SEWAGE WORKS JOURNAL

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Special Features

Sewer Design—Camp

Digester Gas for Automobiles—Imhoff

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FEDERATION OF SEWAGE WORKS ASSOCIATIONS

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FEDERATION OF SEWAGE WORKS ASSOCIATIONS

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FEDERATION OF SEWAGE WORKS ASSOCIATIONS

SEWAGE WORKS JOURNAL

REG. U. S. PAT. OFF.

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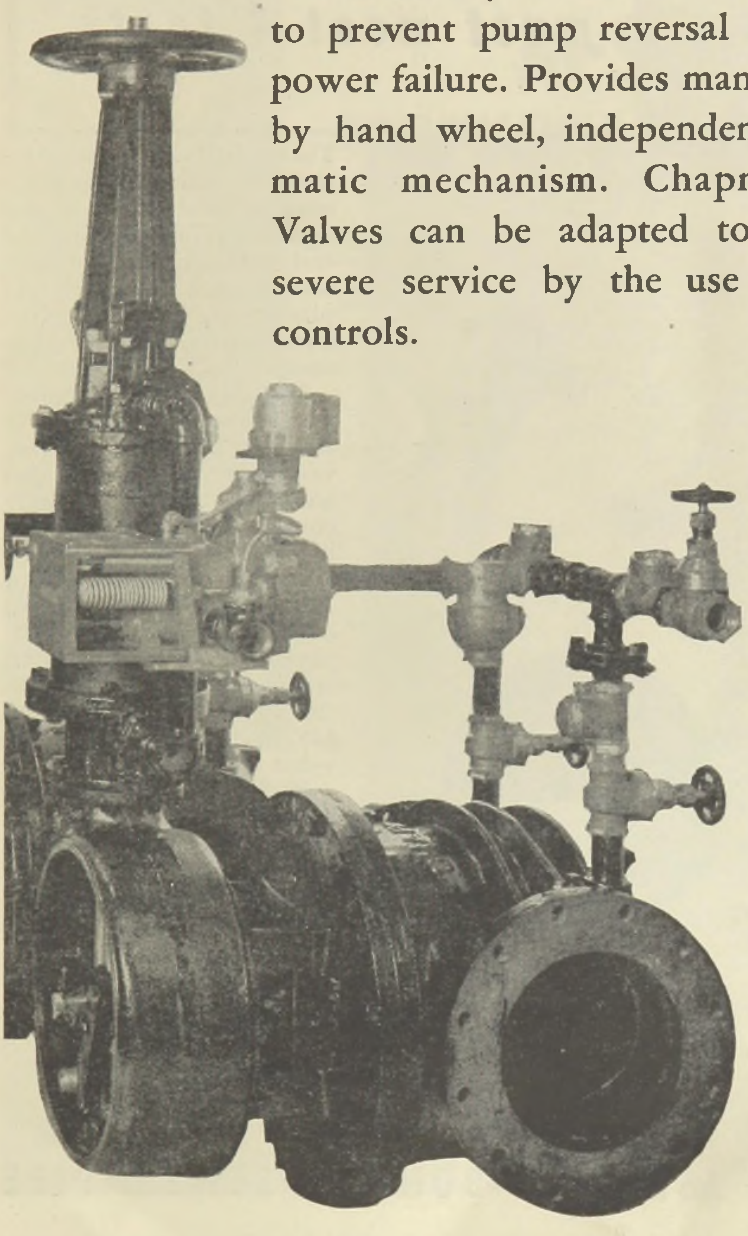

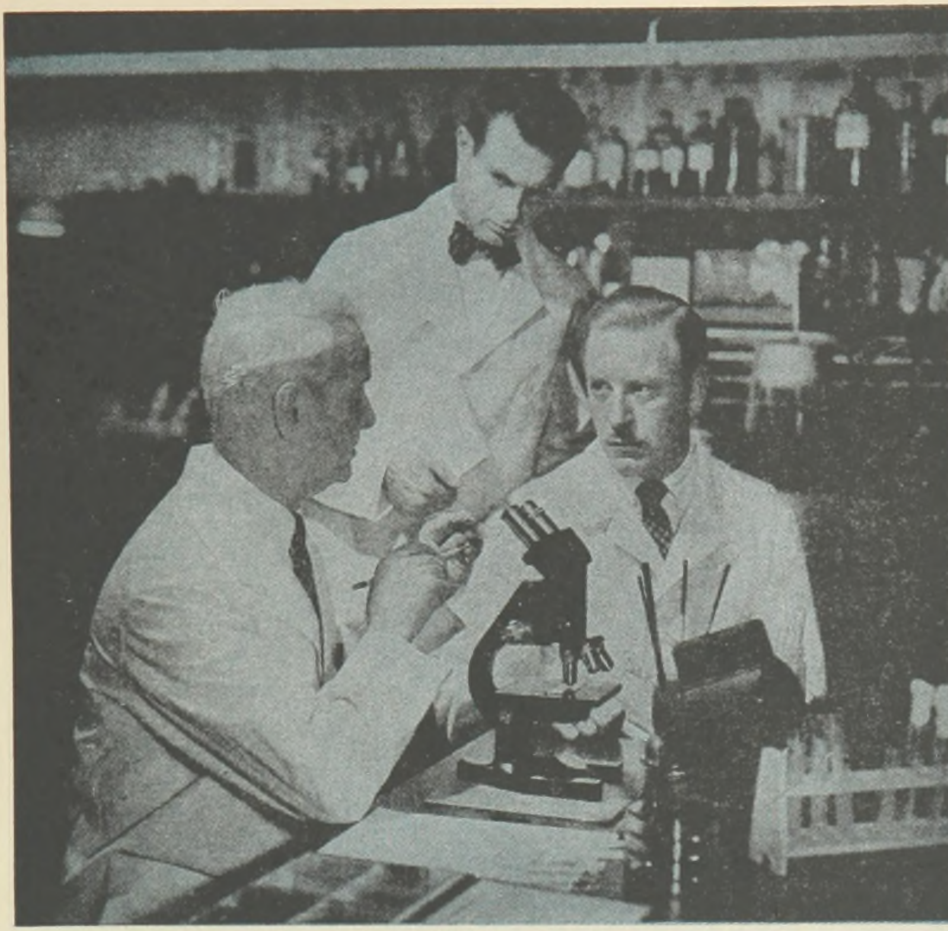

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Sewage Works

DESIGN OF SEWERS TO FACILITATE FLOW

By Thomas R. Camp

Consulting Engineer, Boston, Mass.

This paper on the hydraulic design of sewers has the double purpose of emphasizing an important subject which has long been neglected in the technical press of sewage works engineers and of bringing to the attention of sewer designers some recent developments in fluid mechanics which influence the design of sewers. The paper will be confined to hydraulic design and no consideration will be given to methods of estimating discharge rates for either sanitary sewers or storm drains other than to emphasize the fact that successful design depends upon careful estimates of rates of discharge. It will, of course, be impossible to discuss the hydraulic design of all the numerous special types of structures involved in sewerage systems, but brief mention will be made of some of them which occur most frequently. The paper will be limited to the treatment of sewers of circular cross section, and no consideration will be given to structural design or to the relative merits of materials used for sewer construction.

Functional Considerations

A sewer has two main functions, namely, (1) to carry the maximum discharge for which it is designed, and (2) to transport suspended solids in such a manner that deposits in the sewer and odor nuisances therefrom are kept to a minimum. The first of these functions requires that an accurate estimate be made of the peak flow which the sewer must carry, and the second function requires that the designer have information as to the fluctuation of discharge during periods of low flow and as to the character of the suspended matter to be transported.

For the design of sanitary sewers and sewage works the rates of discharge are significant as shown below in Table 1. The average daily flow, C and D in the table, is the average 24-hour discharge during a period of one year, knowledge of which is essential for estimates of cost of operation of sewage treatment works and pumping stations and for the determination of economic pipe sizes for force mains. Values for C and D have no significance in the design of lateral sewers, except that they are useful in estimating the minimum and peak flows. The minimum daily flow is the minimum 24-hour discharge which occurs during the year of consideration, and the maximum daily flow is the maximum 24-hour discharge which occurs during the year considered. The maximum and minimum daily flows at the end and beginning of the design period,

TABLE 1

	Extreme Minimum	Minimum Daily	Average Daily	Maximum Daily	Peak
Beginning of Design Period..	A	B	C		
End of Design Period.......			D	E	F

E and B, respectively, are of value in determining treatment plant capacities and the number of treatment units. The peak flow determines the hydraulic capacity of sewers and treatment plant conduits, as well as pump capacities. The extreme minimum flow considered together with the minimum daily flow is significant for the design of sewers to insure proper cleansing.

The variation of flow of sewage throughout a day will usually follow a curve such as Figure 1, except for small laterals. The shape of the curve will, of course, vary from day to day and will be different for different sewers and different localities. Figure 1 is hypothetical only and applies to no particular sewer. For a particular sewer the shape of the curve during the early part of the design period is significant in order to design the sewer for self-cleansing velocities. If, for example, Figure 1 represents the day on which the flow is a minimum and computations indicate that during the night hours the velocity in the sewer is low enough to permit deposits, it is essential that the velocity during the remainder of the day be of sufficient magnitude and duration to clean out all the sediment previously deposited.

For any one day, the ratio of the peak flow to the average for the day will range from less than 130 per cent for some large sewers to more than 200 per cent for some laterals. Moreover, the ratio of the maximum daily flow at the end of the design period to the minimum daily flow at the beginning of the design period may range from less than 200 per cent to more than 500 per cent, depending largely upon the rate of growth of the area served by the sewer. Hence the range of flows for which a sewer must be designed, that is, peak flow to extreme minimum, will vary from less than 3 to 1 for large sewers serving stable populations to more than 20 to 1 for small sewers serving growing populations.

The fact that a single sewer must be

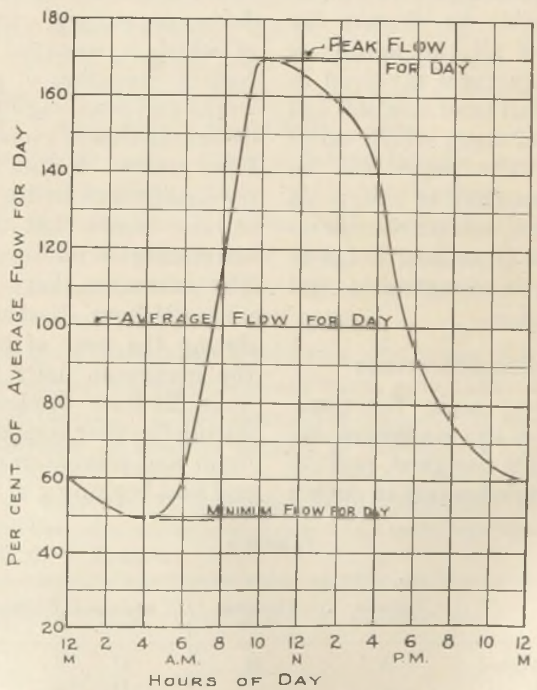


FIGURE 1.—Hourly variation of sewage flow.

designed to keep itself clean over such wide variations in discharge militates against the general use of pressure sewers. A velocity of about 2 f.p.s. is required for self-cleansing. Sewers are commonly designed to flow partially full with the hydraulic grade line substantially parallel to the invert at all rates of flow. Since the depth and the cross-sectional area increase with the discharge, the variation in velocity is considerably less than the variation in discharge rates and scouring velocities may be obtained at low flows without excessive velocities at peak flows.

It is occasionally necessary to design sewers to flow under pressure, as in the case of force mains and so-called inverted siphons. If a scouring velocity is provided at minimum flow in a pressure sewer, the maximum velocity at peak flow will be 3 to 20 times as great or 6 to 40 f.p.s. and the slope of the hydraulic grade line will be increased 9-fold to 400-fold. In the case of inverted siphons, the head is not usually available for so great a slope of the hydraulic grade line; and it has become common practice to provide two or more parallel pipes in order to divide the flow at high rates. It is possible with such a structure to maintain a scouring velocity in one of the pipes, but the other pipes will contain stagnant sewage much of the time which may be a source of odor nuisance. If a pressure sewer is required and sufficient head is not available for peak flows in a single pipe small enough to insure scouring at low flows, it is best to resort to pumping. If pumps are used, the velocity in the force main when the pumps are in operation should be sufficient to scour the pipe; that is, about 3 f.p.s.

For economy, sewers are commonly laid at a depth just sufficient to intercept the house sewers from the lowest buildings and the lowest branch sewers. Where no house sewers or branches are required to be intercepted, the depth is dictated by the requirements of cover or by fixed elevations required of one or both ends of the sewer. The slope of a sewer is thus usually determined by the topography, and the size is computed after the slope is fixed.

In regions where the slope of the ground is very flat, however, it may be necessary to lay sewers at slopes greater than the ground slope, even if pumping is required, or to use sizes larger than ordinarily required in order to insure self-cleansing. In some cases the use of a larger size sewer will result in an increased velocity at minimum flow.

Storm drains are usually designed to carry the tributary storm water runoff for a particular frequency of recurrence. Since the minimum flow for a storm drain is usually zero, the size and slope of the drain should be such as to secure scouring velocities with moderate rain storms. Deposits in storm drains do not ordinarily result in nuisance, but they should not be permitted to accumulate so as to impair the capacity of the drains. Since the sediment to be carried by storm drains is mostly of a granular mineral nature, the particles of which have a greater density than sewage particles, greater velocities are required for scour than with sanitary sewers. It is general practice to design storm drains so that the full velocity will be not less than 2.5 to 3 f.p.s.

Combined sewers should be large enough to carry the desired flood runoff and should likewise have velocities at minimum dry weather flows which are adequate for self-cleansing. Since the range from minimum to maximum flow is usually very great for a combined sewer, it is virtually impossible to insure self-cleansing at low flows. Hence, in modern design, separate systems are usually required for sanitary sewage and storm water.

Determination of Size of Sewers

For a given slope and peak flow, the size of sewer required is usually determined in American practice by means of the so-called Kutter equation

$$V = \frac{41.66 + \frac{1.811}{n} + \frac{0.00281}{S}}{1 + \left(41.66 + \frac{0.00281}{S}\right)\frac{n}{\sqrt{R}}}\sqrt{RS}$$

in which V = the mean velocity in f.p.s. $= \frac{Q}{A}$ where Q is the discharge in c.f.s. and A is the cross-sectional area in sq. ft.,
R = the hydraulic radius in ft.,
S = the slope of the energy grade line in ft. per ft. length of pipe,
and n = the Kutter coefficient of roughness.

This equation has come into general use in the United States, despite its unwieldiness, largely because graphs have been prepared for its use and are available in most texts on sewer design. Sewer designers have become familiar with values of the roughness coefficient n applicable to sewers.

The Manning equation, because of its simplicity and because it employs a roughness factor n whose value is substantially equal to the Kutter n, is coming into more general use. The Manning equation is

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

where the symbols are the same as for the Kutter equation.

Both of these equations are applicable to pipes and conduits of all shapes flowing either full or partially full. The graphs which are commonly available for their solution have been compiled for the full conduit only, and so-called "hydraulic element" graphs are used to determine the depth and mean velocity at other than full flows.

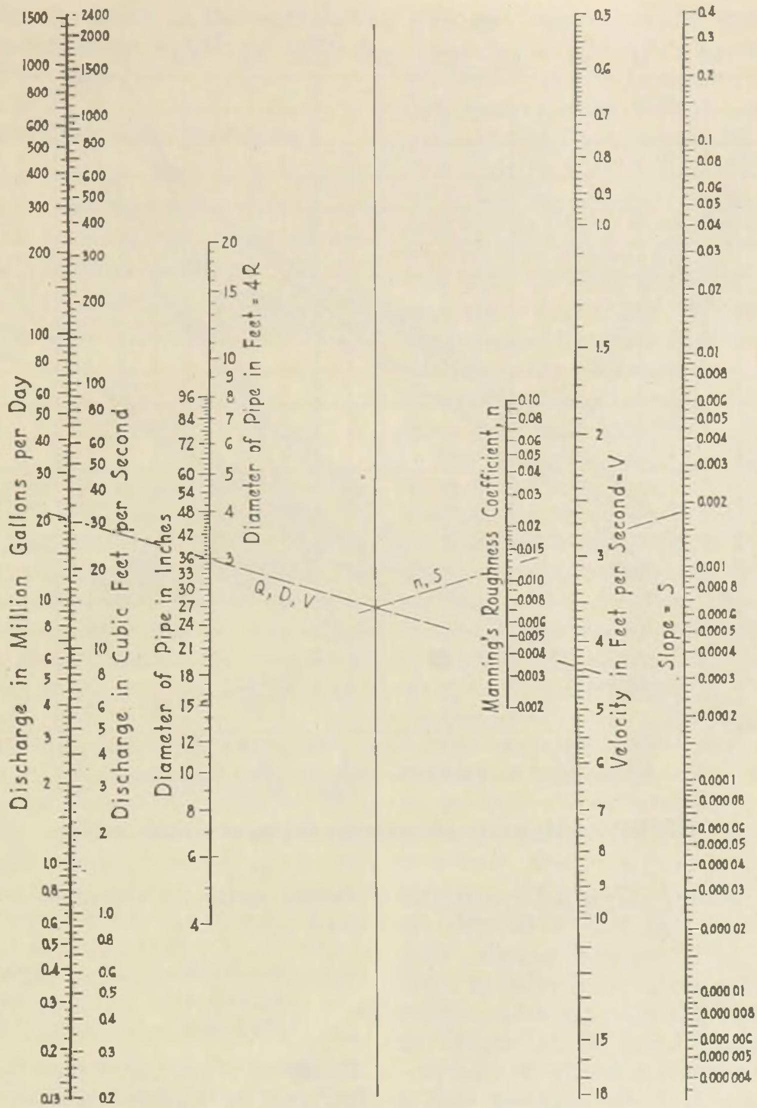
Figure 2 is an alignment chart prepared by the author (1) for the solution of the Manning equation for circular pipes flowing full. It may be used with any value of n from 0.002 to 0.10. This chart, as do most other charts for the same purpose, also gives a solution of the equation $Q = AV$ for the full pipe. The use of the chart is obvious from the example shown by the broken lines. It is also possible to use this chart for other shapes of cross section including conduits partially full, if the discharge scale be ignored and the diameter scale be used such that the diameter taken is four times the value of the hydraulic radius of the actual cross section. The discharge (or velocity) must be computed independently from the relation, $Q = AV$.

The hydraulic element graphs in common use have been prepared on the assumption that the roughness coefficient n does not change with the depth of flow in the conduit. It has been known for many years that this assumption is erroneous, but it has been necessary to continue the use of the charts because of the lack of adequate data with which to correct them.

A study (1) was made recently of this problem by the Committee to Study Limiting Velocities in Sewers of the Boston Society of Civil Engineers, and it was found that the only reliable data available which could be used for corrections were measurements made by Wilcox (2) on 8-in. sewer pipe and by Yarnell and Woodward (3) on drain tile 4-in. to 12-in. in diameter. These data showed that the value of n for a pipe flowing partially full is greater than for the full pipe, and on the average has values such as are indicated by the curve through the points marked by circles in Figure 3. The figure also shows a similar curve for the Weisbach-Darcy friction factor f. The relation between the two friction factors is

$$\frac{n}{n_{\text{full}}} = \left(\frac{R}{R_{\text{full}}}\right)^{1/6} \frac{f}{f_{\text{full}}}$$

The author (4) has made a study of measurements made recently by Johnson (5) in large Louisville sewers



ALIGNMENT CHART FOR FLOW IN PIPES
MANNING'S FORMULA: $V = \frac{1.486}{n} R^{2/3} S^{1/2}$

FIGURE 2.

flowing partially full. The values of the ratios $\frac{f}{f_{full}}$ as estimated from these data are shown in Figure 3 by the points marked with triangles and Xs. The values of $\frac{n}{n_{full}}$ corresponding with the values of $\frac{f}{f_{full}}$ marked with triangles are also shown by triangles.

The experiments of Wilcox and of Yarnell and Woodward indicated that the value of Manning's n for clean sewer pipe and drain tile, both clay and

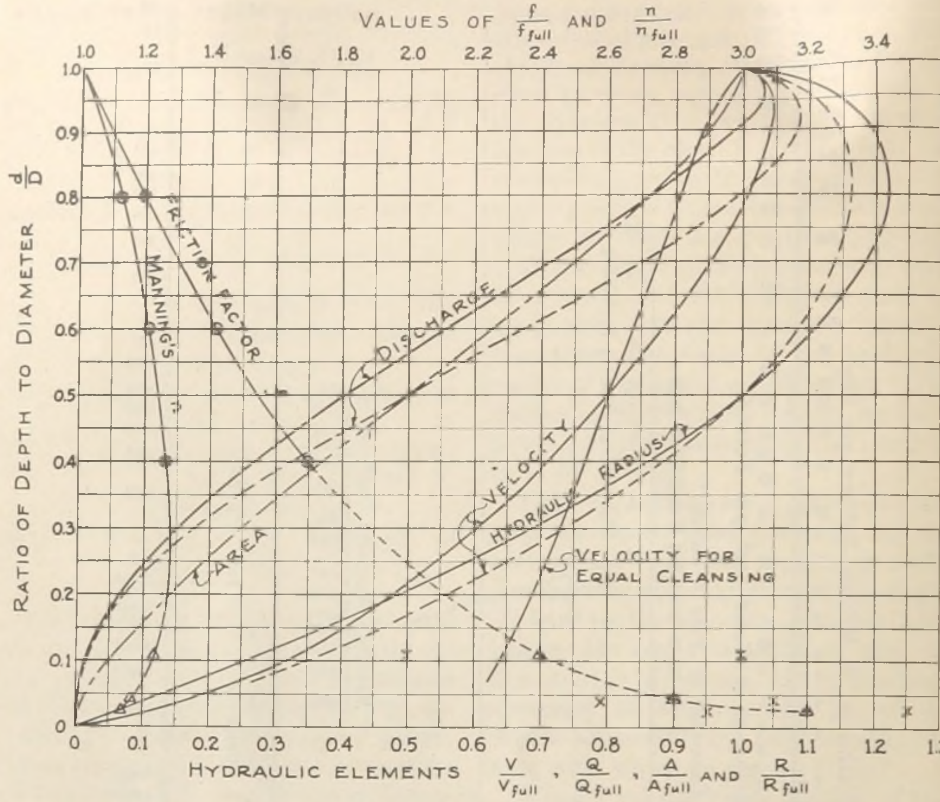


FIGURE 3.—Hydraulic elements for sewers of circular section.

concrete, flowing full ranged from 0.0095 to 0.011 with sizes from 4- to 12-in. inclusive. It is common practice with sewer designers to use a value of 0.013 for all depths of flow, the authority for this practice being based largely on measured values in sewers flowing partially full. If it be assumed that a value of 0.013 is reasonable for a pipe flowing half full, a value of 0.014 is indicated for the full pipe which agrees with the experiments of Wilcox and of Yarnell and Woodward.

In the report (1) of the Committee to Study Limiting Velocities in Sewers of the Boston Society of Civil Engineers, it was "suggested that the following values of Manning's n be generally used for full pipes in the design of sewers of circular cross section, except in cases where the designer has more definite information about the value of the friction factor for the pipes and joints to be used:

Size of Pipe	Manning's n
6-in. to 24-in.	0.012
Larger sizes	0.011

These values are higher than the values indicated by the best experiments available in order to allow for conditions encountered in ordinary practice." It will be noted from Figure 3 that the values of n for pipes flowing half-full corresponding to the values suggested above for full pipes are 0.015 and 0.0138 respectively.

On Figure 3 the curves for discharge and velocity as obtained from the usual assumption of a constant value of n are shown by broken lines. In accordance with this assumption, the velocity is the same for a half-full pipe as for a full pipe, whereas if Manning's n is taken to vary with the depth as shown the velocity at half-depth is only 0.8 the full velocity.

Self-Cleansing Velocities

A theoretical development by Shields based upon experiments by himself and others on bed-load movement of unigranular materials indicates that the velocity (1) required to transport sediment may be estimated by the following equation:

$$V = \sqrt{\frac{8\beta}{f} g(s - 1)d}$$

where V is the mean velocity in the conduit, d is the diameter of the particle to be transported, s is its specific gravity, g is the gravity constant, f is the Weisbach-Darcy friction factor of the conduit, and β is a constant whose value is about 0.04 to start scour and ranges up to 0.8 or more for adequate cleansing.

It will be noted from the equation that the ability of a stream to transport sediment of a given character depends upon the mean velocity and friction factor and is independent of the depth. Since the friction factor f is greater the less the depth of flow in a pipe, it follows from the equation that less velocity is required for self-cleansing a partially full pipe than for a full pipe. The relation between the velocity in a partially full pipe and that for a full pipe for the same cleansing effect is shown on Figure 3 by the curve marked "Velocity for equal cleansing." For smaller depths of flow there is more disturbance in the liquid as evidenced by the higher friction factor, and this increased disturbance assures equal cleansing with lower average velocity.

It has been common practice to design sewers with a full velocity of not less than 2 f.p.s. to insure self-cleansing. Experience indicates that some sewers designed for the velocity full are not self-cleansing while others with lesser full velocities are self-cleansing. The probable reason for this anomaly is that the sewers which are not self-cleansing flow only at shallow depths most of the time. Experience further indicates nevertheless that a 2 f.p.s. velocity is adequate for self-cleansing with an average municipal sewage if the sewer flows more than half-full.

The Boston Society of Civil Engineers Committee recommends that, in general, for adequate cleansing, sewers be designed with slopes at least great enough to develop a cleansing velocity at the minimum daily flow (B of Table 1). In the case of laterals with few house connections, the discharge rates in the following table are recommended as it may be expected that they will be exceeded at least once a day.

Figure 4 was compiled by the author to facilitate the determination of minimum slopes required for self-cleansing. It is based upon a Manning's n of 0.012 for the full pipe, the data of Figure 3 and the assumption that a velocity of 2.0 f.p.s. is required for self-cleansing with a pipe flowing full. The figure applies to pipes ranging from 6- to 24-in. in diameter, each pipe size being indicated by a separate curve. The curves are for pipes flowing half-full and less, the ratio of depth to diameter being shown by small circles at 0.05 intervals in value. For a fuller discussion of the principles underlying the preparation of this figure, see the Boston Society of Civil Engineers committee report. It will be noted from the figure that a

TABLE 2

Number of houses	1	2	3	4	5	10	20
Discharge, g.p.m.	7	12	17	21	25	38	57
Discharge, c.f.s.	0.016	0.027	0.038	0.047	0.056	0.085	0.127
Min. slope, 8-in. pipe, ft./1000	14	11	8.5	7.4	6.7	4.8	3.8

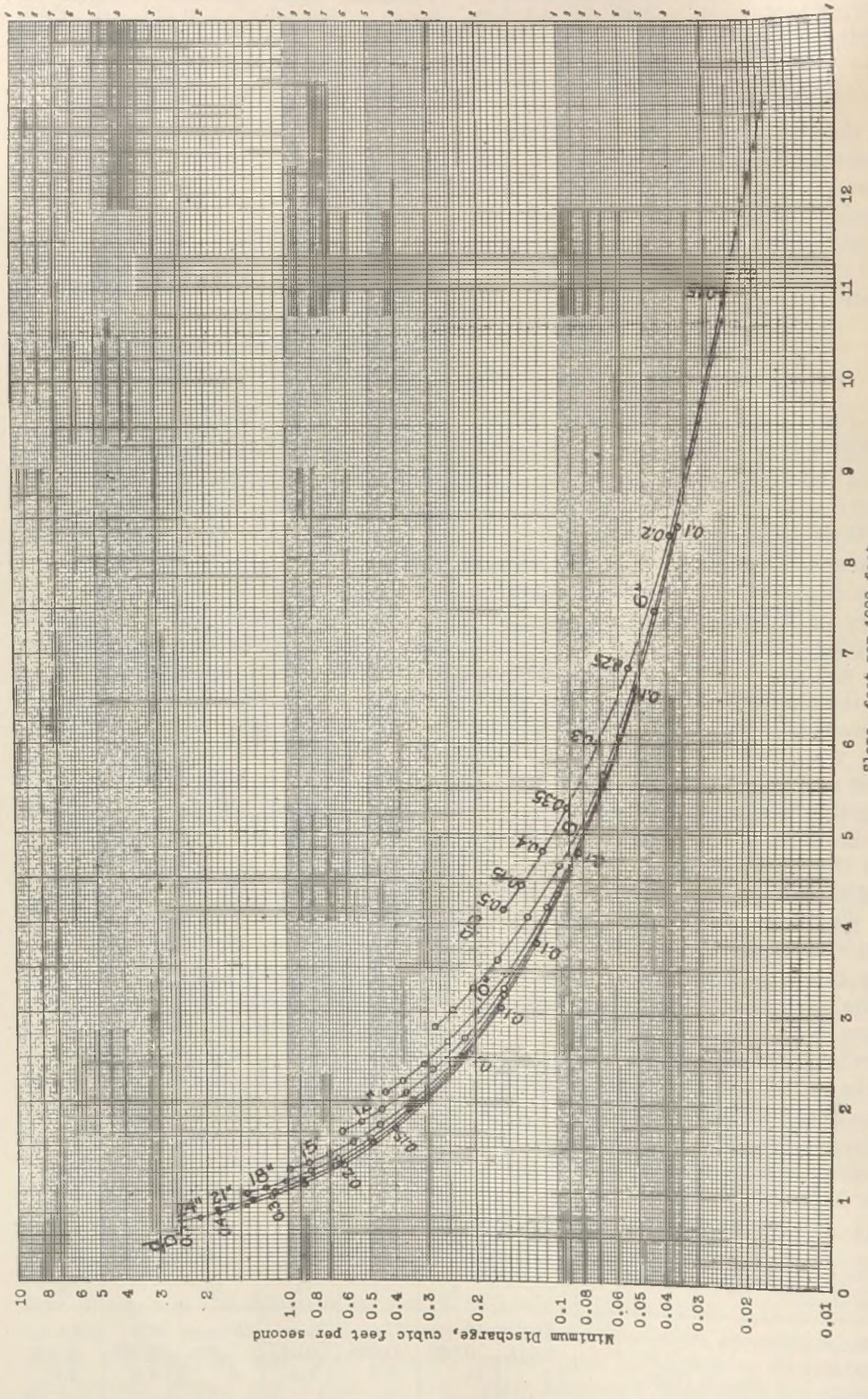


FIGURE 4.—Slopes required for cleansing at minimum discharge equal to cleansing in full pipe at 2 f.p.s. velocity. Manning's n = 0.012 for full pipe.

slope of 4 ft. per 1,000 is adequate for self-cleansing of an 8-in. pipe, provided the minimum daily discharge is not less than 0.13 c.f.s., or provided the depth is not less than 0.31 of the diameter.

As an example of the use of Figure 4 in design, let it be required to determine the minimum pipe size and the minimum slope for a peak discharge of 1.10 c.f.s. and a minimum daily flow of 0.10 c.f.s.

For a minimum discharge of 0.10 c.f.s., from Figure 4 for 8-in. pipe,

$$S = 4.7 \text{ ft.}/1{,}000 \quad \text{and} \quad \frac{d}{D} = 0.26$$

From Figure 3,

$$Q_{\text{full}} = \frac{0.10}{0.12} = 0.833 \text{ c.f.s.}$$

Hence, an 8-in. pipe is inadequate. For a 10-in. pipe, from Figure 4,

$$S = 4.35 \text{ ft.}/1{,}000 \quad \text{and} \quad \frac{d}{D} = 0.19$$

From Figure 3,

$$Q_{\text{full}} = \frac{0.10}{0.063} = 1.58 \text{ c.f.s.}$$

Hence the 10-in. pipe is adequate, and from Figure 3 for

$$\frac{Q_{\text{peak}}}{Q_{\text{full}}} = \frac{1.10}{1.58} = 0.70, \quad \frac{d}{D} = 0.69,$$

and

$$V_{\text{peak}} = 0.95 \times 2.9 = 2.75 \text{ f.p.s.}$$

Sewer Transitions

In sewer design, it is usually assumed for simplicity that the flow is steady and uniform throughout a stretch of sewer between increments of flow, provided of course, there is no change in size or grade within the stretch. If the transitions between stretches are properly designed, the assumption of uniform steady flow within the stretch for the short period during which peak flow takes place is a close approximation and fully warranted. If the transitions are not properly studied, however, and sufficient allowance is not made for invert drops at transitions, the transitions may reduce the expected capacity of the sewer and cause surcharge at the peak design flow. It may be pointed out that the practice of designing transitions so that the crowns (or the inverts) of abutting sewers are placed at the same elevation without regard to the energy conditions is faulty.

It is convenient in transition design to assume, first that the energy loss, invert drop and change in water surface due to the transition are concentrated at the center of the transition, and then to distribute these changes smoothly throughout the length of the transition when it is detailed. The method is illustrated in Figure 5, where h_T represents the head loss due to the transition and y represents the required drop in the invert due to the transition. This procedure permits the sewer design to progress before the transition design is undertaken. It is necessary only that adequate allowances be made for the energy losses, h_T, but precision in estimating these allowances is unnecessary because they are usually small as compared to the invert drops y.

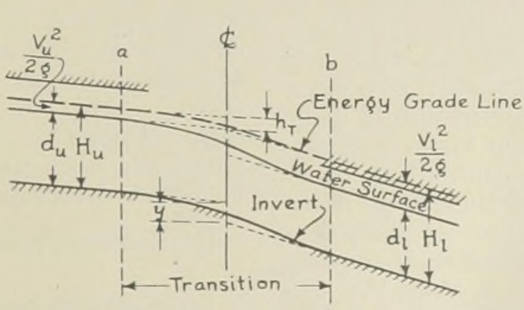


FIGURE 5.—Illustration of energy and hydraulic gradients at transition in size or grade.

It is to be noted particularly that the transition head loss must be applied to the energy grade line and not to the hydraulic grade line (*i.e.*, the water surface). Except for some special and infrequent cases involving junctions, the energy grade line falls through a transition. The hydraulic grade line may rise, however, and usually does in transitions involving substantial decrease in velocity.

For convenience, the sewer inverts may be taken as datum and the total energy heads H_u and H_l in the upper and lower stretches of sewer where uniform flow is assumed to take place may be measured upward from the inverts. In each case, the energy head is the depth plus the velocity head, or

$$H = d + \frac{V^2}{2g}$$

and the energy grade line is parallel with the invert and water surface at a height equal to the velocity head above the water surface.

From Figure 5, it is obvious that the required invert drop y is readily obtainable from the relation

$$y = H_l + h_T - H_u$$

In the design of a transition, y may have a value from zero to several feet in magnitude. If a negative value of y is obtained from the equation, it should not be used in design because it will result in placing the invert of the lower pipe at a higher elevation than that of the upstream pipe. If y is negative from the equation, y should be taken at zero whereupon the head loss h_T becomes greater than the minimum computed and there will be a draw-down curve in the upper stretch of sewer. This is a case which frequently occurs when a small steep sewer discharges into a larger sewer with a flat slope.

Data on the magnitude of the transition loss, h_T, for sewers are almost completely lacking. No reliable measurements of such losses in sewers have ever come to the author's attention. The most reliable data available for use are measurements of head losses in flume and siphon transitions for irrigation purposes made by the U. S. Bureau of Reclamation. These data are analyzed in a paper by Julian Hinds (6), who recommends that the head loss for a well-designed transition may be estimated from the equation $h_T = k\Delta\left(\frac{V^2}{2g}\right)$ where $\Delta\left(\frac{V^2}{2g}\right)$ is the change in velocity head through the transition and k is a factor which may have a value as low as 0.1 for increasing velocity transitions and as low as 0.2 for decreasing velocity transitions. Since the velocity heads are quite small in most sanitary sewers, it is the opinion of the author that larger allowances should be made for transition losses with a minimum value of 0.02 ft. in any case.

