He should, however, know the limitations of the settling tanks and their influence on the overall performance of the plant. If the plant is blessed with multiple units the operator may be able to maintain proper settling conditions by cutting tanks in and out of service as needed. In this respect it is suggested that if a tank is taken out of service for any length of time, it should be kept filled with clean water or else all equipment should be liberally coated with oil or other protective coating to prevent rusting.

The settling rate goes hand in hand with the detention period and, therefore, there is no more control over it than over the detention period. It is expressed as gallons per square foot per day, and is computed by dividing the flow by the tank area. Where there is a plurality of tanks, and they can be cut in or out as the seasonal load may demand, the settling rate will vary accordingly. Just what constitutes the proper settling rate for the different types of settling tanks still seems to be a debatable subject, and several rates have been advocated by various authorities. In general, however, a primary tank settling rate of 1,000 gal. per sq. ft. per day, no matter what the type of treatment, is acceptable. In the case of secondary tanks, those used in activated sludge plants are designed to have rates of from 800 to 1,000, those following conventional trickling filters are designed to have rates from 600 to 1000, and those following high rate filters are designed to have rates of from 600 to 1,200 gal. per. sq. ft. per day.

The horizontal velocity of sewage in a sedimentation basin generally does not come in for much consideration, at least during the design stage. A detention period commensurate with good design practice is usually selected and a length-width ration chosen which will result in an economical structure. Where a certain settling rate is desired, it is used and the corresponding depth computed which will give the required volume and detention. Present day practice is to limit the forward velocity to something less than 2 feet per minute. In some cases the reverse is true, and considerable emphasis is put on the velocity. This was true of the design approach to the Minneapolis-St. Paul sewage treatment plant. After much experimentation on the part of the designing engineers, it was decided that 2.4 feet per minute was the critical velocity on which the design of the tanks was to be based. Cross sectional area was provided to give this velocity, and the tanks were then made of sufficient length to give the required detention period. The velocity in a sedimentation basin will vary, obviously, with a change in flow, and it may also vary because of improper baffling or because of wind effect. In the latter case, however, the induced movement is essentially a surface velocity and is of little importance with respect to overall tank performance. A 20 mile-an-hour wind will, for instance, produce a surface velocity of 1 foot per second, providing the tank is of good size and well exposed to the sweep of the wind, but this surface velocity extends very little distance down into the tank.

Probably the most important design factor influencing tank performance is the need for proper distribution of the flow across the tank width, and right along with that is the problem of proper distribution of flow to a plurality of tanks. This is where the operator comes into the picture very prominently, and where he can begin to exercise ingenuity. Only the operator has the opportunity to observe and study the tanks under all operating conditions and to determine the nature of the changes necessary to improve performance. Distribution can be improved by the use of properly designed feed channels, as well as by the use of inlet baffles. It has been estimated by many authorities that good baffling will increase tank efficiency by as much as 25 per cent.

Every operator should be familiar with the work done by Supt. Walter Sperry on the feed channels at the Aurora, Ill., plant. He determined through exhaustive tests that his four 50-foot square settling tanks as constructed were removing an average of only 40 per cent of the suspended solids. What was particularly disturbing was the fact that the removals varied from this average as much as plus 33 to minus 27 per cent. A very careful check by surveyor's level on the influent and effluent weirs showed that they were very much out of line, and that the flow distribution across the tanks, as measured by current meter tests, varied from 17 to 33 per cent, the theoretical being 25 per cent. After much hard work, involving dye studies to determine short-circuiting, laboratory analyses, and many trial installations, a suitable system of influent baffling was provided which, together with adjustment of the weirs, resulted in marked improvements in tank performance. The average removal of suspended solids increased to 60.3 per cent and the variation from the average was only from plus 5.8 to minus 3.8 per cent. Further, flow distribution was improved to the point where all tanks were receiving within 5 per cent of one another. The range, instead of being from 17 to 33 per cent, was then from 22.5 to 27.5 per cent. The value of the effort and time Mr. Sperry put on this problem is doubly apparent when it is considered that during certain seasons of the year he got along nicely with just two of the four clarifiers in operation.

Another example of what can be done to improve tank performance by experimenting with baffles or altering the existing feed channels is the accomplishment at the Buffalo, N. Y., plant. There, the percentage of suspended solids removed was increased appreciably by reducing the depth of the inlet baffles from 8 feet to 2 feet and perforating them with equilateral triangular openings measuring 12 inches on a side, spaced on 24-inch centers. Although removals in the Buffalo primary tanks still average but 36 per cent, it should be remembered that the sewage is relatively weak, averaging approximately 187 p.p.m. suspended solids.

A well designed settling tank handling a fresh sewage, and having an adequate detention period of say two hours, should remove about 45 per cent of the suspended solids from a weak sewage of less than 100 p.p.m. and not less than 60 per cent from a domestic sewage containing approximately 300 p.p.m. of suspended matter. If performance data are far removed from this range, an investigation into the tank hydraulics would be well worth while. Check the tank thoroughly for short-circuiting, using either a dye such as fluorescein, a salt solution, or possibly floats. Using some such scheme as this, or a better one of your own devising, it will be possible to check the actual detention period. The actual detention period divided by the theoretical detention is generally accepted as the efficiency rating of a settling tank. This rating should certainly be higher than 50 per cent if the tank is to give satisfactory results. If short-circuiting is found to be present, a need is indicated for study and experimentation with different types of inlet baffles placed in different locations, or possibly a different type of inlet itself. Perhaps the sewage is fed into the tank squarely against a wood partition wall which spans the tank. It may be found that this baffle should be raised, or lowered, or perforated, or louvered. Perhaps the sewage is brought into the tank at too high an elevation and should be made to enter at a lower point.

In addition to working out a system of baffling, the operator may also find that he can do much to improve the feed channel itself. If the sewage enters the tank through a series of ports, it may be found that these ports should either be increased in number or enlarged. If the sewage enters the tank through the ports in a horizontal direction, it might be necessary to alter the structure so that the sewage will enter the tank through ports located in the bottom of the channel. If the tanks have an old style feed channel which is of constant width from one end to the other, undesirable flow characteristics may be corrected by filling in the feed channel, to form a tapering channel, thus maintaining a constant velocity and equal proportioning of the flow to all the ports.

Tank performance will be greatly influenced by the arrangement of the take-off weirs. The greater the weir length, the lower will be the rate of take-off and the lower will be the upward velocities over the take-off area. Low upward velocities at the effluent end of the tank are highly desirable since there is then less tendency for the small, flocculent solids of the pinpoint variety to be carried up and over the effluent weir. In primary tank construction, the practice formerly was to provide a single effluent weir across the end of the tanks. Engineers today are recognizing the great benefits to be received from the use of special weir patterns, and primary tank take-off weirs are being designed similar to those heretofore designed only for secondary tanks. Weirs constructed in an H pattern and a U pattern are now in general use, as well as combinations of both. It is now common to extend portions of the weir along the sidewalls up to ⅔ the length of the tank itself. When the settling tanks for the Minneapolis-St. Paul sewage treatment plant were designed, the required length was found to be 290 feet. They were actually constructed that long and, incidentally, are still the longest settling tanks on record. Since the overflow rate in a rectangular tank equals the setting rate (surface loading) times the area served per unit length of weir, it was immediately evident that special consideration would have to be given to the effluent weir design in order to keep the overflow rate within the generally accepted limits of 50,000 to 200,000 gallons per day per foot of weir. At the Twin Cities plant, effluent weirs span the tanks at distances of approximately 190, 230, 260, and 290 feet from the influent end. This weir arrangement provides an overflow rate of about 47,000 gallons per day per foot of weir and undoubtedly contributes immensely to the very fine job these tanks are doing. As a portion of the sewage is withdrawn over each successive weir, the forward velocity decreases and this condition aids in the settling of the very fine materials. Operating performance has improved year after year at the Twin Cities plant, and removals of suspended solids are now averaging about 76 per cent.

The advice and assistance of a consulting engineer is necessary if operation observations indicate a need for modification of the outlet weir system, since the work would constitute a project of some magnitude. Where the construction of new tanks as a part of a plant enlargement program is contemplated, it is well to make certain that the weir design and arrangement receives very careful consideration.

It goes without saying that proper sludge removal facilities are necessary to insure good tank performance. There is much more, however, to the subject of sludge removal than merely having good sludge removal facilities. Too often the operator pays too little attention to this item with the result that performance suffers to an alarming extent. It is necessary to remove the sludge while it is still fresh and do so as often as necessary to prevent septic action in the settling tank. This is advisable as an aid to sludge digestion and to more efficient removal of suspended solids. Septic sludge will evolve gas, and the resulting bubbles as they rise to the surface will disturb the settled material and carry it to the surface, thus interfering with sedimentation of incoming sewage. Further, sludge discharged into a digester should be as fresh as possible in order that the digestion may start under favorable and proper conditions. In the case of final tanks following the activated sludge process, it is even more important to get the sludge out fast before it has a chance to deteriorate.

The length of time the equipment operates in settling tanks is tied in very definitely with the length of time the sludge pump should operate. Except in rare cases, it is generally quite unnecessary to operate continuously conveyor type sludge removers in rectangular tanks. On the other hand, it is common to operate mechanisms in round tanks continuously since the sludge must be moved a greater distance before it finally reaches the center of the tank, and because there is not the sludge storage capacity provided with this type of tank that there is with the rectangular tank. The sludge removal mechanism should be operated at least long enough to make sure that any one scraper has traveled the entire length of the tank bottom. Experience may dictate that best operation can be obtained by having the equipment make one complete revolution. Most primary tank sludge removers of the conveyor type operate at 2 feet per minute, and on this basis it is a simple matter to determine the number of minutes required for a complete turnover, or a sweep of the bottom by any one scraper. If the tank is 80 feet long, for instance, the conveyor should run for at least 40 minutes.

It is good practice to have the equipment in operation at least 15 minutes before the pumping operation is started. Sludge pumping should then be continued during the time the conveyor is in operation until such time as the sludge begins to run thin. All sludge pumps have, or should have, sampling valves on them so that the nature of the sludge being pumped can be checked. By studying the tank, and varying the routine, it will usually be possible to withdraw a sludge having at least 5 per cent solids, and probably higher. Mention has been made of the good removals in suspended solids being obtained at the Twin Cities plant, and this is also reflected in the sludge consistency which is regularly attained there. Sludge is pumped once each shift, or three times a day, at this plant and determined efforts to secure a concentrated sludge have resulted in an average sludge consistency of almost 9 per cent. This is an average figure and it is to be noted that this percentage has been increasing, even though slightly, over the past four or five years. It is a definite indication of what can be accomplished by diligent operation and study of settling tank characteristics. Sludge samples are taken from the sampling valve at the pump every fifteen minutes and a known volume weighed. This is an operation that takes the operator less than two minutes, yet it serves as an accurate control test. The operator knows what the constant sludge volume selected should weigh if it contains 7 per cent solids and sludge pumping is continued until the weight of a sample indicates that the sludge is running less than 7 per cent. As soon as this consistency is reached, the sludge pumps are shut down and no further sludge is withdrawn until the next shift. There are no fixed rules which can set down for the operation of sludge removal mechanisms, or the operation of sludge pumps.

In addition to the time required for operation of the sludge removal mechanism and the time required for sludge pump operation, attention should also be directed to the pumping rate. Most sludge pumps, particularly if they are of the plunger type, can be adjusted to provide at least three different pumping capacities. It is very desirable to pump at the low rate, even though the pump must then be run for a longer time. A high pumping rate will not give as dense a sludge as will a low rate, and is very likely to cause the formation of channels or cones in the sludge blanket, whereby the clarifier liquid is withdrawn from the tank before all the sludge is removed.

If the sludge blanket is broken and the sewage breaks through it, the quantity of liquid in the digester will increase and there will be a consequent increase in the return sludge liquor to the clarifier. The result will be an overloading of the digester, a cooling of the digester and an increased load placed upon the plant by reason of the excessive return of supernatant.

It is also very important that there be adequate scum control. Every effort should be made to provide positive removal of scum from the tank surface. In former days, there was no effort made to obtain full width skimming of the rectangular primary tank surface. A clearance of several inches between the tank walls and the ends of the flight was common, and scum simply flowed around the ends of the flight as it moved on its skimming run. Where this condition exists, it is suggested that wood corbels be installed at the tank surface, bolting them directly to the concrete. A clearance of about ½-inch is ample to leave between the ends of the flights and the corbels without danger of the scrapers binding.

The line leading from the scum box is generally tied in with the raw sludge line, with proper valves being provided, and scum should be removed at the time that sludge is withdrawn from the hoppers.

Automatic, or semi-automatic skimming devices are now in general use. Most of the tanks constructed two or three or more years ago have the old style concrete trough into which the scum must be moved by hand, after it has been concentrated near the lip by the sludge removal mechanism. With this design, about the only way to get the scum into the trough is to pull it in by means of wood paddles or similar devices, and to effect complete removal by creating surface waves which wash the last particles into the trough. While some water is introduced to the scum trough by this procedure, it is usually an insufficient amount to cause the scum to flow from the trough into the sump alongside the tank. The necessary amount of flushing water is generally supplied by hose, since the scum trough should be hosed down at least once a day. Some concrete scum troughs are fitted with simple flushing valves which the operator opens whenever he wants to admit settled sewage to the trough to flush out the scum.

In any event, whether skimming is accomplished manually or by mechanical means, it is necessary to use considerable water in transporting the scum out of the tanks and trough. After the scum is out of the tanks, however, it may be concentrated in a separate chamber. The value of concentration lies in the fact that less water will be pumped to the digester and there will thus be less loading and cooling of that unit.