The transition data studied by Hinds involved flow in the "upper alternate stage" in all cases, and the values of k which he recommends are strictly applicable only to upper stage flow. There are many sewers in which flow must take place in the "lower alternate stage"; and hence sewer transitions may involve flow from upper to lower, from lower to upper or from lower to lower stage. Where a lower stage is involved, the values of k will probably be greater than stated above; and if flow is from lower to upper stage, a "hydraulic jump" will take place with considerable energy loss.

Because of the above considerations, it is advisable as part of design procedure to determine at what stage flow will take place in all sewers. It is also advisable that sewers be designed to avoid flow at or too near the "critical depth." Critical flow is unstable, and slight changes in friction within a stretch may result in substantial changes in depth and velocity.

If in the energy equation $H = d + \frac{V^2}{2g}$, V is replaced by its value $\frac{Q}{A}$ and A is expressed as a function of the depth d, the equation becomes a cubical equation in terms of the depth d. One of the three roots of this equation is negative and unreal but the other two values of d represent the two alternate stages at which flow may take place with a given energy head H. If the flow is uniform, the slope of the sewer determines which of the two stages will obtain. The solution of the cubical equation for a rectangular cross-section is shown graphically in Figure 6, and for circular conduits flowing partially full in Figure 7. These graphs were prepared by the author (7, 8) to facilitate the design of sewer transitions.

Figures 6 and 7 may be used to investigate the stage at which flow will take place. For a rectangular conduit, if $\frac{d}{H}$ is greater than $\frac{2}{3}$, flow is at the upper alternate stage; and, if less than $\frac{2}{3}$, at the lower stage. If $\frac{d}{H}$ is equal to $\frac{2}{3}$ flow is at the critical depth. For stable flow, $\frac{d}{H}$ should not be within the range from 0.60 to 0.72.

For a circular conduit flowing partially full, Figure 7 indicates that flow is at upper stage when $\frac{d}{H}$ is greater than 0.75 and at lower stage when $\frac{d}{H}$ is less than 0.50. For values of $\frac{d}{H}$ between 0.5 and 0.75, it is necessary to consider the value of the ratio $\frac{d}{D}\left(\text{or } \frac{H}{D}\right)$ in order to determine the stage. For example, if the depth of flow is 0.6 times the diameter (or $H = 0.84\ D$), the critical depth occurs at a value of 0.704 for the ratio $\frac{d}{H}$. For stable flow it is desirable that the depth of flow in a circular sewer should be less than 90 per cent or more than 110 per cent of the critical depth.

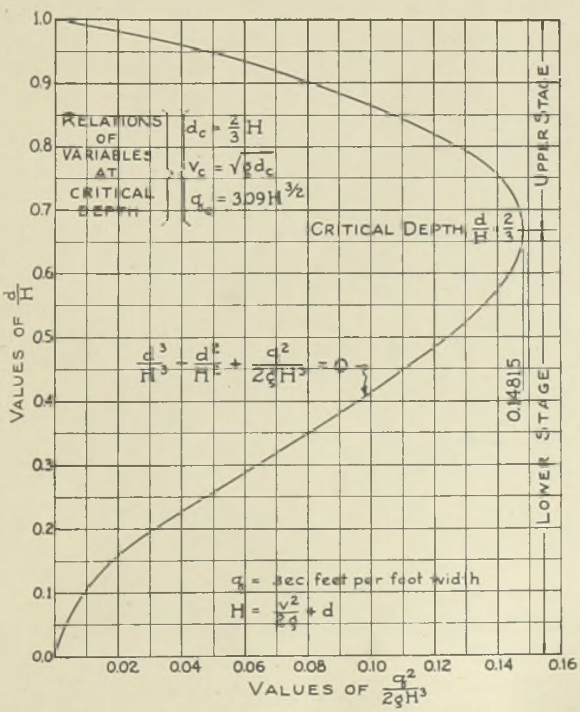


FIGURE 6.—Alternate stages and critical depth as determined for sewers of rectangular section.

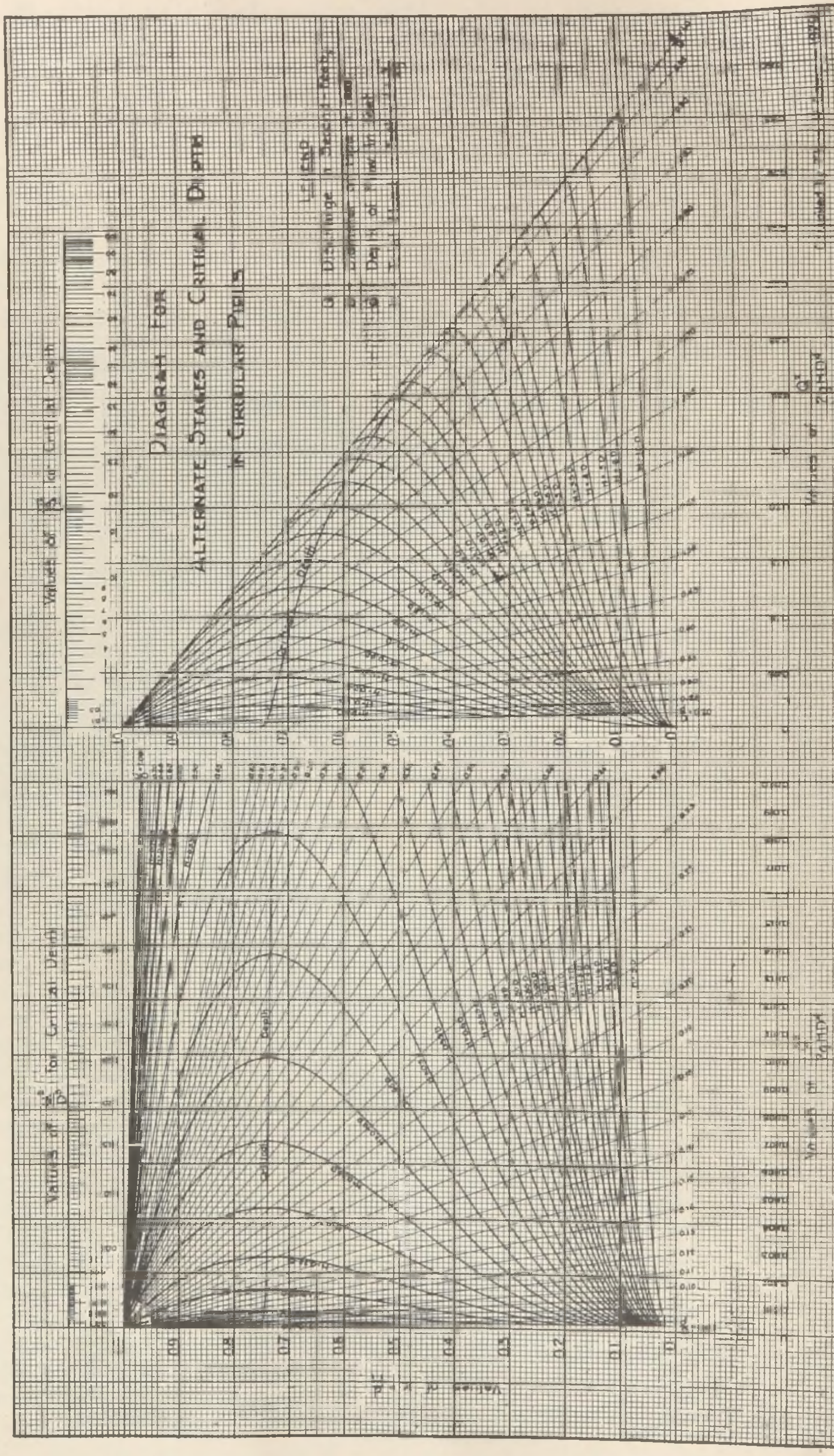


DIAGRAM FOR
ALTERNATE STAGES AND CRITICAL DEPTH
IN CIRCULAR PIPES
LEGEND

FIGURE 7.

Figure 7 is also useful for computing hydraulic profiles for nonuniform flow in circular sewers. By trial and error procedure from one cross section to another along a sewer stretch, H may be estimated and it is required to determine the depth for a given discharge Q. The values of $\frac{Q^2}{2gHD^4}$, and $\frac{H}{D}$ may be computed; and for these values, the corresponding value of $\frac{d}{D}$ or $\frac{d}{H}$ may be read directly from the diagram.

If a sewer is laid at a slope such that uniform flow will be at the upper alternate stage and the sewer discharges freely at the lower end, critical depth will occur a few feet upstream from the end. This point, or for a close approximation the end of the sewer, is a convenient starting point for the computation of the hydraulic profile. To determine the critical depth from Figure 7 for a given discharge and sewer size, it is convenient to compute the value of $\frac{Q^2}{D^5}$ and read downward from the corresponding scale to the "critical depth" line on the graph.

Sewer Junctions

Most sewer transitions are also junctions where a branch sewer enters a main sewer. In this case there are two flow paths, the lower stretch of main sewer being common to both. In at least one of the streams there is curvature and the value of h_T for this path should include the effect of curvature. An additional allowance in head loss should also be provided for both paths to care for the impact loss due to the converging streams. The hydraulic design of a junction is, in effect, the design of two transitions, one for each flow path.

The impact loss at a junction is, theoretically, subject to computation by the momentum principle. This principle has been successfully applied to the computation of head loss in a hydraulic jump occurring in rectangular open channels. For a junction of two or more streams meeting at an angle, the pressure plus the linear momentum below the junction point must equal the sum of the components of the pressure and momentum of each tributary stream in the direction of flow of the stream below the junction. The energy loss due to impact in the junction is the difference between the total energy in the stream below and the sum of the energies of the tributary streams. There will always be an energy loss of appreciable magnitude due to impact at the junction. It is conceivable, however, that in some cases, such as with a large stream at high velocity into which a small low velocity stream is discharged, there may be a gain in energy along one path at the expense of a greater loss along the other path. In sewer design it is not safe to assume that an impact loss may be negative, for if the assumption be in error the upper stretch of sewer will be subjected to backwater and possible surcharge.

Unfortunately, it is not practicable to apply the momentum theory to the actual design of junctions. In making the application, it is necessary to choose cross-sections just above and below the junction for which pressure and momentum computations are made. To the pressures thus computed must be added the pressure components in the direction of flow along the walls and floors of the channels. The pressure components on the walls and floor are a considerable part of the total pressure, but they cannot be accurately determined because their magnitudes are influenced by the impact of the streams and the curvature.

Conclusion

The author hopes that this brief review of some of the important considerations in the hydraulic design of sewers may serve to emphasize the highly technical nature of sewer design. The coming postwar period will see an expansion of sewer construction greater than in any previous period. It is imperative that the design be put in capable hands if we are to avoid discredit to the sewage works engineering profession.

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DIGESTER GAS FOR AUTOMOBILES

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Various kinds of gas have been used as fuel for automobiles instead of gasoline. Methane, having twice the heat value of ordinary city gas, is well adapted to this purpose. Methane is produced by the digestion of organic material under water and is a well known by-product of sludge digestion in sewage treatment plants (1). In most of the large sewage treatment plants of Germany, the digester gas is collected and compressed into steel cylinders for use as fuel in municipally operated automobiles.

The quantity of digester gas produced in sewage treatment plants is small in comparison with the general demand for gasoline, but the available supply is appreciably increased if facilities are provided for the digestion of other organic industrial and agricultural waste materials. Buswell (2) has studied the digestion of cornstalks as a source of gas and has conducted similar experiments with many other waste materials. Considerable work similar to that initiated by Buswell has been done in Germany (3, 4, 5). From these studies the following data on gas production and methane content have been drawn:

	Gas Quantity (Liters per Kg. of Dry Material)	Methane Content (Per Cent)
Sewage screenings	250–312	56–61
Sewage sludge	320	67
Sewage scum	570	70
Activated sludge	134	30
Filter paper (cellulose)	656–855	50
Newspaper	272	56
Leaves	210–294	59
Sugar beet tops	490	60
Weeds	122–320	59
Banana stems	374	62
Pine tree needles	37	69
Cornstalks	424	53
Sunflower shells	300	60
Wheat straw	245–342	58
Flax straw	300–359	59
Apple skins	160	50
Beer slop	500–600	58
Whey	670	50
Garbage	640	50
Slaughterhouse wastes	200–400	60
Stable manure with cornstalks	200–500	50–60
Stable manure with straw	250	56–60

The wide variation in these values, due to differences in the character of the material digested, will be noted. Digestion of stable manure with straw is seen to yield 250 liters of gas per kg. of dry material, which gas contains 60 per cent methane and 40 per cent carbon dioxide. The quantity of manure (with straw) produced per animal is as follows:

	Fresh Manure (Kg. per Day)	Per Cent Moisture	Dry Material (Kg. per Day)
Cow	40	75	10
Horse	30	71	8.7
Pig	6	72	1.7

The dry stable manure of one cow, amounting to 10 kg. per day, therefore, will yield $10 \times 250 = 2{,}500$ liters (88 cu. ft.) of gas containing 60 per cent methane. The fuel value of this volume of gas corresponds to that of about 1.65 liters (0.44 gal.) of gasoline.

Gas production in municipal sewage treatment plants is about 20 liters per capita per day. [This value apparently refers to gas production from primary sludge only. In complete treatment plants, gas production often reaches 30 liters per capita per day.—*Ed.*] It will be noted that the gas produced per cow by the digestion of stable manure is more than 100 times greater than the per capita production of gas by the digestion of sludge in municipal sewage treatment plants.

Digester capacity requirements for manure are very different from those for domestic sewage sludge. Ordinarily, where solid materials such as manure are being digested, 4 kg. of dry solids may be fed daily per cu. meter (0.25 lb. per cu. ft.) of digester capacity. Gas production is then about one cu. meter daily per cu. meter of digester capacity and the detention period of the diluted mass is about 30 to 40 days. On this basis the required capacity of a manure digester is only half that of a conventional sewage sludge digester.

Special Requirements in Digestion of Solid Wastes

In the digestion of solid materials special attention must be given to heating, acid fermentation, control of floating material, and nitrogen content. Heating is almost always necessary; the economical temperature of digestion is about 77° F. The following data (1) show the influence of temperature on the rate of digestion of well-seeded sewage sludge:

Time (*Days*)	Total Gas Production (Cu. Ft. per Lb. Volatile Matter)				
	50° F.	59° F.	68° F.	77° F.	86° F.
5	1.4	2.3	3.5	5.3	7.2
10	2.5	3.9	5.7	8.1	10.1
15	3.5	5.1	7.2	9.6	11.3
20	4.2	6.1	8.1	10.4	11.8
25	4.8	6.7	8.7	10.8	*12.0*
30	5.3	7.2	8.9	*11.0*	12.1
40	6.0	7.8	*9.5*	11.2	12.2
50	6.4	8.1	9.6	11.3	—
60	6.7	*8.3*	9.7	11.3	—
90	*7.1*	8.5	9.8	—	—

Acid fermentation instead of alkaline digestion occurs very easily when solid materials are being handled. This must be avoided, because very little gas production will otherwise take place and odor nuisance will be created.

Buswell (2) has shown that the chemical reactions occur in two steps: first, organic acids are formed; then the acids decompose to methane and carbon dioxide. If too much fresh material is introduced, the bacteria tend to produce more acids than can be decomposed. The acid concentration may become so high that bacterial action is inhibited. The only remedy for this is to decrease the rate of feeding fresh materials. When solid wastes such as manure are being digested, the fibrous material tends to float to the top of the digester leaving almost no bottom sludge. The floating particles accumulate as a compact scum in which only acid fermentation occurs. It is absolutely necessary to circulate the whole mass by means of an efficient mixer so as to break up the scum at least once daily.

A certain amount of nitrogen is necessary in a digestion unit as bacterial food. It has been demonstrated that gas yields are very low when pure cellulose (filter paper) is digested. Buswell (2) by adding nitrogen, was able to gasify nearly 100 per cent of the cellulose, and he recommends an ammonia nitrogen content of 100 p.p.m. as N in the digester. For each gram of decomposed material 7 mg. of nitrogen are necessary. If wastes, such as straw or cornstalks, do not contain the necessary nitrogen, manure or artificial ammonia nitrogen must be added to initiate satisfactory digestion.

Practical Experience in the Digestion of Solid Wastes

Aside from the well known digestion of sewage sludge there are very few plants that digest solid waste materials. One of the oldest installations of this kind was at Milwaukee, Wis., where sewage screenings were digested at one time. A newer similar installation is in operation at Dresden (6). The digestion of sewage screenings as a source of gas is of little importance, however, because the quantity of the raw material is small and the per capita gas production from screenings is at best but 20 per cent of the per capita gas production from sludge.

At Lansing, Mich. (7), ground garbage has been digested with sewage sludge with some success. At Amersfoort, Holland, an experimental digester is handling a mixture of ground garbage and sewage sludge, the digester being a Dorr unit equipped with a Turbo-mixer. The Dutch installation has functioned well and the favorable results reported for Lansing have been confirmed. The digestion of a number of other solid wastes is now being tried at Amersfoort.

A similar large installation is now under construction at a slaughterhouse at Hamburg. The anticipated daily gas production from this plant is 1,930 cu. meters (68,000 cu. ft.) containing 1,160 cu. meters (41,000 cu. ft.) of methane and equivalent in fuel value to 1,280 liters (367 gal.) of gasoline. The digested sludge will be dried and used as fertilizer.

Use of Gas in Automobiles

The net fuel value of methane (wet gas) is 7,970 kg.-cal. per cu. meter (896 B.T.U. per cu. ft.) and that of gasoline is 7,300 kg.-cal. per liter (110,000 B.T.U. per gal.). [The value given for gasoline may be somewhat low and possibly refers to synthetic gasoline as produced in Germany.—*Ed.*] On this basis, one cu. meter of methane is equivalent to 1.1 liters of gasoline (or one gal. of gasoline is equivalent to 123 cu. ft. of methane). For use in automobiles, the gas may be liquefied or it may be drawn directly from high pressure steel cylinders or from bags in which it is stored at atmospheric pressure.

The liquefaction of methane has been proposed by Padovani (8, 9), who suggests that it be made into methyl alcohol. Claude (10) suggests the conversion of methane to a form of liquid gas similar to propane which may be stored in cylinders at only 10 atmospheres pressure. Neither of these ideas has as yet been carried out in practice.

High pressure gas has been used as automobile fuel in Germany for many years. The steel cylinders ordinarily used are at 200 atmospheres (3,000 p.s.i.) pressure. They are 5 ft. long, 9 in. in diameter, have a capacity of 53 liters (1.9 cu. ft.) and weigh 62 kg. (137 lb.). At 200 atmospheres pressure the cylinder content is equivalent to about 10 cu. meters (353 cu. ft.) of pure methane under standard conditions of pressure and temperature or 11 liters (2.75 gal.) of gasoline. Gas compressors for this purpose are in operation in many German sewage treatment plants, including those at Munich, Essen, Stuttgart, Halle and Berlin. The compressors operate at a pressure of 350 atmospheres (5,000 p.s.i) and discharge to large storage tanks 16 ft. high and 2 ft. in diameter. Electric power is ordinarily used for compression, but digester gas engines are used instead in some plants.

Most of the carbon dioxide can be washed out of the gas with water under pressure, but this requires considerable power and a large amount of clean water. At Essen and Stuttgart the gas is left unwashed. The principal disadvantage of this procedure is that the cylinders contain less usable gas so that more cylinders of gas must be carried by the vehicle.

Non-compressed gas in bags has come into use for automobiles only during the past few years, especially using municipal gas as the fuel. The practice was introduced successfully in France and Germany (11, 12). Figure 1 illustrates the usual methods of arranging such gas bags on busses and supplementary cars. Development of the idea by Hans Koch of Neustrelitz (Mecklenburg) for operating small motor vehicles is also il-

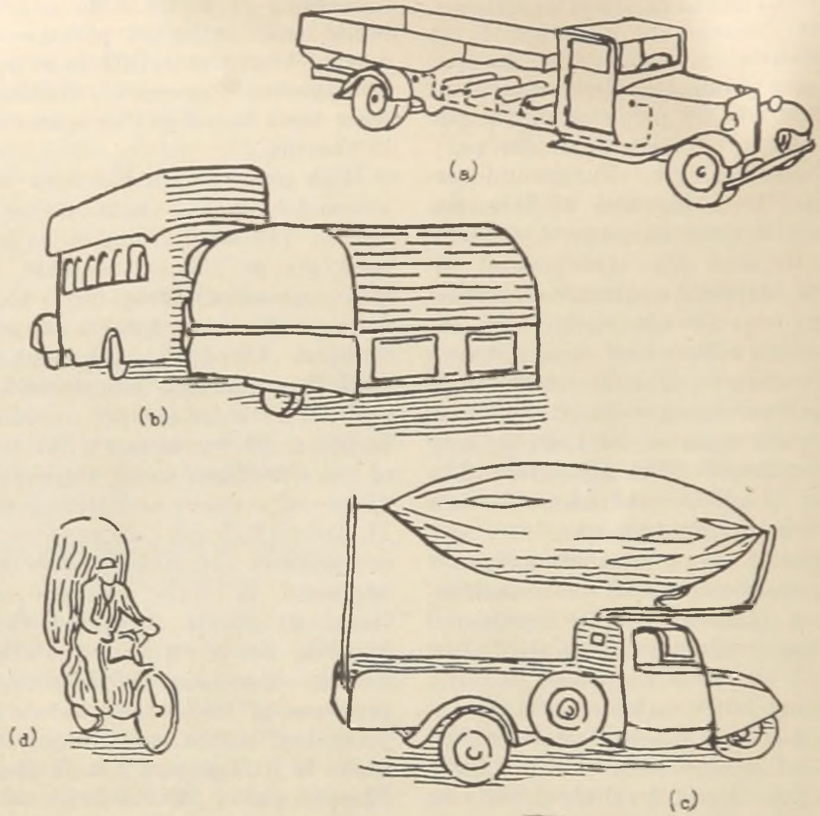

FIGURE 1.—Methods of carrying gas fuel for motor vehicles in Germany. (a) Motor truck with high pressure gas cylinders. (b) Omnibus with gas bag on roof and in supplementary car. (c) Tricycle automobile with gas bag. (d) Motor bicycle and driver with gas in knapsack.

lustrated in Figure 1. The use of gas bags for operating small vehicles is indicated where the gas is produced in small plants for which heavy compressors are too expensive.

Design of Rural Gasworks

No gas plants are as yet operating on stable manure, the most important material of all. The design of rural gasworks does not involve a great deal of difficulty, since broad experience is now available from sewage treatment plants. There is also a wealth of good experimental data to establish the special characteristics of stable manure and other rural waste products.

Figures 2, 3 and 4 illustrate the design of a rural gasworks which is to operate on a farm having 50 cows, 10 calves, 8 horses and 15 pigs. The daily quantity of fresh wet stable manure, including straw, produced by these animals would be 2,500 kg. (650 kg. dry). The daily gas production would be 162 cu. meters (5,720 cu. ft.) of gas containing 60 per cent methane and equivalent in heat value to 107 liters (28 gal.) of gasoline.

The straw is cut before it is used in the stable. During the summer grazing period part of the manure is lost and is replaced by accumulated rape straw which has little value for other purposes.

The proposed digester is 11 ft. deep and covered with earth (Figure 3). It is equipped with a Bucher mixer driven by electricity. This device consists of a long horizontal shaft supporting elliptical mixing blades and has proved to be effective in mixing solid and liquid manures prior to pumping them onto fields, a common practice in southern Germany. The capacity of the digester is 195 cu. meters (6,900 cu. ft.). The fresh manure is fed in daily at one end. At the other end there is a stilling compartment having a volume of 26 cu. meters (920 cu. ft.); it is in this chamber that the digested floating matter accumulates. This is removed from the chamber daily in a dry state and is stored in a pile for use as fertilizer. Digested sludge may be pumped back from the outlet end to the inlet for inoculation of the fresh material, if necessary. The overflowing digester liquor is discharged back to an existing liquid manure tank. The fresh manure is diluted with water to a moisture content of 86 to 90 per cent. The quantity of water required is about the same as that needed for cooling purposes at the compressor so that the water can be used to serve the dual purposes of diluting the manure and heating the digester. In winter, additional heat can be supplied by a hot water heater operating on the digester gas being produced or on other fuel.

The electrically driven gas compressor is located in a separate room of the engine house (Figure 4). The gas is compressed to 350 atmospheres (5,000 p.s.i.) and stored in two cylinders, whence it is delivered to the small automobile cylinders that hold the gas at 200 atmospheres (3,000 p.s.i.) pressure. A low-pressure gas holder of 100 cu. meters (3,530 cu. ft.) capacity serves as an equalizer.

The construction cost of the installa-

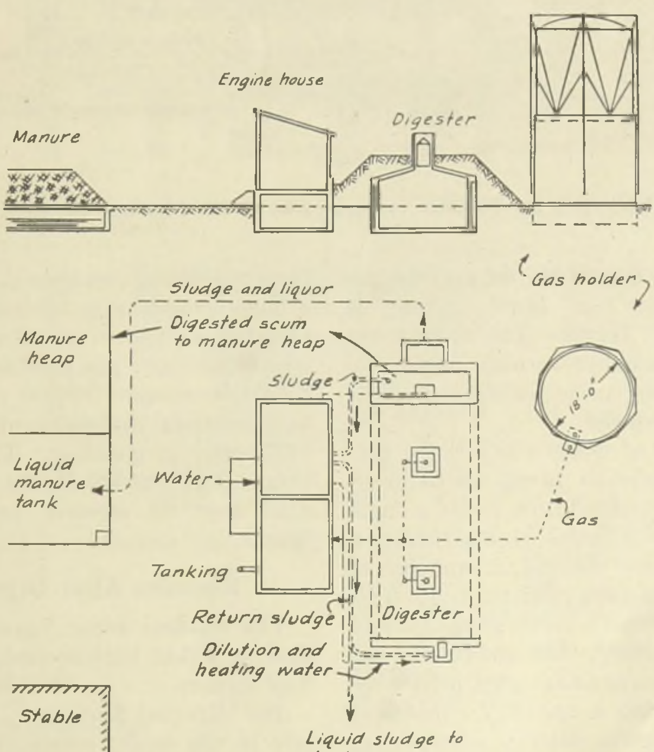

FIGURE 2.—Layout of gasworks at farm having 50 cows.

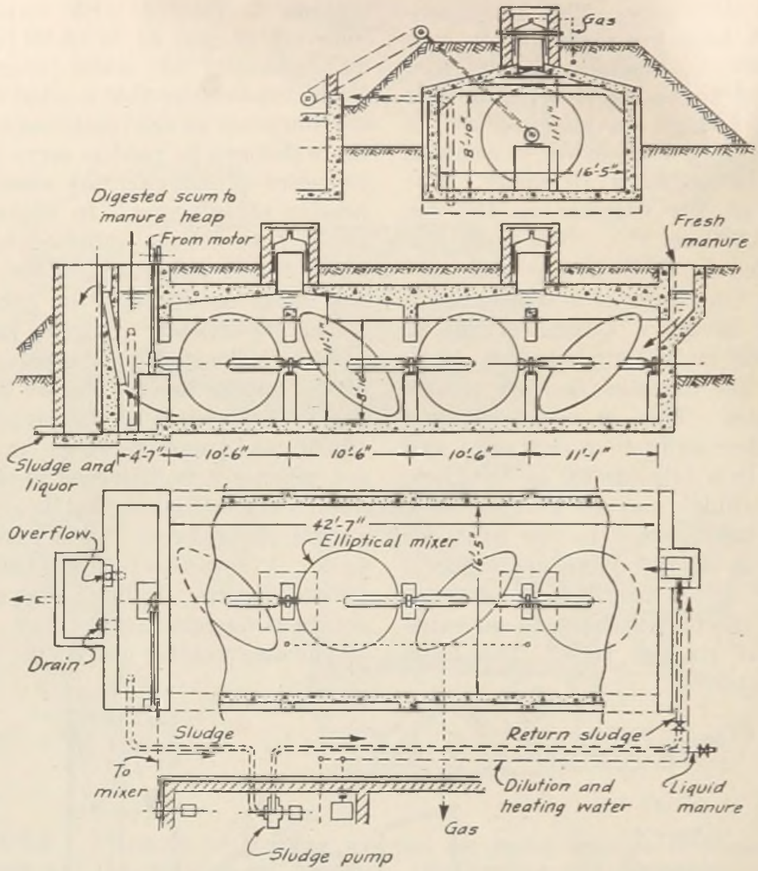

FIGURE 3.—Digester for gasworks at farm having 50 cows.

tion is about 60,000 Marks, and the annual expense for electric power is about 2,300 Marks. The power requirements amount to only about one quarter of the energy contained in the methane produced.

A number of designs have been prepared for German farms of different sizes. The smallest unit is for a farm with 4 cows (Figure 5) and incorporates a digester having a capacity of only 15 cu. meters (530 cu. ft.). This installation would yield from 9 to 15 cu. meters (320 to 530 cu. ft.) of gas daily. An equalizing gas holder or gas bag having a capacity equivalent to the maximum daily production of gas is needed and the gas can be carried in gas bags for cars and small farm machinery, as shown in Figure 1.

The largest unit is designed for a farming village in southern Germany where the daily gas production will be 2,400 cu. meters (85,000 cu. ft.)—the equivalent in fuel value of 1,580 liters (420 gal.) of gasoline. The construction cost is 340,000 Marks and the annual cost of electric power 29,000 Marks.

Residues After Digestion

The residues after digestion include floating solids, bottom sludge and overflow liquor.

The digested floating solids accumulate in the outlet compartment of the digester, from which they are removed daily to be used as fertilizer. The quantity is about half that of the original manure.

The amount of bottom sludge resulting from the digestion of stable manure, straw and similar cellulosic materials is very small, because most of the solids tend to float. This sludge may be removed at long intervals of time. In small plants the sludge may be discharged into the liquid manure tank as is done with the overflow liquor. In large plants, the sludge may be dried on open beds as in municipal sewage treatment plants, or it may be pumped directly onto fields or into lagoons.

The overflowing digester liquor corresponds approximately in quantity to the volume of introduced dilution water and may be about the same as the quantity of solid manure. The liquor contains considerable nitrogen and has value as a liquid fertilizer.

All three residues are practically odorless if the digester is operating properly.

Fertilizer Values

The quantity of solid manure is diminished by digestion and in that sense there is a loss of fertilizer. The same loss is experienced, however, in the course of any other treatment of manure because a part of the material is decomposed by bacteria in the manure pile and on the fields before it can be utilized by the crops. The difference is that the gases resulting from

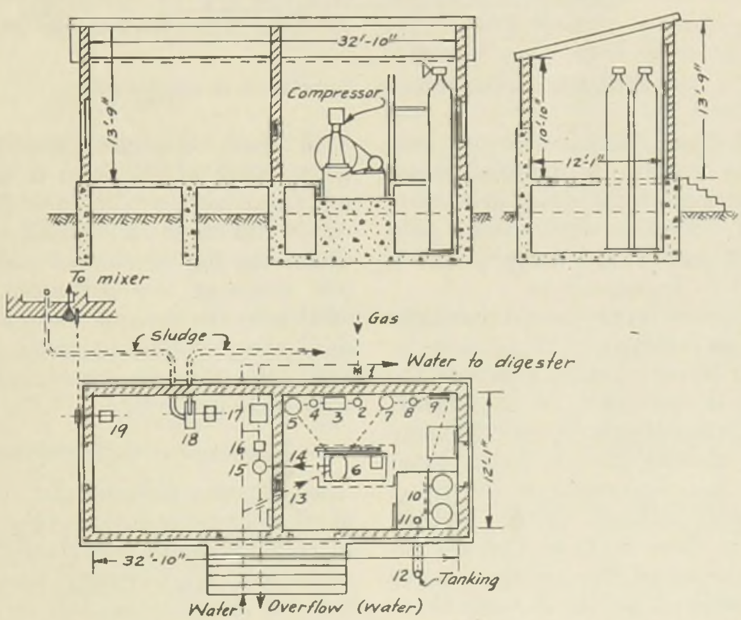

FIGURE 4.—Engine house for gasworks serving farm having 50 cows.

1. Main valve
2. Filter
3. H_2S filter
4. Meter
5. Equalizing tank
6. Compressor
7. Calcium chloride dryer
8. Separator
9. Distributor
10. Gas cylinders
11. Filter
12. Hose connection for tanking
13. Switch board
14. Hot cooling water from compressor
15. Water tank
16. Water pump
17. Heater
18. Sludge pump
19. Motor of mixer

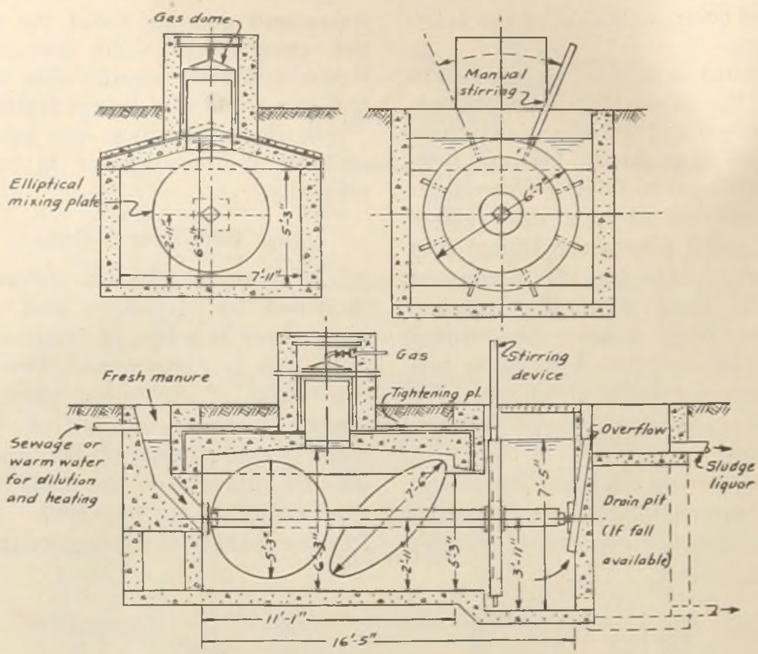

FIGURE 5.—Gasworks for installation at small farm.

bacterial decomposition are conserved when the manure is digested under water, whereas these gases are otherwise lost. Methane is produced only from that part of the manure that is subjected to decomposition.

The overflow liquor should naturally be used as fertilizer if there is to be no loss of nitrogen, since a part of the nitrogen is contained in the liquor. Where the liquid manure and drainage from the manure pile are accumulated in tanks as is customary in Germany, the digester effluent should be discharged to these tanks so that the nitrogen content of the overflow liquor will be utilized as liquid fertilizer.

In the decomposition of organic matter, liquefaction takes place as well as gasification. The liquefied material is contained in the overflowing digester liquor. Nevertheless, the digester can sometimes serve as a waste treatment plant; for example, where the wastes from a dairy or distillery are being treated. The strength of such wastes can be reduced materially by digestion.

In rural biological gasworks, the waste water of the farm is ordinarily increased by the digester. This may result in some additional nuisance where the liquid manure and manure pile drainage are permitted to flow away over the ground, but where these liquids are stored in tanks and utilized, the digester liquor creates no additional problem.