Scum is easiest handled when relatively fluid. It is in this condition when it first rises to the tank surface, and at that time it may be removed with a minimum of excess water. If allowed to remain too long on the surface of the tank, it starts to thicken and solidify and requires considerable water to transport it. Frequent skimming is therefore advisable.

A recent contribution to the art of scum handling was the development of the revolving skimming pipe. This skimmer insures complete removal of scum with a minimum of effort on the part of the operator. It is only necessary to rotate the pipe far enough to induce flow of the scum into the pipe, taking just enough water to cause the scum to flow through the pipe into the scum box or scum concentration chamber. The revolving skimming pipe can be installed equally well in each of any number of new or existing tanks located side by side and the scum made to flow one through the other, making it possible to use just a single scum box located at one side of the battery of tanks. The pipes are so constructed, and the arrangement so made, that independent operation of anyone of the pipes is possible.

It is obvious from the foregoing that the proper operation of a modern sewage plant requires something more than mere elbow grease. The operator must study the plant and be familiar with its faults and good points; he must be able to minimize the faults by making changes in the plant and by intelligent operation; he must operate the plant so as to take full advantage of the flexibility and other good features that have been built into it. The operation budget and present manpower limitations may preclude putting the foregoing suggestions into effect at once. In fact, it is bound to be a long term program since each change in operation or structural design should be based on supporting data from plant operation records which indicate the need for such changes.

Be sure that the accumulation of grease and scum on the surface of the tank is removed at frequent intervals, at least twice a day and oftener when necessary. A thick scum blanket, extending several inches below the tank surface, may well release particles to the tank effluent. A thick accumulation of scum will also tend to hold material at the surface which would otherwise settle. Keep the scum baffle ahead of the outlet weir clean, especially that portion which is submerged.

If sewage is entering the tanks over weirs, some solid matter is bound to accumulate in the bottom of the feed channels. These deposits should be periodically stirred up, either by means of a hose or broom, so that they will mix with the influent and pass on into the tanks before they have had a chance to become septic. Where the feed channels have port holes in them this difficulty will be avoided, although the port holes themselves should be cleaned whenever the start of a build-up of sludge or slime is noticed.

Unless some of the scrapers on the sludge collectors are equipped with squeegees, fine solids and grease will collect on the side walls. In warm weather this material will rapidly decompose. These solids can be removed with a stiff brush or a homemade squeegee. After they have been removed, it is always advisable to wash down the walls thoroughly with a hose.

The outlet weirs should also be kept just as clean as possible. This is one tank appurtenance that should receive daily attention. It is the one portion of the tank that always comes in for attention whenever visitors are shown around the plant. Dirty weirs with sludge built up on them, training long strands of the well-known green slimy material, cannot help but make a poor impression on the visitor. In addition to being kept clean, weirs should be maintained at a uniform elevation so that effluent withdrawal is at the same rate over their entire length.

At least once a year, and preferably every six or eight months, the tank should be dewatered so that the sludge removal mechanism can be inspected. This will afford an opportunity to make any necessary adjustments and to determine just what parts seem to be wearing out. With the long time deliveries now prevalent because of wartime conditions, it is more important than ever to keep a close watch on equipment and to anticipate repairs at least six months ahead. By placing orders at least that far in advance, there can be reasonable certainty that the part needed will be on hand by the time the equipment is in serious need of repair. Remember that the cost of mechanical equipment was incurred in the first place only because its use would improve tank performance, and that all of the component parts should be kept in good repair and well lubricated. Every operator should have complete instructions from the equipment manufacturer as to lubrication and maintenance and he should follow these instructions to the letter. If the instructions or the lubrication chart have been lost, do not hesitate to write the manufacturer for another set.

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## BARK FROM THE DAILY LOG

By Walter A. Sperry

*Superintendent, Aurora Sanitary District*

**May 1**—Remember the story of the borrowed sewer tap and our philosophy of borrowing? Willard Pfeifer, our valued assistant (may Allah increase his race), returned from a visit to his mother-in-law bringing back the tale of a sign he saw in a store window in Leland, Ill. This sign bore the words, in large letters, "Please Bring Back Our Monkey Wrench!"

**May 3**—Another good lost-manhole-cover suggestion. Our Southeast Interceptor runs through a sparsely populated territory with an occasional cornfield. Last spring, some one actually broke out a piece of a manhole wall to drain a cornfield! This year we found that children had built a platform in the bottom of a manhole for a playhouse. The flow is small and mostly ground water. Also several Christmas trees were removed. Six or more manhole covers must be found and replaced in this area yearly.

Our District Engineer, Walter E. Deuchler, reading an account of all this in our report at a recent board meeting, whispered the suggestion that we fill the crack between the ring and the cover with asphalt. Easy to pry loose with the proper tools but hard for the youngsters.

**May 7**—It was a lovely Sunday morning but not for a man stopping at the Leland Hotel. Found a telephone number on the desk when I came out for the usual Sunday chores. It was from a man who said he had been sick during the night and would we please look for his teeth? He did not realize that a set of false teeth could not readily travel through six miles of sewers and negotiate two inverted syphons under Fox River on the way. As a sympathetic courtesy we called to restate more clearly just why we could not possibly recover his teeth. For the man it meant a soup diet and a trip from Aurora back to Denver, Colo., to replace them. This was only one of many such calls that we receive. Seems like the slogan "Don't pull the string—there is little that soap and water can't fix," would save a lot of grief.

**May 10**—The gas production at a sewage plant is always a seven-day wonder to John Citizen. We never did forgive one visitor from Wisconsin who called on us one Sunday. Our operator-guide began at the screen house and was showing him the incinerator with its gas burner in full blaze. On being told that this gas was produced from the sewage, he spat on the floor, pulled his hat over his ears, said "That is a *!*!*!*! lie!"—then climbed in his car and drove off!

Today a chicken farmer called to consult us regarding the production of gas from the chicken manure produced at his place. He had never seen this plant but had heard about the gas and conceived the bright idea that there might be considerable salvage value in the 100 pounds or so of manure which is produced daily by his 3,500 chickens. We explained our gas production system and warned him that the amount of gas he could expect would not nearly be worth the cost and labor required to manufacture it by this means. This is the third or fourth time, in 15 years, that we have had local inquiries about gas production by farm waste.

**May 13**—There is always a first time for new and strange phenomena. We had liked Fred from the first day he was hired; he had been a farmer and knew how to work. He was quiet, efficient and interested (unusual traits these days). He enjoyed his job with us and was popular with the other men.

Then came the surprise. He came in this evening to say that "he just could not take it any more" and resigned his job. It seems that certain odors have nauseated him ever since boyhood. No particular odor around the plant seems responsible for the trouble but the faint odor coming through the sampling hole at the wet well was certain to bother him, especially if he passed that point on his way outdoors. Because of his husky and healthy appearance we could hardly believe his story but he claimed to have visited a doctor without obtaining relief, before deciding to quit. Too bad for him—and us!

From a physiological standpoint, we understand that this trouble may be caused by two nerve centers in the back of the throat which may be hypersensitive to odors. A sagging stomach that retains food too long may cause gastric juices to be thrown back to the throat with similar result. This incident may well cause some interesting speculations about certain individuals and this whole problem of sewage works odors.

**May 17**—An interesting oil problem was put up to us when a machine forging company making steel shells called for help in satisfying a pollution complaint.

We had never seen a forging machine where hot billets are punched and squeezed into shape instead of being hammered. The lubricant is a heavy black crude oil loaded with graphite, which is carried by the cooling water through a series of 3 deep oil traps with the discharge going to a creek. An examination of the material, by diluting it with gasoline and centrifuging, revealed that it contained about 40 per cent water, 5 per cent graphite and the remainder oil. Under the microscope, the water was shown to be occluded by the oil as small clear droplets; it was not an emulsion. The oil trap effluent carried a considerable amount of heavy black oil drops in suspension, causing pollution of the creek.

After considering a skimming tank, with retaining baffles, we found the right solution to be a straw or hay filter as recommended by the American Petroleum Institute.* We had thought of excelsior but this became soaked and slumps down so that it is not effective. A rectangular box of suitable dimensions, with an inlet designed to equalize the flow, is to be built. Four cages 6 or 8 inches wide, extending across the box and made with screen wire sides, are to be fitted in grooves so that each cage may be removed. These are packed with hay or straw repeatedly as required. The flow passes slowly through the four cages, the oil being retained by the straw. The device works surprisingly well.

**May 25**—Hydrogen sulphide to the sewage works operator is personified by the little devil with cloven feet, horns and spiked tail of the patent medicine advertisements. We all know about the failure of the copper parts of switches and wiring. Today we ran across a new one.

The recording dial of our big 5,000 c.f. per hr. gas meter began to dim until it finally became difficult to read even with a flashlight. Eventually, the cause became apparent. The enamel of the dial contains lead, and, in time, the figures completely "blacked out" due to the action by $H_2S$. After long last we got a new dial, which was lacquered well before installation as an additional protection.

**June 1**—We have always been proud of our caterpillar tractor with the sludge saddle bags, that was first dreamed up by W. B. Walraven of the Springfield (Illinois) Sanitary District. There are only four of them to date. Repairs during the last five years have been very reasonable. The chains have required rebushing and new pins but once in that time.

* "Disposal of Refinery Wastes. Section 1—Waste Water Containing Oil." American Petroleum Institute, 50 East 50th St., New York City (1941). Price $1.00.

Then we made the discovery that nearly every chain link had two or more cracks in the corners at the ends. Some were just beginning, some were long and one was clear through. We were afraid to run it and needed some sound advice. The tractor maintenance man came to our rescue, assuring us that such damage was common and could be easily repaired. The tractor was jacked up so as to rotate the tracks and our local welder gave it a six-months or more new lease on life by spot welding all the cracks. Meantime, a brand new chain is in storage. The cracks were caused by wear of the sprockets and stretch of the chain, which caused the links to pound as they came onto the sprocket.

**June 7**—More about oil problems. Frank Olson, Superintendent of the two plants at Batavia, Illinois, came down today with a furrowed brow. His primary sludge is oily, the digesters contain a great quantity of mineral oil that interferes with the supernatant overflow and there is a possibility that his sand filters are being affected. The digested sludge to the drying beds is unusually thick and gummy. In his case, the trouble comes from the discharge of cutting oil from a shell plant.

The oil is in an alkaline emulsion that cannot be handled either by traps or by filters. The Petroleum Institute treatise referred to previously in this column indicates that such an emulsion may be hard to break up. The bulletin suggests a long list of reagents that may have to be tried before one is found that will release the oil. We could not help Frank much but if he finds a solution we will tell about it later.

**June 13**—Here is Chapter Four of the Paper Mill Story. Regular sampling and analysis began the week of January 3, 1944, and have been continued to date. The scheme of sampling was well planned and the weekly accumulation of samples has been regularly exchanged for the empty bottle crate every Sunday at the fire station.

During the year 1944 the flow of waste liquor has averaged 1.25 million gallons per week and has carried 1,460 p.p.m. of suspended solids. This represented a loss of more than 1.38 tons per day or 7.3 tons of pulp per week. There was one high week of 2.1 million gallons of waste liquor discharge and another week which showed a high tonnage loss of 16 tons. This was a disconcerting revelation, quite unsuspected by the mill officials, and constituted a sizable loss when pulp ready for the paper machine was valued at $30 per ton.

In June, the company's engineers came out for a conference. They expressed sincere appreciation for our cooperation and stated that the losses were much more than had been anticipated. They reported that arrangements were being made to reduce the volume of waste liquor by a scheme of recirculation and that pulp loss was to be reduced by substitution of a regular paper mill "saveall" for the Oliver filter then used. (To be continued.)

**June 15**—It was a pleasant variation in the daily routine to appear as guest lecturer before the chemistry and biology classes at Aurora College and to talk about "Sanitary Engineering and Public Health." The class bell rang much too soon.

**June 20**—More than just lucky is the operator that has access to a good local machine shop, managed by a man with mechanical gumption. Aurora has one.

After fifteen years, the shaft and cross arm casting at the head end of the rake mechanism of our Dorr Detritor became so badly worn on one side, due to the unbalanced pressure of the heavy tail weight, as to cause a decided jerking of the rake and misalignment of the machine. It took months of persuasion to get the machinist to accept the job but it was worth the trouble. The cross arm is both heavy and unwieldy. After much maneuvering to get the piece in a lathe and four days of hard work, all worn places were bored out and rebushed. Next time the effort and cost will be much less because it will only be necessary to replace the bushings.

**June 23**—Presented the Biology Department of Aurora College with a six-month fetus. It was in a good state of preservation and they were glad to get it as a museum item. One or two a year come down.

**June 27**—One five-gallon bottle of distilled water to the city chemist and one to the fire department today. This reminds us that, after all, the boys at Olean, N. Y., did get 31 votes for their distilled water "gadget" and might at least have been entitled to honorable mention (**This Journal, 17,** 381 (1945)). Because we have no gas bills, the Aurora plant shares a lot of its distilled water with all the city departments—not for cigarettes, to be sure, but for a lot of friendly good will and cooperation. It pays good dividends.

One day the city chemist had a questionable water analysis—too much calcium. It was traced to the distilled water and sleuthing eventually ran the trouble down to a puncture in the worm coil of our still! It was a difficult repair to make but we did it. Then for a while we were extra cautious and tested every batch of water distilled with standard soap solution and wondered why the hardness was so high until we remembered to boil off the carbon dioxide before testing. Now everyone is happy.