Economical Considerations

In a nation enjoying an abundance of oil and gasoline, such as the U. S. A., there is probably no market for digester gas. In Germany, however, the price of gasoline depends on the cost of producing it artificially from coal. The price is now more than 40 Pfennings per liter and the corresponding value of a cu. meter of methane is 35 Pfennings. At these prices, large biological gasworks are definitely profitable. The installation mentioned previously for the farming community in southern Germany will cost 340,000 Marks to build, but it will yield an annual gross revenue of 170,000 Marks. Agricultural gasworks with compressors are economical down to about 100 cu. meters (3,530 cu. ft.) of pure methane daily, equivalent to the production of 110 liters (29 gal.) of gasoline per day. Below that size compressors should be eliminated and non-compressed gas utilized.

Sufficient stable manure is produced in Germany to yield a quantity of gas which would have a heat equivalent of 4,000,000 U. S. tons of gasoline per year. In 1934 German importation of gasoline and oil was only half that tonnage. This import can be totally replaced by digester gas fuel if only half of the stable manure is digested to methane.

Conditions similar to those in Germany exist probably in other parts of central Europe and in large parts of Asia.

Conclusion

Sanitary engineers have had broad experience in digesting and gasifying organic matter in municipal sewage treatment plants. In Germany, methane produced by such digestion has been proved to be a good substitute for gasoline as an automobile fuel. The gas is ordinarily carried in steel cylinders at 200 atmospheres (3,000 p.s.i.) pressure, but it may be stored in bags which are not under pressure.

The quantity of digester gas produced at municipal sewage treatment plants is small in comparison with the demand for gasoline. The quantity of gas can be increased enormously, however, if solid organic wastes such as stable manure are digested. The quantity of gas available from the stable manure of one cow is more than 100 times the per capita gas production of municipal sewage treatment plants. The residues from stable manure digestion may be used as fertilizer. There is no appreciable loss of fertilizer constituents over those associated with present methods of application of fresh fertilizer to land. The methane is produced only from that part of the manure that would otherwise decompose in the manure pile or on the fields.

Rural digester gasworks may become important sources of automobile fuel for Germany and some other countries.

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SMALL SLUDGE ELUTRIATION PLANTS *

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The economic advantages resulting from the employment of sludge elutriation in any sewage treatment plant depend primarily on the use of continuous vacuum filters. These advantages are measured by the difference in the annual costs of operating the filters with and without elutriation. Similarly, the savings resulting from the employment of vacuum filters instead of open or covered sand beds are measured in annual operating costs and other capital charges.

The law of diminishing returns applies both to the use of vacuum filters in preference to sand beds and to the use of elutriation, *i.e.*, as a plant becomes smaller the returns on the initial investment become proportionately less until a certain threshold value is reached in population service when the savings about balance the annual operating and capital charges. This threshold value will vary with the treatment method adopted and with numerous other factors including those of local significance. In some instances it may be as low as 15,000 population. It is the opinion of the writer that if the use of vacuum filters is found at all advisable in small plants, the use of digestion and elutriation is also advisable.

In draining typical sludges on vacuum filters the chief items of cost, nuisance and trouble frequently relate to the chemicals used for conditioning and rendering various types of sludges rapidly drainable on such equipment. By now we have come to realize that the chief chemical requirements of various sludges are the combination of solids and liquid requirements of any sludge for ferric chloride and its various substitutes. Whereas the former is a function of the amount of organic or volatile matter present in the sludge, the latter is a function of certain biochemical products that accumulate in and foul the natural sludge moisture. Sludge digestion is particularly valuable in lowering the solids demand but does this at the cost of increasing the liquid demand of the highly fouled sludge moisture.

In small plants sludge digestion is a most valuable aid in lessening the amount of solids to be disposed of and is certainly the chief asset to the use of sand beds. Without elutriation to remove the inimical effects of its fouled moisture on chemical dose requirements, however, digestion may become a distinct liability to the use of vacuum filters to the best advantage. These filters may be used on raw solids without digestion. The use of digestion and elutriation, however, combines to reduce both the amount of solids and the chemical demand of a sludge with the result that the economic gain over dewatering raw solids is compounded. The final, lesser total chemical demand of the elutriated digested sludge applies to materially less final solids. The size of equipment and its space required for filtering and subsequent heat drying or incineration and the annual operating charges for chemicals and power are reduced, while objectionable odors and the nuisance of using lime are eliminated. These factors combine to lower the population limit that may be set for the use of vacuum filters in small plants.

Proof of this statement is the experience at Annapolis, Md. (1, 2). This plant is the smallest elutriation layout

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from the standpoint of size and cost of equipment. At present this plant may be serving about 25,000 people but at the time it was equipped with elutriation it was serving less than 20,000. It treats a year's supply of sludge during 710 hours service, *i.e.*, about 8 per cent of the total available time. Strangely enough the law of diminishing returns just mentioned did not apply to the elutriation part of this plant, although it undoubtedly did apply to the vacuum filter layout operating on the digested sludge without the aid of elutriation. The total cost of conversion to elutriation was practically retired by the savings effected during the first year of operation. The large return on the investment here was a combination of a number of items, some of which are pertinent to this discussion, namely, a digested sludge of low solids and high liquid chemical demand, high price of ferric chloride, good engineering foresight on the part of the designers (Whitman, Requardt and Smith—now Whitman, Requardt and Associates) in providing both ample digestion space and a small storage tank for equalizing the feed to the 65-sq. ft. vacuum filter, and the engineering acumen of the plant superintendent who converted this tank to a single stage elutriation tank at exceedingly small cost.

While in a very small plant the economic gain from using elutriation may barely offset expenditures, there are definite advantages included in the elimination of lime. All of these are not necessarily measured in dollars and cents but in terms of accomplishing sludge dewatering without purchasing, storing, handling and using two chemicals, liberating ammonia and other odors, fighting lime carbonate incrustation with acid, and preventing acid action on the metal surfaces of the filtration equipment by using inhibitors.

In a plant serving 20,000 population the annual savings in chemicals may vary from $400 to $800 according to the quantity and nature of the sludge collected and processed, the local price of chemicals and the degree to which the liquid demand of the sludge is diminished.

There are other factors beside the daily sewage flow and solids load which determine the size of an elutriation plant. The kind of sludge digested and dewatered, the amount of digestion space provided, and the weekly operating schedule have material influences on this point. The operating schedule is quite important and is determined largely by the digestion space. Aside from the influence of secondary heat drying or incineration of the filtered sludge on the operating schedule, ample digestion space provides for flexibility in elutriation and filter operating schedules. The operating schedule makes the term "small elutriation plant" relative. For example, a plant serving 20,000 population is classified as small and one serving 70,000 is well out of such a class. Nevertheless, with digestion space sufficient to destroy about 65 per cent of the volatile matter in a primary sludge obtained from average domestic sewage, an elutriation schedule which calls for serving 20,000 people 220 days yearly and but 8 hours daily, *i.e.*, 20 per cent of the total time, will serve 40,000 when operating 40 per cent of the time and 70,000 when operating 70 per cent of the time.

The shortest annual operating time recorded for elutriation plants is at the Petapsco plant in South Baltimore. Here the elutriation and vacuum filter equipment operates approximately one day out of each month and then for only 7 or 8 hours, which is about 1 per cent of the available time. This is due to the fact that the total population to be served by the plant is not yet connected.

The longest annual operating schedule is at the main treatment plant serving about one million of the Baltimore population. Here elutriation and vacuum filtration operate 63 per cent of the available time. Insufficient digestion space is largely responsible for the increased load on the sludge dewatering equipment.

This is mentioned here to emphasize again the fact that one of the best safety factors in determining the optimum economies of elutriation and vacuum filtration is ample digestion space, particularly in small plants where such space is easy to provide. This space will probably average 1.5 cu. ft. per capita for heavy primary sludges and may extend to 2.5 or even 3 cu. ft. per capita for thinner fresh sludge mixtures. The average yearly operating hours for present day elutriation plants is about 1500. This is about 17 per cent of the total available time.

Elutriation Space

Aside from the influence of digestion space on the annual operating schedule, the other factors which affect the size, cost, and efficiency of elutriation plants are: (1) kind of sludge digested and elutriated, (2) the degree to which raw solids may be mineralized and concentrated in digestion and elutriation, (3) alkalinity of wash water used, (4) alkalinity of the fouled digested sludge moisture, (5) washing method used and (6) the amount of wash water used per unit volume of sludge or sludge moisture.

The first two items are important in that they influence both the digestion and elutriation space. In general, a thin primary sludge, such as primary mixed with waste activated sludge fed to digestion will automatically result in a thin digested sludge. This is logical because the specific gravity of the solids before and after digestion depends on the amount of organic matter in the original sludge. The specific gravity of solids increases in digestion. In destroying 65 per cent of the volatile matter in two primary sludges having, for example, an initial volatile percentage of 80 and 60, respectively, the gain in the specific gravity of the solids in the latter heavy raw sludge is 50 per cent greater than is the case of the former thin mixed primary and waste activated.

With good destruction of volatile matter in digestion, both second-stage digestion tanks and elutriation tanks should serve as solids concentration tanks or sludge thickeners. This diminishes the ratio of fouled water to solids and acts to diminish the liquid demand for chemicals. This explains why some digested sludges of rather high alkalinity and high solids content have a lower chemical requirement than do others of similar alkalinity but higher moisture content. Also, an examination of most elutriation installations having ample sedimentation capacity and washing solids of a fairly high specific gravity will show that the solids concentrate to a heavier sludge in elutriation than in digestion. Dilution with fresher water in elutriation automatically lessens the buoyant effect of dissolved digestion gases on the solids, because these gases go into solution, and also reduce the viscosity and density of the fouled water surrounding the solids. Backmeyer (3) experimented with elutriation in the second stage of digestion at Marion, Ind., for this purpose and for the production of clear digester supernatant. Previously the writer (4) described the use of elutriation for removing suspended solids from digester supernatant either within or beyond second stage digestion.

In order to obtain the best economy out of elutriation in the case of thin digested sludges, not only larger elutriation space but purer elutriating water are required than with heavy sludges. To contain a ton of digested solids it takes about 445 cu. ft. of a sludge having 7 per cent solids of about 35 per cent volatile, and over double this amount (905 cu. ft.) of a sludge having 3.5 per cent solids of about 58 per cent volatile. It is actually the moisture content of the digested sludge going to elutriation rather than that of the final elutriated sludge that influences the size of elutriation settling tanks.

As to factor No. 3, the alkalinity of the wash water used, in any plant we are limited to the cheapest available supply of water of minimum alkalinity. At Hartford, Conn., Springfield, Mass., and Cranston, R. I., water is taken from wells used for ground water drainage. At Washington, D. C., Potomac River water is used, while in other plants final effluent from the treatment system is used. In all of these instances the alkalinity varies from about 60 to 300 p.p.m. The lower limits are represented by the river and well water supplies. Obviously, such water is of the most benefit to all types of digested sludges. A plant effluent of 250 p.p.m. alkalinity, however, works remarkably well on heavy digested sludges.

The alkalinity of the digested sludge will be found to vary from 2,000 to 3,000 p.p.m. with ample digestion space and good digestion tank operation. In plants digesting ground garbage, packinghouse waste, and brewery waste along with normal sewage sludge, alkalinities may reach 6,000 p.p.m. Five thousand p.p.m. has been recorded at Winnipeg, Can., and 6,000 p.p.m. at Cranston, R. I. In operating with insufficient digestion at Baltimore the alkalinity is about 4,200 p.p.m. In planning elutriation a safe average is 3,000 p.p.m.

In removing the major fraction of this alkalinity the washing method used and amount of water used combine to produce the desired result. The washing method used is of prime importance. Essentially there are three practical methods of accomplishing the washing of sludge solids, *i.e.: single stage* elutriation involving a single sedimentation tank with a single dilution, sedimentation and decantation step; *two stage* elutrition, involving repetition of the single stage on the same solids with fresh water, requiring twice as much or more water than single stage; and, finally, *counter-current* elutriation in at least two tanks operating in series. This also involves two stage washing but with a material difference. The settled sludge collected in the first stage tank (No. 1) is pumped to a second tank (No. 2—See Figures 3 and 4) while the overflowing decanted supernatant from the two tanks progresses in the opposite direction. The fresh water is added only to the sludge pumped into second stage washing and the decanted top water of relatively low alkalinity from No. 2 tank flows by gravity to mix with the sludge moving from digestion to the first tank. This procedure effects a maximum reduction in sludge alkalinity with a minimum quantity of fresh water.

Single and Two Stage Washing Vs. Counter-Current in Small Plants

Because counter-current elutriation requires at least two tanks or tank compartments does not mean that it requires twice the tank space that could be used for single stage washing. It may even take less space if a fairly good removal of the fouled sludge moisture is desired.

Mathematical equations for solving the relative efficiences of the various sludge washing methods with relation to factors 3 to 6 have been recently published (5) and are of value in determining the choice of washing method for small plants. For example, when washing by the counter-current method a digested sludge of 6 per cent solids and 3,000 p.p.m. alkalinity in 3 volumes of plant effluent of 250 p.p.m. alkalinity, about 85 per cent of the undesired sludge alkalinity is removed. In this case there are 4 total volumes of water and sludge involved in each of two tanks, which is equivalent in tank space to 8 volumes in one tank when using a ratio of 7 to 1 by single stage washing. This single stage washing with the same water would remove less of the undesired sludge alkalinity, *i.e.,* 81 per cent. No tank space is saved. Tank space can be saved by using, for example, a 5 to 1 single stage ratio, *i.e.,* 6 total volumes. However, this is at the additional cost of efficiency. In this example it drops the alkalinity removal to 77 per cent and increases the water pumping cost. By using two stage washing in this smaller tank space the efficiency may be increased, but this obviously requires twice the time. Two tanks in simultaneous counter-current usage not only increase the overall efficiencies in alkalinity removal but decrease tank space, amount of water pumped and time.

Whereas the removal of 85 per cent and more of the fouled sludge moisture is of economic importance in large installations due to the large quantities of sludge washed, dosed and filtered, in plants handling fairly heavy digested sludge and serving 20,000 to 30,000 population the difference between removing 77 per cent of this moisture by single stage and 85 per cent by counter-current is not very important. This depends largely on the local price of chemicals. For example, with ferric chloride at $72 per anhydrous ton the difference between the two foregoing washing methods may mean but $50 annually in a plant serving 20,000 population. Obviously, with ferric chloride at half this price the difference becomes even smaller. Furthermore, with well washed heavy sludge cheaper coagulants like alum and ferric sulfate may be used as demonstrated at Springfield and Annapolis. Therefore, the local price of chemicals plays a definite role in the choice of washing method in small plants.

Capacity and Dimensions of Settling Tanks

The total space required for elutriation settling varies from 0.02 to 0.2 cu. ft. per capita, or from 2 to 10 per cent of the space required for digestion. The variation comes from such of the foregoing factors as operating schedule, pounds of digested solids per 1,000 people served, sludge volume containing a pound of sludge solids, desired efficiency of removal of fouled sludge moisture, and alkalinity of the water used. For reasons already disclosed the combination of thin sludge and short operating schedule accounts for the higher figure. Furthermore, to obtain a fairly high washing efficiency even in counter-current practice when using plant effluent of 300 p.p.m. alkalinity, 50 per cent more water and tank space may be necessary than is the case when using wash water having an alkalinity of 150 p.p.m. Fortunately, increasing the tank space from 1,000 to 1,500, or from 2,000 to 3,000 cu. ft. is a minor item in small plants.

The *dimensions* for continuously operated elutriation settling tanks should be determined from about a 3-hour detention period under maximum sludge and water loading conditions. Three-hour detention provides for at least 2 hours free settling space above a reserve sludge blanket or supply sufficient to keep the filters operating steadily for a few hours. The amount of solids settled and accumulated in this reserve depends primarily on the horizontal tank area. The amount of the reserve sludge storage and the free settling depth above same then depend on the tank area and depth. Practice indicates that the reserve sludge accumulated in a tank should not exceed one-third of the tank depth. The maximum sludge loading conditions should be made up of the maximum cubic feet of digested sludge expected per operating hour at the ultimate population service and the expected minimum solids content. To this maximum quantity of digested sludge must be added at least 3 volumes of wash water for counter-current washing in companion tanks, or 5 volumes of wash water for single-stage washing in one tank. Until the plant capacity reaches its ultimate design limit the foregoing provisions permit using much higher elutriation ratios if desired, especially with heavier average sludge.

Continuous Vs. Intermittent Tank Operation

In using a single tank a question may arise in a small plant handling relatively heavy digested sludge as to whether or not elutriation is to be operated continuously or intermittently. In the former case the dilute mixture of sludge and water is fed to the tank simultaneously with sedimentation of washed solids and decantation of supernatant elutriate. In the latter case the single settling tank is operated on the fill-and-draw batch treatment principle.

In a continuously operated tank the supernatant elutriate overflows the constant level weir in proportion to the rate of feeding. In order to keep the decanted overflow relatively clear the feeding rate is such that the rate of total liquid rise in the tank is definitely less than the rate of subsidence of the top solids in the tank. Depending on the operating schedule and the nature of the sludge being washed, continuous elutriation may or may not operate simultaneously with vacuum filtration. The accumulation of washed sludge in the tank starts previous to vacuum filtration and is continued until a sludge reserve sufficiently uniform and heavy for steady filter operation results, at which time the vacuum filter is started and simultaneously operated with elutriation if desired. With heavy digested sludge the period of reserve sludge accumulation before filtration may be shorter than with thin sludge.

The fill-and-draw system of elutriating a sludge in a single tank cannot operate simultaneously with supernatant decantation and vacuum filtration. The feeding rate of the water-sludge mixture to the tank can be at any desired rate providing the single tank is made large enough to hold the dilute mixture for an entire day or shift of vacuum filter operation. With fairly heavy digested sludge this may require little tank space in a plant serving 25,000 persons.

Here the desired amount of sludge is drawn from the digestion tank and washed either on the day before or shift preceding vacuum filtration. The operator starts with the tank practically empty and fills the tank with mixed sludge and water at any desired rate. At a fairly rapid rate the tank may be full in an hour or two and after another two or three hours he will be able to decant clear supernatant by means of an adjustable overflow weir. Fill-and-draw tanks should be equipped with any of the various common types of adjustable supernatant draw-off devices, *i.e.*, swivel or telescoping pipe with a floating weir.

As most digested solids when diluted with fresh water will settle back to the original solids concentration in two hours time, two stage washing may be resorted to if ample time remains after giving the sludge a single wash. In this case the sludge accumulated through the first wash may be recirculated back into the same fill-and-draw tank with a new batch of water. In either case the remaining concentrated sludge constitutes an entire filter operating day's sludge supply.

In all types of tanks the storage of some washed sludge ahead of vacuum filtration is essential to providing a flow of sludge having uniform characteristics to the vacuum filters. In every installation, regardless of tank system and washing method, washing operations necessarily start in advance of filtration. Furthermore, as most installations provide for an average operation schedule of 15 per cent of the total available time, the off-period for both elutriation and vacuum filtration averages 85 per cent of the available time. Consequently, provision has always been made for rewashing any sludge reserve left in the elutriation system before beginning filter operations. With any single tank this is just as simple an operation as with a dual tank system because whatever recirculation may be necessary is usually confined to the second or final tank.

Taking all of the foregoing factors into consideration it may be generally stated that with a filter operating schedule calling for 8 hours or less per operating day, not over 5 operating days weekly, and a well digested sludge containing an average of more than 6 per cent solids, and using a water of fairly low alkalinity (average of 200 p.p.m. or less), the continuously operated single tank may be somewhat cheaper to install for 30,000 and less population service. In single tanks serving less than 75 per cent of this population, *i.e.*, tanks having about 150 sq. ft. and less horizontal cross section, a single fill-and-draw tank will probably be preferable to a continuously operating tank. With such small tank cross-sections and dimensions continuous feed and overflow may result in the tank being too sensitive to eddy currents and less subject to quiescent settling, with a consequent increase in suspended solids in the tank overflow. It has been the writer's observation that the supernatant elutriate drawn from a fill-and-draw tank is considerably clearer than that from most continuous flow tanks.

With sludges containing less than an average of 5 per cent solids and using plant effluent for washing, the companion counter-current tank system may prove cheaper to install and operate, even in installations serving 25,000. The same is true when the vacuum filters are operated 14 to 16 hours daily in conjunction with heat drying or sludge incineration equipment.

Sludge and Water Pumping and Metering

Wash Water Pumps—Type and Capacity

Any reliable make of variable capacity centrifugal pump is satisfactory for delivering water to elutriation mixing and settling. With continuously operated tanks the capacity should be variable from zero to at least 1.5 times the estimated maximum rate requirements in order to provide for sludge that may be occasionally thinner than estimated, or for using a higher elutriation ratio if conditions permit. For use with a fill-and-draw tank, pumping may be at a much higher rate so that the pump capacity will have to be increased accordingly.

Number of Wash Water Pumps

For the intermittent service common to most elutriation installations, and especially the small ones, one pump is sufficient.

Sludge Pumps

Ordinary centrifugal pumps should not be used on any sludge going to or leaving elutriation because they not only frequently clog but tend to chew up and destroy the natural sludge floc. Bucket elevators are superior to all other sludge lifting means but require more room and have a higher initial cost. Next in order of recommended types are plunger and "Scru-peller" pumps. The former will handle heavier sludge than the latter but will clog more readily. The "Scru-peller" pump will do excellent work especially when equipped with a vacuum primer. Even with this aid, however, it cannot be used on sludges containing low volatile and much over 8 per cent solids without danger of clogging, nor can it be used as a rough metering device.

It is quite essential that any sludge elevating or pumping device be of both variable capacity and speed.

Number of Sludge Pumps

With a single tank system, sludge washing on shifts preceding vacuum filtration and gravity feed of digested sludge to elutriation, one sludge pump or elevator is enough. This pump is then used for either returning washed sludge back to elutriation (Figure 2) or for delivering washed sludge to the filter. Where gravity feed of sludge to elutriation is not possible another similar pump may be required.

With gravity feed of digested sludge to elutriation and the use of companion tanks in counter-current operation, two pumps will be required: one for moving the sludge from the first to the second washing compartment, called the return sludge pump, and one for delivering washed sludge to the vacuum filters (see Figures 3 and 4).

Capacity

The capacity of sludge elevating or pumping equipment should also be variable from zero to at least 1½ times the estimated maximum requirements.

Sludge and Water Metering

In order to obtain the best efficiency with any elutriation installation a fairly constant ratio of water to sludge should be maintained in the dilute mixture flowing to the settling tanks. This means the provision of fairly reliable flow rate controls. Water is always easily metered and usually the installation of variable capacity pumping equipment for sludge permits easy control of same.

In small installations, however, the sludge metering methods usually differ from those used in large installations where the use of more elaborate equipment is practical, *i.e.*, the use of venturi meters with motor operated plug cone valve rate controllers and adjustable rate setters on the downstream side of the venturis. Due to the heavy, sluggish nature of well digested primary sludges and such elutriated sludges, the minimum permissible throat diameter for venturi metering is about 2¾ inches. At sludge flow rates common to small plants, *i.e.*, from 40 down to 10 g.p.m. the velocity of sludge flow through a 2¾-inch throat may become too low to permit meter readings.

Where bucket elevators are used for transporting sludge, revolution counters, with known bucket capacities and number of buckets dumped per hour, provide an easy method of metering sludge providing the buckets are hosed down occasionally. Where plunger pumps are used they will function reliably enough as meters when equipped with stroke counters and operated at fairly low speed with ample plunger stroke.

All of these devices may be used for roughly metering sludge transferred by the return sludge pump in the companion tank counter-current system and for transferring sludge to elutriation from a storage well located between digestion and elutriation. If the well is equipped with a calibrated depth gauge a "Scru-peller" pump may be used. Where digested sludge can be delivered directly to elutriation by gravity the extra cost of pumping merely for the sake of rate control and metering should be eliminated. If an ordinary telescopic valve with handwheel regulation may be used for delivering sludge to elutriation, the rate control and metering problem becomes quite simple.

This is best exemplified by the Annapolis, Md., installation illustrated in Figure 1. The sludge storage tank converted to a fill-and-draw single or two stage elutriation tank has but 650

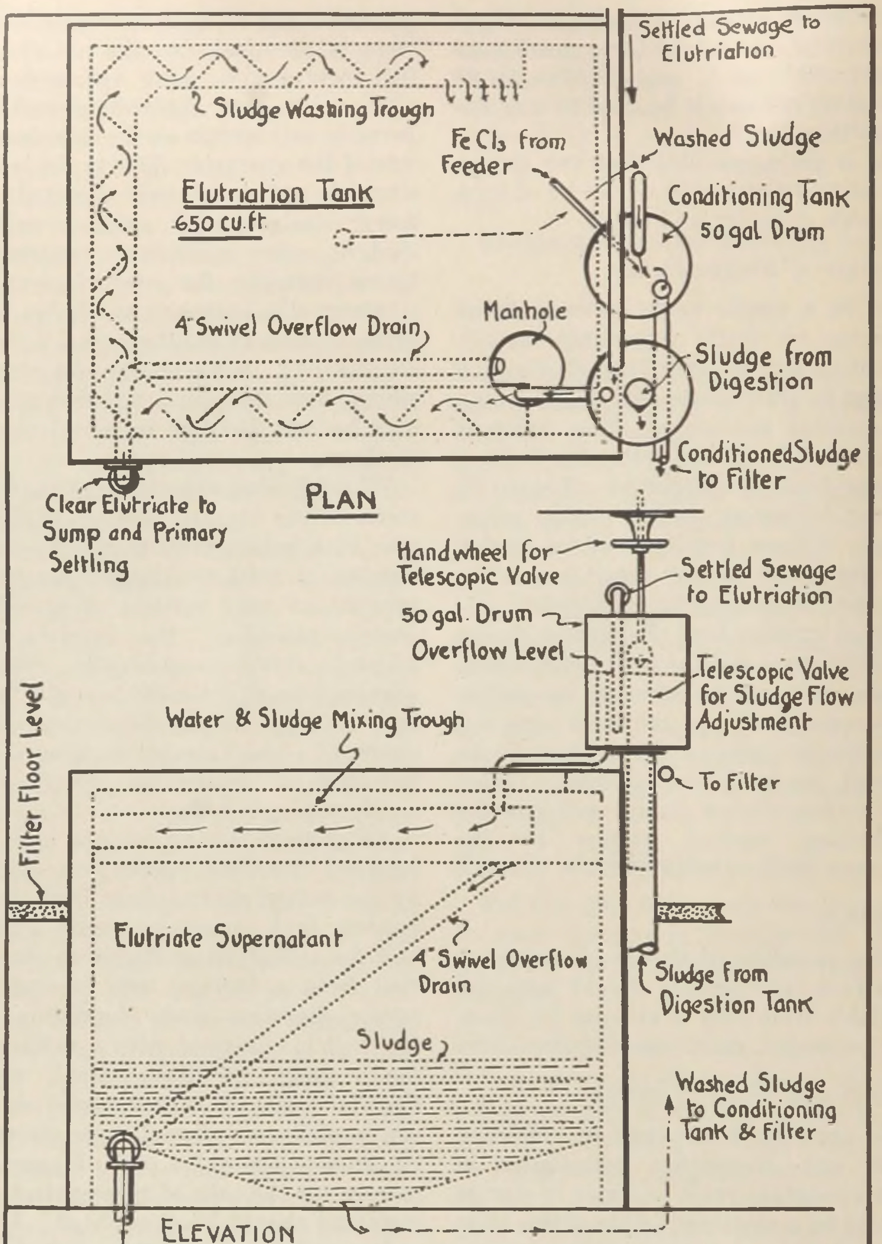

FIGURE 1.—Elutriation at Annapolis.

cu. ft. settling space, which under present operating conditions is about 0.026 cu. ft. per capita. It has been in service for the past six years. As shown in Figure 1 the flow of sludge from the digestion tank is by gravity and is easily regulated by the telescopic valve delivering sludge to the improvised metering and pre-mixing tank (made of a 50-gal. oil drum) which has a removable overflow level. The rate of flow of sludge into the tank is easily determined by the time it takes for sludge alone to fill the tank space up to this overflow. As in this case the capacity of the elutriating water pump is constant and can be checked by the same method, the rate of sludge flow is easily adjusted to the water flow. The water-sludge mixing system is evident from the drawing. After filling the tank the operation is typical of such fill-and-draw layouts. Sludge and water feed are stopped and after the solids have settled the clear supernatant is syphoned off through the swivel overflow drain. A small plunger pump removes the washed sludge from the bottom of the tank. It may be rewashed if desired or sent direct to the conditioning tank which will be described later.

In such layouts the dilution ratio of water to sludge may easily be checked by simple sampling and alkalinity titrations. For example, with D, E, and W representing the p.p.m. methyl orange alkalinity of the digested sludge, elutriated sludge and plant effluent or other wash water, respectively, the ratio (R) of water to sludge moisture for single stage washing is:

$$R = \frac{D - E}{E - W},$$

and to convert this ratio to the actual ratio of water to sludge, multiply R by the fraction of water (per cent moisture) present in the sludge. Thus, with $D = 3{,}000$, $E = 643$, $W = 100$, and 8 per cent solids in the digested sludge, R is 4.34, and 4.34×0.92 (sludge moisture) $= 4$, which is the ratio of water to digested sludge. Other equations for two stage and counter-current washing may be found in the reference (5) from which the above equation is taken.

Mixing of Water and Sludge

The foregoing instance of the smallest and one of the most successful elutriation installations has been repeated here to illustrate the simplest method of elutriating sludge solids. In larger installations, water and sludge are frequently mechanically stirred together to insure thorough mixing before settling. In the first installations, rather elaborate mechanical layouts and longer mixing times were provided. In more recent layouts the mixing equipment has become not only smaller but the detention time in the mixing chamber has been shortened to 30 seconds. Meantime in a few installations, as at Annapolis, it was demonstrated that turbulent flow conditions in a baffled launder, or in a common pipe leading to elutriation settling, as at Washington, D. C., are sufficient for good mixing. In small installations either of these methods should be sufficient. In any case the velocity of the diluted sludge in the launder or common pipe should, under minimum flow and dilution conditions, be sufficient to prevent grit from settling out. Where sufficient heavy grit is actually present some mechanical stirring in a small pocket or chamber in the feed trough of the settling tank may be necessary.

In small installations, mixing sludge and water in a common pipe line leading to the elutriation tank incidentally permits the use of a venturi meter for measuring the sludge feeding rate. Figure 2 shows such a scheme in connection with a single stage elutriation tank. This is somewhat more elaborate than the scheme used at Annapolis, without the baffled launder method of mixing, but is more practical for determining the ratio of wash water to sludge.

The method of feeding sludge from digestion by gravity through a telescopic valve into a small constant head tank, similar to Annapolis, is shown in plan and sectional elevation. The visible flow of sludge is a material operation asset.

With the exception of the venturi meter shown at the left in Figure 2, the method of mixing water and sludge in a common pipe line, after metering the water, is taken from the second stage

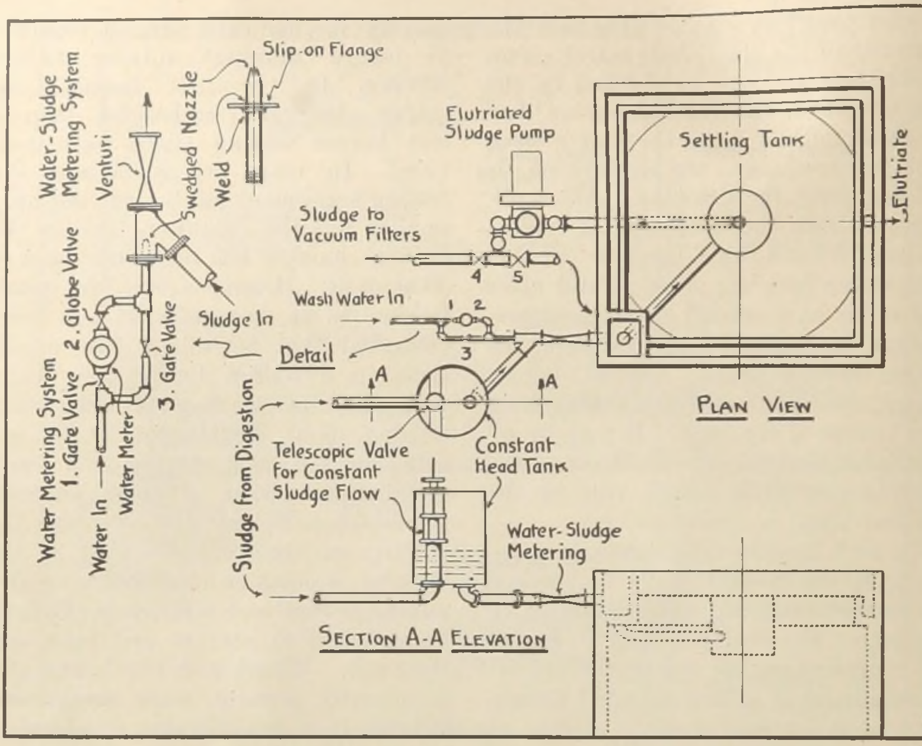

FIGURE 2.—Single tank, square type.

metering and pre-mixing arrangement used at Springfield, Mass. After passing through an ordinary 2- or 3-inch water meter (with Valves 1 and 2 open and Valve 3 closed) the wash water under pump pressure enters the enlarged lateral in a direct line through the swedged nozzle. The digested sludge on its way to elutriation meets the water jet in this lateral and in proceeding to elutriation both are well mixed. The three valves surrounding the water meter are for cutting the meter out of service, for cleaning, etc., and principally for regulating the water flow rate through the meter, *i.e.,* Valve 3 is kept closed and Valves 1 and 2 used for regulating the water flow through the meter and into the sludge.

The diluted sludge then flows through the venturi meter, which is not necessarily directly adjacent to the outlet of the lateral mixer as indicated in the diagram. As the actual water rate is determined by the water meter, the sludge feeding rate is the venturi rate minus the water rate and the ratio of water to sludge is equal to the water meter volume per hour or operating day divided by the venturi volume for the same period minus the water meter volume; at a water meter reading of 80 g.p.m. and a venturi reading of 100 g.p.m. the ratio of water to sludge is 80/100 — 80 or 4.

Measuring the water-sludge mixture in a venturi eliminates the venturi throat diameter minimum of 2¾ inches because the sludge is now materially diluted. A much higher velocity of the mixture through the throat results and fairly accurate readings become possible.

Types of Elutriation Tanks

All types of elutriation settling tanks, whether large or small, should be equipped with mechanically operated sludge collectors.

With *fill-and-draw tanks* a small tank of square horizontal cross section with corners filleted near the bottom to a circular bottom and having a circular sludge collecting mechanism and center feed may prove the cheapest kind of concrete structure. If the digested sludge is thin (below 5 per cent solids) a standard Dorrco picket fence thickening mechanism may aid in concentrating the washed solids to a thicker elutriated sludge. Otherwise, with a normally heavy digested sludge, any standard radial sludge raking mechanism may be used in the square tank, or the tank can just as well be of longitudinal flow. For fill-and-draw purposes such tanks should be equipped with a telescoping or swivel decantation weir.

Figure 2 indicates a mechanically operated, continuous flow square settling tank. Valves 4 and 5 on the discharge of the elutriated sludge pump are used for rewashing operations. Valve 5 is normally kept closed and Valve 4 opened so that the sludge pump may deliver washed sludge to the vacuum filter. If it is desired to refreshen any sludge left in the tank over week ends, or to give the sludge a second stage wash, Valve 5 is opened and Valve 4 closed and the previously washed sludge is recirculated back to the constant head tank and thence with fresh water through the mixing pipe back to the settling tank. During this procedure the flow of sludge from the digestion tank is stopped.

The choice between fill-and-draw and continuously operated tanks for small plants has already been discussed.

As elutriation tanks for small plants vary from 100 sq. ft. to rarely over 300 sq. ft. liquid surface area, square and rectangular tanks are cheaper to construct than circular tanks due to less expensive form work. However, with small tanks constructed of steel, redwood or cypress, circular tanks are obviously the cheapest of all.

With *companion tanks* operating in series, either counter-current or two stage washing, the best space economy will result from building either rectangular or square tanks having a common dividing wall. Due to simpler form work, like in the single tank construction, they are also considerably cheaper to construct in concrete than are small circular tanks of equivalent settling area.

Figure 3 illustrates diagrammatically the special type of companion square tank, *i.e.*, an oblong tank having a center wall dividing it into two square tanks similar to Figure 2 with similar center stilling well feeding and peripheral overflow arrangements. The Dorrco picket fence type of thickening mechanism is also indicated.

As in all such companion tank arrangements the peripheral weir overflow of Settling Tank No. 2 is elevated 8 inches or a foot higher than that of Tank No. 1 (see Section A–A) to provide for gravity flow of supernatant elutriate from No. 2 to No. 1. The sludge and wash water destined for Tank No. 2 are mixed as already described. With such a mixing arrangement the overflow weir and launder system of Tank No. 2 may extend around four inner sides of this tank compartment instead of 3 sides where mechanical mixing is used, as at Cranston and Stamford. As the weak elutriate overflowing this tank compartment cannot be very well mixed with the incoming digested sludge in a common pipe header, one of the upper sides of Tank No. 1 is reserved for a mixing channel equipped with baffles or other mixing means.

The operation of this system is just as simple as single stage washing and really simpler than intermittent washing in one tank, even though intermittent washing produces the clearest supernatant. In starting operations both tanks are filled with wash water

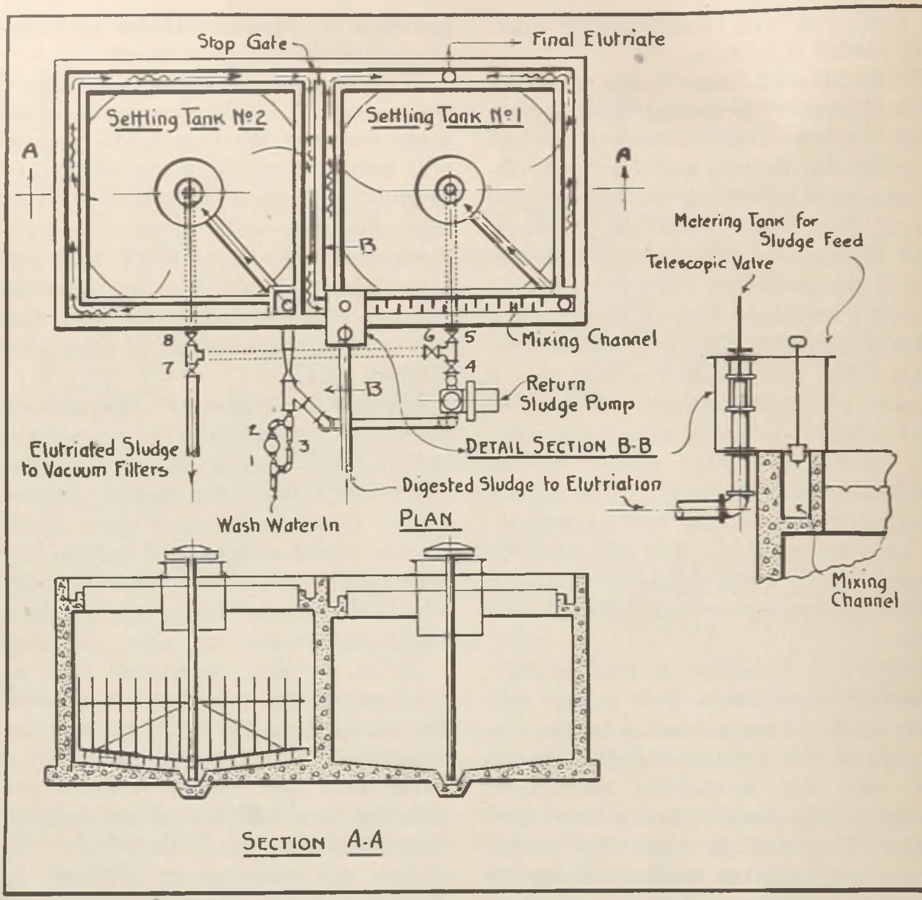

FIGURE 3.—Counter-current in companion square tanks.

and water at the desired flow rate is kept flowing into Tank No. 2 which provides overflow to the Tank No. 1 mixing channel where it meets the sludge coming from digestion through its rate controller in larger installations, or the telescopic valve and metering box shown in the detail for small installations (Section B–B). This small tank or box merely functions as a digested sludge feed tank in which the telescopic valve is located and may occasionally be used as a metering tank. For this purpose the box may be calibrated in gallons per inch and whenever desired the plug valve may be inserted in the bottom outlet and the rate of sludge flow measured. Normally the bottom outlet of this feed box is left open. The rate of Tank 2 overflow is determined from the water meter reading as already noted. Both this overflow and incoming digested sludge are mixed in the Tank No. 1 mixing channel and proceed to Tank No. 1 where the solids settle out. When a foot or so of settled sludge is collected in Tank No. 1 the return sludge pump is started at the desired rate and after mixing with the fresh water flows to Tank No. 2.

For this operation Valves 3 and 6 are normally closed and the others kept open. With a stroke counter on the return sludge pump (or revolution counter on a bucket elevator) and a fairly accurate calibration of the pump capacity at various speeds the venturi meter may be eliminated. However, such a device offers a good check on the sludge pumping rate and elutriation ratios. With the sludge streams (proceeding to Tank No. 1 and being pumped to Tank No. 2) flowing at somewhere near the same rate true counter-current washing equilibrium is soon established. With a sufficient reserve blanket of sludge in both tanks sludge is started moving to chemical conditioning and vacuum filtration.

The purpose of Valves 4 to 8, inclusive, is to transfer the washed sludge to various places in the system and for sludge recirculation and washing after prolonged shutdowns, when any sludge left in Tank No. 2 may become too heavy for proper conditioning. It is then recirculated back to No. 2 by closing Valves 5 and 7, and opening Valves 4, 6 and 8 with fresh water entering the mixing system and using the return sludge pump. This is continued until the sludge is sufficiently rewashed.

The main features of this compact arrangement of companion square tanks with picket fence thickeners and with mechanical mixers operating in mixing troughs for both settling tanks and different sludge metering is best represented by the installations at Cranston, R. I., where the idea was first developed and used, and at Stamford, Conn. Here the two compartments of an old Imhoff tank system were converted to continuously operating elutriation tanks of this type.

Figure 4 shows the adaptation of the same counter-current flow, metering and pumping system and tank structural features to mechanically operated longitudinal flow and sludge collection in rectangular tanks. This diagram adapts the open overflow launder system of the square companion tank layout to the dual rectangular layouts at Washington, D. C., Hartford, Conn., San Francisco, Calif., and Springfield, Mass., with a consequent simplification of their elutriate piping. The most compact rectangu-

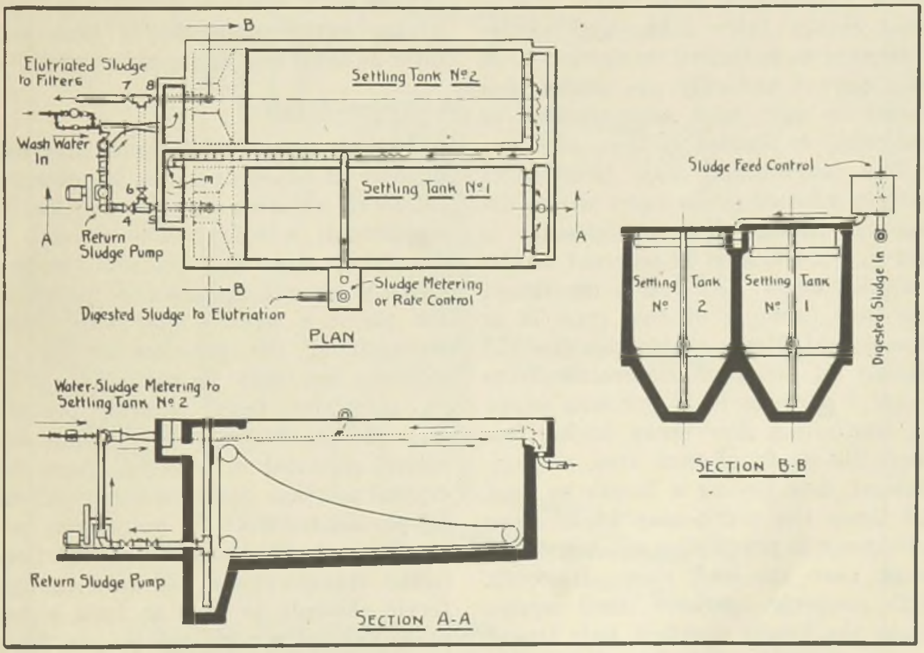

FIGURE 4.—Counter-current in companion longitudinal tanks.

lar tank layout is that of Springfield, Mass.

In Figure 4 the dividing wall between the companion tanks is formed at the top into an open launder with a bottom sufficiently inclined to insure a rapid flow. As shown in the plan view the sludge drawn and measured from digestion can flow into this launder at any desired point along its length and become thoroughly mixed with the overflow leaving Tank No. 2 either by baffles or mechanically as indicated at "m."

On account of visibility and accessibility the open launder system of Figures 3 and 4 is preferred for returning counter-current elutriate. Even where sludge and fresh water are mixed in the common fitting for single and companion tanks this mixture should become visible in some small mixing compartment located directly at the head of the settling tank. This permits any plant operator to see at a glance if either sludge or water has ceased flowing.

Regardless of the size of the plant in using longitudinal flow tanks, experience favors fully submerged sludge collectors as indicated in Section A–A of Figure 4 and only one sludge well outlet in each tank compartment as indicated in Section B–B.

The longitudinal flow tank offers certain advantages in cases where the digested sludge fed to digestion is heavy, *i.e.,* contains 50 per cent or less volatile matter. As before mentioned the best example of this type is at Springfield, Mass., where the digested sludge is easily concentrated from about 8 per cent to 15 per cent solids. In continuous flow tanks having less than 100 sq. ft. of tank area, a longitudinal tank having a length at least 2.5 times the width may be of some advantage in preventing solids entrainment over the end weir. However, with properly operated small square tanks the longer overflow weir length means a smaller velocity of overflow approach. Due to the bottom corners being filleted in the square tank layout some tank volume is lost and the capacity should be slightly increased over that required for rectangular tanks.

The square tank system equipped with the picket fence thickening mechanism offers advantages for installations serving 25,000 and more population where relatively thin sludges are washed, *i.e.,* 5 per cent and less solids.

Sludge Conditioning and Vacuum Filtration

Some of the advantages gained through sludge elutriation may be lost with the improper installation of dosing equipment and vacuum filters. As but one chemical is used in dosing elutriated sludge, such as, in the order of effectiveness, ferric chloride, chlorinated copperas, ferric sulfate and alum, the definite nuisance and bother incidental to the use of lime are eliminated. Consequently the dosing method and equipment should be as conveniently small as possible and the piping between the dosing tank and filter as short and as simple as possible.

Chemical Solution

In most small installations, and frequently in larger ones, the use of crystal ferric chloride is preferred to the commercial solution. The crystal is dissolved and the solution stored. Usually enough solution is provided for about a week's filter run. The strength of the solution should be scarcely less than 15 per cent (10.61 lb. anhydrous ferric chloride per cu. ft.). If one desires to store more dissolved chemical in a given space the crystal solution should scarcely exceed 40 per cent (35.41 lb. anhydrous per cu. ft.). On this basis 30 cu. ft. of solution storage space will hold enough ferric chloride to dose at least a ton of elutriated sludge solids per filter operating day for at least five days when using a 15 per cent solution, for 10 days when using a 25 per cent solution and 18 days when using a 40 per cent solution. At the average dose used during the last four years at either Annapolis or Springfield the above periods could be doubled. Thus, for an installation filtering about 1.5 tons of elutriated digested solids per operating day (about 25,000 population) and 220 operating days yearly, the solution storage space would be about 45 cu. ft.

This solution should flow by gravity to the automatic feeder and conditioning tank. The best and least expensive method of piping this solution was developed at Hartford, namely, through a chemical rubber hose equipped with a hard rubber shut-off cock and supported in a sufficiently large electric wiring conduit.

The automatic chemical feeder delivering carefully metered ferric or alum solution to the sludge in the ferric mixer (conditioning tank) should also deliver all of its contents to the sludge under gravity head. In large and small installations the precision volumetric type (Omega or equivalent) is preferred for this purpose. Its supply tank should be large enough to hold a full day's supply of ferric chloride, *i.e.*, about 100 gallons for 25,000 population. The mechanically actuated feed syphon should be capable of delivering from zero to the desired maximum volume of solution per hour and the tank should have an accurate volumetric gauge showing the exact contents of the tank over its full range of depth.

Mixing of Chemical with Sludge

As we have progressed in dosing elutriated sludges the equipment for mixing chemical and sludge has become smaller and smaller. Today the actual conditioning space and stirring mechanism used for mixing chlorinated copperas solution and sludge for half a million population at Baltimore is no

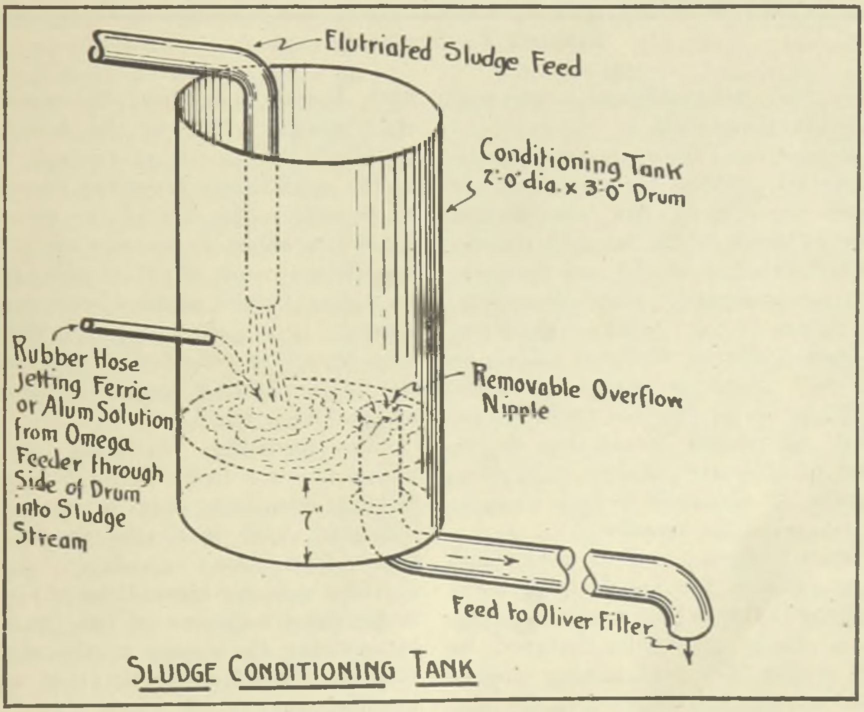

FIGURE 5.—Coagulation at Annapolis.

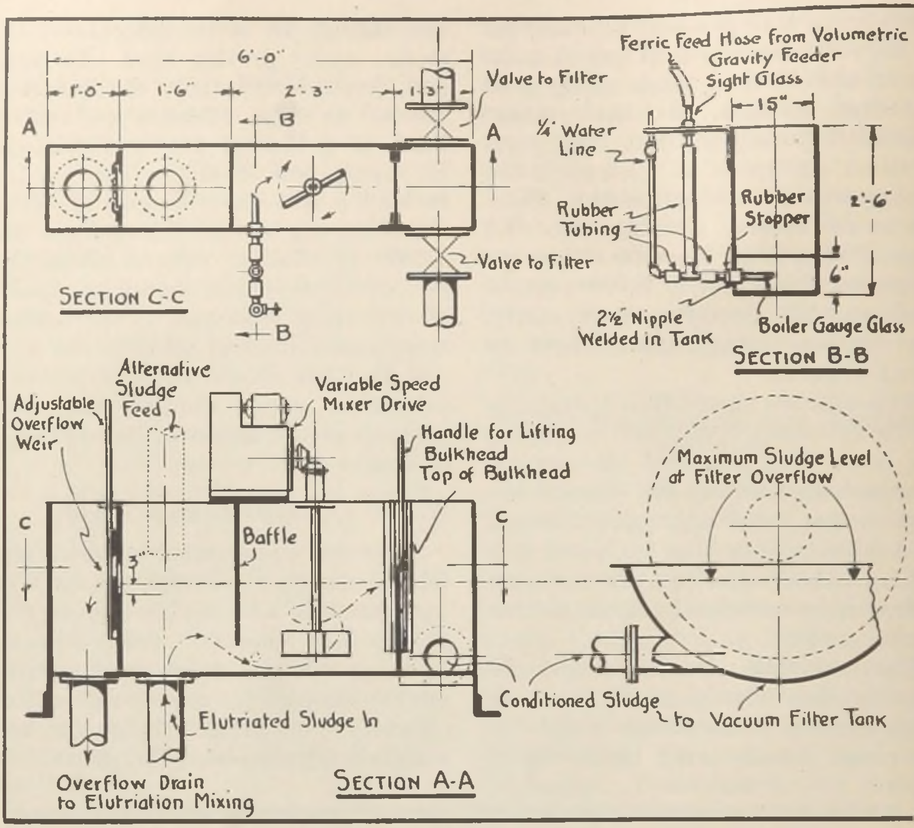

FIGURE 6.—Conditioning tank.

larger than that originally required for 50,000 population.

Chemical dosing or sludge coagulation in its simplest form is shown in Figure 5. The entire coagulating space is about 14 gallons and the detention period of sludge and ferric in this space is normally about 45 seconds. The jetting of the small stream of ferric (now a solution of ferric sulfate or Ferrifloc) into the cascading sludge stream serves to produce rapid coagulation. McDonald found that flocculation of elutriated sludge with alum solution at Springfield had to take place in a similar manner (6).

Figure 6 shows a type of mechanical mixer suitable for installations serving from 15,000 to half a million population. It is purposely designed to keep sludge flow and mixing visible at all times. The dimensions for the larger population figure need be but little larger than those indicated on the drawing. Due to the minimum practical size of sludge delivery lines to the conditioner or mixer and then to any filter, the size of the mixer is limited to about 15 inches wide. This type is the result of experience gained at Annapolis and about 4 other larger plants. It is quite similar to the recent layout at Stamford, Conn., with the ferric feeding arrangement used at San Diego, Calif.

The incoming elutriated sludge passes under a baffle, through a small mixing chamber, over a removable bulkhead, and then directly to the filter tank. An adjustable sludge overflow weir for unconditioned sludge is provided adjacent to the point of introducing the sludge to the mixing trough. This is done to avoid wasting chemical.

Every filter is equipped with a maximum sludge level overflow at the end of the filter tank. Overflowing sludge at this point not only means a waste of conditioned sludge, but operation of the filter at the most inefficient cake building and drying level. The small adjustable overflow weir has its lowest overflow opening at least 3 inches below the filter overflow. Any sludge feed reaching this level overflows before it is dosed. With proper dosing, filter speed and bridge setting on the automatic filter valve, sludge will rarely overflow from this weir or from the filter itself.

The ferric mixer speed may be constant if desired (about 30 or 40 r.p.m.) but is preferably variable from 20 to 80 r.p.m.

Experience with dosing fairly heavy sludges has definitely taught that the ferric solution should be fed into the sludge under submergence and about as shown in the three tank views of Figure 6, *i.e.,* just after the inflowing sludge passes under the first baffle and enters the actual mixing chamber. Furthermore, as the sludge may be too heavy for effective mixing with the chemical solution, water should be introduced. The method of doing this shown in Section B–B of Figure 6 is quite effective, *i.e.,* directly where the ferric enters the sludge. This provides for two important conditions, such as quicker distribution of the solution through the sludge, and due to the increased velocity of the dilute solution through the glass tube the end of this tube is kept thoroughly flushed out. In some instances when not using water the end of the ferric feed tube becomes plugged with coagulated sludge.

Every filter operator should be able to see at a glance if ferric with or without water is feeding into the sludge. This is the purpose of the sight glass in the rubber tubing leading from the feeder to the ferric mixer, and the glass tee at the bottom water and ferric mixing connection. The glass tubing may be of Pyrex or heavy walled boiler gauge glass.

As tap water is best for diluting the ferric entering the mixer it should obviously be drawn from a small constant head tank located above the feeder and equipped with a float controlled inlet valve out of all contact with the contents of the tank, in order to avoid any danger of cross connections.

In starting a filter the sliding bulkhead at the end of the mixing chamber is shoved down in place and the agitator, sludge feed and chemical feed started. The thoroughly conditioned sludge mixture overflows the bulkhead and proceeds directly to the filter. After the sludge level in the filter is sufficiently high for regular operation the conditioned sludge will automatically back up to a common working level in both the mixer and filter so that the mixing paddle remains submerged. Then the bulkhead is lifted and left up during the complete filter run.

Piping for Conditioned Sludge

For reasons elsewhere emphasized (7) and indicated on the lower left hand corner of Figure 6, the conditioned sludge should be fed quickly and directly through a straight pipe directly into the filter tank. This can be either at the end of the filter or into the side as shown in the two plan diagrams of Figure 7 where the single conditioning tank is located equidistant between two filters. This arrangement may be variously adapted to one, two and three filters. Its primary aim is to eliminate unnecessary storage of dosed sludge in transit to any filter, frictional traffic jams due to the sluggish flow of coagulated sludge in any pipe and unnecessary delay in filtering dosed sludge.

At Annapolis the flash conditioned sludge flows into one end of the small 65 sq. ft. filter and is then distributed back of the drum by overflowing an open trough. At Springfield, Mass.,

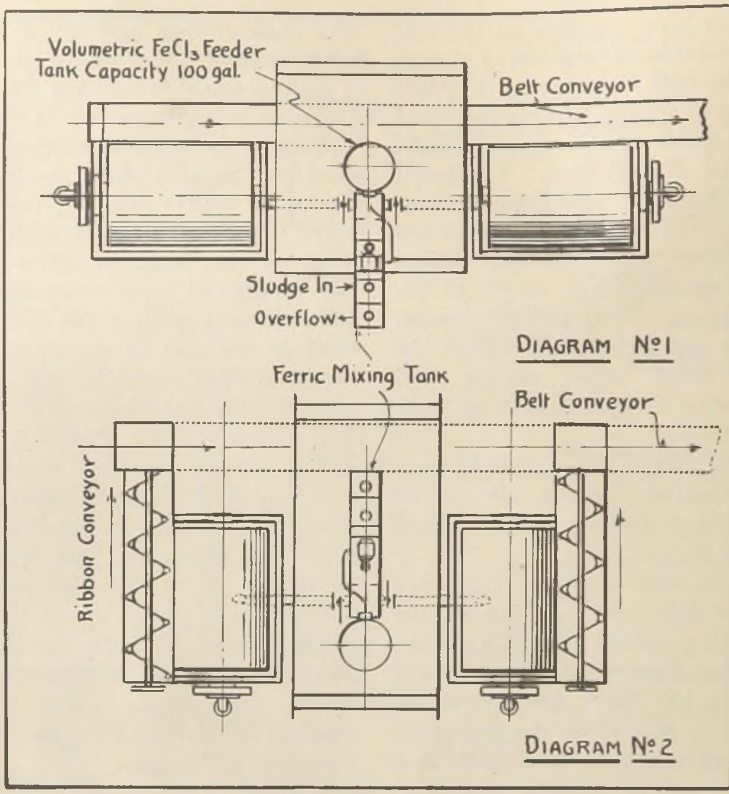

FIGURE 7.—Feeding conditioned sludge to two filters.

Cranston, R. I., and San Diego, Calif., the conditioned sludge likewise feeds into one end of each of the two filters used. At Stamford, Conn., the feed is into the side of the tank. Here three units are installed parallel with the conveyor belt and each unit is equipped with its individual ferric mixer located at the back of the filter.

With end filter tank feeding as in Diagram No. 1 of Figure 7 the filters should be definitely able at all times to operate at a low submergence level in order that the sludge agitators may readily distribute the sludge throughout the filter tank. Otherwise the cake will be thicker at one end of the filter drum than at the other.

The layout in Diagram No. 2 shows the use of a ribbon conveyor for evenly distributing sludge cake on the conveyor belt passing over a weightometer to a heat dryer or incinerator. In the writer's opinion there are simpler methods of doing this, thus permitting the filters to parallel the cake conveyor belt as in Diagram No. 1. An example of such simpler practice may be found in the simple cake distributor used at Hartford, Conn.

The layout of Figure 7 is roughly proportioned for two 65- or 75-sq. ft. filter units, either one of which can easily drain the elutriated sludge from 25,000 population at the normal 5-day weekly schedule of 6 or 7 hours per day. With two larger units capable of handling the elutriated digested sludge from half a million population on a 12- to 16-hour operating day schedule the size of the conditioning tanks will increase but little in floor space dimensions and the layout will evidently become more compact. In such larger filter units side feeding is preferable.

In all elutriation installations both the surplus filter feed overflow from the conditioning tank and the filter drainage left after any filter run and during showering of the drum should be piped back to the mixing trough of a single stage elutriation tank or to the mixing trough of the second settling tank in the companion tank layout. This keeps all digested solids out of the plant primary system and provides for relatively immediate disposal. Likewise the filtrate from the vacuum filters should flow to elutriation. It contains some iron salts, has a very low B.O.D. and should be of some value in elutriation.

The supernatant elutriate is normally conveyed back to primary sedimentation and may flow directly to trickling filters where such are present, or it may be partially or completely by-passed to the plant effluent. With ample elutriation space and time the B.O.D. of the elutriate will normally be found less than that of the influent to a primary treatment plant because the B.O.D. of digested supernatant is associated with suspended solids which may be rather high in straight supernatant and considerably lower in the elutriate. With elutriating water of 50 p.p.m. or less B.O.D. the elutriate in a primary treatment plant may be short circuited to the effluent without appreciably increasing the B.O.D. of same.

Labor, Power and Installation

In a small plant the operator or his assistant has ample time in which to inspect occasionally and care for the operation of the few elutriation equipment items. Continuous counter-current washing in a companion tank does not require any more attention than does single stage washing, and perhaps less attention than fill-and-draw operations. Although one more sludge pump may be required for counter-current operations, there is materially less water and power required per ton of solids washed. The best adaptation of the elutriation equipment relative to the digestion tanks, water supply and filters in the hydraulic profile mean more than do relative pumping costs for water in small installations. As noted at Annapolis, the cost of pumping ample elutriating water for single or even two stage washing is but 13¢ per operating day with power costing 3½¢ per kwh. With power at a cent a kwh. this would be less than 4¢ per operating day.

Location of Tanks

In small plants it is particularly important to have the elutriation layout as close as possible to the vacuum filters. Much is gained in initial installation cost and convenience of operation by having the elutriation system located in the basement of the building housing the vacuum filters and directly beneath the filter floor. In this case special excavation for the elutriation tank or tanks is unnecessary and the piping from elutriation to the filter and back is the simplest possible. A floor grating may also be installed over the elutriation tank with the driving mechanism for the elutriation sludge collector located on the filter floor and in full sight of the filter operator.

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PRELIMINARY GREENHOUSE STUDIES OF DIGESTED SLUDGE AS A FERTILIZER *

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Thanks to the persistent efforts of L. W. Van Kleeck, the energetic Secretary-Treasurer of this association, we have become interested in sewage sludge as a fertilizer and have been able to make a few studies in the greenhouse. Lack of time and facilities have prevented our carrying out more complete investigations inside, and any at all in the field. It is not the purpose here to discuss the merits and demerits of sludge for use on the land, nor to go into the literature on the subject; rather, this paper will merely report the results obtained from the use of digested sludge from several Connecticut sources when applied in greenhouse pots.

pH Changes in Sludge and Sludge-Treated Soils

Inasmuch as sludges vary widely in pH, depending upon type of treatment, the first question that came to mind was "what is the effect of alkaline sludges on soil reaction?" On the afternoon of March 19, 1943, a sample of lime-conditioned sludge from the New Haven Sea Street plant was received at our laboratory through the courtesy of K. E. Foote, laboratory engineer. The sample tested pH 10.9 at the plant, and 11.98 at the laboratory immediately upon receipt. Part of the sample was then spread out in a large evaporating dish; the remainder was left enclosed tightly in the paper bag in which it came.

Subsequent tests made after 18 hours (1 day), and 3, 5 and 8 days gave the results shown in Figure 1A. The extremely high pH was due mostly to the ammonia present which vaporized rapidly when the sludge was exposed, but at a relatively slow rate when confined in a paper bag. Presumably, further changes are slight and take place slowly. By the time such sludge is spread out in the field, its pH has dropped markedly.

The next step was to treat a soil (Cheshire fine sandy loam) with alkaline sludge at the rate of 10, 20 and 40 tons per acre, and ascertain the changes in the soil reaction. The soil was not cropped. The data in Figure 1B show that the original soil pH of 4.8 was changed but slightly by the ten-ton application, and in only one case did it get above 6.5. The averages for the 4 determinations for the different rates were:

No sludge	4.83
10 tons	4.97
20 tons	5.44
40 tons	6.13

No reason is known for the somewhat erratic behavior of soil treated with the highest rate aside from possible sampling error. Soil tests showed that the higher rates were reflected in an increase in available calcium and a decrease in available aluminum, as would be expected.

Turning now to cropped soils, tests made on the soils used in Experiment I (to be described) three months after sludge treatment, gave the data shown in Figure 1C, in which it is seen that the pH increases more or less directly with the increase in rate of application. In this case the sludge was not highly alkaline but had a pH of 7.2 to

* Presented at Sixteenth Annual Meeting of New England Sewage Works Assn., Springfield, Mass., Sept. 12, 1945.

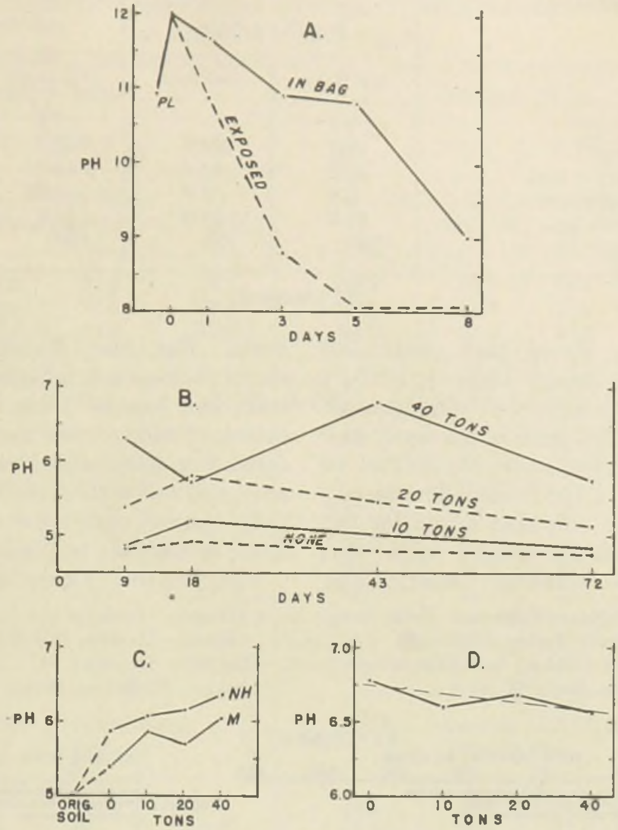

FIGURE 1.—Effect of Sludge on pH.

A. pH of fresh New Haven sludge (PL—plant lab.; all other tests at Expt. Sta. lab.).
B. pH of soil after adding alkaline sludge. No crop.
C. pH of cropped soil after three months (NH—New Haven sludge; M—Middletown sludge).
D. pH of limed soil six months after applying lime and sludge.

7.5. The frequent use of such sludge would seem to be effective in correcting soil acidity.

When lime is applied to a soil, the use of sludge appears to have a buffering effect on soil reaction. The data illustrated in Figure 1D show the mean pH of all New Haven and Hartford sludge-treated soils in Experiment II six months after treatment. The highest pH occurred where no sludge was used, with a slight decrease accompanying the increase in rate of application. This is what one might expect from peat moss, manure or any other kind of organic matter and is not peculiar to sludge.

Effect of Sludge on Crop Yields

Two experiments were made on crop yields. In the first, sludge cake was used from the New Haven Boulevard (Sea Street) plant, and from the Middletown Connecticut River plant. In both cases the materials had been conditioned with hydrated lime and ferric chloride, and vacuum filtered. They possessed the following properties as received:

	New Haven Sludge		Middletown Sludge	
	Wet Basis*	Dry Basis	Wet Basis*	Dry Basis
pH	7.2		7.5	
Moisture, per cent	69.2	224.0	63.0	171.0
Loss-on-ignition, per cent	15.2	49.4	13.4	36.1
Total nitrogen, per cent	0.6	1.9	0.58	1.57
Weight per bushel, lbs.	83.3	44.9	84.8	37.7
Weight per cu. yd., lbs.	1,820	980	1,850	822

* Dewatered.

Two-gallon, glazed pots containing Cheshire fine sandy loam (pH 5.0) were treated with 3–8–7 fertilizer at the rate of 1,200 pounds per acre, and sludge as follows: none, 10, 20 and 40 tons per acre of the moist (dewatered) material. The cropping order for the New Haven sludge-treated soils was: beans,* beans, cabbage, celery, and beets. For the Middletown sludge series: tobacco, † tobacco, carrots, lettuce, and beans. Only the one application of sludge was made, but mixed fertilizers were added as crop appearance and soil tests dictated. The cropping period extended from March, 1943, to October or November, 1944.

The relative yields are plotted in

* Beans—Stringless Valentine bush snap.
Cabbage—Early Jersey Wakefield.
Celery—Paris Golden, Self Blanching.
Beets—Crosby Early Wonder.

† Tobacco—Turkish.
Carrots—Danvers Red Cored.
Lettuce—Imperial 847.
Beans—Stringless Green Pod.

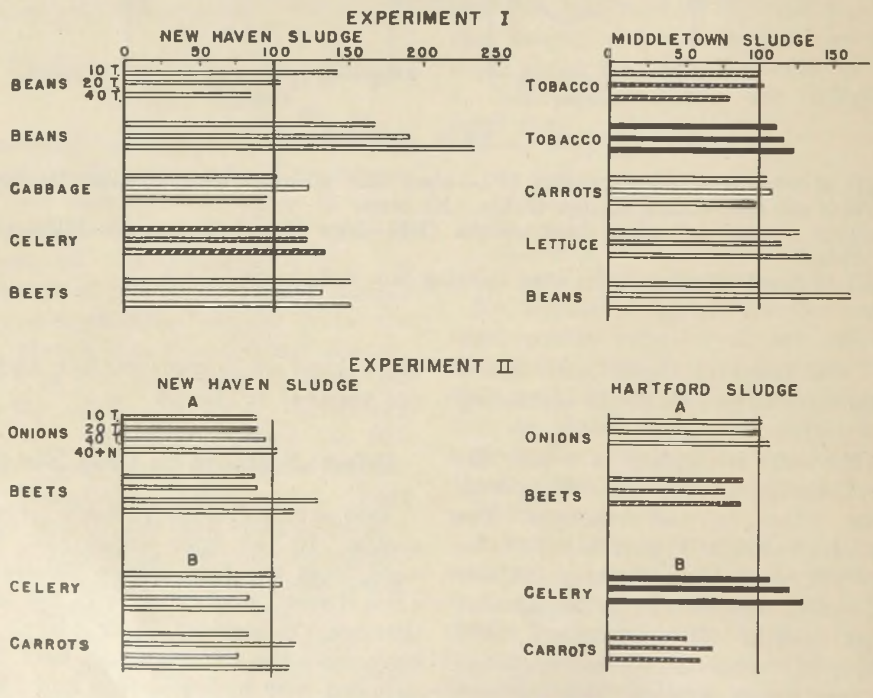

FIGURE 2.—Effect of increased amounts of sludge (10, 20 and 40 tons per acre) on relative yields of various crops. The 100 line represents yields on the no-sludge pots.