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## INTERESTING EXTRACTS FROM OPERATION REPORTS

CONDUCTED BY LEROY W. VAN KLEECK

*Operators!*

Your cooperation, please! Send me direct a copy of your annual reports as soon as they are prepared—Address: LeRoy W. Van Kleeck, Connecticut State Department of Health, State Office Building, Hartford, Conn. This will assure prompt extracting in this Section.

And to you operators who have never prepared an annual report, did you read Pete Wisley's editorial in the January, 1945, issue, page 99? Let's extract that editorial here and now:

"It is our positive opinion that the preparation of an annual report is a definite responsibility . . . an essential duty to the municipality served.

"Volumes have been written and spoken about the value of operation records with never a dissenting voice. But when it comes to annual reports, we hazard the guess that these are prepared in less than ten per cent of all treatment works in existence!

"The busy plant superintendent can waste much time in sifting through daily, weekly or monthly reports for what may be located quickly in the annual and he will get an over all picture from the annual summary that is not possible in data representing shorter periods.

"It is not essential that the annual report be presented as an elaborate printed brochure, replete with photographs and illustrations, such as is distributed from plants serving very large cities. A neatly mimeographed report will answer the purpose admirably and the reproduction cost is almost negligible.

"Through the newspapers the superintendent may achieve the transformation of his annual technical report into a story that the average citizen will understand. (The editorial then lists the seven essential elements of a good report.)

"Why not put your plant in the 'big time' by preparing your first annual report to cover the year 1944?"

Why not? The Federation has an "Operation Reports Committee" now functioning. This committee in due time will undoubtedly present aids and guides to operators in the preparation of annual reports. It is also the aim of the Federation through this committee to present awards for operator's reports, along the lines of awards now offered by some of the local sewage works associations.

One immediate aid to operators is the report of the New England Sewage Works Association committee on "Sewage Plant Records." In an appendix of this report the general and detailed data for yearly reports are listed for all types of plants and for specific plant processes. The report will be found in *This Journal,* Vol. 3, No. 1, page 108 (January, 1931).

Another useful guide which includes fixed, operation and maintenance costs is a report by a Federation committee submitted in 1931 to Mr. C. A. Emerson, Jr., at that time Chairman of the Board of Control. This report likewise lists the items on which records should be kept. It was published in *This Journal,* Vol. 4, No. 1, page 3 (January, 1932).

Of more recent date, and in even greater detail, is the report of the rating committee of the New York State Sewage Works Association. In the committee's revised rating schedule is an outline form of reports for submission to the rating committee. Operators should guard however against following too mechanically a set listing of items. Originality lends interest, readability and increased value to annual reports. Operators will find the schedule in *This Journal,* Vol. 11, No. 3, page 524 (May, 1939).

Among the sources of information do not forget this Section. By a study of these extracts you will obtain ideas on what is wanted by other operators for comparing and improving the performance of their plants.

Good luck in your undertaking—am looking forward to receiving your report this year!

# THIRD ANNUAL REPORT OF THE GARY, INDIANA, SANITARY DISTRICT SEWAGE TREATMENT WORKS FOR 1943 *

By W. W. Mathews, *Superintendent*

## *General Description*

The main Gary sewage treatment plant is an activated sludge, diffused air type, with separate sludge digestion. Garbage grinding equipment is included as part of the plant. The design is based on a flow of 40 m.g.d. or 170,000 population. The plant was constructed in 1939–40 at a cost of $1,901,793.57. The plant site covers 52 acres. A description of the individual treatment units will be found in the previous extract on this plant.*

## *General Comments*

Aeration demands have been somewhat lower than at similar plants, air consumption being only 0.41 cubic feet per gallon of sewage treated for 1943. With a high rate of gas production and a low air requirement, it has been possible to operate the Gary plant with low power costs.

Dried sludge was again available at no cost to persons wishing to use it as a fertilizer. There was a decrease in yardage removed and the number of persons obtaining it during the year, which was caused, we believe, by gasoline rationing. During 1942, which was the first calendar year in which sludge was available over the entire year, 4,039 persons removed 5,130 cubic yards, while corresponding totals for 1943 were 2,656 and 3,329, respectively.

*Summary of Operating Data, Gary Sanitary District (1943)*

| Item | Average |
|---|---|
| Population served | 100,000 |
| Sewage flow, m.g.d. | 21.5 |
| Cu. ft. air per gal. sewage | 0.41 |
| Lbs. B.O.D. removed per 1,000 cu. ft. air | 1.2 |
| Cu. ft. gas produced daily per capita | 1.44 |
| Cu. ft. gas per lb. solids added | 2.6 |
| Cu. ft. gas per lb. volatile solids added | 5.5 |
| Screenings, cu. ft. per m.g. | 0.206 |
| Grit, cu. ft. per m.g. | 8.73 |
| Lbs. solids removed per m.g. | 2,430 |
| Primary settling period, hrs. | 1.91 |
| Lbs. B.O.D. removed per m.g. | 1,003 |
| pH raw sewage | 7.0 |
| pH settled sewage | 7.1 |
| pH final effluent | 7.3 |
| pH raw sludge | 6.9 |
| pH returned sludge | 7.2 |

* For a previous extract see: *This Journal*, 16, 3, 637 (May, 1944).

*Summary of Operating Data, Gary Sanitary District (1943)*—Continued

| Item | Average |
|---|---|
| 5-Day, B.O.D., p.p.m. | |
| Raw sewage | 129.5 |
| Settled sewage | 63.3 |
| Final effluent | 9.3 |
| Per cent reduction, raw and final | 92.8 |
| Suspended solids, p.p.m. | |
| Raw sewage | 301.6 |
| Settled sewage | 95.4 |
| Final effluent | 10.3 |
| Per cent reduction, raw and final | 96.6 |
| Suspended solids in mixed liquor, p.p.m | 1,353 |
| Sludge index | 101.5 |
| Suspended solids in return sludge, p.p.m | 4,532 |
| Per cent return sludge | 32.5 |
| Aeration period, hrs | 3.9 |
| Secondary settling period, hrs | 2.95 |
| Secondary settling period, gals. per sq. ft. daily | 734 |
| Total cost of operation, dollars | 68,273.95 |
| Cost per m.g., dollars | 8.70 |
| Cost per capita, dollars | 0.056 |
| Cost per 1,000 lbs. B.O.D. removed, dollars | 8.68 |

*Additional Items*

| | |
|---|---|
| Raw sludge* pumped daily, gals | 128,976 |
| Per cent dry solids in raw sludge | 5.93 |
| Per cent volatile solids in raw sludge | 48.02 |
| Sludge gas analysis, per cent | |
| Carbon dioxide | 27.4 |
| Oxygen | 0.4 |
| Methane | 64.1 |
| Hydrogen | 4.3 |
| Nitrogen | 3.9 |
| Hydrogen sulphide, raw (grains per 100 cu. ft.) | 6.2 |
| Hydrogen sulphide, scrubbed (grains per 100 cu. ft.) | 4.48 |
| B.T.U., net | 596.43 |
| Grand Calumet river (effluent stream) | |
| Dissolved oxygen, up-stream, p.p.m | 3.81 |
| B.O.D., up-stream, p.p.m | 3.98 |
| Dissolved oxygen, down-stream, p.p.m | 4.0 |
| B.O.D., down-stream, p.p.m | 3.33 |
| Total sewage pumped, m.g | 7,847.65 |
| Sewage pumped with sludge gas, m.g | 6,999.34 |
| Cost of electric pumping, dollars | 2,400 |
| Value of gas used for pumping, dollars | 9,721.47 |
| Total air blown, 1,000's c.f | 2,954,211 |
| Air blown with sludge gas, 1,000's c.f | 2,883,711 |
| Cost of electric aeration, dollars | 773.24 |
| Value of gas used for aeration, dollars | 10,805.60 |
| Total suspended solids removed, lbs. for year | 19,073,538 |
| Total B.O.D. removed, lbs. for year | 7,869,441 |

* Includes primary and waste activated sludge, plus solids in digester supernatant liquor.

## ANNUAL REPORT ON THE JACKSON, MICHIGAN, SEWAGE TREATMENT PLANT FOR THE YEAR 1944 *

By A. B. Cameron, *Superintendent*

This is an activated sludge plant employing separate sludge digestion. See a recent extract for a description of the plant units and a plant diagram.*

### *General Remarks*

The effluent from this plant is uniformly higher in quality than the receiving body of water (the Grand River), and continues to bring many favorable comments from visiting sanitary engineers and laymen. This efficiency is indicated by the continued exceptionally high removal of suspended solids and biochemical oxygen demand, these removals being 93 and 97 per cent, respectively.

During the last year, little if any trouble has been encountered in

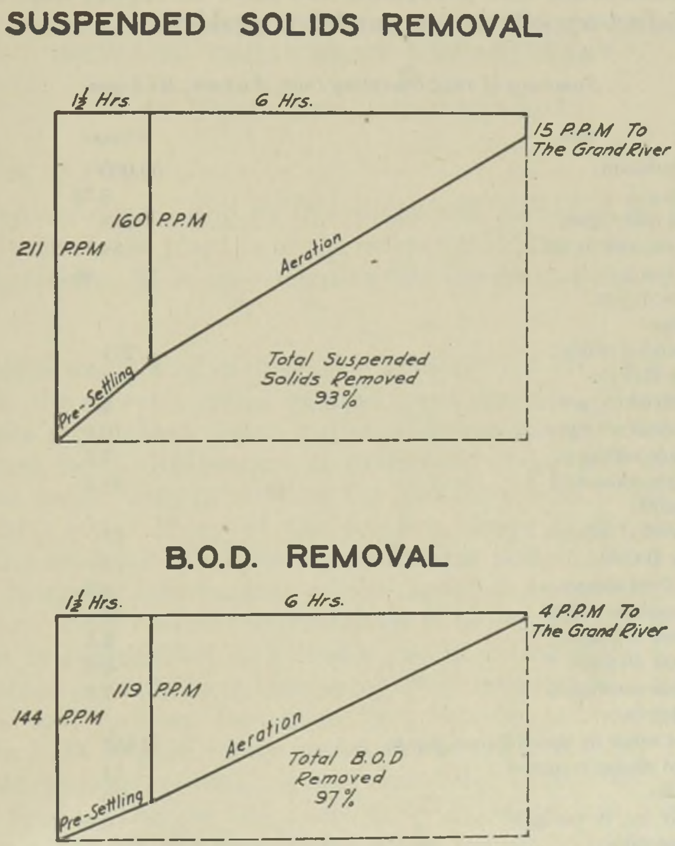


Figure 1.—Suspended solids and B.O.D. removals by Jackson, Mich., sewage treatment plant—1944.

* For a previous extract see: *This Journal*, 16, 5, 995 (Sept., 1944).

keeping the filtros plates free and open. An occasional application of chlorine into the main air line, or the blowing out of the system by using additional blower capacity for twenty-four hours, has solved all of these problems. Results have been so satisfactory that we have not had to drain the tanks this year for inspections.

The digested sludge drawn to the beds this year was a little thinner than the previous year. This is accounted for by the manner in which we have operated these digesters on some experimental work for the last year. These experiments are nearly completed and will be taken up in a separate report in the reasonably near future.

During the past year we have again made every effort to maintain the plant grounds, as we feel them to be a very good investment in public good will. They are being used more extensively each year and the grounds will warrant the building and operating of a comfort station and wash room in a separate building to be used by the general public. It is planned to design and build this comfort station during the coming year. We still had to depend upon high school boys for ground maintenance this year, and will have to report that this is not a very satisfactory solution to our labor problem.

*Summary of 1944 Operating Data, Jackson, Michigan*

| Item | Average | Average 1939–1943 |
|---|---|---|
| Connected population | 50,000 | — |
| Sewage flow, m.g.d. | 8.73 | — |
| Per capita daily, gals. | 174 | |
| Grit removal, cu. yds. total | 54.1 | |
| Cu. ft. per m.g. | .46 | |
| Analytical data, p.p.m. | | |
| Raw sewage: | | |
| Suspended solids | 211 | 210 |
| 5-day B.O.D. | 144 | 147 |
| Dissolved oxygen | 2.7 | 1.5 |
| Ammonia nitrogen | 10.9 | 13.5 |
| Organic nitrogen | 7.7 | 8.5 |
| Oxygen consumed | 48.3 | 51.1 |
| Final effluent: | | |
| Suspended solids | 15 | 16 |
| 5-day B.O.D. | 4 | 10 |
| Dissolved oxygen | 5.2 | 5.4 |
| Ammonia nitrogen | 11.1 | 9.2 |
| Organic nitrogen | 2.5 | 4.0 |
| Nitrate nitrogen | 0.4 | 4.7 |
| Oxygen consumed | 7.6 | 8.5 |
| Activated sludge data: | | |
| Suspended solids in mixed liquor, p.p.m. | 2,857 | 3,240 |
| Per cent of sludge returned | 14 | 17 |
| Sludge index | 40 | 37 |
| Applied air, cu. ft. per gal. | 0.6 | |
| Sludge digestion data: | | |
| Lbs. dry solids removed per m.g. | 1,634 | |
| Wet sludge removed, cu. yds. | 24,090 | |
| Dry sludge removed, cu. yds. | 5,395 | |

*Summary of 1944 Operating Data, Jackson, Michigan—Continued*

| | |
|---|---|
| Per cent solids: | |
| Primary sludge | 5.5 |
| Return sludge | 1.9 |
| Digested sludge | 7.4 |
| Per cent volatile solids: | |
| Primary sludge | 63 |
| Digested sludge | 48 |
| Suspended solids, supernatant, p.p.m. | 8,952 |
| pH digested sludge | 7.2 |
| Total alkalinity, digested sludge, p.p.m. | 3,065 |
| Gas produced, cu. ft. per capita daily | 0.99 |
| Gas produced, cu. ft. per lb. volatile solids | 12.1 |
| Digested sludge temperature, F.° | 91 |
| Dried sludge solids (open beds), per cent | 39 |
| Operation cost, total dollars | 52,681.67 |
| Per m.g. treated | 20.56 |
| Per capita yearly | 2.23* |

* Including fixed charges.