TABLE 1.—Sewage Sludge Experiment I, Yields 1943–44
(All weights in grams per plant)

New Haven Sludge				Middletown Sludge			
Ck	10 T.	20 T.	40 T.	Ck	10 T.	20 T.	40 T.
Mar.–May, 1943 Beans (Sum of green wt. of pods and dry wt. of stalks)				Mar.–May, 1943 Tobacco (Dry wt., tops)			
25.5	29.0	37.2	18.0	33.3	36.8	36.8	31.5
28.0	59.5	21.2	25.5	34.3	33.0	34.0	23.7
25.2	23.7	23.9	22.5	35.5	33.1	35.8	27.0
Ave. 26.2	37.4	27.4	22.0	Ave. 34.4	34.3	35.5	27.4
Rel. 100	143	105	84 NS*	Rel. 100	100	103	80 S*
May–Aug., 1943 Beans (Green wt. of beans only)				May–July, 1943 Tobacco (Dry wt. of tops)			
6.8	5.7	11.9	10.4	20.2	20.3	23.3	26.4
3.0	3.3	5.9	10.4	20.4	24.2	22.0	26.4
2.5	11.7	5.5	7.9	20.5	22.3	25.5	25.9
Ave. 4.1	6.9	7.8	9.6	Ave. 20.3	22.3	23.6	26.3
Rel. 100	168	190	234 NS	Rel. 100	110	116	124 HS
Oct., 1943–Mar., 1944 Cabbage (Fresh wt. of heads only)				Oct., 1943–Feb., 1944 Carrots (Fresh wt.)			
187	201	144	179	16.3	12.8	20.3	16.3
159	203	261	188	13.7	22.3	15.9	17.0
199	147	269	151	28.2	25.7	26.5	23.5
Ave. 182	184	225	173	Ave. 19.4	20.3	20.9	18.9
Rel. 100	101	124	95 NS	Rel. 100	105	108	98 NS
Mar.–May, 1944 Celery (Fresh wt.)				Mar.–May, 1944 Lettuce (Dry wt.)			
41.5	57.0	54.5	59.5	14.67	21.60	16.85	19.77
52.0	59.0	72.5	75.0	16.71	15.88	13.38	20.52
45.5	62.0	58.0	73.0	10.59	14.75	16.84	15.65
Ave. 46.3	59.3	61.7	69.2	Ave. 13.92	17.74	15.69	18.65
Rel. 100	128	133	149 S	Rel. 100	127	113	134 NS
July–Nov., 1944 Beets (Fresh wt.)				July–Oct., 1944 Beans (Fresh wt. of pods only)			
8.5	18.4	9.2	14.8	9.00	4.00	10.70	5.00
10.6	15.4	8.6	10.8	3.25	4.50	4.75	1.50
10.8	11.2	21.6	19.6	3.25	7.00	9.75	7.25
Ave. 10.0	15.0	13.1	15.1	Ave. 5.17	5.17	8.40	4.58
Rel. 100	150	132	151 NS	Rel. 100	100	162	89 NS

* NS = Differences between treatments *not significant*
S = Differences *significant*
HS = Differences *highly significant*

Figure 2, the no-sludge pots being repsented by 100 in every case. It is believed that the two sludges were sufficiently alike to preclude any difference in crop response. Yields of the first crop, which was planted immediately after applying the sludge, tended to decrease with increase in sludge application, but in the case of the beans the differences are not significant. The second crop showed marked *increases* with treatment although the bean results again were not significant. Increases were shown for celery, beets and beans but only those of celery were significant.

The data (Table 1) on the first two crops (both beans and tobacco) would indicate that insufficient nitrogen was present at the start to satisfy the requirements of the cellulose-decomposing organisms, and the crop suffered as the result. By the time the second crop was growing, the C–N ratio of the soil humus had been sufficiently narrowed and nitrogen previously tied up was being released.

Experiment II consisted of a comparison of New Haven and Hartford digested sludge cakes, the latter not conditioned with lime and iron. Their properties were as follows:

	New Haven	Hartford
pH	7.72	5.61
Moisture (as received), per cent	61.70	62.70
Loss-on-ignition, per cent (dry basis)	52.20	46.75
Total nitrogen, per cent (dry basis)	2.00	2.01
Phosphoric acid (P_2O_5), per cent (dry basis)	1.18	1.70

The soil before treatment had a pH of 5.38, and tested moderately high in nitrates and low in phosphorus and potash. Lime was added at the rate of 1,250 pounds of dolomitic limestone and 1,750 of precipitated chalk per acre; fertilizer consisted of 1,200 pounds of 5–10–10, and in certain cases calurea at the rate of 50 pounds of nitrogen per acre. Sludge treatments were the same as before—none, 10, 20 and 40 tons. The cropping order for both sludges was: onions* followed by beets in one case; celery followed by carrots in the other. The cropping period extended from January to November, 1944. There was but one sludge application, but subsequent fertilizer treatment consisted of the equivalent of 1,000 pounds of 5–5–10 on February 25 to all pots, and 200 pounds of muriate of potash on September 16 to beets only.

The yield data (Table 2) shown graphically in the second part of Figure 2, do not appear to be very promising for sludge. For the most part New Haven sludge yields were lower than those without sludge. Extra nitrogen applied to high sludge pots (New Haven sludge only) seemed to be somewhat beneficial but in no cases are the differences significant.

Where the Hartford sludge was used, onions showed no response, beets and carrots were significantly poorer, but celery yields were increased 7, 19 and 29 per cent respectively for the 10, 20, and 40 ton treatments, the differences being highly significant.

These results are difficult to fathom. Soil tests showed relatively little difference in the pH of the soil treated with the two sludges, even though the Hartford product was considerably more acid. The tests indicated also a generally low level of available potash which might have been a limiting factor in spite of additional applications of potash fertilizers. Some of the celery plants suffered from boron deficiency which was eventually corrected in most cases by the use of boric acid. There appeared to be no correlation between either source of sludge or amount applied and the degree of injury.

* Onions—Danvers Yellow Globe.
Beets—Crosby Early Wonder.
Celery—Paris Golden, Self Blanching.
Carrots—Chantenay Red Cored.

TABLE 2.—Sewage Sludge Experiment II, Yields 1944

New Haven Sludge					Hartford Sludge			
None	10 T.	20 T.	40 T.	40+N	None	10 T.	20 T.	40 T.
(A) Onions and Beets								
Jan.–June				Onions	Fresh wt. per plant (gr.)			
70.5	69.8	54.5	67.2	81.7	82.5	76.3	67.8	84.8
76.2	59.3	62.5	81.2	60.2	81.2	78.8	83.5	83.8
65.5	60.3	68.3	53.0	71.7	73.8	86.7	87.8	81.3
Ave. 70.7	63.1	61.8	67.1	71.2	Ave. 79.2	80.6	79.7	83.3
Rel. 100	89	87	95	101 NS†	Rel. 100	102	101	105 NS†
July–Nov.				Beets	Fresh wt. per plant (gr.)			
21.8	16.4	20.8	26.8	28.6	25.4	29.4	17.2	27.0
13.7	4.0*	14.0	23.4	23.2	32.8	21.0	28.6	28.8
18.7	15.2	13.0	19.6	9.4	32.0	28.6	23.4	23.0
Ave. 18.1	15.8	15.9	23.3	20.4	Ave. 30.1	26.3	23.1	26.3
Rel. 100	87	88	129	113 NS	Rel. 100	87	77	87 S
(B) Celery and Carrots								
Jan.–June				Celery	Dry wt. per plant (gr.)			
27.0	35.8	34.4	34.3	29.8	28.3	31.1	28.5	39.3
30.3	24.2	21.1*	16.6	27.5	28.4	29.8	34.1	41.9
27.7	26.4	25.5	21.7	23.3	19.7*	15.9*	38.7	28.9
Ave. 28.3	28.8	29.9	24.2	26.9	Ave. 28.4	30.4	33.8	36.7
Rel. 100	102	106	85	95 NS	Rel. 100	107	119	129 HS
July–Nov.				Carrots	Fresh wt. per plant (gr.)			
8.3	10.4	7.2	6.0	10.2	18.0	10.8	16.0	10.7
6.2	3.3	10.8	10.0	8.8	20.0	8.8	12.8	16.3
12.0	8.6	12.8	5.0	10.5	22.0	10.7	12.8	9.2
Ave. 8.8	7.4	10.3	7.0	9.8	Ave. 20.0	10.1	13.9	12.1
Rel. 100	84	116	79	111 NS	Rel. 100	50	69	60 S

* Omitted from average. † See table 1, footnotes

Note.—In calculating analysis of variance and in plotting relative yields of celery grown with Hartford sludge, the fresh weights were used rather than dry weights.

Outdoor Experiments in a Home Garden

Determined to try out sludge in the field, digested cake from the New Haven plant was applied to four 10 by 20 ft. plots in the writer's own garden, using 6 bushels per plot (1,307 bu. or about 56 cu. yds. per acre). To two of the plots extra nitrogen was added at the rate of 50 lbs. of N per acre. Potatoes, sweet potatoes and corn were planted but no results were obtained on the corn. The first season (1944) was very unfavorable and growth was rather poor. Inspection of the field during the growing season revealed that the sludge-treated potato vines remained green longer than did the others. This difference was quite pronounced and persisted for considerable time.

In 1945 potatoes were planted on all plots. More nitrogen was used but no sludge. It should be remarked that in all cases the usual fertilizer treatment was made (approximately 1,500 to 1,800 pounds of 5–10–10 per acre). No differences in growth could be observed, largely because of the abundance of rainfall. The results of the two years work are as follows:

ther states that the beneficial physical effects from sludge are of a different nature than those produced by farmyard manure. There have been reports that sludge is unsuited for carrots, potatoes, and turnips.

On the other hand, Rost and Pinckney (5) found sludge equal to or slightly better than manure when applied to nine different soils (mostly sandy) seeded to oats. The addition of phosphate and potash fertilizers gave further increases in yields. And in Baltimore experiments (6) sludge increased yields of potatoes, spinach, beans, tomatoes, sweet corn and cabbage.

Average Grams of Tubers per Hill

Cobblers	None	Sludge	Sludge + N	No Fert. or Sludge	Double Fert., No Sludge
1944 Cobblers	231 (100)	227 (98)	259 (112)	—	—
1944 Green Mountain	215 (100)	208 (97)	265 (123)	160 (74)	288 (134)
1944 Sweet potatoes	587	436		—	—
1945 Sebago	357 (100)	354 (99)	333 (93)	—	—

Discussion

The results obtained in these experiments do not appear any too favorable for sludge. We must not overlook the fact, however, that significant gains were obtained in some cases. It appears now that it would have been better to have made repeated plantings of the same crop in order to avoid confounding crop differences with residual effect of the sludge.

Both Barnes (1) and Fraps (2) compared sludge with no fertilizer, and obtained increases, but the yields with sludge were somewhat less than yields with other organic materials such as dried blood and cottonseed meal, and considerably lower than where commercial mixed fertilizers were used. DeTurk (3) stated that nitrogen in sludge is less available than in manure; and the British Agricultural Research Council (4) found that crop yields were, in general, less with sludge than with manure. The Council fur-

Thus it is seen that crop response to sludge is by no means consistent. Considering the differences in crop requirements, in soils, in weather conditions, in types of sludge and in the way it is used, this inconsistency is not surprising.

On our relatively poor New England soils one can hardly expect to depend upon sludge as the sole source of nitrogen and phosphorus. The writer prefers to think of sludge principally as a soil conditioner, improving its physical condition and increasing its water and nutrient-holding capacity. It is very important to apply sufficient fertilizer, especially potash, if satisfactory yields are to be expected. Perhaps repeated applications of sludge, supplemented with potash, would eventually be sufficient but our short time experiments give no information on that angle of the problem.

The unfavorable effect on beets and carrots in Experiment II may be due to their being only the second crop after sludge treatment, for in Experiment I, where they were fifth and third crops, respectively, there was no reduction in yield.

In Experiment II the New Haven Series of pots showed lower yields, especially of beets and carrots than the Hartford Series, even in the case of the pots which receive no sludge. Comparisons of soil tests do not reveal any consistent differences either in pH, available nutrients or total soluble salts.

Conclusions

On the basis of the results reported in this paper it would appear that immediate increases in crop yields from the use of sludge can hardly be expected under all conditions and with all crops. Undoubtedly, occasional or frequent use of such material is beneficial to the soil in the long run, and the sandier the texture and the lower the fertility, the more likely this would be true. Inasmuch as sludge is not a balanced plant food, it is imperative that adequate supplies of potash be provided, particularly for those crops with high potash requirements.

From the standpoint of yield of the first crop as well as the matter of possible health hazard, sludge should be applied at least several months prior to planting. Supplementary applications of nitrogen can be made to advantage at planting time.

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EXPERIENCE IN GRIT REMOVAL AND HANDLING AT RACINE, WIS.

By Thomas T. Hay

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The dearth of information on the operation and effectiveness of grit chambers was noted in reviewing the seven years of operation of these units at Racine, Wisconsin, with the thought of comparing such operation with other plants. In view of this it is felt that a statement of the experience at Racine would be of interest to other operators, and an invitation for comparison and discussion.

John W. Johnson reports that at Buffalo there has been excessive trouble due to grit, following the grit chambers as well as before, but that it was not considered feasible to increase the detention for more complete grit removal. C. E. Keefer tabulates the results from several plants in his book "Sewage Treatment Works," which data show a great deal of variance. If this is an indication of operation in general over the country, a study of grit removal is very much needed so that desired results may be obtained from this step in sewage treatment.

Theoretical Considerations

To obtain satisfactory results from grit removal units there are three fundamental requirements which are of paramount importance: hydraulic design, equipment design and proper operation. There are many authorities on hydraulic design, and all agree fundamentally on the application of Stokes' law and the Hazen formula for settling particles, and that a removal of a minimum size of grit of 0.2 mm. diameter is a practical aim. Thus, the length of the chamber is a result of the velocity and the depth. This is shown in Figure 1. A particle of 0.2 mm. diameter entering the chamber at the highest point will settle out under the maximum velocity (Path A) when $L = (V/v)H$

when V = mean velocity of flow,
v = settling velocity (0.075 ft. per sec. for 0.2 mm. diameter sand),
H = effective depth.

Most designs are based on a velocity of 1 ft. per sec. as the optimum flow velocity, with a recommended range of 0.5 to 1.0 ft. per sec. Velocity is determined by the ratio of the volume of flow to the cross sectional area. The velocity is maintained for variations in flow by cutting in or out of service several parallel units, or by use of approximately parabolic cross sections with their controlling devices, and/or proportioning weirs. To these fundamentals Thomas T. Camp has added the importance of scour (This Journal, Vol. 14, No. 2, p. 368). Many particles

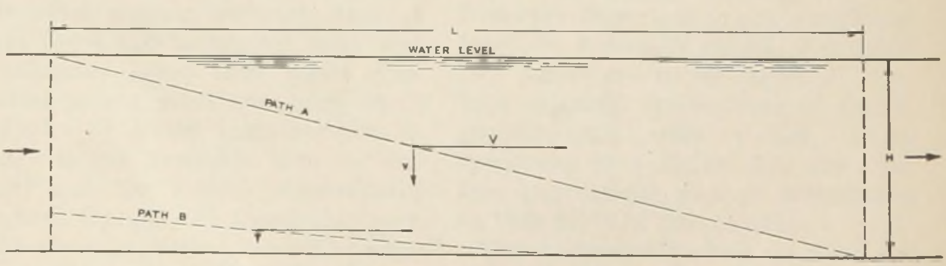

FIGURE 1.—Theoretical length of grit chamber,

of organic matter having a lower settling velocity than the 0.2 mm. diameter sand particle actually enter the chamber at a lower point and settle with the grit (Path B, Figure 1). Scour or movement along the bottom will tend to free this lighter particle and allow it to be washed from the grit. To move a particle of 0.2 mm. diameter, the minimum velocity must be 0.75 ft. per sec. This will be discussed again in regard to performance of the grit chambers at Racine.

In the matter of equipment for grit removal there is a wide divergence of practice. This ranges from hopper bottoms which require draining and manual cleaning, through hoppers cleaned by clam buckets when filled, to the ultimate of continuous collection, removal and recirculation, followed by washing with clean water and drainage. To facilitate good results this equipment should be so designed that no change in cross sectional area occurs by variation in loading. The grit can be recirculated by being re-introduced to the flow at the top of the channel at or near the entrance end, and the collected grit can be washed with clean water as a separate operation from the collection. Each of these points are important to good operation. In addition, the equipment should be designed so that it is simple and easy to operate, for at times of sudden changes in volume of flow the grit chamber is only one of several units requiring additional attention of the operator without any delay. If the operational changes cannot be made with ease and speed, the quality of the work done will be materially affected.

Correct hydraulic design and proper equipment is all a designing engineer or manufacturer can provide to obtain good quality of grit separation. It then becomes the responsibility of the operator to see that the equipment is handled in a skillful manner and is properly maintained. By observation of the working of the equipment and the product produced, together with the laboratory analyses of samples collected, he can in a short time become proficient in this work. The best design and the finest equipment will not produce good work in the hands of a careless or ignorant workman. It is, therefore, of utmost importance that these tools be placed in the hands of a skilled craftsman to produce the results desired by all operators, namely, the removal of grit from the sewage and the separation of putrescible matter from the grit.

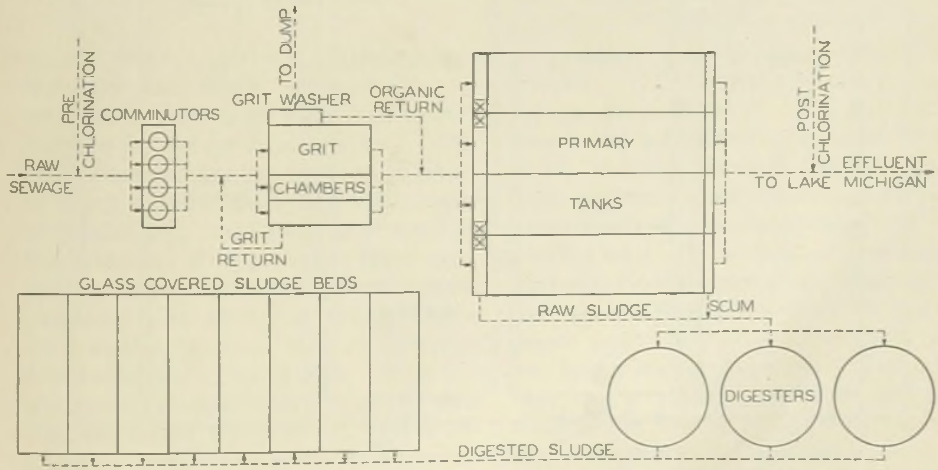

FIGURE 2.—Layout of sewage treatment plant, Racine, Wis.

Description of Racine Facilities

As following results are gathered from the operation of the treatment plant at Racine, Wisconsin, a brief description of the plant will indicate the other units which would be affected. This plant was put in service on June 14, 1938. Upon entering the plant the sewage is chlorinated, passed through comminutors, then through the grit chambers and clarifiers. The settled sewage is chlorinated and discharged to Lake Michigan at a depth of 14 ft. below the water surface. The washed grit is disposed of by dumping. The sludge and scum are separated from the sewage in the clarifiers. These solids are pumped to separate digesters, digested, dried on glass covered beds and ground. This is shown diagrammatically in Figure 2.

The plant serves a connected population of 68,000 in a highly industrialized community. The average daily flow is 11 m.g.d. varying from 8 m.g.d. at night to 16 m.g.d. during the day under normal conditions. The designed capacity of the plant is 48

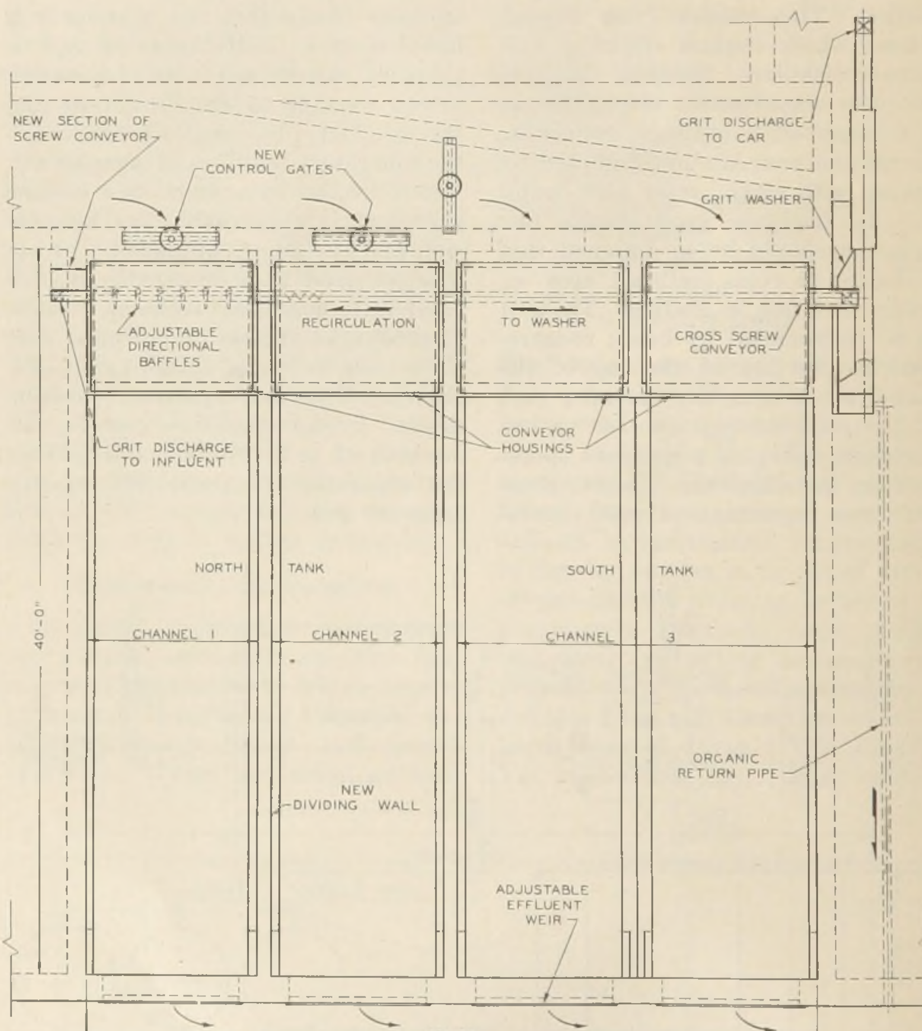

FIGURE 3.—Plan of grit chambers, Racine, Wis.

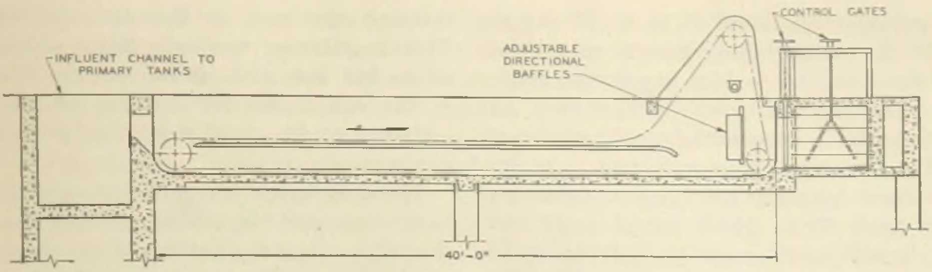

FIGURE 4.—Longitudinal section of grit chambers, Racine Wis.

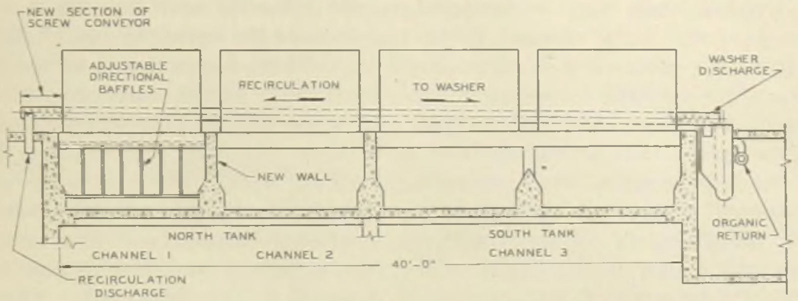

FIGURE 5.—Cross section of grit chambers, Racine, Wis.

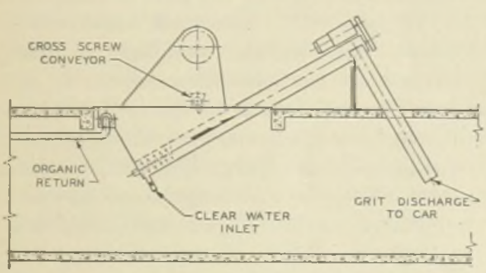

FIGURE 6.—Grit washing arrangement, Racine, Wis.

m.g.d. Only 9 per cent of the area of the city has storm sewers; the remainder is served by combined sewers varying in age up to 68 years. These conditions subject the treatment plant to sharp fluctuations and a wide range of conditions. As Racine is located in the terminal morain area, these sewers are laid in all types of soil which, combined with the many varied industrial wastes, produce a very complex solids content in the sewage. This has given us the opportunity to study grit removal under many of its varied aspects.

The grit collecting equipment shown in Figures 3, 4, 5 and 6 is that used in this study. The structures were designed by Alvord, Burdick and Howson, consulting engineers, and are equipped with Chain Belt Company's Rex Grit Removers. The figures also include the alterations and additions made for the purpose of improving performance as dictated by operating experience. The original designers were hampered to some degree by the necessity of designing alternate types of equipment to produce competitive bidding. The original channels were two in number, 20 ft. wide and 40 ft. long, with an effective depth of 33 in. Each of these channels had two 5-ft. wide entrance ports on the 20 ft. end and two 7½-ft. discharge weirs on the effluent end. According to the design principles previously given these channels should function best at 32 m.g.d., which would give a velocity of 1 ft. per sec. and a 40-sec. detention period. To maintain a velocity of 0.5 ft. per sec. a minimum flow of 15 m.g.d. is needed, and to consider the condition of scour advanced by Camp, this channel should operate with flows of 24 to 32 m.g.d. As the average daily flow to this plant runs from 9.5 to 11.5 m.g.d. the original results were not satisfactory. As might have been anticipated, an excessive amount of organic matter was deposited with the grit, and the periods of peak flows which would wash the grit sufficiently were too infrequent to produce a satisfactory material. To improve this condition a temporary wood division wall was constructed lengthwise of the north channel, dividing it into two channels 9 ft. 4 in. by 40 ft., together with the necessary gates to control the flow. This proved of such great value that it was later replaced by a permanent dividing wall of reinforced concrete. This made a further reduction in cross sectional area so that a flow of 16 m.g.d. will now create a velocity of 1 ft. per sec. in one of these channels. The other original channel was not divided and is operated as a double channel, or as the two smaller channels would be used together. Another improvement made to these channels was the installation of directional baffles at the entrance to the north channel to reduce eddying caused by both the shape of the distributing channel ahead of the grit channels and the need for changing the direction of flow suddenly through 90 degrees, and also to distribute the grit load more evenly when more than one channel was in service. Although this was not a function of the equipment, we were given the services of the engineers of the Chain Belt Company to assist us in overcoming the difficulty, as they were interested in the equipment performance. A minor addition which assists materially in the maintenance of these units was the installation of drains in each channel, which eliminates the necessity of pumping to remove the water and so facilitates inspection and repairs.

The housings over the grit collectors were vented. These vents were connected to a stack which discharges through the roof to the atmosphere. This ventilation not only keeps down odors but has also prolonged the life of the equipment by drawing off the moisture under the hoods, thus reducing corrosion.

The equipment for grit removal collects the grit in V-shaped buckets traveling along the bottom of the channel in a direction opposite to the flow at a speed of 5 ft. per min., lifts the solid material and deposits it in hoppers over the entrance end of the channel. These hoppers are served by one continuous screw conveyor which conveys the grit automatically to one side of these channels and deposits it in a washing unit. The grit is churned in clean water by an inclined screw which gradually raises the washed grit from the water, thoroughly drains it, and deposits it in a dump car. The car is moved out on a narrow gauge track to the lake bank where the grit is dumped for fill material. The wash water containing the organic washings is discharged to the clarifiers where it is properly handled as sludge. Two additions have been made to the original equipment; in November, 1939, the screw conveyor was lengthened on the north end so that by reversing the direction of rotation the solids removed from the chambers could be re-introduced into the sewage at the beginning of the distribution channel ahead of the grit chambers, and the washing was improved by placing a V-notched weir at the discharge end of the washer and introducing the clear water at the bottom of the washing reservoir, causing an upflow through this unit. This equipment enables the operator (1) to remove the solids as often as necessary so that no change takes place in the effective depth of the chamber, (2) to recirculate the grit in such a manner that the particles may follow the theoretical path used in the design of grit chambers, and (3) to wash this material after its removal from the sewage. By recirculating at opportune times, when flows are normal and velocities correspondingly correct, true grit resettles and undesirable organics are carried on through to the primary tanks where they are properly handled as sludge. Some plant operators have used water jets or other means to cause turbulence in the grit channels to remove the objectionable putrescible matter that settles out with the grit, but recirculation and washing with clean water is a sure method of removing the putrescible matter without allowing the grit to be washed out of the chambers, causing difficulties in the following treatment units.

Operation and Maintenance

The better the equipment and the greater the flexibility of control, the greater becomes the responsibility of the operator. Before the above alterations and additions were completed on the grit channels and removing mechanisms, the removal of grit was a more or less haphazard process. The only controlling factor was quantity, *i.e.*, grit was removed as it was deposited. After the control was improved, a normal schedule of operation was established but with the reservation that the operator on duty could vary this as he deemed necessary. The equipment is operated 30 min. during each 8-hr. shift for a total of 90 min. per day for recirculation. When the quality of the grit appears to have a putrescible content under 2 per cent and a quantity of ⅓ ton (dry solids) this material is collected, washed and disposed of by dumping. The operator decides when this condition is reached by observing the grit brought up during recirculation. The experienced operator can determine this to a high degree of accuracy if he is given the laboratory analyses of the samples from his previous operation. For accurate estimation these reports are necessary as the composition of the grit varies with the season. These reports assist the operator in adjusting his estimate. At the beginning of a storm, any amount of grit of a satisfactory character is removed before the storm flow reaches the plant in anticipation of the increased load. This clearing of the chambers allows more efficient handling of the excessive load always brought down with storm flows.

The regular cleaning of the equipment is charged as a part of operation, but it also has a bearing on maintenance cost, as this combats corrosion as well as odors. It is our practice to hose down the interior of the housings and the hoppers, and flush the screw conveyor with clean water after each time the equipment is operated. While doing this the operator automatically makes a visual inspection of the equipment and any unusual condition is noted and remedied before any major difficulty arises. Here, as elsewhere throughout the plant, the encouragement of the pride of the operator in the appearance of his equipment and cleanliness pays dividends. It is not only a source of satisfaction to plant personnel and visitors, but interest in the condition of the equipment goes hand in hand with the quality of the product.

The maintenance of this equipment has been at a minimum. Repairs were conspicuous by their complete absence until the latter part of 1944—the seventh year of operation. During that year it was necessary to make repairs to one electric motor, build up the horizontal worm and trough by welding, replace the bearings on the horizontal worm and replace one clear water jet. During 1942 there was a period when several shear pins were broken. This was chargeable to grease which appeared in the sewage while industry was converting to war production. The grease coated the grit, making a mucilaginous mass which built up on the equipment and occasionally produced an overload. As the plant is going into the eighth year of operation, it will be necessary to replace the wearing shoes on one-quarter of the flights. This portion of the equipment has been in continuous service, being shut down only to permit inspection and painting.

The major maintenance item is that ever present problem in all sewage treatment plants—painting. The chamber walls, housings, troughs and control gates are painted once a year with an additional "touching up" around the base of the housings where the corrosion is greatest. The housings are painted green outside and light gray inside, for light reflection and ease of cleaning; the surfaces which come in contact with the grit are painted with bituminous paint; the channels are painted aluminum down to the water line and with bituminous paint below. The water line is set for a flow of 16 m.g.d. and this warns the operator when the point of critical flow is being approached so that he may watch the flow meter and be ready to cut in additional units. A word of caution is warranted on the use of aluminum paint in channels containing sewage. If the aluminum paint is carried below the water line, the paint, in connection with the iron in the equipment, will set up a most active electrolytic cell, causing rapid deterioration of the equipment. We know—it happened to us.

The mechanical equipment is greased weekly through pressure fittings, the electric motors monthly. Every six months the shear pin hubs are inspected to see that they are free and will function properly in case of an overload, and a complete inspection is made of the mechanism. The protective equipment has never failed to function perfectly.

Performance

The performance of these units is measured by the quality and quantity of grit removed and by the cost of operation and maintenance. Samples of grit are collected regularly at the discharge from the washer whenever grit is removed. These samples are analyzed for moisture, solids, volatile matter, putrescible matter and occasionally, weight per volume. The tests for moisture, solids and volatile matter are performed in accordance with the standard method for sludge analysis except that the size of the sample used is approximately 100 grams. Putrescible matter is determined by the Dazy Churn test, currently in use for measuring putrescibles but not entirely satisfactory. Although this is not accepted as a standard method nor does it appeal to the scientific researcher, it has proven its worth at Racine as an operational control.

The quantity of grit removed at Racine in seven years has been 1,354,140 lb. of dry solids from a flow of 27,250,650,000 gal. This represents an average rate of 49.7 lb. per m.g. or 530 lb. per day (dry solids). The amount of solids removed as grit was 5.1 per cent of the total suspended solids. The average daily flow, the total tons of grit removed, and the pounds of grit per million gallons are shown in Figure 7 for each month of the 7-yr. period. The heaviest loading of grit is received in the spring months when the first thaws and rains bring down the winter accumulations. As might be expected, the grit load is more nearly proportional to the intensity of the storm than to the duration or total precipitation. It is for this reason that the amount of grit removed is not always in proportion to the flow.

Recirculation of the grit was started in November, 1939. The putrescibility test was checked at this time and several months later was added to the regular procedure as a check on operation. As can be seen in Figure 8, the use of recirculation brought about a reduction in solids removed as grit, which was due primarily to the improved quality.