## 1943 ANNUAL REPORT OF THE BELVIDERE, ILLINOIS, SEWAGE TREATMENT DEPARTMENT *

By Miles Lamb, *Superintendent*

### *Description of Plant*

A complete description of this plant will be found in the last abstract. In brief, the plant is of the activated sludge type with separate sludge digestion. It is now treating the design population of 10,000.

### *History*

The plant was placed in operation January 1, 1937. Simultaneously with this, the sewer service rentals were started. Major plant improvements since construction include a digester roof, a 3.0 m.g.d. propellor pump for the lift station, an extra turn of digester heat coils, and a new gas boiler with provisions for auxiliary heat in the old boiler. (*Extractor's note:* Many of the smaller plants in the country have learned the need for two boilers: one for gas and one for coal or oil in order to insure proper heating of the digestion tanks and buildings in the winter. Under some circumstances it is practical to use manufactured gas in conjunction with sludge gas in a single boiler.)

The plant grounds have been completely landscaped and bituminous roadways and parking lots have been constructed. Concrete walks have been built to give ready access to the various parts of the plant.

In 1942, the control building was remodeled to provide more suitable working space. During this same year, a lagoon was constructed to provide a place for the raw sludge while cleaning the digester and to provide relief for overloaded sludge beds.

* For a previous extract see: *This Journal,* 11, 5, 897 (Sept., 1939).

Considerable progress has been made in the construction of a dike for flood protection. This dike is being built at practically no cost with waste foundry material and waste dirt from street work. About 75 per cent has been completed.

*Administration*

The Belvidere sewage treatment works operates under the sewage revenue bond and service charge law enacted in 1933, and all monies are derived from this source. The responsibility for the operation and maintenance together with the collection of the revenue for sewer service rests with the sewage treatment department.

Bills are issued quarterly and are payable at the collection office of the department, which is in the city hall. The amount of the bill is based on the water consumption. The minimum charge, with the 10 per cent discount allowed for payment before the 20th of the month, is 68 cents per month. For the purpose of billing, the city is divided into three sections. These sections are billed in rotation. By this method a steady monthly income is assured. Delinquent bills become a lien on the property. As of December 31, 1943, delinquent accounts were less than 2 per cent of total collection. In 1943, the cost of collecting the revenue was about 6 per cent of the total billings. Collections from the sewage revenue during the year were $24,704.71, which was sufficient to cover all items of expense.

*Digestion Tank*

With the exception of a short foaming period, which occurred in January, the digester operated in a very satisfactory manner during the year. This foaming was an aftermath of the 1942 cleaning of the digester, and was described in the 1942 report. The effectiveness of the work done on the digester and heating equipment during 1942, is shown by the fact that an average temperature of 92 degrees was maintained for the year, and that the temperature in December was 95 degrees or about 10 degrees higher than it was formerly possible to maintain.

*Summary of 1943 Operating Data, Belvidere, Illinois*

| Item | Average |
|---|---|
| Sewage flow, m.g.d. | 1.05 |
| Per capita per day | 129 |
| Population served | 10,000 |
| Analytical data: | |
| 5-Day B.O.D., p.p.m. | |
| Raw | 199 |
| Final | 2 |
| Per cent reduction | 99 |
| Suspended solids, p.p.m. | |
| Raw | 233 |
| Final | 3 |
| Per cent reduction | 98.6 |

*Summary of 1943 Operting Data, Belvidere, Illinois—Continued*

| | |
|---|---|
| Primary treatment | |
| Average detention period, hrs. | 1.14 |
| Secondary treatment | |
| Per cent settleable solids, 30 mins. | 23 |
| Suspended solids, p.p.m. | 564 |
| Sludge index | 408 |
| Return sludge, 1,000 g.p.d. | 201 |
| Per cent of return sludge | 19 |
| Aeration period, hrs. | 7.6 |
| Dissolved oxygen, outlet, p.p.m. | 3.2 |
| Sludge digestion | |
| Lbs. dry solids added, daily | 2,420 |
| Gals. sludge added, daily | 7,060 |
| Per dry solids in sludge added | 4.12 |
| Volatile solids in sludge added, per cent | 63.3 |
| Temperature, F.° | 92 |
| Gas produced, cu. ft. per capita per day | 1.78 |
| Cost data | |
| Cost of plant operation, dollars | 8,487.41 |
| Cost of pumping station operation, dollars | 1,400.00 |
| Cost of administration, dollars | 2,447.68 |
| Cost of fixed charges, etc., dollars | 11,849.06 |
| Total expenses for year, dollars | 24,184.15 |
| Cost per m.g. (including fixed charges) | 63.31 |
| Cost per capita (including fixed charges) | 2.42 |

# TIPS AND QUIPS

**Moments from Montana**, when the infant Montana Sewage Works Association held its First Annual Meeting at Lewistown on April 12–13 . . . the registration of 33 was considered excellent, under the circumstances, and was well within the limit set by O. D. T. . . . interruption of the first afternoon session with the shocking announcement of the death of President Roosevelt . . . and the pause taken while everyone present stood in silence and with bowed head, in respect to his memory . . . the amusing but instructive remarks made by Superintendent K. J. Winebrenner of Kalispell, who told of his trials and tribulations in putting the Kalispell plant into operation, after it had been left unfinished by the W. P. A. . . . the timely reminder by A. W. W. A. President Leonard Thompson of St. Paul, Minn., to the effect that sewage and water works departments have been remiss in failing to conduct adequate public relations programs . . . the lucid explanation of the manpower and materials procurement situations by Lt. Col. Gerry Arnold, U. S. P. H. S. engineer assigned to the Water Division of W. P. B. as director of such services in the western region . . . and his quip that "A priority rating on an order for lumber is just a hunting license," in emphasis of the critical present supply of that material . . . the visit to Lewistown's modern sewage treatment plant, proudly exhibited by City Engineer Joe Schmidt . . . and the compliments of the Federation to Herb Foote, Joe Schmidt, Dean W. M. Cobleigh and others for their efforts in launching so successfully the youngest Member Association of them all!

• • •

**Zinc metallizing** as a means of combatting corrosion appears to be attracting considerable interest in sewage works. Upon receipt of an inquiry from Supt. T. R. Lovell of Marshalltown, Iowa, for information as to the effectiveness of metallic protective coatings as applied to equipment exposed to sewage, he was promptly referred to Supt. W. A. Sperry of Aurora, Ill., who has tried zinc metallizing on a sludge meter. The Aurora experience with zinc metallizing is the first which has come to our attention from a sewage treatment plant.

The following extracts from the ensuing exchange of correspondence will be of interest to other operators; the first extract is from Mr. Sperry's reply to the original inquiry:

"We have long been impressed by the possibility of zinc metallizing in sewage treatment plants because zinc is relatively unaffected by hydrogen sulfide. Further, we have been interested in Palmer's experiences at Erie, Pa., as reported in *Water Works and Sewerage,* September, 1942, Page 391.

"We undertook recently to rebuild the tipping bucket sludge meter which has been in use at Aurora for more than 10 years. In the course of this job, we accidentally learned that a local firm was in a position to furnish the equipment a zinc metallizing treatment, that is, sprayed zinc. We immediately availed ourselves of the opportunity and had the sampling tank, hopper, body, cover and tipping bucket of the meter completely metallized. The zinc was sprayed to an approximate thickness of 0.004 inch, which is considered a good weight of protective coating. The spray was passed over the meter repeatedly in various directions so that the zinc is built up of overlapping layers. The cost was about $30, which is considered reasonable in view of the protection which is anticipated.

"The sludge meter has been in operation only 3 months since the above work was done and there has not yet been sufficient time for us to evaluate the protective treatment. While attending an operators' meeting not long ago, some doubt was cast on the advisability of the sprayed application, based on the statement that spraying was likely to leave porous spots at which moisture might penetrate and instigate rusting behind the zinc. Note that the objection was not to the use of zinc, but rather to the method of application. The counter suggestion was that a dipped job would be better because it would result in a heavy continuous film of zinc that could be built up to any desired thickness. The procedure in this case would be to clean the metal thoroughly with acid, dip the part into a saturated solution of ammonium chloride to act as a flux and then plunge it into a bath of molten zinc. We have performed this operation on certain small items exposed to weathering, with exceedingly gratifying results, but it is pointed out that the method could be used on pieces as large as the sludge meter only by someone equipped for the work.

"We expect to watch carefully our experimental trials of zinc metallizing and consider them as pilot studies for reference at some future time when we might use this method of protecting the equipment in our primary clarifiers. We are particularly watchful for any evidence of porosity in the spray job but have been assured by those who have had considerable experience with this type of coating that porosity is not to be greatly feared, particularly if care is taken to apply the zinc by successive passes of the torch and to build it up in overlapping layers. I think the method has good possibilities and have been careful to furnish reasonable details but you will have to use your own judgment on the application of the method in your plant."

Mr. Lovell responded to the above by relating some of his experiences with corrosion at Marshalltown and in the plant at Fort Dodge, Iowa, which he formerly supervised:

"The Marshalltown plant has been in operation 5 years; it comprises separate sludge digestion and activated sludge units, and handles a sewage which is concentrated by industrial wastes. The aeration tanks are equipped with Chicago swing diffusers and the final tanks are equipped with Tow-Bro sludge removal mechanisms. It is in these tanks that our corrosion is worst. The wrought iron diffuser headers and even the cast iron feed pipes that are submerged are badly pitted and corroded. The same applies to the multiple weir troughs and to the Tow-Bro piping, bracing and sludge heads in the final tanks.

"It is possible, of course, that some of this is due to electrolysis. At Omaha, where they have similar diffusers, cathodic protection was installed to eliminate the condition, but at last reports the method was not a success. I have tried cleaning and painting the equipment but the expense has not been warranted because of the short time the paint lasts. We must find some way to protect the equipment or will find it necessary to replace many parts within two or three years.

"My experiences at the Fort Dodge plant and here have convinced me that zinc or galvanized equipment stands up about the best. I might mention, however, that we have a good many stop-gates and guides, proportional weirs, etc., that are made of cast aluminum and that to date they show no signs whatever of corrosion or pitting. If I can get the metallizing equipment, I intend to try some aluminum to see how it compares with zinc.

"Our sewer department owns a large portable compressor and I feel that we would be justified in spending about $900 for the metallizing equipment, including the sand blast equipment which we should have even for painting. We have a good many other applications for the equipment since this plant is highly mechanized and maintenance has become our biggest problem.

"We have another problem at our grit removal equipment, flocculator and primary tanks in that excessive wear of flight shoes, underwater drive chains, grit buckets, sprockets, underwater bearings, etc., is caused by fine sand which enters the system and plant due to defective joints in some of the old sewers which lie in quicksand. The sand is so fine that much of it passes through the grit channels and collects in the flocculators and primary sludge hoppers. Last year we replaced all underwater drive chains and bearings in the flocculators and rebuilt all of the wearing shoes of the sludge collector flights. I do not know whether metallizing with an abrasion resistant metal would help or not; I am rather doubtful on that score."

Mr. Sperry's second response reviews corrosion experience and other experiments with protective coatings at Aurora:

"After reading your interesting letter it seemed that you might possibly profit further by some additional comments arising out of experience at Aurora. In the first place, we carried out a 3-year experiment by exposing a large variety of metals to the presence of moist plant gas to observe the corrosive effect of the sulfur constituent. This work was done under conditions of known moisture hydrogen sulfide content of the gas. Careful observation was made of the test pieces and we found, generally speaking, aluminum, zinc and lead to be unaffected. Unfortunately, we neglected to add tin to the group, but are firmly of the opinion that tin would take its place among this group. Iron, in various forms, as cast, malleable, steel and wrought, was possibly affected partly by reason of sulfur and oxidation. Coppers were severely attacked and the large number of copper bearing alloys were attacked in rough proportion to the amount of copper present. We agree with you, therefore, in the suspicion that zinc is generally unaffected by the sulfur in the sewage. We also are of the opinion that sprayed metal applications are fairly resistant to abrasion. We hazard this guess based on experiences related to us by a large local conveyor manufacturing concern, which applied zinc metallizing to large conveyor belt rollers used in mine work, where the equipment has been subjected to severe moisture and wear conditions with a very long and satisfactory history of the zinc retaining its protective properties, *i.e.,* it did not wear off or give out.

"The specific reason that we have been attracted to metallizing as a protective covering on underwater clarifier mechanisms is that two of our clarifiers are in use and the other two lie empty and unused. If all four clarifiers were continuously in use we doubt if we would ever bother to apply any paint coating due to the fact that the greases of the sewage, in the absence of oxygen, are quite completely protective. The destruction comes from long exposure to moist air. Every time we have applied a paint coat, not only was it a difficult and unsatisfactory job to prepare the metal due to complicated construction, but not a vestige of the paint remained after a year. To date, we know of no paint that will 'stay put.' The most promising treatment for the shut-down period now appears to be the application of 'Rust Proof L' (Texaco product), which is a glorified axle grease. This is messy to apply but is reported to be doing excellent work, and recently the State Highway Department of Illinois, following exhaustive tests, has adopted it for bridge structures and other highway equipment.

"One other interesting comment is in connection with our Dorr Detritor mechanism which has operated for about fourteen years. When we finally had to withdraw it, those portions of the rake which were continuously submerged in raw sewage were in perfect condition except for wear on the edge of the rake teeth, and the paint, possibly a baked enamel, was still intact. Those portions alternately in and out of the raw sewage had worn to knife edges or had completely rusted out.

"We have long felt that aluminum might have many valuable possibilities as a structural material, but the sensitiveness of aluminum to alkali might prove a factor and one would want knowledge of some long exposure before venturing too far in this direction."

Mr. Lovell's last letter refers to the application of metallizing in British sewage works:

"In your last letter, you refer to your three-year experiment with various types of metals exposed to moist plant gas. At the Fort Dodge plant the engineers specified copper flashing, eaves trough and downspouts and then, unfortunately, connected these downspouts to the bypass sewer. These served quite well as ventilator stacks for the sewer, with the result that the copper was completely eaten through in less than a year. Eaves trough and flashing were attacked but to a lesser extent. Similarly, a copper skylight frame and ventilator on the sample room between the digesters were completely ruined in a very short period. At the outlet of the trickling filters, the filter effluent from a number of filters was combined in manholes ahead of final tanks. These manholes were equipped with cast iron manhole steps and with cast iron sluice gates for bypass arrangements. This cast iron scaled off and deteriorated in the same manner as steel normally does under such conditions.

"We also found the same conditions at our primary clarifier mechanisms at Fort Dodge as you have at Aurora, that is, that the mechanism was protected by the coating of greases in the sewage except for those parts that became worn from abrasion. We assumed that this same condition would prevail with reference to the underside of the floating covers on our sludge digesters. However, after about four years of operation we made an examination of these covers and found them badly corroded. They considered metallizing at that time but finally decided to paint following sand blasting. I don't know what their experience will be when they find the opportunity to examine these covers again. I don't believe this condition is normally experienced with floating covers, at least I haven't heard of anyone else who has had this same experience. I feel that the high sulfate content of the Fort Dodge water may have something to do with this as the sludge gas at Fort Dodge normally contains anywhere from 150 to 400 grains of $H_2S$ per 100 cu. ft.

"Your reference to 'Rust Proof L' is of interest since we received a sample of this material from Texaco and tried it on our underwater equipment in the aeration tanks. We found no evidence of it after several months of service. I assumed that the constant agitation of the mixed liquor would wear it off. For protecting idle equipment such as you describe it would probably give good service.

"I have just received a letter from the Metallizing Engineering Company, Inc., 38–14 30th Street, Long Island City 1, N. Y., in reply to an inquiry as to whether they had ever had an application of their process in sewage plant work. They sent me the subject matter of an article that is soon to appear in their publication *Metco News,* which article has been received from their English representatives. In brief, the article refers to the metallizing of cast iron sludge trays or containers used in the silica-gel process of sewage treatment. I am not familiar with this process but from the article I take it that these trays are submerged. The article states that the trays had been showing extreme corrosion conditions and that in 1937 sewage engineers ran tests on both old and new trays, metallizing with 0.002 inch, 0.005 inch and 0.010 inch zinc and with galvanizing. It is added that just before the war the following specification was adopted by these engineers:

1. All new sludge plates should be metallized with 0.005 inch zinc on the inner faces.
2. All used sludge plates should have a minimum of 0.005 inch zinc over the whole inner surface, but the thickness should be increased up to a maximum of 0.010 inch on any area which was badly corroded, and any deep local pitting should be roughly filled with the sprayed zinc."

• • •

Placement of fire extinguishers according to the following suggestions of the Safety Research Institute, Inc., will assure their availability in time of need:

"Portable fire extinguishers should be placed where they are readily available and access to them is not likely to be cut off by fire.

"When used to provide general protection for an area containing normal fire hazards, extinguishers should be so placed that at least one large or two small ones can be reached by traveling no more than 50 feet from any point in the area. Fewer extinguishers are required when the fire hazards are light, and more when they are severe.

"Extinguishers may be mounted on columns or walls, with hangers, brackets or shelves as supports. The tops of easily handled units should not be more than 5 feet from the floor; with heavy units, this distance should not exceed 3½ feet.

"Extinguishers should be placed where they can be plainly seen. When they are wholly or partly concealed, their locations should be marked with conspicuous signs.

"Nothing that might interfere with the accessibility of an extinguisher should be placed under or near it. All extinguisher locations should be checked at least once a day, and any obstructions found should be removed immediately."

• • •

Chemist Justin J. Alikonis of the Bloomington-Normal (Ill.) Sanitary District reports an experience that points to a loss of digestion capacity at Imhoff tanks in which grit may have accumulated over a period of years.

A persistent case of foaming this spring in all of the four Imhoff tanks could not be brought under control by the usual remedies of rest (by removal from service) and pH adjustment. The foaming would subside during the rest period but resumed within a week after the tanks were replaced into service.

At the suggestion of District Engineer J. J. Woltmann, one of the tanks was drained and an explanation of the foaming tendency in the tanks became evident. This tank was found to contain a surprising amount of grit and stiff, over-ripe sludge so that the volume of the sludge compartments was measurably reduced. About 110 cubic yards of grit and 364 cubic yards of a mixture of grit and "dead" sludge, in a ratio of approximately 1:3, were removed from this one tank. The volume of material removed represented about a third of the effective sludge storage capacity of the unit.

A case of indigestion brought on by a collection of "gall stones," as it were!

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A new policy on charges for cleaning sewers which are clogged by industrial wastes has been adopted by the city of Chicago, according to an item appearing in *The Chicago Tribune* of February 26, 1945, as follows:

"Thomas D. Garry, superintendent of sewers, said the city collected its first bill yesterday in a new policy of charging industries for the expenses of flushing and scraping sewers clogged by industrial wastes. The Western Shade Cloth Company, 2141 Jefferson St., paid $173.58 for which it was billed by the city for labor and other costs of cleaning oily waste from a sewer. Garry and Public Works Commissioner Hewitt said the city will continue to bill factories responsible for clogged mains. City engineers will co-operate with the industries, they said, in designing catch basins to prevent clogging."

Looks like a good way to make industry realize that even a sewer has some limitations.

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"Just like a shot in the arm" is the way C. O. Baetz of the Repairs and Utilities Section office at Salt Lake City described his chance meeting at Camp White, Ore., with Capt. S. C. (Sandy) Martin, who is now located at Camp White and is on leave from the Illinois Department of Public Health. A long way from home were these two "Central Staters."

Baetz, who was formerly superintendent of the Appleton, Wis., sewage treatment plant, tells of an experience encountered in his travels through the West. It appears that the effluent from a sewage treatment plant serving an army air base in Arizona is used for irrigation of alfalfa fields. A rancher pasturing cattle in these fields hired a new hand to attend the herd. At the end of a week, the rancher called on the cowhand to see how he was getting along and inquired about the water supply, referring, of course, to the sewage works effluent which was depended upon for watering the cattle. The cowhand's response, "Say, where does that water come from anyhow? It's the best darn water I ever drank!" perturbed the rancher no end, and sent him forthrightly to the air field in search of an antidote and medical advice. Apparently, no harm was done except to the rancher's peace of mind.

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And then there was the gentleman from the hills, who is said to have written to a clay pipe association in response to an advertisement he had seen. After extolling the virtues of smoking and expressing his own enjoyment of the habit, he wanted to know if he might not have a complimentary sample!

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# Editorial

## CONGRESS STUDIES FEDERAL CONTROL OF STREAM POLLUTION

Despite the many pressing domestic and international questions of the moment confronting the 79th Congress, a surprising interest is being evidenced in Federal stream pollution control legislation. The fact that no less than three House bills and two Senate bills have been introduced at this writing, all proposing the establishment of Federal authorities to administer problems of water pollution, demonstrates the importance of the matter in the minds of our national lawmakers, who have been considering pollution control legislation for several years. Had it not been for the war, it is likely that one of the earlier bills would have become law by this time; it is significant that the problem is one of the first items of unfinished business to be taken up as peace begins to brighten the horizon.

All of the bills now under consideration by Congress have essentially the same objectives, *i.e.*, the establishment of a Federal coordinating agency to function with state and local bodies in stream pollution investigations and abatement programs, to facilitate interstate action, to conduct research, etc.; and to provide for loans and grants to municipalities for the purpose of planning and constructing works necessary to abate pollution. There are important differences in the bills, however, particularly in regard to enforcement authority.

The Barkley-Spence Bill (S. 1037 and H. R. 592) is identical to the one introduced by Senator Barkley and Congressman Spence in the 78th Congress and which was endorsed in principle by the Federation Board of Control in 1944 (*This Journal*, **17**, 2, 392). The measure invests the Sanitary Engineering Division of the U. S. Public Health Service with new duties and responsibilities, and establishes a Water Pollution Advisory Board which would function only to review programs and policy. No direct Federal enforcement authority is provided by the bill. An appropriation of $50,000,000 per year is provided for approved loans and grants-in-aid, the latter being limited to 50 per cent of the total cost of the project. An additional $1,500,000 per year is appropriated for distribution among state pollution control agencies to finance investigations and special studies.

The White and Smith Bills (S. 330 and H. R. 587) provide for a new Division of Water Pollution Control in the U. S. P. H. S. and for the creation of a Board of Water Pollution Control in the new division. The Board is to comprise four sanitary engineers of the U. S. P. H. S. and one representative of the Office of Chief of Engineers of the War Department. The bills require the Board to classify all navigable waters into "sanitary water districts," to fix "standards of purity" in each, and provide that action shall be taken by the U. S. District Attorney to bring about abatement of pollution which violates the "standards"—an enforcement provision which is most inflexible and allows no exercise of discretion. A maximum appropriation of $50,000,000 per year is authorized for approved loans and grants, with such grants limited to 33⅓ per cent of the cost of the project. The sum of $700,000 per year is appropriated for distribution among state pollution control agencies for technical investigations.

The Myers and Mundt Bills (S. 535 and H. R. 519) establish an entirely new Federal agency, designated as the National Board of Water Pollution Control, to comprise the Surgeon General with certain members of the Cabinet and representatives of Congress. For administration of the Act, the Board is empowered to appoint an operating Commission, which consists of designated representation from seven existing Federal Bureaus and services engaging in activities associated with the conservation of natural resources. Enforcement authority similar to that provided under the White-Smith Bills is invested in the Board proposed by this legislation but such authority is specifically devised to supplement action by state pollution control agencies and allows the Board to exercise discretion in special cases. Loans and grants for the construction of works needed to abate pollution are authorized upon recommendation by the Board "in the amounts and under the conditions that may be prescribed by Congress for other public works."

The U. S. Public Health Service, prominently represented in all of the above pollution control measures, is intensely interested in the legislation. The opinions and recommendations of that agency are contained in the following statement of policy, dated March 13, 1945:

"The general magnitude and importance of the water pollution problem in the United States, and its relation to the various uses of water and the public health have been well established. Likewise, the inability of State and local authorities to adequately control the pollution of interstate waters without the assistance of a central coordinating agency has been demonstrated over the years.

"It is generally recognized that there is a need for Federal legislation to provide a stimulus to water pollution abatement activities and the necessary coordination of existing control authorities.

"The Public Health Service has been engaged for many years in the investigation of interstate water pollution problems, individually and in cooperation with State and Federal agencies. This activity has been limited in scope since it has, of necessity, been confined to investigations.

"The Public Health Service is interested in any Federal legislation dealing with the pollution control of interstate waters which provides for the following items:

1. Provisions for a Federal agency to act as a coordinator and advisor in matters pertaining to water pollution and its abatement, with authority to carry on investigations and other activities necessary in developing more efficient methods of treatment of sewage and wastes and in preparing comprehensive water pollution abatement programs.
2. The authorization for appropriations of funds sufficient in amount to permit the Federal agency to properly carry on the duties assigned to it.
3. Provision for an advisory board to the agency, the membership of which will include representatives of Federal agencies officially concerned with uses and control of water resources which may be affected by pollution.

4. Permission for States to form interstate compacts for cooperative effort in the prevention and abatement of pollution of interstate waters.
5. The authorization for appropriation of funds for allocation to States for promotion, investigations and preparation of engineering reports and plans necessary for the prevention and abatement of water pollution.
6. The authorization for appropriation of funds for grants-in-aid or loans to civil subdivisions of government and loans to persons for the purpose of constructing sewage and waste treatment works.
7. Provision for the continuing interest by the Federal authority in the efficient operation of completed projects to insure that maximum benefits are derived from improvement works on which Federal funds have been expended.

"The Public Health Service makes no recommendations at this time relative to the nature or degree of regulatory or enforcement provisions in water pollution control legislation. The decision as to the extent to which the Federal government should be provided with, and exercise police powers in the control and abatement of water pollution is a matter primarily of legislative policy to be determined by the Congress."

The Federation, in acting through its Board of Control on the Barkley-Spence Bill last year, has approved the general objectives of Federal pollution control legislation which embodies the retention of the rights of the state pollution control agencies insofar as possible. No definite stand has been taken on the important issues of financial participation and enforcement of abatement through Federal channels, which issues are at greatest divergence in legislation presently proposed.

On the question of Federal loans and grants-in-aid, the writer subscribes to the common opinion that pollution abatement projects should find sufficient financial support on their own merits to be self-liquidating as financed through independent channels but that in the event that a broad Federal public works construction program is found essential to the national economic structure and welfare, such projects should be among the foremost to receive impetus through Federal subsidy. There is also a personal feeling that all provisions for loans and grants might well have been eliminated from this particular legislation, since, first, they are likely to overshadow the fundamental intents and purposes of the bills and, second, there would appear to be considerable logic to the provision of Federal public works subsidies in a single, separate measure covering all of such works, if and when Congress deems such subsidies to be necessary to the national economy. There is no fault to be found, however, with the proposals to give financial aid to state agencies for the conduct of technical studies.