The quality of the grit is the important item to the operator for it is on

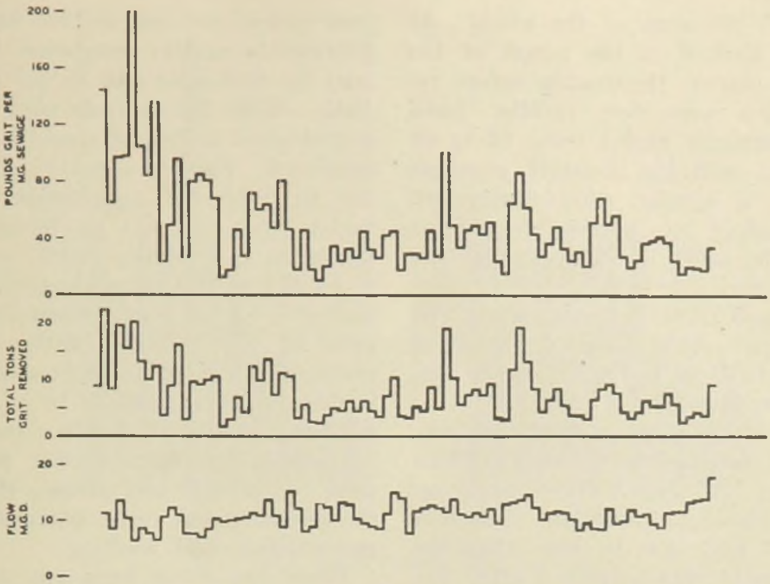

FIGURE 7.—Grit removal at Racine, Wis.

this that schedules and variations from schedule are based. There are many authorities on grit chamber design but none seem to care to talk of results. To the operator, results speak loudest. To discuss the results at Racine it is necessary to make a division before and after recirculation was introduced in November, 1939. The great difference is shown in the graph of the quality of the grit (Figure 8) which shows the percentages of putrescible matter and volatile matter.

Before recirculation the weight per cubic foot of grit was 63.9 lb. wet and 27.4 lb. dry. This is 58.5 per cent moisture and 41.5 per cent solids. The volatile matter was 65.9 per cent. Relatively few samples were examined for putrescible matter but these aver-

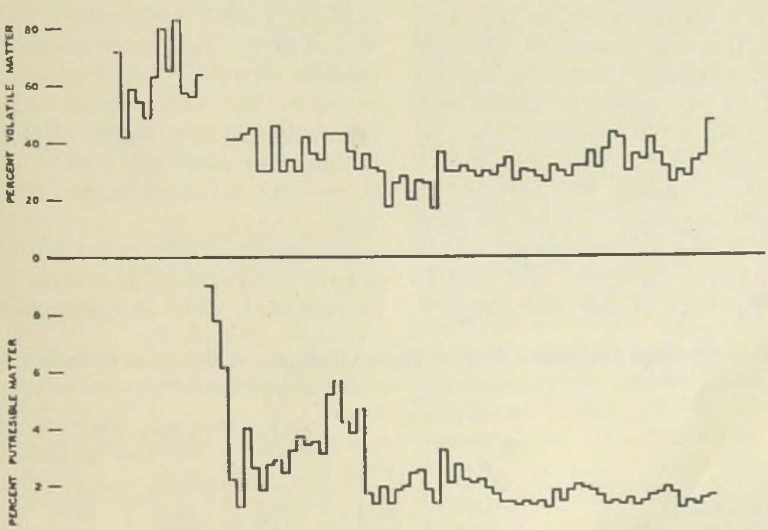

FIGURE 8.—Volatile and putrescible matter content of grit at Racine, Wis.

aged 8.5 per cent of the solids. As can be noticed in the graph of the volatile matter, the results before recirculation were very erratic. Individual samples varied from 32 to 94 per cent with the monthly averages showing a similar wide divergence. The content of putrescible matter shows the same trend even over the short period this test was used, varying from 5.92 to 14.4 per cent. The weight per cubic foot (dry) varied from 16 to 34 lb. and the moisture content from 49 to 67 per cent.

The results after recirculation was installed demonstrate the value of this principle. A very marked improvement is illustrated by Figure 8 at this time. It may also be seen that the improvement was increased after another 18 months had elapsed. During this period we were learning the possibilities of the equipment in its more flexible form and were coming to place more dependence on the putrescibility test. This test, being more sensitive than the volatile matter test, enabled us to make a more rapid compensation to meet changing conditions and thus to produce a more constant quality in the grit. The comparison shown in Table 1 for three periods of different operation bears this out. Although the wet weight of the grit remained constant, there was an increase in the dry weight of 12 per cent the first year after recirculation and 35 per cent in 1945. That this change was due to a change in the type of solids is further borne out by the fact that though the percentage of solids remained fairly constant, the volatile matter decreased 43 per cent the first year and 47 per cent in 1945 while the putrescible matter decreased 67 per cent the first year and 85 per cent in 1945. With the controls used almost any desired degree of quality can be produced. For our operative limit we try to hold the putrescible matter under 2 per cent as a maximum. The minimum for volatile matter appears to be 25 per cent when the putrescible matter is 1.5 per cent. Since 1942 the ratio of the volatile matter to the putrescible matter has increased. This is due in large measure to inorganic greases and oils which are a result of industrial conversion to war production. These oils and greases cling to the particles and resist separation by recirculation and washing.

There has never been any trouble due to grit in any of the treatment units following the grit chambers. We operate two sludge pumps for 15 to 20 min. each hour and in seven years have replaced only one piston. If any amount of grit escapes the chambers, these pumps should show a very rapid wear.

A series of samples taken in 1939 and 1940 are represented in Figure 9. These samples were collected in co-operation with the Chain Belt Company as a study of the principle of recirculation of grit. They were selected under various operating conditions intended to cover the more usual variations. Recirculation was started after the 5th sample was collected. Here again is shown the value of controlled operation.

The work of the grit washer which is part of the complete system was also investigated. The grit equipment was

TABLE 1.—Average Analyses of Grit for Three Conditions of Operation at Racine, Wis.

	Weight (lb. per cu. ft.)		Per Cent Moisture	Per Cent Solids	Per Cent Volatile Matter	Per Cent Putrescible Matter
	Wet	Dry				
Before Recirculation	63.9	27.4	58.5	41.5	65.9	8.5
First year after Recirculation	64.7	30.7	54.2	45.8	37.5	2.8
First five months of 1945	62.8	37.0	59.3	40.7	35.0	1.3

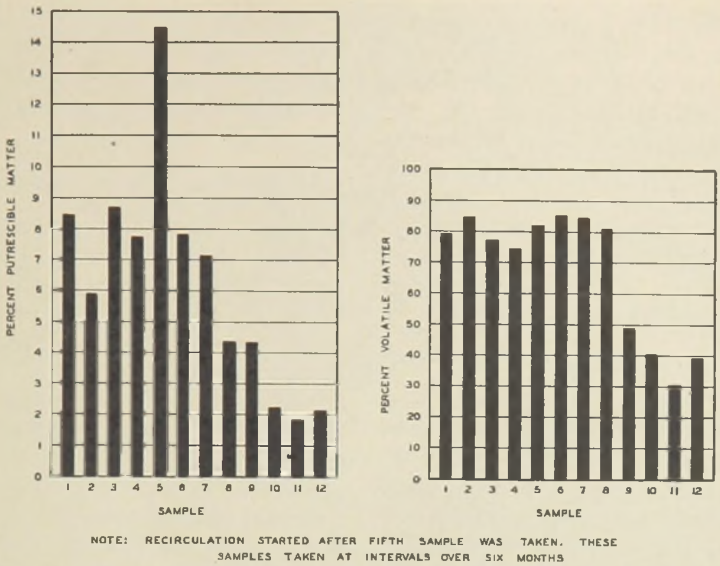

FIGURE 9.—Comparison of grit analyses made in 1939 to study effects of recirculation.

operated in various ways and samples of grit taken before and after washing. All of these runs were made after the fresh water inlet was relocated so as to cause an upflow of the wash water through the grit. This investigation does not cover the seven years of operation but were made during two spring months when there was variation of flow which made available the varied conditions. These results are shown in Table 2. Washing with clear water has reduced the amount of putrescible matter from 65 per cent to 75 per cent. This clearly demonstrates the value of the unit. Also noted during these runs was the necessity of utilizing flow to the greatest advantage. During these runs the recirculation alone reduced the volatile matter 39 per cent and the putrescible matter 79 per cent. When recirculation and washing are combined the volatile matter was reduced 51 per cent and the putrescible matter 93 per cent. This shows that recirculation and washing reduces both volatile matter and putrescible matter. Final washing produces a grit which contains little putrescible matter.

TABLE 2.—Effect of Washing Grit with Clear Water

	Per Cent Moisture	Per Cent Solids	Per Cent Volatile	Per Cent Putrescible
Not recirculated—not washed	86.4	13.6	57	18.4
Not recirculated—washed	68.6	31.4	40	4.7
Recirculated at low flow—not washed	80.0	20.0	79	8.7
Recirculated at low flow—washed	65.2	34.8	65	3.1
Well recirculated—not washed	61.0	39.0	36	4.1
Well recirculated—washed	46.6	53.4	23	1.4

Grit with less than 2 per cent putrescible matter is relatively free of objectionable characteristics. The location of the Racine treatment plant warrants the effort expended to produce this quality, since the grit is used for fill material on the plant grounds. The grounds are immediately east of Franklin D. Roosevelt Park which is used extensively. This park attracts many people as it has several baseball diamonds, one of which is lighted for night games, tennis courts, a band stand, playground apparatus, picnic areas, etc. The shore protection around the plant site is a popular fishing spot. In addition to these factors which bring many persons to the grounds, it is only a short distance to a good residential area. For these reasons any obnoxious odors or other undesirable conditions would bring immediate complaint. The grit removal must, therefore, be done efficiently as well as other phases of treatment.

Costs

The first year any repairs were necessary was 1944. Wage increases were also given to the employees at the beginning of that year. A breakdown of the cost of operation and maintenance of the grit chambers for this year may be of interest to other operators. The total cost for the year was $1,868.93 or 50½¢ per m.g. This cost would be greater except for the constant and careful inspection and prompt and excellent care given the equipment by the plant mechanic. Too much credit can not be given to the attention and service of the mechanic in charge. The cost for 1944 is distributed as follows:

Any time spent on special investigations is charged as a part of the operating cost as the results are reflected in reduced cost or improved quality of operation.

Summary and Conclusion

Racine experience reveals five items of prime importance for proper grit removal: (1) Hydraulic design must be sound. The accepted principles of design function in practice as in theory. Minimum flow should be given as much weight as maximum flow, however, and attention should be given to scour along the bottom. (2) The equipment should be designed so as to maintain the hydraulic conditions and handle the solids in such a manner that they follow the theoretical laws used in design. (3) The equipment must be flexible so that the operator can meet changing conditions. (4) The grit collectors should be designed so that they are in proper balance with other units of treatment. (5) The units must be operated intelligently. This calls for study of the conditions under which they are operated and experience. Proper maintenance is

Operation: Time of operator running equipment, regular cleaning after operation, disposing of grit and regular cleaning of area devoted to grit collection, 1,095 hours @ $0.92 per hour			$1,007.40
Greasing and Inspection: Time of mechanic for greasing and weekly and semi-annual inspection, 26 hours @ $1.01 per hour			26.26
Cleaning: Cleaning channels (not grit removal) and equipment for inspection, repair or painting, 244 hours @ $0.89 per hour			217.16
Painting: Interior and exterior of housings, channel walls and oiling chain and track, 164 hours @ $0.92 per hour		$150.88	
Material		34.80	185.68
	Labor	**Material**	**Total**
Repairs:			
Motor rewound	—	$ 53.00	$ 53.00
Welding screw conveyor (16 hours @ $1.01)	$ 16.16	5.50	21.68
Welding trough (8 hours @ $1.01)	8.08	2.00	10.08
Replace clear water jet (8 hours @ $1.01)	8.08	—	8.08
Replace bearings (32 hours @ $1.01)	32.32	22.29	54.61
	$ 64.64	$ 82.79	$ 147.43
Control and Supervision:			
Laboratory	$125.00		
Supervision	160.00		285.00
Total Cost (1944)			$1,868.93

FIGURE 10.—View of grit chambers at Racine, Wis. Washer at right.

also an important part of operation. Tests must be made constantly and the analyses used in controlling the operation.

When these conditions are met the proper results can be obtained. The grit can be removed from the sewage and the putrescible matter separated from the grit. The quality of grit attained will depend on the five items mentioned in the preceding paragraph. Without recirculation of the grit, the volatile and putrescible content will be high and will fluctuate greatly. With recirculation and collection under the proper conditions of flow the quality can be materially bettered. Separate washing further improves the quality. When recirculation and separate washing are used in combination, the limit of putrescible matter can be held under 1.5 or 2.0 per cent and when this is done the volatile matter will hold in the neighborhood of 30 to 40 per cent.

Design and operation are both necessary to good work and when both are adequate, results are satisfying.

OPERATION EFFICIENCY AND FACTORS AFFECTING OPERATION AT THE ELIZABETH JOINT MEETING PLANT *

By Willem Rudolfs and Edward P. Decher

Chief, Dept. of Sanitation, N. J. Agricultural Experiment Station and Acting Chief Engineer, Elizabeth Joint Meeting Plant, Respectively

The Elizabeth Joint Meeting for the construction and maintenance of a trunk sewer and sewage treatment plant handles the wastes from eleven municipalities and part of the city of Elizabeth, serving a population of over 360,000. The trunk sewer has a length of 43 miles. The treatment plant (Figure 1) consists essentially of coarse screens to remove rags and large pieces of floating matter, automatically operated screens to remove garbage, comminutors, grit chambers with screw conveyors and pneumatic ejectors, settling tanks equipped with Mieder machines for scum and sludge removal, and tanks for storage and concentration of sludge. At intervals the concentrated sludge is pumped to a barge and transported to sea.

After 7½ years of continuous operation a mass of data has been collected pertaining to the operation and cost of treatment. The accumulation of operation records is primarily for the purposes of (*a*) indicating the degree of purification accomplished, (*b*) determining the effect of changing conditions, (*c*) serving as a basis for improvement and expansion, (*d*) measuring the efficiency and improvement in operation, and (*e*) determining total cost to the municipalities and the variation in cost with changes in operation.

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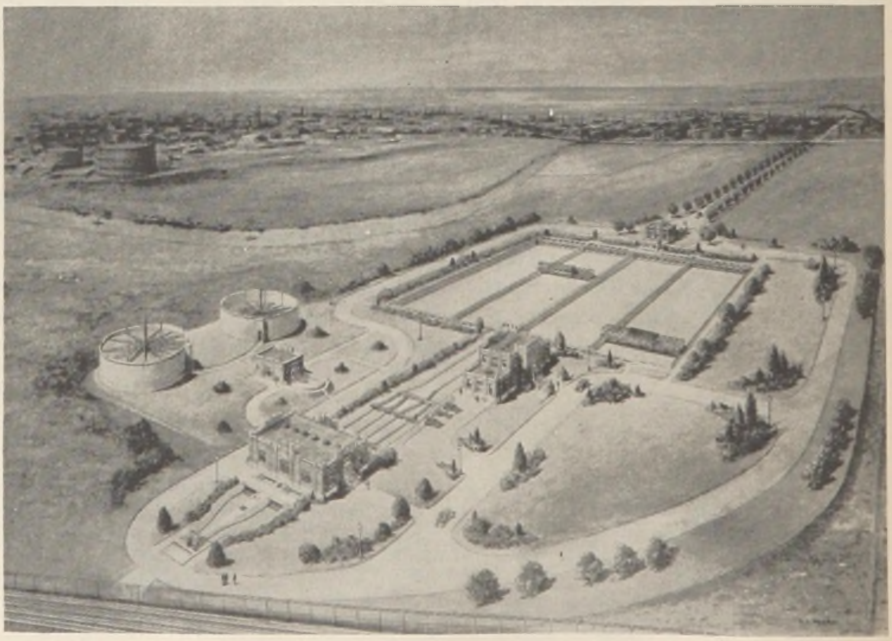

FIGURE 1.—General view, Joint Meeting sewage treatment plant.

Table I.—Average Annual Flow, Plant Efficiency and Sludge Production

Year	Flow (M.G.D.)	Suspended Solids		B.O.D.		Total Wet Sludge (Tons)
		Raw Sewage (P.P.M.)	Per Cent Removal	Raw Sewage (P.P.M.)	Per Cent Removal	
1938	26.28	184	66.8	202	39.2	118,943
1939	25.45	197	69.5	243	40.7	118,937
1940	28.04	188	69.7	238	41.2	112,456
1941	27.89	212	66.0	262	36.6	118,131
1942	37.10	194	67.0	240	40.4	145,375
1943	36.59	190	65.8	235	42.1	145,050
1944	37.12	200	66.5	245	40.4	149,332

The data collected have been analyzed in an effort to determine:

1. What changes, if any, have taken place in the degree of purification,
2. How purification and sludge production are affected by rainfall, sewage flow, and the strength of sewage received,
3. How various factors (rainfall, strength of sewage, temperature, decantation) affect sludge concentration and barging,
4. To what extent improvements in plant operation have taken place,
5. How changes have affected cost of operation.

Flow and Plant Efficiency

Data on average daily flow, strength of sewage as indicated by suspended solids and B.O.D., together with the average percentage removals for the years 1938–1944, inclusive, are shown in Table I. It will be noted that the average daily flow of sewage during the first four years was fairly constant but increased by nearly 10 m.g.d. or about 30 per cent when Elizabeth was connected in 1942. The total tonnage of wet sludge collected from the settling tanks was fairly constant during the first four years and also increased by nearly 30 per cent. The sewage is of medium strength and somewhat stale when reaching the plant as indicated by the average suspended solids and B.O.D. The average degree of purification as shown by the percentage removal of pollutional matter was high for plain settling, and removal was practically constant.

Rainfall, Sewage Flow and Strength of Sewage

It is a well known fact that the sewage flow increases during rainstorms, mainly because of the street wash entering the sewerage system in some of the municipalities and because of general infiltration. If the rainwaters entering the sewerage system were uniform over the entire area served, it would be expected that a direct relation existed between increase in sewage flow and total rainfall. When the total inches of rainfall for the entire year are compared with the total sewage flow received, it appears that no such direct relation exists (Table II).

TABLE II.—Comparison of Total Annual Rainfall and Sewage Flow

Year	Rainfall (Inches)	Sewage Flow (M.G.)	Increase or Decrease—Rainfall (Per Cent)	Increase or Decrease—Flow (Per Cent)
1938	40.19	9,590	—	—
1939	31.02	9,290	−23.0	−9.5
1940	41.68	10,230	4.5	7.3
1941	31.07	10,170	−23.0	7.2
1942	48.61	13,540	27.0	41.7
1943	38.81	13,335	−4.5	38.5
1944	53.57	13,550	25.0	42.2

This does not necessarily mean that there is no relation between rainfall and sewage flow, but rather that the

TABLE III.—Comparison Between Average Daily Rainfall, Sewage Flow and Strength of Sewage

Year	Rainfall (Inches)	Sewage Flow (M.G.D.)	B.O.D. (P.P.M.)	Suspended (P.P.M.)
1939	0.085	25.45	243	197
1941	0.085	27.89	262	212
1943	0.106	36.59	235	190
1938	0.111	26.28	202	184
1940	0.114	28.04	238	188
1942	0.133	37.10	235	194
1944	0.147	37.12	245	200

variation of rainfall and sewage flow over an entire year does not correspond when all results are averaged.

In the area served, comprising 12 municipalities, it may be assumed that the average daily per capita production of sludge is fairly constant. The total quantities of wet sludge collected (Table I) indicate that this is the case. It would be expected, therefore, that the strength of the sewage as indicated by the p.p.m. suspended solids and B.O.D. would vary with the variations in rainfall. Comparison of the average daily rainfall with the flow and strength of the sewage (Table III) shows that neither the variation in flow nor the strength of sewage is related to the rainfall. As much as 58 per cent increase in the average daily rainfall failed to change the average strength of the sewage. This means that other factors, such as flushing of sewers during storms and debris entering the sewers from street wash, interfere with this type of average comparison.

An effort was then made to determine whether any relation existed between rainfall and strength of sewage, if the average monthly results were grouped at increments of about one inch of rainfall (Table IV). The results show no apparent relationship between rainfall and sewage flow or strength of sewage. Other factors appear to overbalance the variations caused by rainfall. This is shown by the average results obtained in the colder months (January to February) compared with the average results obtained during the warmer months (July to August) for the seven years:

TABLE IV.—Variation of Rainfall and Strength of Sewage

Number of Months	Rainfall (Inches)	Flow (M.G.D.)	Suspended Solids		B.O.D.	
			Influent (P.P.M.)	Effluent (P.P.M.)	Influent (P.P.M.)	Effluent (P.P.M.)
4	0.595	20.96	220	62	280	166
16	1.550	27.97	202	66	252	151
26	2.457	30.80	195	65	238	143
18	3.556	30.53	195	61	238	167
7	4.511	32.26	188	62	223	137
4	5.628	41.99	156	62	181	119
4	6.570	38.91	185	62	219	131
2	7.890	37.23	177	52	203	114
3	8.930	35.29	192	61	223	128

	Rainfall (Inches)	Flow (M.G.D.)	Suspended Solids		B.O.D.	
			Influent (P.P.M.)	Effluent (P.P.M.)	Influent (P.P.M.)	Effluent (P.P.M.)
Jan.–Feb.	2.77	34.90	180	66	222	143
July–Aug.	3.86	27.45	208	60	247	142

TABLE V.—Sewage Flow and Degree of Purification

Number of Months	Sewage Flow (M.G.D.)	Suspended Solids			B.O.D.		
		Influent (P.P.M.)	Effluent (P.P.M.)	Removal (Per Cent)	Influent (P.P.M.)	Effluent (P.P.M.)	Removal (Per Cent)
8	18.86	215	62	70.7	265	157	40.8
16	21.91	216	63	70.5	268	160	40.4
16	26.33	192	62	67.6	217	130	40.0
16	29.82	209	67	67.8	254	149	41.2
13	33.97	191	64	66.4	234	139	40.6
12	38.12	176	63	64.2	219	134	38.8
11	45.47	148	59	60.2	174	112	35.6

The figures indicate, however, that the strength of the sewage may vary with the total sewage flow.

Relation Between Sewage Flow and Degree of Purification

The method of operating the settling basins is such that normally only a part of the capacity is utilized. A study pertaining to the relation between sewage flow and the degree of purification is of some importance in the determination of tank capacities required to produce required results. The pertinent questions are: (1) What is the relation between sewage flow and strength of sewage, (2) What is the effect of increased sewage flow on the degree of purification, and (3) At which flows should the present method of operation be changed?

A comparison was made by averaging the monthly flows at increments of about 4 m.g.d., the strength of sewage and the percentage removals obtained (Table V). It appears from this study that (1) the strength of the sewage does not materially change at this plant until the higher flows are recorded; (2) the quality of the effluent does not change with increasing flows; (3) the percentage removal of suspended solids decreases gradually, but the percentage B.O.D. removal decreases only at the highest flows; (4) with an average flow of 45 m.g.d. the percentage purification is still sufficient to pass the requirements.

Storms of short duration and high intensity have a pronounced effect on the sewage flow and may dilute the sewage to such a degree that little treatment is required. Prolonged wet periods also increase sewage flows and, from an operation standpoint, it is of interest to know how purification is affected during such periods. The records were examined and the results obtained during the months with a total rainfall of less than 2 inches were compared with those obtained during months with more than 6 inches of rainfall. The effect of these relatively low and high rainfalls on the strength of sewage and the degree of purification is indicated by the following figures:

Number Months	Rainfall (Inches)	Flow (M.G.D.)	Suspended Solids			B.O.D.		
			Influent (P.P.M.)	Effluent (P.P.M.)	Per Cent Removal	Influent (P.P.M.)	Effluent (P.P.M.)	Per Cent Removal
20	1.38	26.57	206	65	68.0	257	154	39.8
14	6.44	34.21	179	62	65.3	281	128	54.3

In terms of suspended solids the sewage appears to be somewhat weaker during the wet months, with a slight decrease in the percentage of purification, whereas the strength of the sewage in terms of B.O.D. was actually greater and the percentage removal was higher. Attention is directed to the fact that with increasing rainfall the p.p.m. suspended solids remaining in the effluent is practically constant (Table IV) and the same holds for high and low flows as indicated by the above results.

The effect of prolonged wet weather on the total sewage flow is evident. With increased sewage flows and fixed settling capacity, it would be expected that the removals calculated on an equated basis would be lower because of the decreased detention times. The reason for the slight effect on suspended solids removal at this plant is that under all conditions of higher flows the detention time was still sufficient to remove over 60 per cent of the suspended material present.

Quantity of Pollutional Matter

The volume of sewage has increased over the years. When the sewage flow is compared with the total tonnage of pollutional matter present in the sewage (Table VI) it is seen that the total quantity of suspended solids increased from 1938 to 1944 in proportion to the sewage flow. The increase in flow is due primarily to increased connections, population growth and new industrial activities. The flow contributed by new connections was about 25 per cent, leaving the additional 16 per cent to population increase and industry. Of particular interest is that the B.O.D. is always higher than the suspended solids quantities. A large portion of the sewage received at the plant has traveled a considerable distance and consequently has become somewhat stale. This, however, does not explain why the percentage increase in B.O.D. is materially higher than the percentage increase in suspended material. As a matter of fact, the B.O.D. should be relatively less with the addition of Elizabeth sewage, because of its proximity to the plant. Examination of the table will show that the B.O.D. increased more rapidly than the suspended solids before Elizabeth was connected in 1942. For instance, the suspended solids increased from 1938 to 1941 by 23 per cent and the B.O.D. by nearly 41 per cent. Since 1942 neither the total tonnage of suspended solids nor the B.O.D. increased materially, but the relationship between suspended solids and B.O.D. remained the same. In other words, for each pound of suspended solids received about 1.2 pounds of B.O.D. was present, irrespective of increase in flow. There is, therefore, no evidence that increased industrial activity producing wastes containing soluble or semi-soluble organic substances is particularly responsible for the increased B.O.D.

TABLE VI.—Sewage Flow and Pollutional Matter

Year	Total Flow (M.G.)	Total Dry Susp. Solids (Tons)	Total B.O.D. (Tons)
1938	9,590	7,360	8,100
1939	9,290	7,580	9,300
1940	10,230	8,080	10,200
1941	10,170	9,050	11,400
1942	13,540	11,000	13,650
1943	13,355	10,550	13,020
1944	13,548	10,380	13,950
Per Cent Increase, 1938–1944	41.2	41.4	72.1

Purification and Sludge Production

The purification required by the New Jersey State Department of Health is essentially based upon the removal of suspended material and B.O.D. A percentage removal of 60 per cent is required, based upon the suspended solids and B.O.D. in the raw sewage and effluent from the settling tank. The average annual removal of suspended solids has been persistently above 60 per cent, as shown by the data in Table I. There have been only minor fluctuations. The removal of B.O.D. has also been constant and higher than normally obtained by settling alone. The average daily amount of sludge pumped from the settling tanks remained fairly constant during the first 4½ years and increased thereafter with the increase in flow, but apparently again remained fairly constant during the last three years. In effect, the removal of pollutional matter is greater than indicated by these figures, because the grit and screenings removed have not been taken into consideration.

After the sludge is pumped to the storage tanks, the material concentrates and a portion of the liquor is decanted. From Table VII it can be seen that beginning with 1941, the percentage of liquor decanted has been gradually increased. This means that less sludge needed disposal by barging. The data in this table do not clearly indicate the magnitude and importance of improved decantation.

TABLE VII.—Quantities of Sludge Pumped and Stored

Year	Total Sludge Removed (Tons)	Wet Sludge Produced (Tons/M.G.)	Liquor Decanted (Per Cent)	Sludge Stored (Tons/M.G.)
1938	118,943	12.30	42.6	7.14
1939	118,937	12.80	43.4	7.21
1940	112,456	10.95	36.1	7.04
1941	118,131	11.25	42.1	6.68
1942	145,370	10.78	43.3	6.08
1943	145,050	10.58	44.9	5.99
1944	149,332	11.00	45.9	5.96

It is of interest to show the actual quantities of sludge pumped each year, the amounts of liquor decanted and the sludge stored. Table VII shows the actual tonnage per year as well as the tons of sludge stored for each million gallons of sewage treated. The average amount of sludge removed from the clarifiers was well over 110,000 tons annually during the years 1938 to 1941 and increased to about 145,000 tons per year during the years 1942 to 1944. The total sludge removed by the clarifiers varied over the years.

It is significant that the tonnage of sludge stored per million gallons treated, after decantation, has gradually decreased on account of the improved decantation procedure. The importance of improved decantation is better shown by the following data, where performance is compared for the periods 1937 to 1941 and 1942 to 1944:

	1938–1941	1942–1944
Total yearly flow—m.g.	9,820	13,481
Total sludge produced per year—tons	117,114	146,584
Total sludge stored per year—tons	68,861	81,065
Sludge stored per m.g.—tons	7.02	6.01
Reduction in sludge stored per m.g.—per cent	—	14
Reduction in sludge stored per year—tons	—	12,200

On account of improved decantation, 14 per cent less sludge was stored during the last three years than would have been if the operation procedure had remained the same; during the last three years efficient and effective operation resulted in a decrease of sludge to be stored of some 36,000 tons.

Sewage Flow and Sludge Production

The dry suspended solids present in the sewage for the year 1944 amounted to approximately 0.16 lb. per capita per day, whereas the total dry suspended solids removed by the settling tanks amounted to about 0.11 lb. per capita per day. In an effort to determine the relation between sewage flow and the total sludge

TABLE VIII.—Sewage Flows and Sludge Production

Number Months	Flow (M.G.D.)	Total Tons Sludge per Month	Total Solids (Per Cent)	Ash Content (Per Cent)	Liquor Decanted (Per Cent)	Sludge Stored per M.G. (Tons)
8	18.86	9,877	5.53	23.8	35.3	11.25
16	21.91	10,176	5.71	22.4	44.2	8.57
16	26.33	9,563	5.75	23.8	40.4	7.06
16	29.82	10,904	5.57	22.7	40.7	6.90
13	33.97	10,021	6.03	22.0	45.8	6.23
12	38.12	11,514	5.68	22.9	42.5	5.74
11	45.47	10,173	5.48	22.4	51.2	4.31

production the monthly average results were grouped in accordance with increasing flows. A comparison of the results (Table VIII) shows that the quantities of wet sludge remained fairly constant no matter whether the flows were high or low. This checks with the fact that the suspended solids in the effluent remain practically constant and the percentage removals decrease with increased flows. The higher flows have no effect on the total solids concentration of the sludge pumped from the settling tanks; neither is the ash content of the sludge affected. In general, however, the percentage of liquor which could be decanted increased with higher flows, probably indicating that less finely divided suspended matter settled out at higher flows, compensating for the larger quantities of total solids present at higher flows. The result is that the sludge stored per million gallons of sewage treated decreases with increased flows. From a practical standpoint this means that the volume of sludge to be barged does not materially increase when flows are higher, i.e., the additional material which may enter the sewerage system on account of street wash is balanced by the passage of fine suspended matter through the tanks, leaving the quantity of sludge to be handled practically constant. Sludge volumes will, therefore, increase only in proportion to additional sewage received from new connections or increased industrial activities.

It has been mentioned previously that the strength of sewage is different during periods of prolonged wet weather as compared with periods of relatively dry weather. The question arises whether sludge production and sludge characteristics are materially different during such periods of wet weather. The results obtained for periods of less than 2 inches of rainfall per month as compared with those obtained when rainfall exceeded 6 inches show the following:

Rain-fall (Inches)	Sludge Pro-duced (Tons/ Month)	Total Solids (Per Cent)	Ash (Per Cent)	Liquor De-canted (Per Cent)	Tons Sludge Stored per M.G.
1.38	10,496	5.59	21.6	42.0	7.46
6.44	11,530	5.63	24.3	45.0	5.96

The total sludge production was about 9 per cent higher with high rainfall, probably caused by street wash and cleansing of sewers; the latter is indicated by the higher ash content, which increased about 10 per cent. The concentration of the sludge in the settling tanks was not affected, but the sludge stored increased by 240 tons a month despite the higher percentage of liquor removal. In general, therefore, the actual removal of suspended material is higher during rainy months.

Since the sewage is stronger and the percentage removal of suspended material higher during the warmer summer months, the sludge production should be affected. The difference in quantity and character of sludge produced during the coldest and warmest month of the year is indicated by the following average results over 7 years:

Period	Sludge Produced (Tons/Month)	Total Solids (Per Cent)	Ash Content (Per Cent)	Liquor Decanted (Per Cent)	Tons Sludge Stored per M.G.
Jan.–Feb.	9,840	5.54	21.3	38.5	5.39
July–Aug.	11,350	5.65	25.5	39.6	8.21

Total solids production appears to be higher during the warmer months; this is probably related to food habits, consumption of more vegetable matter, and increased settling efficiency at higher temperatures. Solids concentration is about the same during the two periods, but the ash content is higher during the warmer period. In winter, the average quantity of sludge stored amounted to 5.39 tons per m.g., whereas in summer the quantity was 8.21 tons per m.g., or 52.2 per cent more. From an economic standpoint, the cost of sludge handling and disposal per unit of flow is higher in summer than in winter.

Factors Affecting Sludge Barging

There are a number of factors which affect the collection, concentration and disposal of solids. The factors affecting the concentration and barging of solids can be ascertained from the extensive and rather complete records available. A study of the records is of considerable practical value as indicated by the following example. The total amount of sludge collected during 1944 was about 149,000 tons. The sludge was concentrated and the liquor, amounting to about 45 per cent of the total volume, decanted and returned to the clarifiers. The total quantity of sludge stored was 80,805 tons, having a concentration of 8.2 per cent total solids. If the sludge concentration can be increased by one per cent some 8,950 tons less would have to be stored and barged, amounting to a saving of roughly $4,500 a year. It is important, therefore, to determine the factors affecting sludge concentration.

In addition to increasing the sludge concentration, other measures may be taken to improve operation and reduce costs. The main ones are: (1) thorough mixing of sludge in the storage tanks to make it more uniform and easier to flow; (2) introduction of dilution water if the sludge is too thick or too cold; (3) application of air pressure for mixing and facilitating flow through the 4,000-ft. pipe line to the dock; (4) removal of obstructions to allow free sludge flow through the force main; (5) improvement of pumping equipment; (6) increased operation efficiency.

This study concerns itself with a determination of the importance of various factors affecting the conditions of the sludge produced, whether general operation efficiency has improved over the years, what the possibilities are for further improvement, and whether actual savings in operation costs have been accomplished.

Sludge Barged

The actual quantities of sludge barged are always higher than the quantities of sludge stored. The amounts of sludge barged, together with the total solids concentration and ash content are shown in Table IX.

TABLE IX.—Total Sludge Barged with Average Annual Solids Concentration and Ash Content

Year	Tons Sludge Barged	Solids (Per Cent)	Ash (Per Cent)	Tons Sludge per M.G. Sewage
1937	50,435	6.70	26.5	9.36
1938	67,820	7.80	26.0	7.88
1939	76,065	7.80	25.2	8.19
1940	80,545	8.00	24.3	8.33
1941	75,920	7.84	24.3	7.44
1942	89,050	8.26	25.1	6.62
1943	85,324	8.25	23.3	6.39
1944	87,475	8.20	24.3	6.40

TABLE X.—Relation Between Sludge Stored and Barged

Year	Number Bargings	Sludge Stored (Tons)	Sludge Barged (Tons)	Sludge Concentration (Per Cent)	Water Added	
					Tons	Per Cent
1937–38	36	116,331	117,375	7.31	1044	0.9
1939	22	66,967	76,065	7.80	9092	13.6
1940	23	71,895	80,545	8.00	8650	12.0
1941	22	68,035	75,920	7.84	7885	11.6
1942	26	82,285	89,050	8.26	6765	8.2
1943	25	80,110	85,324	8.25	5214	6.5
1944	25	80,805	87,475	8.20	6670	8.2

Several interesting points may be noticed. The sludge barged during 1937 represents about eight months of the year. During the years 1938 to 1941 sludge volumes barged varied materially and increased sharply after the Elizabeth connection was made, but the quantity of sludge per million gallons of sewage treated decreased considerably. At the same time the sludge concentration increased. The reduction in sludge barged per million gallons treated is more clearly shown when the periods 1938 to 1941 and 1942 to 1944 are averaged:

1938–1941 . . . . 7.96 tons per m.g.
1942–1944 . . . . 6.44 tons per m.g.
Reduction . . . . 19 per cent

The increase in sludge volume barged is related to the sewage flow and the amount of sludge removed by the settling tanks. Calculations show that the sewage flow in 1944 was 42 per cent higher than in 1938, but the amount of sludge barged was only 23 per cent higher. If the results for the periods 1938 to 1941 and 1942 to 1944 are averaged, we find:

	1938–41	1942–44	Per Cent Increase
Ave. yearly flow—m.g.d.	9,800	13,475	37.3
Ave. yearly sludge settled—tons.	117,114	146,584	33.4
Ave. yearly sludge barged—tons.	75,087	87,433	16.5

Whereas the average yearly sewage flow increased 37 per cent, the increase in sludge removed was 33 per cent and in the sludge barged only 16 per cent. This means, therefore, that the amount of sludge pumped to the storage tanks was considerably less during the period 1942 to 1944 than from 1938 to 1941, resulting in less labor and power cost, but what is of still more importance, the amount of sludge barged was about 12,200 tons a year less than would have been expected if operation procedures had remained the same.