A Federal authority empowered to supplement the enforcement authority of state agencies in effecting pollution abatement is believed to justify support. There should be a careful integration, however, of the national and state authorities in their powers to prescribe standards of stream sanitation and to act against parties responsible for objectionable pollution. Above all, the national agency should be given discretionary authority, in line with that provided in most state legislation, so that all regulations may be administered fairly in every case. There is believed to be merit in a requirement that the Federal authority could take enforcement action only when so requested by the state or states involved.

A third issue at divergence in the legislation now before Congress, not previously emphasized, is the creation of a new Federal agency to administer water pollution control, as proposed in the Myers and Mundt Bills. The writer is strongly of the opinion that such a new agency is not desirable, for reasons other than the fact that there is already a surplus of conflicting Federal bureaus. The Division of Sanitary Engineering of the Public Health Service is well equipped in staff and background to assume the additional duties which would be required of it; the legislation actually merely authorizes an expansion of some of the functions now carried on by that Division. The Public Health Service has already contributed heavily to the knowledge and technic of stream pollution investigations and enjoys the confidence and respect of everyone engaged in that work. Furthermore, most state pollution control activities are conducted by the sanitary engineering personnel of departments of health and it is only reasonable that the national coordinating agency should be a similar organization. It would be indeed unfortunate if the experience and understanding of the problem represented in the Public Health Service were to be sacrificed by the creation of a new pollution control agency outside of the Service.

Of the three types of legislation now under consideration, it is believed that the Barkley-Spence Bill, with certain revisions, is best fitted to pollution control requirements. Amendments have been proposed which would: (1) provide a more definite state enforcement procedure in pollution abatement, (2) reduce the amount of Federal grants-in-aid from 50 to 33⅓ per cent, (3) increase the annual appropriation for loans and grants-in-aid from $50,000,000 to $100,000,000 per year and (4) make the Federal appropriation available immediately for planning purposes.

It is hoped that Congress approaches the Federal pollution control problem with due exercise of judgment and that a sound, practical and progressive law will result. It is timely to repeat the recommendation of the Board of Control that "all individuals and organizations interested in the elimination of stream pollution communicate their views to members of the Congress to the end that adequate implementing Federal laws may be enacted."

W. H. W.

# Federation Affairs

## 1945 CONVENTION AT TORONTO POSTPONED!

In accordance with the requirements of the War Committee on Conventions of O. D. T., the Board of Control of the Federation has postponed for an indefinite period the annual convention which had been planned to be held in Toronto, Canada, on October 1–3, 1945. The next convention of the membership-at-large will take place at Toronto at a time to be determined by the Board, in compliance with Federal regulations and the Constitution and By-Laws of the Federation.

The regular annual business meetings of the Board of Control, usually held in conjunction with the convention each year, will be held on October 17–18, 1945, probably in Chicago. Attendance at these sessions will be restricted to officers, directors and committee chairmen.

Despite the postponement of the 1945 Convention, the technical program already in assembly by the Program Committee headed by F. W. Gilcreas will be brought to the membership-at-large through the medium of Sewage Works Journal. These papers will appear in issues of the Journal beginning with that of September, 1945, which issue has been designated as the "Annual Convention Number" as has been customary in recent years. Among the outstanding papers comprising the tentative program are the following:

- The Development of the Activated Sludge Process of Sewage Treatment. By Samuel A. Greeley.
- Installation and Maintenance of House Sewer Connections. By N. MacNichol.
- Accomplishments and Future Applications of Trickling Filters. By E. Sherman Chase.
- Experiences with Activated Sludge at Toronto. By Wm. Storrie.
- Rising of Activated Sludge in Final Settling Tanks. By Claire N. Sawyer and Leland Bradney.
- Conditioning of Supernatant Liquor for Addition to Aeration Tanks. By L. S. Kraus.
- Operating Experiences in the West Middlesex (England) Activated Sludge Plant. By C. B. Townend.
- Disposal of Pickling Liquor. By Richard D. Hoak.
- Standards of Stream Sanitation. By Harold W. Streeter.

The complete program as finally arranged by the committee will be given in the September issue of the Journal.

W. H. Wisely, *Executive Secretary*

# Reviews and Abstracts*

Conducted by
GLADYS SWOPE
Mellon Institute of Industrial Research,
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## STREAM POLLUTION IN TENNESSEE

State of Tennessee, Stream Pollution Study Board, Nashville, Tennessee
1943–44
(48 pages, 28 figures)

In 1943 the General Assembly passed a resolution authorizing the Governor to appoint a Stream Pollution Study Board. In December of that year a board of seven members was appointed, selected to represent municipalities, industries, and the state. It was felt that such a board could investigate the questions of stream pollution to the interest of the three groups mentioned.

Tennessee is drained by five river basins; the Cumberland, Tennessee, Mississippi, Green and Conasauga. The first three were divided into smaller natural drainage basins for purposes of study. The following table shows the population and area of each major basin.

| Drainage Basin | Population | | | Area in Sq. Mi. | Population per Sq. Mi. |
|---|---|---|---|---|---|
| | Rural | Urban | Rural | | |
| Cumberland | 471,192 | 223,391 | 694,583 | 10,450 | 66.5 |
| Tennessee | 976,072 | 443,760 | 1,419,832 | 22,864 | 62.1 |
| Mississippi | 413,009 | 360,055 | 773,064 | 8,127 | 95.1 |
| Green | 24,054 | 0 | 24,054 | 400 | 60.1 |
| Conasauga | 4,308 | 0 | 4,308 | 120 | 35.9 |
| Total | 1,888,635 | 1,027,206 | 2,915,841 | 41,961 | 69.5 |

Surface waters are used for many purposes and by most of the people of the state. About 20 per cent of the population are dependent on such waters as a source of domestic water supply. As for industrial water supplies, about 80 per cent of the water used by industrial plants is obtained from surface supplies. The table at top of page 853 shows information on public and industrial water supplies in the state.

Fishing and other recreational uses of the waters of the state are of importance. There are 200 lakes with an area totaling more than 500,000 acres, and some 15,000 miles of rivers and streams. Commercial fishing may become of importance. In 1943 it is reported that the commercial value of fish taken from the Wheeler, Wilson and Pickwick reservoirs in Alabama was in excess of $200,000.

Production of electric power has become of great importance in Tennessee. Stream pollution adversely affects this industry because of damage to equipment and structures, and because of depositing of silt in reservoirs.

* It will be appreciated if Miss Swope is place on the mailing lists for all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in this *Journal*. Publications of public health departments, stream pollution control agencies, research organizations and educational institutions are particularly desired.

| | Cumberland | Tennessee | Mississippi | Green | Total |
|---|---|---|---|---|---|
| *Public Water Supplies* | | | | | |
| Communities, | | | | | |
| Surface Supplies | 22 | 33 | 1 | 0 | 56 |
| Ground Supplies | 23 | 98 | 52 | 1 | 174 |
| Total | 45 | 131 | 53 | 1 | 230 |
| Population, | | | | | |
| Surface Supplies | 235,322 | 354,380 | 1,503 | 0 | 591,205 |
| Ground Supplies | 35,188 | 171,006 | 401,256 | 1,212 | 608,662 |
| Total | 270,510 | 525,386 | 402,759 | 1,212 | 1,199,867 |
| *Industrial Water Supplies* | | | | | |
| Number of Plants | 75 | 162 | 41 | 0 | 278 |
| Surface Supplies, G.P.D., | | | | | |
| From Munic. System | 2,302,700 | 8,633,400 | 0 | 0 | 10,936,100 |
| From Private Supply | 26,259,600 | 149,679,500 | 0 | 0 | 175,939,100 |
| Ground Supplies, G.P.D., | | | | | |
| From Munic. System | 147,200 | 947,500 | 421,000 | 0 | 1,515,800 |
| From Private Supply | 306,100 | 7,404,200 | 34,713,800 | 0 | 42,424,100 |
| Total | 29,015,600 | 166,664,700 | 35,134,800 | 0 | 230,815,100 |

*Note: No municipal or industrial supplies on Conasauga basin.*

| Municipal Systems | River Basin | | | |
|---|---|---|---|---|
| | Cumberland | Tennessee | Mississippi | Total |
| Number of Communities | 31 | 77 | 34 | 141 |
| Population of Communities | 250,483 | 476,093 | 396,281 | 1,122,856 |
| Population Connected | 189,240 | 364,040 | 382,990 | 936,220 |
| Type of Treatment | | | | |
| Communities: | | | | |
| None | 14 | 41 | 13 | 68 |
| Primary | 12 | 33 | 24 | 69 |
| Secondary | 7 | 7 | 2 | 16 |
| Population | | | | |
| No Treatment | 153,070 | 285,660 | 339,260 | 777,990 |
| Primary Treatment | 9,720 | 53,750 | 42,130 | 105,600 |
| Secondary Treatment | 26,450 | 24,630 | 1,600 | 52,680 |
| *Industrial Wastes* | | | | |
| Number of Industries | 63 | 172 | 47 | 282 |
| Population Equivalent | 235,040 | 718,350 | 314,430 | 1,267,820 |
| *Population Equivalent Discharged to Sewers:* | | | | |
| Domestic | 164,660 | 331,200 | 370,650 | 866,530 |
| Industrial | 232,200 | 711,180 | 311,430 | 1,267,820 |
| Total | 396,860 | 1,042,400 | 682,080 | 2,121,340 |

Surveys of the sources of pollution show a population within the state of 936,270 served by sewerage systems, and an industrial population equivalent of 1,267,820. It is estimated that these figures are reduced by treatment to 866,530 and 1,254,810, respectively. The industrial equivalent is based on the 5-day B.O.D. determination, using a factor of 0.168 pounds B.O.D. per capita per day. The table at bottom of page 853 shows data relative to municipal sewage and industrial wastes.

The preceding table shows 282 industrial plants in the state. These may be divided into 10 types of industry as shown by the table below. The list is not complete. Most of the plants built since 1940 and munitions plants are not included because, in general, data were not available. Wastes from small local industries such as laundries, milk plants, and others were included as part of the municipal sewage load in the above table.

*Type of Industrial Pollution*

| Type of Industry | Number of Plants | Estimated Population Equivalent | |
|---|---|---|---|
| | | For Plants | Per Cent |
| Canning | 38 | 62,870 | 5.0 |
| Cellulose | 7 | 554,800 | 43.8 |
| Chemical | 28 | 34,900 | 2.8 |
| Meat | 27 | 149,090 | 11.8 |
| Milk | 62 | 29,460 | 2.3 |
| Mining | 9 | — | — |
| Pulp and Paper | 6 | 274,000 | 21.6 |
| Tanning | 3 | 34,100 | 2.7 |
| Textile | 67 | 90,800 | 7.2 |
| Miscellaneous | 35 | 37,800 | 3.0 |
| Total | 282 | 1,267,820 | 100.0 |

Pollution from other states received by Tennessee streams amounts to an estimated population equivalent of 851,380. This figure is made up of 257,490 from domestic sewage and 593,890 from industrial plants. These figures represent the load as discharged to the streams and do not take into account the natural recovery that takes place before the streams enter the state.

Estimates of the cost of providing intercepting sewers and treatment works were prepared. These estimates are based on the assumption that at least primary treatment would be provided for all communities, plus secondary treatment where stream damage has been shown on smaller streams.

The need of water pollution control for surface waters in Tennessee is recognized. The miles of streams in a critical condition at the present time is relatively low compared to the total stream miles in the state. The mileage is great enough, however, to

*Estimated Cost of Facilities for Treating Domestic Sewage and Industrial Wastes in Tennessee*

| Drainage Basin | Total Costs in Thousands of Dollars | | | |
|---|---|---|---|---|
| | Intercepting Sewers | Municipal Treatment Plants | Industrial Treatment Plants | Total |
| Cumberland | 5,700 | 2,630 | 290 | 8,620 |
| Tennessee | 15,500 | 8,850 | 1,200 | 25,550 |
| Mississippi | 6,670 | 8,450 | 90 | 15,210 |
| Total for State | 27,870 | 19,930 | 1,580 | 49,380 |

cause great economic and enjoyment loss and the pollutional load reaching the streams is increasing each year.

In order to provide a convenient method of describing the surface waters of the state a classification based on the minimum acceptable qualities of water for various uses is proposed. This classification does not fix the condition of the stream or indicate the desired quality but only describes the quality of the water that existed at the time it was studied or under calculated conditions. There are four classes proposed, as follows:

*Class I Condition.*—Waters suitable for public water supplies with minimum treatment such as chlorination or disinfection with possibly filtration to remove turbidity. They are preferred for swimming and recreational sites.

*Class II Condition.*—Waters in this classification can be treated by normal filter plant operation to produce satisfactory water supplies. This is the normal classification of streams in the state that receive surface run-off and distant pollution. They may be acceptable for swimming if the number of bacteria of the coliform group is low. They are suitable for healthy fish life.

*Class III Condition.*—Waters in this classification can be treated by advanced treatment methods. They are not desirable as sources of public water supply due to taste-producing substances and low factor of bacterial safety. They are not considered safe for swimming and are not desirable for other recreational uses. They will support fish and other aquatic life but the most desirable types of fish may be absent.

*Class IV Condition.*—Waters in this classification are not suitable for public or industrial supplies. They are not suitable for swimming and will not support desirable aquatic life.

Additional standards for waters of the first three classifications are shown in the following table.

| Stream Conditions | Class I | Class II | Class III |
|---|---|---|---|
| Appearance: | | | |
| Oil, floating solids, scum or debris except from natural sources | None | None | Moderate, localized |
| Color, p.p.m. | 20 (desirable) | Amount of color and turbidity which can be removed with normal equipment by standard practices | Amount of color and turbidity which can be removed economically by advanced methods |
| Turbidity, p.p.m. | | | |
| 5-day B.O.D., p.p.m. | | | |
| Monthly average | 1.0 | 2.0 | 4.0 |
| Maximum observation | 2.0 | 4.0 | 6.0 |
| Dissolved Oxygen, p.p.m. | | | |
| Monthly average | Above 7.0(*a*) | 6.5 | 5.5 |
| Minimum observation | 7.0(*a*) | 5.0 | 4.0 |
| Coliform Group | | | |
| Monthly geometric | | | |
| Average M.P.N. per ml. | | | |
| Swimming | 0.5 | 10 | Not approved |
| Water supply | 0.5 | 50 | 200 |
| pH | 6.5–8.6 | 6.5–8.6 | 5.0–9.5 |

(*a*) Upper layers of stratified lakes and pools.

The Study Board recommends legislation which will place the responsibility for water pollution control in a Stream Pollution Control Board. The Control Board should be composed of the Commissioners of the State Departments of Health, Conservation, and Agriculture, and two appointive members to represent municipalities and industry. The administration of the program should be centralized in the State Department of Public Health. The Board should have the following powers:

1. Power to define what constitutes pollution, with the definition based on the consideration of all phases of water use.
2. Power to promulgate rules and regulations to interpret and facilitate its authorized powers and functions.
3. Authority to investigate pollution and to issue orders against those causing pollution, requiring abatement of pollution.
4. Power to seek injunctions when necessary to protect the public interest.
5. Power to review plans of new waste systems and treatment works prior to construction and to require suitable treatment.
6. Control over the maintenance and operation of waste treatment works.
7. Power to order the construction of sewage and waste treatment works.

*Note: The report contains a copy of the Bill proposed to authorize the proposed stream pollution program, and a general plan of the program.*

T. L. Herrick

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# SOME EXPERIENCES WITH RISING SLUDGE IN HUMUS TANKS

By L. F. Mountfort

*The Surveyor,* 104, 65–66 (February 2, 1945)

The phenomenon of rising sludge has been observed at the East Middlesex Main Drainage Works for several years and various methods have been tried for ridding the surface of the final settling tanks of the sludge blanket.

The sewage dealt with receives the effluent from the sulfate of ammonia plant of a gas company which discharges about 60,000 gallons per day of waste or nearly one per cent of the total sewage flow.

Sewage at the works is treated in sedimentation tanks, percolating filters and humus tanks following the filters. The filters are six feet deep and are filled with broken flint gravel in the lower three feet of depth with three feet of metallurgical coke on top of the gravel. All medium is graded three inch to one inch. Sewage is applied to the filters by self-propelled rectangular travelling distributors.

The humus tanks have a water depth of 26 feet and the ratio of normal flow to tank surface area is about 8, the units being square feet and hours.

Sludge can accumulate to a depth of 4 to 5 inches on the surface of the humus tanks.

In the absence of gas effluent the amount of nitric nitrogen in the final effluent ranges from 30 to 40 p.p.m. When gas effluent is being treated, the final effluent may contain from 50 to 60 p.p.m. of nitric nitrogen. The amount of nitrous nitrogen does not vary much and is usually not more than 0.5 p.p.m. The effluent from the filters and the final effluent from the humus tanks usually are about 60 per cent saturated with dissolved oxygen.

There appears to be a direct and immediate relation between the presence of gas effluent and the occurrence of rising sludge. On every occasion where there has been a cessation of gas effluent discharge, the tank surface has remained reasonably free from sludge during the whole period, but within 24 hours of the arrival of gas effluent, the whole surface of the tank is covered with a blanket of sludge.

The humus tanks are of the hopper bottom type and are not equipped with sludge withdrawal mechanisms. Experiments were conducted to determine the rate at which sludge should be drawn from the desludging pipes. It was found that if 5 per cent of the tank flow was withdrawn through the desludging pipes, there would be no accumulation of sludge on the tank surface. This was a large quantity of sludge and it was found necessary to provide sludge concentrating tanks for separating the excess water from the sludge.

K. V. Hill

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## EFFECT OF SPENT GAS LIQUOR ON COLD SLUDGE DIGESTION

By A. Sciver and E. H. M. Badger

*Gas Journal* (London), 242, 520–521 (Oct. 27, 1943)

The Ascot District Gas and Electric Co. petitioned the Windsor District Council for permission to discharge spent gas liquor into the sanitary sewerage. The Windsor sewage treatment works is equipped with cold digesters designed for a population of 9,000 but during the war the District population increased to 13–14,000 and the permission was refused. Upon appeal to the Ministry of Health, however, the petition was granted under the following stipulations:

1. Volume discharged in any day of 24 hours not to exceed 2,200 gal.
2. Volume discharged in any hour from 6 A.M. to 10 P.M. not to exceed 120 gal., and in any hour from 10 P.M. to 6 A.M., 60 gal.
3. The composition of the gas liquor as determined at the point of measurement must meet the following conditions:
   - (*a*) Oxygen absorbed from N/80 acid $KMnO_4$ in 4 hrs. at 26.7° C. shall not exceed 12,000 parts per million by weight.
   - (*b*) Free ammonia (as $NH_3$) determined by simple boiling without addition of alkali, and distilled into standard acid, shall not exceed 400 parts per million.
   - (*c*) Sulfide (as S) shall not exceed 100 p.p.m.
   - (*d*) Suspended solids shall not exceed 60 p.p.m.
   - (*e*) The pH shall not be less than 6 nor more than 10.
   - (*f*) Tar and other oils not dissolved by the aqueous liquor shall not exceed 60 p.p.m.
4. Temperature of liquor at point of discharge shall not exceed 110° F.
5. Ascot District Gas and Electric Co. shall pay the District Council 25 s. 6 d. ($5.10) per 1,000 gal. of liquor discharged to the sewerage.

The sewage of the community is pumped 4½ miles to the treatment works and arrives there in a septic condition, and this was one of the reasons for refusing the admission of the gas liquor in the first place, but, after operation with the liquor for about a year the following conclusions were drawn:

"Owing to the fact that gas evolution from the sludge digestion tanks could not be measured for an extended period when no gas liquor was being admitted to the sewers, it is not possible to draw any rigid conclusions as to the danger or otherwise of this admission to sludge digestion. It seems evident, however, that in this case, while the flow of gas liquor was being properly controlled, no adverse effect on cold sludge digestion was produced.

"With this particular unheated sludge, alkalinity of the digestion process was never attained, even when the capacity of the digesters was increased by 50 per cent over their designed capacity."

Richard D. Hoak

## USE OF SEWAGE FOR AGRICULTURAL PURPOSES

A Directive Issued by the Inspector-General for Water and Energy (Germany), 1942

*Kleine-Mitteilungen,* 18, 229–230 (1942)

The use of settled sewage for agricultural purposes was widely urged in Germany during the early years of the war. The method used was spraying the sewage into the air for distribution (artificial rain). The Inspector-General for Water and Energy issued a series of directives pertaining to sewer construction, sewage treatment plant operation, saving of materials and labor, etc. The directive concerning the use of domestic sewage for agricultural purposes contains a number of precautions which may be of more general interest. The directive was based upon investigations and could be changed by the Inspector-General when indicated by further studies. The directive, ordered printed in *Kleine Mitteilungen,* 18, 229–230, 1942, was substantially as follows:

I. (*a*) City sewage must be treated by screens, grit chamber and settling tanks with sufficient detention time. The sludge must be properly treated by digestion, dewatering, composting or by similar methods. The treated sludge can be used for agricultural purposes.

(*b*) For enlargement of treatment works sufficient area must be made available.

II. The sewage must be delivered as fresh as possible, to prevent loss of fertilizer value and odors; for small and medium size cities this is always possible, provided no putrefaction is allowed to take place in the sewers. The sewers should be tested to determine whether putrefaction of sewage takes place and the city authorities notified to take the necessary measures to prevent putrefaction as much as possible. To prevent odor, proper methods must be used, such as aeration, chlorine addition, maintenance of sufficient velocity, etc.

III. Main distribution lines should be enclosed in underground lines; open laterals should be constructed of concrete.

IV. Pollution of ground water and streams should be prevented.

V. Plants, roads, highways, railroads, etc., must under no circumstances be troubled with odors; fruit and vegetable gardens should not be touched by sewage sprays. Therefore, between the above named structures, etc., and the sewage plants a sufficiently wide protection strip must be constructed. During strong winds no spraying with sewage should be practiced.

VI. No artificial rain system can be used in the neighborhood of water works; if close together, report and obtain advice.

VII. Flooding practice shall be in co-operation with the Food Administration Service; the last flooding must be completed one week before harvest.

VIII. Potatoes must not be flooded after blooming. Land for vegetables receive sewage only on base soil. During growth, irrigation must be with fresh water.

IX. Sewage and sludge which may contain anthrax spores (tanneries or hair spinning) must not be discharged into municipal sewage used for agricultural purposes.

WILLEM RUDOLFS

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## ROLE OF PROTOZOA IN THE AEROBIC PURIFICATION OF SEWAGE

BY S. C. PILLAI AND V. SUBRAHMANYAN

*Nature,* 154, 179–180 (August 5, 1944)

The protozoan *Epistylis* sp. was isolated from the mucilaginous masses adhering to the aeration tanks by repeatedly centrifuging and washing. It was inoculated into sterilized decoction of fecal matter and aerated. After the sludge was built up, a careful selection of cells was made. This operation was repeated a number of times until the associated bacteria were eliminated and the medium consisted exclusively of protozoa. They were at least as active in purifying sewage as the normal activated sludge. Conditions affecting the life and activity of the protozoa also affect the efficiency of purification. When protozoa are killed or inactivated by heating (50° C.), partial sterilization (methylene blue and acridine yellow) chronomous larvae and fermenting yeasts, sludge formation and clarification is nil. Wherever purification is proceeding satisfactorily, protozoa are active. If the protozoa are dead or encysted there is no purification. It is concluded that aerobic purification of sewage is essentially due to the protozoan activity. Bacteria play only a secondary part.

H. Heukelekian

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## SEWAGE BACTERIA BED FAUNA IN ITS NATURAL SETTING

By Ll. Lloyd

*Nature,* 154, 397 (September 23, 1944)

Bacteria beds are a very favorable environment for insects. It is well aerated and supplied with food. It is protected from temperature extremes. The insect fauna is characterized by a small number of successful species which are found in great numbers. In eight years of trapping on the Knostrop beds at Leeds, out of one hundred different species 99.7 per cent belonged to six species, namely, *Metriocnemus longitarsus, M. hirticolis, Spaniotoma minima, S. peremis, Psychoda alternata* and *P. severnii.* The enchytraeid worm, *humbricillus lineatus,* is also very abundant in the Knostrop beds. *Achorutes viaticus* and *Spathiophora hydromyzena* are the only other insects recorded as prevalent. A similar fauna was located in a mud flat which is waterlogged but rarely flooded.

H. Heukelekian

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## HISTORY OF STREAM POLLUTION IN INDIANA

By Thurman B. Rice

*Monthly Bulletin,* Indiana State Board of Health, 47, 9 (Sept., 1943)

A review of stream pollution problems, legislation and abatement progress in Indiana.

Paul D. Haney

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## DUTIES OF THE NEW STREAM POLLUTION CONTROL BOARD

By Thurman B. Rice

*Monthly Bulletin,* Indiana State Board of Health, 47, 202–203 (Sept., 1943)

The bipartisan control board was authorized by legislative action in 1943 and will begin the study of pollution problems with a view toward working out plans for stream pollution abatement in the postwar period.

Paul D. Haney

## CLEAR WATER AHEAD

By Joseph L. Quinn, Jr.

*Monthly Bulletin,* Indiana State Board of Health, 47, 204 (Sept., 1943)

Planning for stream pollution abatement in the postwar period should be undertaken now and should be carried to the point of having complete plans and specifications prepared.

Paul D. Haney

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## PROGRESS OF SEWAGE TREATMENT AND STREAM POLLUTION ABATEMENT

By Martin A. Milling

*Monthly Bulletin,* Indiana State Board of Health, 47, 205 (Sept., 1943)

The first sewage treatment plants in Indiana were built in 1903. These were septic tanks and are still in use. By 1920 there were only eight plants, but in 1943 there were 126 sewage and industrial waste treatment plants. The 81 municipal plants cost $17,000,000. The cost of treatment plants (interceptors not included) has averaged $15 per capita. Operating costs have averaged about $0.80 per capita per year. The average operating cost per million gallons for cities under 30,000 has been about $25. At several of the larger plants the cost is $10 per million gallons.

Paul D. Haney

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## STREAM POLLUTION

By G. G. Fassnacht

*Monthly Bulletin,* Indiana State Board of Health, 47, 206 (Sept., 1943)

Stream pollution is caused by human and industrial wastes. The amount of pollution permissible in a stream depends upon the size of the stream and the use to which it is put. The amount of pollution contributed by a given waste depends upon the strength of the waste and its volume. Streams may be grossly polluted without being loaded with typhoid germs, and conversely streams which appear clear, bright and sparkling may contain pathogenic organisms.