The various factors which affect barging and the results of measures taken to improve efficiency are briefly discussed herewith.

Water Addition

Frequently during bargings it has been found necessary to add fresh water or sewage to the sludge stored in the storage tanks in order to move the viscous material. This is particularly necessary during cold weather. The addition of water is undesirable because it increases the volume of material to be barged and must be paid for on a tonnage basis, and it requires extra labor and time. To reduce the quantities of water added during barging, the sludge in the storage tanks is recirculated by pumping for a number of hours before actual barging commences. In addition, compressed air is used to move the sludge and to clean out the lines. Recircula-

TABLE XI.—Effect of Temperature on the Rate of Pumping and Time Required for Barging of Sludge

Number Bargings	Temp. (° F.)	Sludge Barged (Tons)	Barging Time (Min.)	Rate of Pumping (G.P.M.)	Solids Conc. (Per Cent)	Head on Pump (Ft.)	Ash Content (Per Cent)	Time/1,000 Tons (Min.)
24	52.2	3390	422	1476	7.59	41	22.4	125
22	54.0	3465	469	1870	7.61	40	22.3	135
14	57.0	3465	400	2189	8.11	36.5	21.9	115
9	59.5	3450	382	2162	8.05	32	21.8	111
15	62.0	3470	359	2161	8.02	33	23.1	103
12	65.0	3423	312	2662	8.86	30	24.8	91
17	68.1	3600	295	2910	8.35	23	26.4	82
17	70.6	3436	222	3660	8.64	21.5	26.8	65
19	72.4	3431	224	3633	7.86	21	22.7	65
10	74.2	3437	227	3673	7.94	21.5	26.6	66

tion and use of air has been modified and presumably improved. More judicious use of water has been made.

It is difficult to determine separately the actual effects of all these measures, but in total they can be assayed by a study of the relation between the quantities of sludge stored and barged. The amounts of sludge stored are those after concentration by decantation has been accomplished. A comparison of the pertinent factors can be made from the data given in Table X. It will be noticed that during 1937–38, the average sludge concentration was lower than any other year. This, together with the fact that these results include bargings during two summers and only one winter, accounts for the rather low percentage of water addition. For the period 1939–41, the percentage of water added was materially greater than during the period 1942–44. When the results for these two periods are averaged, we find:

	1939–41	1942–44
Ave. yearly solids concentration—per cent	7.88	8.24
Sludge stored—tons per year	68,966	80,732
Water added—tons per year	8,542	6,216
Ave. water added—per cent	12.5	7.7

If no improvements had been made and the same percentages of water had been added to the increased volumes of sludge, the additional tonnage of water would have amounted to about 10,000 tons a year, or roughly three more bargings a year for the three-year period.

Effect of Temperature

The time required for loading the sludge barge varies throughout the year. In general, the average barging time is greater in winter than in summer. In averaging the data pertaining to bargings at different sludge temperature increments (Table XI), it becomes evident that the rate of pumping increases with the sludge temperature, that the head on the pumps decreases and the time required to load equal quantities of sludge also decreases with increased sludge temperatures. These general tendencies are more clearly illustrated in Figure 2 where the average rates of pumping in gallons per minute, the average head on the pump in feet and the average minutes required to place 1,000 tons of sludge into the barge are plotted against the average temperature of the sludge during barging.

The difference in barging time at the higher and lower temperatures is illustrated by averaging all bargings when

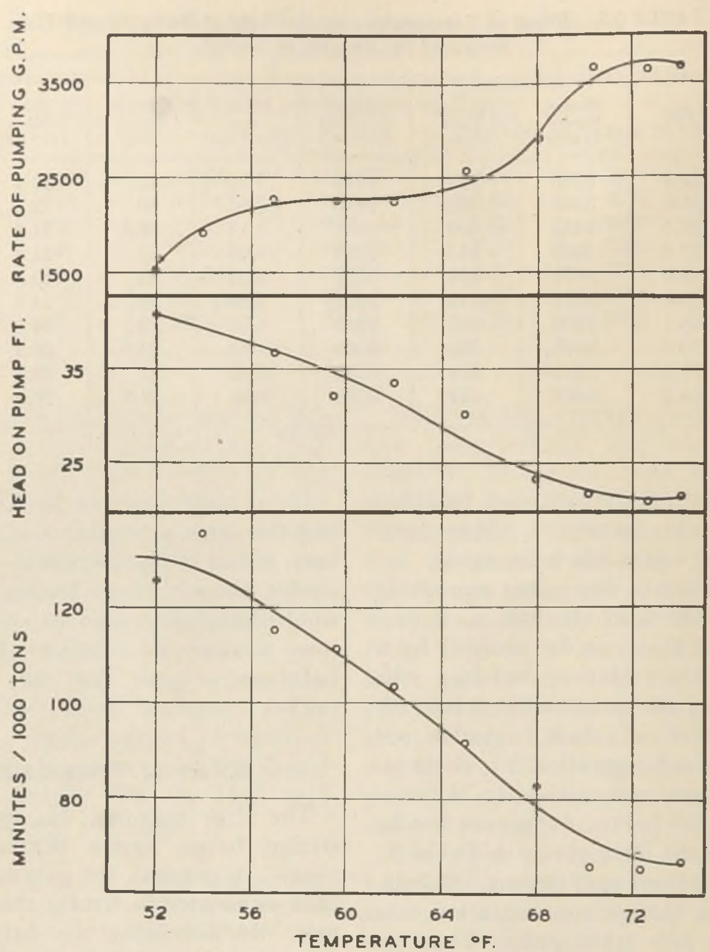

FIGURE 2.—Relation between temperature and rate and time of loading of barge.

the sludge temperatures were from 49° to 55° F. and comparing the results with those when the sludge temperatures were from 70° to 75° F.:

Temperature of sludge—° F.	52.5	72
Number bargings	46	46
Solids concentration—per cent	7.62	8.01
Ash content—per cent	21.7	28.2
Sludge barged—tons	3413	3414
Total barging time—min.	436	240
Pumping rate—g.p.m.	1912	3448
Head on pump—ft.	40	21
Time per 1,000 tons sludge—min.	127	70

With the same number of bargings, but somewhat higher solids concentration at the higher temperature, and the volumes barged each time the same, the pumping rate was about 45 per cent less with about half as much head on the pumps. The actual barging time at the low temperature averaged 7 hours and 16 minutes as compared with 4 hours at the higher temperature, or one hour less for each 1,000 tons of sludge barged.

The pumping time at lower temperatures is longer than at higher temperatures because the hydraulic characteristics of the sludge change. As sludge moves more sluggishly at low temperatures, the time required for pumping increases. To illustrate this, the velocity of the sludge moving through the 4,000-ft. pipe to the barge has been calculated (Table XII). It is evident that the velocity increases with the temperature but not in direct proportion. The velocity increases at an accelerated rate until the temperature reaches about 70° F. At an average temperature of 53° F. the velocity is 1.30 ft. per sec. and at 72.5° F. it is 2.59 ft. per sec., or doubled. The pumping time is cut in half. If the velocity could be increased to 5 ft. per sec., the pumping time could again be cut in half. It has been asserted that if velocities reach 5 or more ft. per sec., the sludge will flow like water, provided the temperature is above 60° F. Methods of achieving such higher velocities are being given further study.

TABLE XII.—Relation Between Temperature and Velocity of Sludge Flow in Pipe

Temp. (° F.)	Time/1,000 Tons (Min.)	Calculated Velocity (Ft./Sec.)
52.2	125	1.35
54.0	135	1.25
57.0	115	1.47
59.5	111	1.53
62.0	103	1.64
65.0	91	1.86
68.1	82	2.06
70.6	65	2.60
72.4	65	2.60
74.2	66	2.56

Effect of Recirculation

The flow of sludge is affected by the apparent viscosity of the sludge. The apparent viscosity is made up of a true viscosity and a plastic resistance of the sludge. The resistance is probably caused by the nature of the sludge particles and the gelatinous formation which develops on quiescent standing of the sludge. The nature of the sludge particles cannot be changed, but the gelatinous condition can be largely overcome by agitation of the sludge. It is well known that the apparent viscosity of the sludge changes when the sludge is stirred, hence the greater the amount of mixing or the more effective the mixing of the sludge prior to barging, the less viscous the sludge will be and the greater the resulting velocity of flow in the pipe. Since the velocity of travel is related to time, the more effective the mixing, the shorter the time required for barging.

The method of mixing before barging has been improved, but it is difficult to show the specific effect of improved mixing because other improvements were made about the same time. Simple laboratory experiments, conducted by vigorously shaking samples of sludge, showed that the viscosity of the sludge could be lowered greatly. The method of mixing practiced at the plant will aid in reducing barging time. In addition, the agitation of the sludge will feed it more uniformly to the pumps and reduce cavitation.

Effect of Sludge Concentration

There are two important points to be considered in sludge concentration: (1) reduction in volume of sludge to be barged by increasing the sludge concentration, and (2) the speed of barging to reduce pumping time. The reduction in volume of sludge is brought about by effective decantation. The question is, therefore: How far can decantation be continued without causing undue interference with sludge pumping for barging?

The percentages of increase in sludge concentration during the years of operation are shown in Table XIII. The average annual results show a gradual increase in the percentage of concentration obtained after settling. The percentage solids barged increased gradually to 1942 and thereafter remained practically constant, because with the equipment available the ap-

TABLE XIII.—Increase in Solids Concentration of Sludge Collected as Compared with Sludge Barged

Year	Settled Solids (Per Cent)	Barged Solids (Per Cent)	Increase (Per Cent)
1937	5.41	6.70	19.3
1938	5.48	7.80	29.6
1939	5.94	7.80	24.0
1940	6.22	8.00	22.4
1941	5.64	7.84	28.2
1942	5.80	8.26	29.6
1943	5.58	8.25	32.0
1944	5.36	8.20	34.5

parent limit of sludge concentration had been reached.

A comparison of the quantities of sludge handled at each barging, the loading rates and average solids concentrations (Table XIV) shows that for about the same volumes of sludge barged the rate of pumping has greatly increased and, consequently, the time required decreased. This is especially the case during the last three years. A comparison of the average rate of pumping during 1939–41 and 1942–44 shows 2,108 and 2,728 gallons per minute, respectively, or an increase of 23 per cent. Pumping rates can be expected to increase when the solids concentrations decrease. During these same periods, the average solids concentrations were 7.88 and 8.24, an actual increase rather than a decrease. The reduction in barging time is, therefore, due to improvement in operation (recirculation, judicious use of air and water, etc.) and equipment (removal of obstructions, larger pumps, etc.) and is not due to reduction in the solids concentration.

TABLE XIV.—Average Sludge per Barging, Time of Pumping and Rate of Loading

Year	Sludge Barged (Tons)	Pumping Time (Min.)	Time per 1,000 Tons (Min.)	Pumping Rate (G.P.M.)	Solids Concentration (Per Cent)
1937	3152	379	120	1910	6.70
1938	3391	398	117	1960	7.80
1939	3438	381	110	2090	7.80
1940	3502	362	103	2225	8.00
1941	3451	395	114	2010	7.84
1942	3425	286	83	2760	8.26
1943	3413	310	90	2530	8.25
1944	3499	278	79	2895	8.20

The average concentration of solids barged varied between 6.5 and 9.0 per cent. Grouping the concentrations at lower and higher temperatures in an effort to determine the effect of solids concentration (Table XV) showed some unexpected results. At the lower temperature of 52° to 53° F. the loading time decreased with increasing solids concentrations, contrary to expectations. At the higher temperatures (72° F.) the loading time fluctuated somewhat, but the differences were much less apparent. As indicated above the concentration of solids has gradually increased over the years on account of improved operation and equipment. The results in Table XV, as far as solids concentration is con-

TABLE XV.—Effect of Sludge Concentration at Low and High Temperatures

Number Bargings	Temp. (° F.)	Solids Concentration (Per Cent)	Sludge Barged (Tons)	Barging Time (Min.)	Pumping Rate (G.P.M.)	Head (Ft.)	Ash Content (Per Cent)	Time/1,000 Tons (Min.)
3	52	6.74	3492	602	1350	38	21.0	173
18	53	7.22	3430	455	1867	40	21.8	135
17	53	7.78	3370	435	1893	42.6	22.7	122
8	53	8.42	3449	364	2262	38	23.3	104
8	72.8	7.00	3437	261	3113	23.5	26.7	76
13	72.0	7.77	3353	249	3437	20	27.7	71
15	72.5	8.22	3438	220	3699	20	29.2	64
10	71.8	8.82	3438	244	3354	23	28.4	71

cerned, correspond with the improvements. It appears, therefore, that the improvement in operation and equipment was sufficient to overbalance any effect of increased solids concentration.

The results indicate further that the effect of sludge concentration can be offset by better operation procedures and that the supposed limit of about 8 per cent solids concentration may not hold with improved equipment.

Since ultimate solids concentration is primarily a function of initial concentration and time of storage, there is a definite limit to which decantation or sludge thickening may be carried with the storage capacity available.

There seems to be a general tendency that with increased ash content of the solids, pumping time decreases. Since the type of solids plays an important part in the plasticity of the sludge, it is possible that more ash would affect the flow characteristics of the solids. In summer, the percentages of ash are greater than in winter, possibly making the solids more "gritty." With increased "grittiness" the velocity of flow (at constant head and temperature) may increase and hence reduce the loading time. This factor is probably of minor importance.

Effect of Increased Pumping Capacity

Originally, two pumps with 15 h.p. motors were considered sufficient by the designing engineers to force the sludge through a 24-in. pipe for a distance of about 4,000 ft. to the dock. These motors proved to be inadequate and were replaced by one 30 h.p. motor and one 40 h.p. motor. The barging results reported were obtained with these motors. Study of the records together with experience indicated that increased performance, reduction in loading time and costs might conceivably be obtained with motors of higher capacity. Consequently, the 40 h.p. motor was replaced by a 75 h.p. motor. During 1944, other improvements consisting of removal of a restricted cone valve in the sludge line and introduction of compressed air in the sludge storage tanks for mixing, were made. In an effort to appraise the value of these improvements the results obtained from 1942 to 1945 for the periods of January to August, in respect to sludge handled and pumping time required, have been compared. These average data follow:

Year	Number Bargings	Sludge Barged (Tons)	Total Solids (Per Cent)	Ash (Per Cent)	Temp. (° F.)	Pumping Time (Min./1,000 Tons)	Rate of Pumping (G.P.M.)
1942	17	58,225	8.30	25.5	61.4	89	4920
1943	18	59,400	8.00	23.7	60.2	95	4680
1944	17	60,075	7.93	23.6	62.2	86	5240
1945	16	59,870	8.90	24.7	59.4	74	6060

The sludge barged during 1945 had the highest average concentration in the history of the plant. Concentrations of as high as 9.73 per cent solids were reached on an individual barging. Comparison of the average 1945 results with the best previously obtained (1942) shows that the sludge handled had a 7.3 per cent higher concentration, whereas the time required for pumping per unit volume was 8.3 per cent less. These figures may not sound impressive, but actually mean that about 1,800 tons less sludge was barged and the total loading time was reduced by about 15 hours. Loading time signifies labor, power and dock charges. Translating the results in dollars, it means that a saving of some $750 was accomplished. The cost of the motor was about $650.

General Efficiency

At the start of operation of the treatment plant a personnel organization was created, consisting of some trained persons and a number of untrained operators. Through the years many of the untrained men took special courses and others were instructed in details of operation. Gradually this force, in spite of some losses, has become a closely knit, well trained group, capable of handling the work efficiently. During the last few years war conditions have caused reductions in labor and temporary absences of trained personnel. To make up for these losses the staff was more intensely and more widely trained to be able to perform the necessary tasks and substitute for others. The result has been an organization that was able not only to continue operation without interruptions and to make necessary repairs, but to maintain the same degree of plant efficiency. Furthermore, the results show that increasingly larger quantities of sludge were produced without corresponding larger quantities being barged, resulting in material savings.

The longer the plant is in operation, the more deterioration of buildings and structures can be expected. Machinery and equipment wear out and repairs and replacements are required to maintain efficiency. To keep the plant in good condition requires constant vigilance and planning. The neat appearance of the plant, together with the fact that high efficiency has been maintained and actually considerable money has been saved, speaks well for the ability, competency and skill of the supervising and operating personnel.

Cost of Operation

In addition to the sewage treatment plant, the Joint Meeting maintains and operates 43 miles of collecting and trunk sewers. Frequently the cost of operation and maintenance of such sewers is not considered a part of the treatment plant. Furthermore, when operation costs are published, the cost of maintenance, engineering, and administration may or may not be included in operation costs. This method of calculation may show an apparent low cost, but does not present a complete picture. The factual data given below include all items pertaining to operation, maintenance and administration and constitute the total cost to the member municipalities:

Year	Sewers		Treatment Plant	
	Dollars per M.G.	Cents per Capita per Year	Dollars per M.G.	Cents per Capita per Year
1941	3.26	9.4	8.99	30.7
1942	2.13	8.0	7.91	30.0
1943	2.08	7.7	8.01	29.5
1944	2.24	8.3	8.31	30.8

On the basis of an estimated population of 360,000 served, the total annual cost varied from 37.2 to 40.1 cents per capita during the last four years for collection and treatment of sewage and disposal of sludge. The cost for disposal of sludge (barging and dock fees) varied between 29.7 to 31.5 per cent of the total cost of treatment, while supervision and labor varied from 37.3 to 44.0 per cent of the treatment plant cost. The sludge disposal cost amounts to nearly one-third of the total cost, and on the basis of dry solids disposed of, the cost varied from $4.55 to $4.73 per ton.

Value of Complete Records

The plant structures are fixed and maintenance of adequate purification, relative reduction in sludge stored with increased sewage flows and proper plant maintenance can be brought about only by efficiency in plant operation. Analyses of results obtained, savings in cost and projection of expansion and justification of needs can be based only on adequate and complete records. Proper studies of such records can and should be presented from time to time to the governing boards, aside from annual reports, for the specific purpose of review of accomplishments. This phase of the use of good records is frequently insufficiently utilized by the supervisors of municipal utilities.

Summary

The Joint Meeting trunk sewer and treatment plant is operated by commissioners representing eleven municipalities with an aggregate population of over 360,000. The volume of sewage treated averages about 37 m.g.d. A study of operation records over a period of 7.5 years was made to determine: (1) the degree of purification maintained, (2) the effect of rainfall and sewage flow on the strength of the sewage and the degree of purification, (3) the effect of various factors which affect sludge handling and disposal, (4) the general efficiency, and (5) the total costs. Examination of the data shows that the average sewage flow and sludge production has increased about 30 per cent, but that the percentage purification has remained practically constant. There was no direct relation between total annual rainfall and sewage flow or purification. The average strength of the sewage remained fairly constant and did not vary with the sewage flow, except during prolonged wet or dry periods. The total amount of the pollutional matter present in the sewage increased with the sewage flow and produced greater volumes of settled sludge. The average annual degree of purification accomplished by settling varied from 65.8 to 69.7 per cent removal of suspended solids and from 36.6 to 42.1 per cent in B.O.D. reduction. The sewage was stronger and the degree of purification was higher during summer than winter, and about one-third more sludge was collected and stored during the warmest months as compared with the coldest months of the year. Increased efficiency in concentration of stored sludge by decantation resulted in decreased amounts of sludge barged, despite increased amounts of sludge collected. Effective sludge concentration resulted in a decrease of over 36,000 tons of sludge barged during the last three years. With the present method of operation the sewage flow can increase to 45 m.g.d. before revised procedures will be required. Low temperatures and high sludge densities affected the flow of sludge through the 24-in. line to the dock. The effect of these factors was partially overcome by removing obstructions and increasing pumping capacity. Total cost of operation and maintenance of trunk sewers and treatment plant and of disposal of sludge varied from 37.2 to 40.1 cents per capita during the last four years. The cost of sludge disposal varied from \$4.55 to \$4.73 per ton of dry solids barged. General efficiency is indicated by the neat appearance of buildings, equipment and grounds, by the manner in which purification has been maintained, and by the cost economies that have been realized.

Industrial Wastes

THE TOXICITY THRESHOLDS OF VARIOUS SODIUM SALTS DETERMINED BY THE USE OF DAPHNIA MAGNA

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Many pollution abatement programs will undoubtedly call for maintaining the levels of polluting substances in receiving waters below the point at which they are deleterious to aquatic life. Inasmuch as the effects of wastes vary with their composition, the nature of the receiving water, and the organisms encountered, studies on the toxicity of industrial wastes should be conducted along many different lines to determine the levels at which the wastes may be said to be innocuous. Experimental studies on fish alone, at least as they have been conducted, are inadequate for determining the toxicity of industrial wastes, for as Gabrielson (1945, pp. 189–190) points out, "It has been found that very dilute pollutants present in quantities much too small to be directly harmful to fishes may, nevertheless, in time completely eliminate all fishes from the polluted waters." For the present the writer has limited himself to studying the effects on one particular organism of various chemical substances when added to Lake Erie water.

The aim of this paper is to present the threshold concentrations of toxicity for thirty-eight sodium salts, anions of which occur in industrial wastes, when these were added to centrifuged Lake Erie water with *Daphnia magna* as the test animal. The experimental work on which the thresholds are based was carried out during the summer of 1944. The method used was that recently described by Anderson (1944) except that the immobilization time-concentration curves, from which the threshold concentrations were estimated, were constructed on the basis of forty-eight hours of observation rather than sixteen hours. In the earlier work the control animals did not survive consistently over sixteen hours so that it was not considered justifiable to base the curves on a longer period. In the experiments on which the present thresholds are based, eighty to one hundred per cent of the controls remained alive and active forty-eight hours or more. The toxicity thresholds for the thirty-eight sodium salts are given in Table I.

As a consequence of using a longer observation time the threshold concentrations have been found to be lower for seven of the eight sodium salts presented in the earlier report (Anderson, 1944). The segments of the new survival curves covering times up to sixteen hours coincide with the curves upon which the earlier report was based. In many instances, however, the segments of the curves in the present experiments for the period from sixteen to forty-eight hours, the period not covered in the previous experiments, have definite inflections occurring between sixteen and thirty-two hours (Figure 1). In some instances the inflections were very pronounced, as in the case of sodium sulfite. These inflections may be explained on the assumption that *Daphnia* are more susceptible during ecdysis than at other times (Banta, 1939, pp. 192–193). Anderson and Jenkins (1942) found

TABLE I.—Threshold Concentrations for Immobilization of Daphnia magna by Substances when Added to Lake Erie Water

Substance	Formula	Molarity*	P.P.M.*
Sodium acetate	$NaC_2H_3O_2$	<0.071	<5800
Sodium arsenate	Na_2HAsO_4	<0.00011	<20
Sodium arsenite	$NaAsO_2$	0.00007	9.1
Sodium benzoate	$NaC_7H_5O_2$	<0.0045	<650
Sodium borate	$Na_2B_4O_7$	≪0.0012	≪240
Sodium perborate	$NaBO_3$	≪0.000063	≪5.2
Sodium bromate	$NaBrO_3$	0.0014	210
Sodium bromide	NaBr	0.08	8200
Sodium carbonate	Na_2CO_3	<0.0040	<424
Sodium bicarbonate	$NaHCO_3$	0.028	2350
Sodium chlorate	$NaClO_3$	0.040	4240
Sodium chloride	NaCl	<0.072	<4200
Sodium chromate	Na_2CrO_7	<0.0000020	<0.32
Sodium dichromate	$Na_2Cr_2O_4$	≪0.0000012	≪0.31
Sodium citrate	$Na_3C_6H_5O_7$	0.0032	825
Sodium cyanide	NaCN	<0.000069	<3.4
Sodium ferrocyanide	$Na_4Fe(CN)_6$	<0.0020	<600
Sodium fluoride	NaF	0.012	504
Sodium formate	$NaCHO_2$	<0.076	<5200
Sodium hydroxide	NaOH	0.0039	156
Sodium iodate	$NaIO_3$	≪0.00080	≪158
Sodium iodide	NaI	0.000022	3.3
Sodium nitrate	$NaNO_3$	0.059	5000
Sodium nitrite	$NaNO_2$	<0.00029	<20
Sodium nitroprusside	$Na_2Fe(CN)_5NO$	≪0.00080	≪210
Sodium oxalate	$Na_2C_2O_4$	0.0016	214
Sodium monobasic phosphate	NaH_2PO_4	≪0.013	≪1560
Sodium dibasic phosphate	Na_2HPO_4	≪0.00042	≪59
Sodium tribasic phosphate	Na_3PO_4	≪0.00032	≪52
Sodium salicylate	$NaC_7H_5O_3$	0.0091	1450
Sodium sulfate	Na_2SO_4	0.042	5960
Sodium bisulfate	$NaHSO_4$	0.0016	190
Sodium sulfide	Na_2S	0.00012	9.4
Sodium sulfite	Na_2SO_3	0.0035	440
Sodium bisulfite	$NaHSO_3$	<0.0014	<145
Sodium tartrate	$Na_2C_4H_4O_6$	<0.018	<3500
Sodium thiocyanate	NaSCN	<0.00014	<11.3
Sodium thiosulfate	$Na_2S_2O_3$	≪0.0033	≪520

* On the basis of the formula given.

that well fed *Daphnia magna* at 25° C. undergo their first ecdysis about twenty hours after their release from the brood chambers of the mothers. Some cast carapaces can be observed on the bottom of the experimental bottles at the sixteen hour observation when the animals are sixteen to twenty-four hours old. In Table I the concentrations preceded by either (<) or («) are not true threshold concentrations since the immobilization time-concentration curves for the salts designated had not reached their vertical asymptotes at forty-eight hours. The threshold concentration for any salt with (<) might be about nine-tenths of the value given if the trend of the curve were continued in each particular instance. The threshold concentration for a salt with («) might be as low as one-half the value given or less. The lack of (<) or («) does not mean, however, that the curve for any one salt might not be inflected were the observations continued for a longer period.

From a pollution standpoint the most

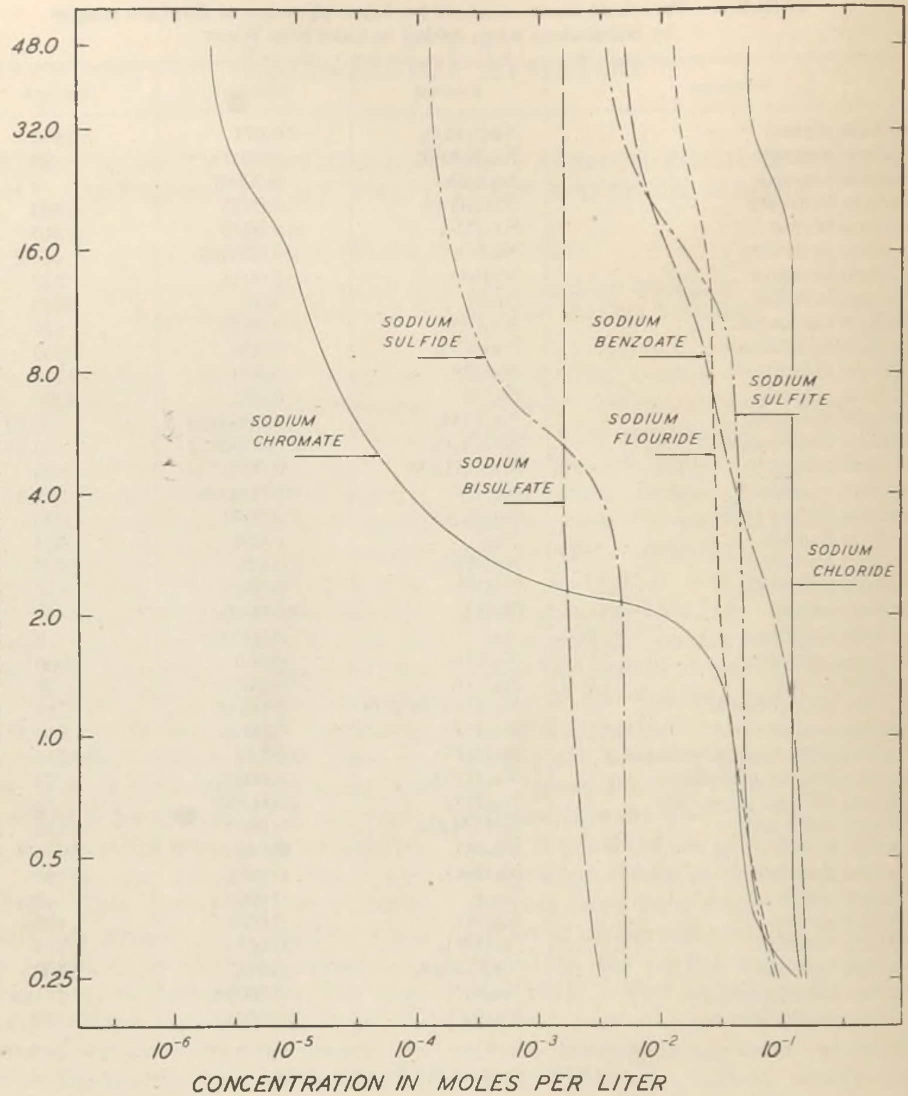

FIGURE 1.—Relation of immobilization time to concentration for Daphnia magna.

important aspect of toxicity studies is the determination of toxicity thresholds. The modes of action of the various salts are of secondary interest and will be discussed in detail elsewhere. Comparisons of the threshold concentrations of certain salts can be made, however, at this time.

All salts are toxic when they are present in concentrations high enough to exert an unfavorable osmotic pressure. Some salts, namely: sodium acetate, sodium bromide, sodium chloride, sodium formate, and sodium nitrate have approximately the same threshold concentrations in terms of molarity and are probably toxic only when their concentrations are high enough to exert an unfavorable osmotic effect when added to Lake Erie water.* To the

* The only published reports on the composition of Lake Erie water of which the writer is aware are those of Dole (1909) and Clarke (1924). Of the analyses that they

	Parts per Million		
	Range		Mean
Silica (SiO_2)	2.1	11.0	5.9
Iron (Fe)	0.03	0.18	0.07
Calcium (Ca)	30	33	31
Magnesium (Mg)	6.8	8.2	7.6
Sodium and potassium (Na K)	5.8	7.2	6.5
Carbonate radical (CO_3)	0.0	5.3	3.1
Bicarbonate radical (HCO_3)	104	124	114
Sulfate radical (SO_4)	11	14	13
Nitrate radical (NO_3)	0.0	0.6	0.3
Chlorine (Cl)	7.9	9.2	8.7
Total dissolved solids	126	143	133

above may be added sodium sulfate and perhaps sodium bicarbonate as being innocuous except when their concentrations are high enough to exert an unfavorable osmotic pressure.

Naumann (1934a) also found that the chloride, nitrate, and sulfate of sodium were relatively innocuous. While he did not determine the toxicity thresholds for each of these salts, one can, on the basis of the data he presented, estimate the limits of concentration in which the thresholds would fall. The threshold concentrations for these three salts in the present experiments fall within these limits.

All the other salts tested are toxic in concentrations lower than for those mentioned above and their toxicities are due to other factors. Sodium bisulfate is toxic when added to Lake Erie water in sufficient quantity to render the pH of the resulting solution less than 6. Sodium bisulfite may also fall into the same category but because it is toxic in solutions of slightly higher pH than 6 its toxicity at the threshold concentration may be due to some other factor. Of all the salts listed these two appear to be the only ones that were toxic at threshold concentrations because of their acidity. Sodium carbonate and sodium hydroxide appear to be the only sodium compounds tested which were toxic because of their alkalinity. The pH at the threshold for the carbonate was 9.2 and that for the hydroxide was between 9.1 and 9.5.

A comparison of the threshold concentrations of sodium arsenate and sodium arsenite indicates that the latter is slightly more toxic on the basis of molarity or on the amount of arsenic. A study of the immobilization time-concentration curves reveals, however, that forty times as much arsenate is required to immobilize *Daphnia* in one hour as is needed of arsenite. From the point of view of pollution the latter fact is of little consequence since exposures are likely to be continuous.

In contrast to the slight differences between the threshold concentrations of the arsenicals the differences between those for the nitrate and nitrite and those for the sulfate and sulfite are very great. The threshold concentration for the nitrite is $\frac{1}{200}$ of that for the nitrate. The threshold concentration for the sulfite is $\frac{1}{12}$ of that for the sulfate.

The halides, except for the iodide which is very toxic, are relatively innocuous. The bromate and chlorate are more toxic than the bromide and chloride, respectively, but the iodate is much less toxic than the iodide.

The chromate has almost the same threshold concentration as the dichromate when compared on the basis of the chromium content of the molecule.

The threshold concentration for the monobasic phosphate is much higher than those for the dibasic and tribasic phosphates. Both the dibasic and the tribasic phosphates produce flocculent precipitates while the monobasic produces none. The low threshold concentrations of the dibasic and tribasic phosphates can hardly be due to their

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present the most representative of Lake Erie as a whole are probably those made at Buffalo, New York, at monthly intervals between September 19, 1906, and August 28, 1907. These analyses are summarized below.

alkalinities since the pH values at their thresholds are 8.7 for the tribasic phosphate and less for the dibasic, while that for the carbonate is 9.2. The explanation may be that given by Naumann (1934 a and b) in that the HPO_4 ion is more toxic than the H_2PO_4 ion. Again the precipitates may exert a mechanical effect by obstructing the straining mechanism of the *Daphnia.* Naumann used sodium monobasic phosphate and potassium dibasic phosphate in his experiments and apparently did not consider the possibility of the potassium ion being more toxic than the sodium.

Ellis (1937) lists the results of experiments on fish with eight of the sodium salts included in Table I. For four of these the toxicity thresholds are higher for *Daphnia* than for fish, but for two of the others they are lower. It is impossible to judge, from the data presented by Ellis, whether the other conditions of the experiments are comparable.

Jones (1941) determined the toxicity thresholds for twenty-seven anions (sodium salts and sodium salt-acid mixtures) in distilled water for *Polycelis nigra,* a planarian. For twenty-two of these anions the thresholds are lower for *Daphnia* than for *Polycelis,* for one (sodium nitroprusside) the threshold is the same, and for four (sodium nitrate, sodium fluoride, sodium ferrocyanide, and sodium hydroxide) they are higher. The results which Jones presented are not strictly comparable to those given here since the experiments on *Polycelis* were carried out using distilled water while those on *Daphnia* were performed using Lake Erie water. In the writer's experience *Daphnia* did not survive long in distilled waters where only single salts were added. On the other hand it seems probable that had Jones used a natural water his threshold values would have been higher in some instances at least, especially in the case of sodium hydroxide.