Paul D. Haney

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## A CHALLENGE—THE ABATEMENT OF STREAM POLLUTION

By Joseph L. Quinn, Jr.

*Monthly Bulletin,* Indiana State Board of Health, 47, 114–117 (May, 1944)

A stream pollution control board was established by an act of the Indiana legislature in 1943 and the citizens of the state are becoming more stream pollution conscious. Stream pollution abatement has the active support of numerous organizations throughout the state. Stream pollution problems in Indiana involve damage to water supplies, animal and aquatic life and the loss of recreational values. The problems are varied in scope and in the requirements of treatment.

About 1,127,640 people or 59.7 per cent of Indiana's urban population are being served by sewage treatment plants at present. It is estimated that 81 Indiana municipalities have spent approximately $17,000,000 for sewage treatment alone and will spend $28,000,000 more. At the present time approvals have been issued by the Indiana State Board of Health and the Stream Pollution Control Board on 18 completed and 19 preliminary sets of plans and specifications for municipal sewage treatment plants. In addition four engineering reports have been accepted. Efforts are concentrated on each drainage basin as a unit. The Control Board has formulated and adopted a set of minimum standards for the determination of what qualities and properties of water shall constitute a polluted condition. Its philosophy is based upon the consideration that there is a fair economic balance between the cost of treatment and the benefits received beyond which it is not reasonable to expend money for treatment.

A map of the state shows sources of pollution and degree of treatment.

PAUL D. HANEY

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## REPORT OF STREAM POLLUTION IN THE ST. JOSEPH RIVER BASIN

BY ROBERT W. HEIDER

*Monthly Bulletin,* Indiana State Board of Health, 47, 136–137 (May, 1944)

The St. Joseph River's headwaters are in Southern Michigan and it flows southwesterly through Indiana and then back through Michigan, finally discharging into Lake Michigan.

There are 31 municipalities in the Indiana portion of the basin and their population is 204,146. There are four municipal sewage treatment plants which treat the sewage from only about 10 per cent of the population. Industrial wastes are contributed by the milk, meat, brewery, metal, pulp, paper, rubber, textile and canning industries.

Ground water supplies are abundant in the basin and there are no surface water supplies. The availability of ground water probably is one reason why so little has been done to abate the pollution of this river.

PAUL D. HANEY

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## STREAM POLLUTION FROM THE STANDPOINT OF FISH LIFE

BY HUGH A. BARNHARDT

*Monthly Bulletin,* Indiana State Board of Health, 47, 131, 142 (June, 1944)

Sewage is harmful to fish life when it is first introduced into a stream and for some distance downstream because of oxygen depletion. On the White River this harmful effect was noted for forty miles below the source of pollution. Below this point microscopic plant and animal growth became abnormally abundant and persisted at a high level for 60 or 70 miles. The growth of microscopic organisms, which serve as fish food, was stimulated by the sewage. To this extent the sewage was beneficial to fish life. However, the limited beneficial effect should not be permitted to overshadow the harmful effect and sound conservation practice should be directed toward the elimination of the discharge of untreated sewage into streams.

PAUL D. HANEY

## EFFECT OF POLLUTION ON WATER TREATMENT

By C. K. Calvert

*Monthly Bulletin,* Indiana State Board of Health, 47, 155, 161 (July, 1944)

The pollution of surface water consists mainly of industrial waste and domestic sewage, and if the water supply intake is located on a stream near the point of contamination, grave interference is experienced in the process of water purification. Water containing an undue amount of organic matter is very difficult to coagulate and has a high chlorine demand. Industrial wastes containing iron, manganese and hardness producing compounds add to the difficulty of water treatment. Pollution may also stimulate the growth of microscopic organisms which produce offensive tastes and odors difficult to remove at the water treatment plant.

All pollution, whether from trade waste or domestic sewage, interferes with water purification methods in direct proportion to its extent.

Paul D. Haney

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## THE EFFECT OF STREAM POLLUTION ON AGRICULTURAL PURSUITS

By Charles M. Dawson

*Monthly Bulletin,* Indiana State Board of Health, 47, 185 (August, 1944)

The greatest source of stream pollution in Indiana is industrial wastes. Manufacturing plants, mines, etc., have contributed to stream pollution, some unconsciously, others as a matter of convenience and economy. Business as a whole cannot be indicted because successful business operation is as necessary to the economy and progress of the state as are fish in the streams to the conservationist and the grazing cattle to the farmer. Any solution to the problem of stream pollution must be as fair to business as it is to the farmer and the conservationist. There must be a common meeting ground. Co-operation of all interests concerned is the key to successful stream pollution abatement.

Paul D. Haney

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## STREAM POLLUTION IN THE LOWER WABASH RIVER BASIN

By Robert W. Heider

*Monthly Bulletin,* Indiana State Board of Health, 47, 186–187 (August, 1944)

This basin extends southward from Clinton along Indiana's west boundary to the Patoka River basin and includes the White River drainage area below the confluence of that river's East and West Forks. There are 32 cities and towns in the Indiana portion of the basin with populations over 300. The total population of these communities was 117,525 in 1940. Only two cities having a total population of 5,600 provide sewage treatment. Pulp, paper, meat, milk, distillery, brewery, creosote, coke, canning, and mining industries contribute to the pollution problem.

Seventy-two per cent of the population in this basin is served by surface water supplies. Sewage and industrial waste treatment at Terre Haute is of prime importance because wastes from this city enter the stream above the Vincennes water supply intake.

Paul D. Haney

## STREAM POLLUTION AND PROPOSED SOLUTIONS TO IT

By Richard Lieber

*Monthly Bulletin,* Indiana State Board of Health, 47, 209 (September, 1944)

Stream pollution abatement cannot be attained by passing laws or ordinances. To solve the problem in a fair and sensible way, a properly organized stream hygiene bureau should be created which could devote its efforts to scientific study of ways and means of locating and removing the sources of pollution.

Paul D. Haney

## STREAM POLLUTION IN THE KANKAKEE RIVER BASIN

By Robert W. Heider

*Monthly Bulletin,* Indiana State Board of Health, 47, 210–211 (September, 1944)

The headwaters of the Kankakee River are located in St. Joseph County, Indiana. The river flows southwesterly and ultimately joins the Des Plaines River in Illinois. The total population of the 37 cities and towns in the Indiana portion of the basin is 52,798 and only one municipality (pop. 14,000) provides sewage treatment. There are no public water supplies taken from the river in Indiana. Pollution by industrial wastes is not extensive. Milk plants are the major contributors. The Indiana State Board of Health and the Stream Pollution Control Board strongly recommend that plans for treatment facilities be prepared now so that construction work can start as soon as labor and materials are available.

Paul D. Haney

## LICENSING WATER AND SEWAGE PLANT OPERATORS

By Ralph B. Wiley

*Monthly Bulletin,* Indiana State Board of Health, 47, 248 (October, 1944)

A suitable licensing law should provide for the appointment of a competent board composed of men of recognized experience in the field and free from political domination. The licensing board should have the power to classify the water supplies and sewage treatment plants of the State on the basis of the qualifications necessary in the responsible operating personnel of each plant, to examine applicants, to issue licenses, to publish lists of qualified personnel, to force compliance with the law, to formulate rules for rating each plant, and to revoke licenses when necessary. The board should not have the power to dictate to municipal officials as to the appointment of particular operators. Operators should be chosen from a published list of licensees. It would not be necessary to license all employees. Only those in responsible charge need be licensed. Such a law would protect the public, municipal officials, and competent plant operators.

Paul D. Haney

## STREAM POLLUTION IN THE EAST FORK WHITE RIVER BASIN

By Robert W. Heider

*Monthly Bulletin,* Indiana State Board of Health, 47, 243–244 (October, 1944)

The East Fork White River Basin is located in the southern half of Indiana and has an area of about 4,460 square miles. The total population of the 54 cities in the basin is 144,915. Sewage treatment plants at eight cities serve a total population of 44,700 or about 31 per cent of the population. The milk, metal, paper, pulp, meat, tannery, textile, creosote, and canning industries contribute industrial wastes. Public surface water supplies serve a total population of 63,530 and stream pollution creates important water treatment problems. Sewage and industrial treatment facilities should be planned now so that construction work can be undertaken as soon as possible.

Paul D. Haney

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## THE HISTORY AND LEGAL BACKGROUND OF STREAM POLLUTION CONTROL IN INDIANA

By Robert Hollowell, Jr.

*Monthly Bulletin*, Indiana State Board of Health, 48, 280 (December, 1944)

Pollution control has been influenced by the social and economic conditions of the times. The results of a number of court decisions have been contradictory, but may be reconciled upon the broad proposition that the court at the time was seeking what it thought was the best for the general welfare. In the latter part of the last century the general welfare required a city to have a sewage system and at that time it was a matter of necessity that it be discharged into a stream. With the development of sewage treatment processes, which are scientifically sound and economically possible, the rule of necessity disappears. Therefore, a case with similar facts at the present time can consistently be determined in favor of pollution abatement by the application of the same rules of law.

A number of court decisions are cited.

Paul D. Haney

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## STREAM POLLUTION IN THE UPPER WABASH RIVER BASIN

By Robert W. Heider

*Monthly Bulletin*, Indiana State Board of Health, 48, 285 (December, 1944)

The upper Wabash River Basin has an area of about 10,000 square miles. There are 154 cities in the basin with populations over 300. The total population of the 154 cities is 335,092. Sewage treatment plants provide complete treatment at twelve cities having a combined population of 116,950. Primary treatment only is provided at two cities having a total population of 3,500. Thirty-seven cities over 1,000 population do not provide municipal sewage treatment.

Surface water supplies serve a total population of 29,834.

Milk, meat, metal, pulp, paper, brewery, textile, canning, explosives, and mining industries contribute industrial wastes to the streams in the basin.

The Indiana State Board of Health and the Stream Pollution Control Board urge that plans for pollution abatement be made now so that the construction phase of the abatement program will not be delayed when labor and materials are again available.

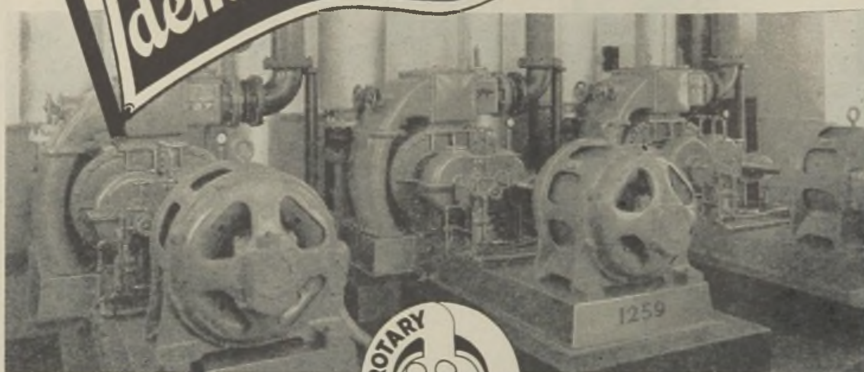
Paul D. Haney

*Lithographed on stone by Edward A. Wilson*

# DIRECTORY OF ENGINEERS

(Continued on pages 36 and 37)

# PROPER SEWAGE TREATMENT demands adequate air

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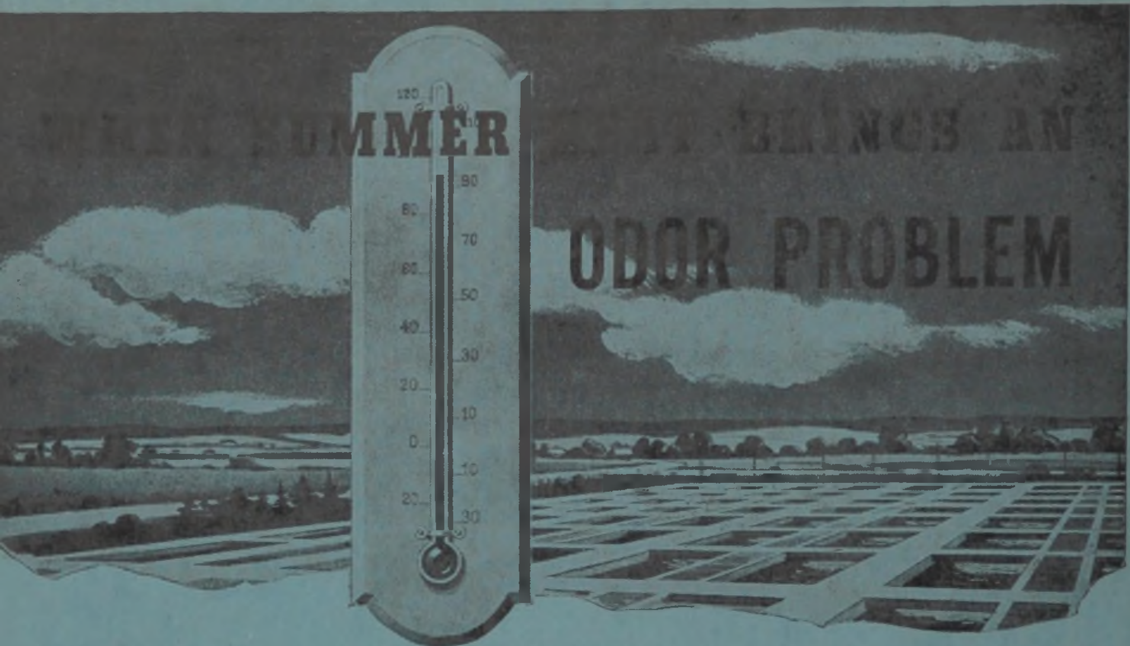
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