With Lake Erie water the toxicity thresholds so far presented are not likely to be raised but may possibly be revised downward as studies involving other aspects of the life history of *Daphnia* are carried out. Other organisms may be less tolerant of toxic materials but until their toxicity thresholds have been established the values presented here can be used to estimate the quantities in which many industrial wastes can be discharged into Lake Erie without endangering one phase of its aquatic life.

Acknowledgment

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THE OPERATOR'S CORNER

PERSONAL COURTESY AND PUBLIC RELATIONS

Courtesy is such an obvious requirement in dealing with the public that there may seem to be little justification for devoting even a single page to this discussion, the second of our modest series on public relations. The point sought to be made here, however, is that there are different degrees of courtesy and that the special kind that is founded on a sincere desire to be of maximum helpfulness will yield the most in good will.

Suppose a troubled citizen phones the sewage treatment plant to report a failure in sewerage service. A reply, "Sorry sir, but that does not come under this department. Afraid we cannot help you," would be courteous but in a negative way. A much better reply would be to say, "Sorry sir, but such matters come under the Sewer Maintenance Division. I suggest that you call Mr. Brown, the Superintendent, at Superior 5000. If it is your own house service that is clogged, however, you will have to have it cleared by your own plumber because the municipal department has jurisdiction only over public sewers." And, if the inquirer appears to be interested, a brief statement about the common causes of sewer clogging and the usual methods of correction might be in order, possibly to the end that the householder is able to clear the line himself. That citizen would feel that he had been given a special and personal service.

Or say that a gardner inquires as to the merits of sludge as a soil conditioner, a matter of a few bushels of sludge being involved at most. His query should be given just as complete and careful a response as if he were a farmer or florist who might be interested in using hundreds of bushels. Some of the questions asked may be far afield of sewage works service (the prize one in our experience being the problem of the lady who wanted to know how to keep her stored linens from getting moldy), but even these should be received sympathetically and handled tactfully.

A visitor at the sewage treatment plant is worthy of special attention because the very fact that he calls demonstrates initial interest. The visitor should be made to feel that he is welcome, his tour of the plant should be made as interesting and educational as possible and, above all, he should leave with a strong impression of the enthusiasm and pride of stewardship with which the staff undertakes to operate and maintain *his* property. The models, charts and literature provided for visitors at many plants, though commendable, are not sufficient in themselves; it is the personal attention that counts the most.

The smaller the community and sewage works facilities, the easier it is to extend the personalized kind of courtesy that is advocated here. The chief engineer or superintendent in the very large plant cannot, of course, devote all his time to telephone inquiries and to welcoming visitors, although he will do well to set an example for his staff insofar as possible. In such large works, personnel who are delegated to handle public contacts should be selected for their interest, tact and diplomacy.

Each person who has been given reason to feel favorably toward his municipal sewage works service becomes a nucleus of good will, whose reactions will radiate to others. The practice of personalized courtesy costs nothing; it yields big dividends in public relations and satisfaction.

W. H. W.

THE TRICKLING FILTER AND ITS OPERATION *

By Frank Woodbury Jones

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Historical

The trickling filter was originally developed to reduce the area required by intermittent sand filters. Early development work by Col. George E. Waring, Jr., and the Massachusetts State Department of Health in 1891 and 1892 was important. The first municipal trickling filter plant to go into operation in this country was at Reading, Pa., in 1908 and one of the earliest and best landscaped American installations was the so-called Pennypack plant at Philadelphia, Pa., about 1912.

Much experimental and demonstrative work was done between 1905 and 1916 at Columbus, Ohio; Gloversville, N. Y.; Brooklyn, N. Y.; Philadelphia, Pa.; Worcester, Mass.; Akron and Cleveland, Ohio. Hundreds of municipal installations followed in rapid succession.

The trickling filter after 50 years is still recognized as an effective and dependable agent for secondary treatment or oxidation of sewage.

Types of Trickling Filters

There are two types of trickling filters in general use today: (1) the standard or conventional filter which is designed to receive flows of about 2 m.g.a.d. and applied B.O.D. of something less than 600 lb. per ac. ft. and (2) high rate filters which are designed for volume loadings from 10 to 30 m.g.a.d. and B.O.D. loadings from 3,000 lb. per ac. ft. upward. High rate filters are a relatively new development, the first plant scale installation having been made about 1936.

The Biofilter, Accelo-filter and Aerofilter represent 3 types of high rate units. The high rate filters all involve the recirculation of the filter or final effluent, or the final tank underflow back to the primary settling tank or directly to the filter. They may be operated in single stage or in 2 or even 3 stages.

Essential Parts of a Trickling Filter

By a definition a trickling filter is:

"An artificial bed of coarse material, such as broken stone, clinkers, slate, slats, or brush, over which sewage is distributed and applied in drops, films or spray, from troughs or drippers, moving distributors, or fixed nozzles and through which it trickles to the underdrains giving opportunity for organic matter to be oxidized by biochemical agencies."

Essential to the effective and consistent performance of a trickling filter are (1) a suitable underdrainage system, (2) proper filter media, (3) provision for uniform distribution of applied sewage and (4) provision for clarification of the final effluent.

The underdrainage system should be of adequate carrying capacity and so

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designed as to provide free and adequate ventilation throughout the filter bed. Forced aeration does not appear to be practicable.

The filter media should be uniform in size, clean and free from fines, and durable against disintegration. For standard filters the best media size appears to be about 2 to 3 in.; for high rate filters the media is usually somewhat larger, in the order of 3 to 4 in. Trap rock, granite, limestone and slag are common trickling filter materials. The depth of the media ranges from 6 to 10 ft.; the relative merits of shallow vs. depth filters are somewhat controversial.

Spray nozzles, revolving distributors and traveling distributors (on rails) are used to effect equal distribution of the applied sewage to the surface of the filter. Dosing tanks are nearly always required to maintain uniform distribution under varying conditions of flow, although such tanks may be omitted where the flow to the filter is controlled within certain limits as by pumping.

The effluent from a trickling filter carries varying amounts of suspended solids and these must be removed to secure a satisfactory final product. The clarification unit should be considered as an integral part of the filter. Sedimentation tanks equipped with mechanical sludge removal mechanisms are best suited for clarification of trickling filter effluents, the sludge being discharged either to the raw sewage or directly to sludge digestion facilities. Such secondary sludge or humus is likely to create odors if discharged to open lagoons.

Operation

Operating problems and suggestions as to routine work necessary for consistent filter performance follow:

1. Nozzle clogging material should not be permitted to reach the distributing nozzles. Fine mesh screens at outlets of settling tanks or inlets to dosing tanks will be effective if kept clean. Mechanical screens are sometimes used in large plants.

2. Inspect dosing equipment frequently. Air piping in siphons is subject to clogging with accumulated grease which builds up rapidly—clean regularly and watch for air leaks. Keep the dosing tank clean and free from grease; a good stiff broom, properly applied, can work wonders. Where pumping is used, the pumps must not suffer from oil deficiency and gland troubles. Watch the electric contacts and relays. A grease laden float is lazy.

3. Spraying of sewage into the air is likely to cause odor at times. Also, there may be a salt water, mud flat and eel-grass odor from the surface. To Morris Cohn's excellent three "C's," "Care, Cleanliness and Chlorine," another might be added—Circulation. A well nitrified effluent discharged into the raw sewage minimizes odor potentialities.

4. Nozzle clogging affects distribution adversely, and poor distribution deteriorates the effluent. Keep the nozzles and rotary arm orifices clean. Occasionally the whole nozzle should be cleaned with a stiff brush and soda ash solution. Flush the main distributors occasionally.

5. Watch the seals and holding cables on rotary distributors. Follow the manufacturer's instructions to avoid cold weather troubles, and to assure uninterrupted service.

6. The surface of the filter is subject to clogging by sewage solids, organic growths and disintegrated patches of media, resulting in "pooling." Accumulations of sewage solids should be removed manually if very heavy. Resting the filter may permit drying, which may be hastened by picking or harrowing. Chlorination is effective in control of pooling caused by organic growths. Copper sulphate will aid in growth elimination. Patches of disin-

tegrated filtering material or fines should be dug out and replaced with clean and sound material. Disintegration does not occur if the original media was durable and free from dust and fines. Not much can be done if the filter is grossly overloaded and the slimes essential to purification become "sick." When this stage approaches, begin asking for additional capacity.

7. An abundant air supply within the filter is necessary to its proper functioning. Keep the underdrains free from growths, fallen stones, or stone dust, and be sure the ports are clear. Hosing under pressure or rodding is effective. Without ventilation a filter will perish.

8. Filter flies, the *psychoda alternata,* are a nuisance and a vexing problem. Flooding controls flies, but also nauseates the effluent, so there is a problem as to which is the greater evil. A water springtail, *achorutes viaticus,* if indigenous or cultivated is said to be an effective fly eradicator. Resting the bed for a period of two weeks in spring has been beneficial in diminishing the fly population. Filters dosed with preaerated settled sewage are relatively free of flies. High rate filters count control of the fly problem among their advantages. There is considerable interest at present in the possibilities of DDT as a means of filter fly control and the results of studies now underway are anticipated with interest. Chlorine for fly control has both advocates and opponents. It should not be overlooked.

9. The filter effluent contains varying amounts of suspended matter sloughed from the filter stones. This "slough" is intermittent and hence quite heavy at times from standard filters; it usually occurs constantly and uniformly at high rate filters. Keep the final tank clean. Remove the algae growths and do not allow the sludge to accumulate so that it floats and fouls the effluent. A final tank should be emptied, inspected and thoroughly cleaned occasionally.

10. Watch the point of effluent discharge and permit no rubbish or other debris in the vicinity of the outlet. If on a small stream, keep the channel clear and preferably narrow. Avoid bays and pools and induce ripples if possible.

Accomplishment

A properly designed and carefully operated conventional or standard filter should accept a volumetric loading of 4 m.g.a.d. and a B.O.D. loading of up to 600 lb. per ac. ft. per day, if not subjected to poisoning or overloading slugs of deleterious wastes. Most filters carry less load. The high rate filters are operated at much higher apparent loadings, but their net output has not yet been completely evaluated.

Irrespective of type and disregarding all mention of percentage removals, an acceptable trickling filter effluent for discharge into a small stream without creating a nuisance or destroying fish life, should contain on the average:

Suspended solids	20–30	p.p.m.
5-Day B.O.D.	20–25	p.p.m.
Dissolved oxygen	4–6	p.p.m.
Nitrogen (as nitrates)	4.0	p.p.m.

Conclusion

A trickling filter, particularly one of standard or conventional design is a dependable and reliable device for oxidation of sewage. It can be operated properly at relatively low cost. It can withstand sudden shocks and temporary overloads without serious deleterious effect on the effluent. It is best suited to small and medium sized communities, say, under 60,000. It is effective for many industrial wastes. It has some problems in operation but they are not insurmountable. It can and does produce a stable effluent of good appearance. It has had an honorable and useful past and, on its record, deserves a bright future.

SEWAGE PLANT RECORDS AND OPERATING REPORTS *

By L. S. Morgan

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Sewage treatment plants are constructed and operated for the specific purposes of (1) eliminating stream pollution and (2) protecting the public health. Various degrees of treatment of sewage are necessary to control pollution of streams to the extent required to protect the waters thereof, which are subsequently used for sources of public and industrial water supplies, for bathing places and other recreation and for the support of animal, fish and other aquatic life.

Satisfactory operation of the sewage treatment works to accomplish these desired purposes will generally be reflected in the plant records and operating reports maintained by the plant operators. It is essential that proper plant records and operating reports be maintained for the following seasons:

1. To indicate to the plant operator and responsible officials that the individual units of the plant and the plant as a whole are maintained and operated so as to produce the desired results.
2. To serve as the basis of reports to proper responsible officials.
3. To warn the operator of circumstances which may produce troubles in operation, with resulting lowered efficiency.
4. To serve as a guide for future operations in the light of past experience.
5. To serve as a permanent record of plant performance for use as legal evidence.
6. For reference as a basis for determining future treatment requirements.

The required type of operation records will depend largely upon the degree of treatment provided in the plant, the type of units installed and the personnel and facilities available for plant control work. As a general rule, these records will consist of charts which are produced from operating mechanisms installed at the time the plant was constructed or added thereafter, and those which are made up by the plant operators. This discussion will deal with the latter group.

Operation report forms should be provided for the use of the plant operator at the time the plant is constructed, and these forms should be made up for the individual plant under consideration. While it is true that plants having the same degree of treatment and the same types of units can use similar operation reports, some variations may be necessary in the type of data to be recorded.

In addition to the information to be specifically recorded on the standard report form, the plant operator should maintain a daily log book which should contain certain notations on circumstances encountered in plant operation and control which are not otherwise recorded, and thus serve as a record of unusual occurrences. Forms for recording the information to be kept as an operating record should be printed and preferably made up in tablet form so that multiple copies can be produced at the time the original is made. Generally, the Pennsylvania Department of Health requires sewage works operation reports to be submitted at weekly intervals, such reports containing the daily records of operation and the results of such tests and analyses as are deemed necessary for the proper control of the operation of the plant.

All operation report forms should contain certain essential information.

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This would include the day of the week and date, the general weather conditions, the daily temperature and preferably daily precipitation. The report should also show the total sewage flow and the sewage temperature; the particular plant units in and out of service; the amounts of chemicals used at the designated points of application; the volumes of screenings, scum and sludge removed from each unit or transferred from one unit to another, the final disposition of these materials; the dates of cleaning various units; the depth of sludge accumulated in tanks, introduced onto beds or other drying facilities and removed therefrom; and should include a space for general remarks in which can be placed specific information concerning the condition and use of units in the plant, prevalence of odors in the vicinity of the plant, condition of receiving body of water above and below the point of discharge of the plant effluent, and other pertinent data.

No operation report is complete without the results of physical and chemical determinations made of samples of the sewage as it enters the plant and passes through successive steps in treatment, as well as a record of the removals obtained by each successive step. The minimum determinations which should be recorded as a part of the operation report include tests for settleable solids, pH values of sewage and sludge, chlorine residual and relative stability, with the latter test being supplemented by 5-day B.O.D. determinations where adequate facilities are available.

An index map and flow diagram placed as a permanent record on the report form is a material aid in designating the various units of the plant by number and in the interpretation of the detailed data reported.

Operation Data

It is rather difficult to outline in general the specific information which should be included on each operation report because of the variation in the type of units and the degree of treatment provided for individual sewage treatment plants. The following summarized data, however, will give each plant operator an indication of the type of information he should record on his daily log and on his operation report, in accordance with the more common types of units found in sewage treatment plants:

Sewage Pumping Station:

1. Pumps in operation
    a. Hours operated
2. Times trash screens cleaned
    a. Quantities of trash removed

Weather Conditions:

1. Notation of weather prevailing
2. Air temperature
3. Daily precipitation

Raw Sewage:

1. Total daily flow
    a. Minimum flow rate
    b. Maximum flow rate

Grit Chambers:

1. Units in service
2. Amount of material removed daily
3. Disposition of grit
4. For mechanically cleaned chambers, hours mechanism operated

Screen Chambers:

1. Units in service
2. Amounts of material removed
3. For mechanically cleaned screens, hours mechanism operated
4. Disposition of screenings

Sedimentation Tanks:

1. Septic tanks:
    a. Tanks in use
    b. Period in service
    c. Depth of sludge and scum
    d. Scum broken up
    e. Volume of sludge and scum withdrawn
    f. Disposition of sludge
2. Mechanically cleaned tanks:
    a. Units in service
    b. Hours mechanism operated
    c. Volumes of sludge and scum removed
    d. Disposition of sludge and scum

3. Inhoff tanks:
    a. Units in service
    b. Volume scum removed
    c. Cleaning of septum walls and slots
    d. Disposition of scum

Sludge Digestion Tanks:

1. Imhoff:
    a. Thickness of gas vent scum
    b. Depth of sludge
    c. Scum broken up in gas vents
    d. Amount of lime added when needed
    e. Volume of sludge withdrawn
    f. Disposition of scum and sludge
2. Separate digestion:
    a. Volume of sludge added
    b. Volume supernatant liquor withdrawn
    c. Hours agitation equipment operated
    d. Volume of water circulated
    e. Temperature heating water and return
    f. Volume of sludge removed
    g. Volume of sludge transferred
    h. Amount of lime added
    i. Sludge temperature
    j. Volume of gas produced
        (1) Volume of gas used
        (2) Volume of gas wasted
    k. Depths of sludge and scum in tank

Dosing Chambers:

1. Number of doses
2. Dosing equipment and tank cleaned

Trickling Filters:

1. Number of units in service
2. Inspection of surface media to detect clogging
3. Method of treatment to prevent pooling
4. Method of treatment for control of filter flies
5. Distribution system
    a. Number of nozzles cleaned
    b. Number of orifices opened
    c. Flushing and cleaning distributor lines
6. Underdrain system
    a. Flushing and cleaning

Activated Sludge:

1. Number of tanks in service
2. Volume of air applied
3. Volume return activated sludge
4. Volume of waste activated sludge
5. Air diffusers cleaned
6. Disposition waste activated sludge
7. Amounts and kinds of chemicals used for conditioning activated sludge

Final Settling Tanks:

1. Units in service
2. Depth of sludge in tanks
3. Tanks cleaned
4. Volume of sludge removed
5. Disposition of sludge
6. For mechanically cleaned tanks, hours mechanism operated

Intermittent Sand Filters:

1. Number of units in service
2. Depth of dosage applied to beds
3. Number of doses
4. Number of beds cleaned
5. Volume of material removed
6. Disposition of material removed
7. Depth sand replaced

Sludge Drying:

1. Sand beds:
    a. Number of beds in service
    b. Depth of dosage and volume sludge applied
    c. Period necessary for drying
    d. Depth and volume of sludge removed
    e. Drying beds cleaned
    f. Disposition of sludge
    g. Depth sand replaced
2. Vacuum filters:
    a. Number of units in service
    b. Hours operated
    c. Volume of sludge filtered
    d. Amounts of conditioning chemicals added
    e. Filters cleaned
    f. Quantity of sludge cake produced

Chlorination:

1. Weight of chlorine tanks daily
2. Amounts of chlorine applied per day at designated points of application
3. Rates of chlorine application in lb. per m.g. or p.p.m.

The terms used for indicating the volumes of material removed in various processes will generally be in cubic feet where the material is removed in a fairly dry state, such as from trash screens, grit chambers, screen chambers and detritor tanks and skimming mechanisms for sludge removal and drying facilities. For sewage flows the results should be given in terms of gallons for small plants, thousands of gallons for intermediate size plants and millions of gallons for large plants. For miscellaneous items such as temperature, rainfall, gas produced, etc., the conventional terms generally applied to the specific items should be used. All entries for miscellaneous data not included as daily operational procedure should be made opposite the dates on which such observations or operations are made.

Analytical Determinations

Such physical and chemical determinations as are necessary for the particular plant should be made at sufficiently frequent intervals to indicate that the various processes of treatment and the plant as a whole are functioning in a proper manner.

Selection of the proper determinations to be made will depend on the type of processes involved, the degree of treatment provided and facilities available, and the frequency of the determinations will depend on the number of operating and laboratory personnel employed.

It is difficult to set forth the kind and frequency of analytical tests to be made at each particular plant. The following summary will, however, give the minimum determinations which should be made for proper plant control for all sewage treatment plants, the additional desirable determinations which should be made where facilities and personnel are available, and other determinations necessary or desirable for special treatment processes and for special conditions.

Determinations of pH should be made of the raw sewage daily, the sludge in the digestion tanks at least semi-monthly, the supernatant liquor from the separate sludge digestion tanks at least semi-weekly, and of the raw and conditioned sludge where it is chemically treated prior to filtering, daily.

Settleable solids determinations should be made daily of the raw sewage, the primary effluent, the secondary effluent and of the final effluent, and the per cent removals noted. Where facilities and personnel are available, the determination for settleable solids should be supplemented by the determination of suspended solids.

Methylene blue determinations of relative stability should be made daily where possible, but at least twice weekly, of the effluents from trickling filters, intermittent sand filters and activated sludge processes. Where personnel and facilities are available, the relative stability tests should be replaced by 5-day B.O.D. determinations made at the same frequency but in addition, made of the raw sewage and of the primary effluent.

Residual chlorine determinations of the disinfected effluents should be made at least daily.

Where separate sludge digestion is employed or where better control is desired of digestion and sludge drying processes, total and volatile solids contents of the raw, digested and dried sludges should be determined. Volatile acids determinations may be helpful in control of heavily loaded digesters.

Where the activated sludge process of treatment is employed, tests for dissolved oxygen should be made of the sewage in the aeration and final settling tanks, as well as mixed liquor settleability tests. The suspended solids content should also be determined of the mixed liquor and of the return activated sludge.

Where the sewage is discharged into streams used as sources of public water supply or for bathing or other recreational purposes below the point of discharge and in close proximity thereto, bacterial tests of the effluent should be made.

Other desirable tests, for more complete control of operation and for additional information concerning the efficiency of treatment, include dissolved oxygen, free ammonia, nitrites, nitrates, organic nitrogen, chlorides, chlorine demand and oxygen consumed.

Special determinations are also necessary at times if industrial wastes, which are not normally present in the raw sewage, are suspected and if interference with treatment efficiencies is being experienced.

Sampling

The results of analytical determinations included in the operation report can only represent true conditions if the samples collected are representative of the sewage flow and the determinations are made in accordance with accepted standard practice.

It is best to collect individual samples at definite intervals, and to combine these individual portions into a composite sample for analysis. Daily composite samples can be made up from individual samples collected over 12- or 24-hr. periods, and weekly composite samples can be made from composite daily samples. If at all possible, the individual samples should be combined into the composite sample in volumes proportional to the volumes of flow. The analyses of composite samples will be much more representative of conditions at the plant than results obtained from mere "catch" or "grab" samples.

If personnel is not available to permit the collection and compositing of individual samples over 12- to 24-hr. periods, than a composite sample might be made covering a shorter period, provided that such period is selected to coincide with the general prevailing periods of greatest sewage load.

Care should be taken in collecting sewage samples to use wide-mouthed sampling containers. In making composite samples definite intervals for the collection of the individual portions that make up the composite sample should be established and followed. If a short period of compositing is used, individual samples should be collected at least every half-hour, and if a longer period is used, individual samples should be collected at least every hour.

The manual *Standard Methods of Water and Sewage Analysis* should be followed closely in all laboratory procedures.

Miscellaneous Records

Permanent records should also be kept of the power consumption within the plant by the taking of daily meter readings, with separate readings of power consumption for special processes.

Regular checks should be made to determine the conditions of all mechanical and electrical equipment in the plant, and notations made in the daily log of any replacements or repairs made to such equipment, and of all maintenance done in connection therewith.

Where records are made of such things as air temperature, rainfall, time of emptying and filling tanks and other related matters, they should be made at a stated time each day.

No plant records are complete without a detailed record of the costs of operation. In addition to the usual fixed charges, the plant operator should maintain a complete record of the costs of materials and chemicals used for maintenance and operation of the plant, cost of power purchased, cost of equipment replaced and cost of additional labor employed.

If adequate and satisfactory weekly or monthly records are maintained, then annual operation and cost reports can be readily made up in a convenient manner.

Use of Operation Reports

Records maintained just for the sake of having them are of little value to the plant operator or to the officials responsible for the supervision of the treatment works. They should be referred to frequently by the plant operator and should be used as yard-sticks for measuring the efficiency of the plant, for indicating changes in operation and treatment methods to secure better plant performance, and to show the need for additions or enlargements to the plant, or the need for additional treatment.

THE EFFECT OF INDUSTRIAL WASTES ON SEWAGE TREATMENT *

By Christian L. Siebert

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This paper is intended primarily as an aid to sewage works operators and interested municipal authorities in their establishment of policies and regulations concerning the discharge of industrial wastes to the public sewer system. In approaching this subject, it appears desirable to classify industrial waste problems into three groups, according to the general method of handling: (1) the discharge of untreated wastes directly to the public sewers, (2) the discharge of partially treated wastes, after preliminary treatment by the industry, to the public sewers for final treatment and disposal and (3) complete treatment and disposal by the industry in its own facilities and with no discharge to the public sewers. This paper deals only with problems of the first two classes.

In most of our older and larger cities, and also in many smaller communities, the discharge of untreated wastes to public sewers has become established from earlier days when the town drain, usually an open ditch, constituted the beginning of the sewer system. As sewage treatment works were added to sewer systems it became common practice to continue to accept industrial wastes for treatment with sewage. The increasing complexity and magnitude of industrial waste problems, as well as the refinement and increased sensitivity of sewage treatment processes, have brought about difficulties in the operation of sewage treatment works. The history of such difficulties confirms the importance of so regulating the discharge of industrial wastes to public sewer systems that abuse of the treatment works will not result. This is now ordinarily accomplished by private preliminary treatment of the industrial wastes or, in some instances, by the exclusion of particularly troublesome wastes from the sewers.

The acceptance of untreated industrial wastes by the public system is ordinarily most economical in over-all cost. This is particularly true in the larger communities having diversified industries of ordinary type and magnitude wherein the waste waters, of varying character and of not disproportionate volume, mix with domestic sewage so that their objectionable characteristics are largely neutralized or offset to permit unimpaired operation of sewage treatment works. Very real difficulties may result, however, in relatively small communities due to the discharge to the sewer system of incompatible waste waters from one or a few large industrial establishments.

It is obvious that, even if industrial wastes are of generally acceptable

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character, proper consideration must be given to the type of sewage treatment selected and to the capacities to be provided. Also, some industrial establishments are so located that, due to space limitations or other considerations, it is not practicable to provide private treatment worthy of the term, and municipal authorities may elect to accept the untreated waste waters into the sewer system and to design the sewage treatment works to treat the sewage and industrial wastes jointly.

Objectionable Industrial Waste Characteristics

Certain industrial wastes are of such character that they will disturb sewage treatment processes, harm structures or add unduly to the cost of operating the treatment plant. Obviously, such wastes must be excluded from the sewer system and the responsibility for disposal must be placed entirely on the industrial management.

A number of characteristics making industrial wastes objectionable or unacceptable in public sewer systems are listed and discussed:

Excessive Volume

Whether continuous or periodic, large volumes of industrial wastes would ordinarily require unreasonably large sewage treatment units and would usually justify the installation of private treatment works particularly designed for the character of the individual waste. Waste waters from some paper mills would be typical of this category.

Clean Water

There would be nothing to gain and everything to lose in adding clean or very slightly polluted waste waters to sewage, unless dilution is desired. Waste water from condensers, air conditioners and refrigerating systems should be discharged directly to streams or to storm drains and relatively clean rinse waters may sometimes be disposed of similarly. Arrangements are under way in Philadelphia for the construction of separate drains to convey to the river the tremendous volumes of slightly polluted waste waters from the barometric condensers of evaporating systems for treating the highly polluting slops from large commercial alcohol distilleries. At Paterson, New Jersey, diversion to the river of an average of 11 m.g.d. of rinse waters from textile dye houses relieved the overloaded Passaic Valley trunk sewer to save an annual expense in sewage treatment of $35,000 as well as an estimated $908,000 for construction of a relief trunk sewer.

Hot Water

Appreciable increase in the temperature of sewage stimulates septic action in sewers, releases offensive gases at manholes, accelerates deterioration of cement and bituminous joints in sewers and increases odors at sewage treatment works.

Excessive Inorganic Solids

Grit or insoluble slurries may overload grit chambers, add to sludge volumes, compact sludge to clog hoppers and pipes and, possibly, develop heavy inert accumulations difficult to remove from sludge digestion tanks. Coal ash from boiler rooms, foundry sand, surface wash, automobile laundry wastes, lime wastes from tanneries, acetylene gas generator sludge and wash water from vegetable canneries are among the waste waters containing such substances. The literature contains references to difficulties at Milwaukee attributed to wastes from stone and marble works and acetylene sludge, and to the clogging of sewers in Massachusetts by tannery lime wastes. The removal of sand and grit from Imhoff tanks has been frequently reported.

Coarse Suspended Matter

Obstruction of sewers, overloading of screens, excess scum in settling and digestion tanks, putrefaction in sewers and disturbance of digestion may be caused by coarse suspended matter such as spent grains from breweries and distilleries, fleshings from meat packing houses and tanneries, solids from vegetable canneries and yarn and fabric from textile mills. Some years ago the writer found that foul odors from sewer manholes in Erie, Pa., were caused by decomposition of stranded fleshings from a meat packing plant and the trouble was solved by installing specially locked screen plates in all floor and tank drains to prevent workmen from lifting the loose screen plates and flushing the scraps to the sewer. At a shoddy mill in Norristown, Pa., it was necessary to install mechanical fine screens to prevent clogging of municipal sewers with matted masses of yarn and fabric resulting from the shredding of woolen cloth.

Excessive Suspended Solids

Sewage treatment works are intended to remove suspended solids but an excess of such matter over the designed capacity, particularly if rapidly decomposable, often impairs plant operation by preventing effective clarification, increasing sludge volumes and causing difficulties in sludge digestion. In the small community of Jeanette, Pa., brewery wastes, including the explosively decomposable proteins of spent yeast flushed from the bottoms of ageing vats, caused such violent disturbance in the activated sludge plant that it was necessary to suspend entirely its operation until the brewery wastes were excluded. At the South plant in Lancaster, Pa., also an activated sludge plant, brewery wastes were again responsible for at least part of the disturbance in plant operation. At Akron, Ohio, rubber reclamation wastes carried more suspended solids than the sewage from the entire city. It is reported from Michigan that paper mill white water produces excessive sludge volumes, although mention is not made of particular difficulties in sludge digestion.

Dissolved or Colloidal Organic Matter

Overloading of sewage treatment works with reduced efficiency, septic disturbances and offensive odors may be caused by excessive organic matter in solution or as colloids. Milk and milk products plants produce waste waters ordinarily having a B.O.D. of about 1,000 p.p.m., or about five times that of average sewage, and heavy discharges of such wastes will affect sewage treatment processes. Many instances have been reported of foaming in Imhoff tanks due to milk wastes. The waste waters from vegetable canneries (corn 2,500 p.p.m. B.O.D., peas 1,400 p.p.m. and tomatoes 850 p.p.m), usually large in volume and seasonal in incidence, may easily disrupt plant operation. Wastes from distilleries, breweries, tanneries, rubber reclamation plants, wool scouring and textile washing may also be troublesome. Cherry and tomato cannery wastes seriously affected the sewage treatment plant at North East, Pa. Dissolved and colloidal matter in brewery wastes has contributed to operating difficulties at Jeannette, Lancaster, and Norristown, Pa. A large meat-packing plant in Allentown, Pa., quite effectively removes grease and the larger solids from its waste waters but, nevertheless, odors and other objectionable conditions result therefrom at the municipal sewage treatment plant. In Washington, D. C., yeast plant wastes, high in both sulphur and temperature, have been held responsible for disintegration of sewers. It is reported that in Gastonia, N. C., textile wastes not only colored the effluent of the sewage treatment plant but disrupted the activated sludge process.

Grease, Oil and Tar

Many sewage treatment plants have been somewhat affected by floating oil and accumulations of grease. Grease and oil, as well as heavy tar, may become incorporated with settling solids to disturb normal sludge digestion. Furthermore, oil in a treatment plant is a possible fire hazard. Automobile laundries, garages and service stations, oil refineries, machine shops, meat packing plants, hotel and institutional kitchens, wool scouring plants, and gas works are common sources of such objectionable matter. Garages and service stations, particularly, are a potential danger because of the convenience of the floor drain for disposal of oil by the careless employee, and suitable separators or traps should always be required and their frequent cleaning enforced. At Clifton Heights, Pa., the waste waters from wool scouring plants are separately collected and subjected to preliminary sedimentation and grease flotation before discharge to the public sewer.

It seems pertinent to mention the inadequacy of most grease traps installed in the drains serving large kitchens, and their almost universal neglect. It is the writer's opinion that, in most instances, the commercial grease trap as installed by the average plumber is of practically no value to anyone, except for the profit to the plumber, because it is invariably filled with grease in a very short time and, not being cleaned at proper intervals, is about as useful as is the human appendix.

Inflammable Substances

Explosions in sewers, pumping stations and sewage treatment plants caused by gasoline or other inflammable liquids have been all too frequent and have resulted in loss of life, personal injuries and great property damage. Waste waters from garages, dry cleaning plants, chemical industries and gas works are among the possible sources of such dangerous liquids. The literature records an explosion in a sewage pumping station in East Boston in 1914 which killed six persons and injured others, and also a serious explosion at Springfield, Mass., in 1934. The writer recalls viewing the damage of a sewer explosion in Pittsburgh some years ago when several blocks of a street were destroyed.

Acid Wastes

The disintegration of concrete sewers, cement joints, treatment plant structures, pumps and iron pipe may be caused by acid wastes, which sometimes may be sufficiently strong to interfere with biological sewage treatment processes. Waste waters from metal pickling, certain oil refining processes and many miscellaneous industrial processes contain acid. At Fostoria, Ohio, acid-iron wastes completely clogged a trickling filter and Cleveland also reported serious difficulties from such wastes. At West Pittsburgh, Pa., some years ago, the piping valves and concrete of the small community sewage treatment plant were so disintegrated by the spent acid pickle liquor of the town's principal industry that major reconstruction was necessary. It seems pertinent to mention here the danger of the clogging of air diffusers in activated sludge plants by acid-iron wastes discharged to sewers.

The Maryland Board of Health has established a minimum pH of 4.0 for wastes discharged to concrete sewers and some other authorities consider pH 5.5 as the acceptable minimum.

Strongly Alkaline or Caustic Wastes

Pumps and metal pipe may be attacked by strong alkaline or caustic wastes which may also affect biological treatment processes. Kier liquor from textile mills and caustic rag digester wastes from some paper mills are possible causes of such trouble. Salt from the leaching of green salted hides at Hanover, Pa., caused the destruction of a pump serving to lift the waste waters from a hide and tallow plant to the public sewer system, and the overflow from the inoperative pumping station killed thousands of fish over a stretch of several miles in the receiving stream.

Toxic Substances

The disruption of biological processes of sewage treatment by a number of toxic wastes has become more common recently, due in no small part to the development of metal plating and to the more common application of chemical processes in many of the smaller industrial establishments. Cyanides as wasted from metal plating, although not cumulative, are toxic to biological activity when present in dilutions as low as 1 p.p.m. Copper, also common in plating wastes, is cumulative in effect and even small amounts will prevent sludge digestion. Phenols from gas works, arsenic and lead compounds are also harmful. Activated sludge plants and trickling filters are particularly susceptible to disinfectant or toxic substances.

At the Calumet plant of The Sanitary District of Chicago, wastes from the paint industry, containing copper, arsenic and lead interfered seriously with activated sludge and trickling filter units. At Muskegon Heights, Mich., copper and cyanides from metal plating practically stopped sludge digestion. At Lancaster, Pa., overflow of phenolic wastes from a gas works to the public sewers disrupted the action of an activated sludge plant.

Miscellaneous Wastes

Appearance or odor of sewage treatment plant effluent may be affected, as well as disturbance of biological treatment processes, by dye wastes, spent tanning liquor and strong wastes from meat packing, wool scouring and other industries. Faint color, of itself, need not be objectionable in a treatment plant effluent, as considered by the sanitary engineer, but most complaint from the public is based on appearance of a stream. Most of the dyes now used in the textile industry are of the "direct" type and the wasted color is largely absorbed by sewage particles or dissipated in oxidation processes. Odors in sewage treatment plant effluents are, however, sometimes quite significant and may lead to the identification of industrial wastes whose harmful effects on the sewage treatment process might not otherwise be recognized.

Although often overlooked, laundry wastes are sometimes a disturbing factor in sewage treatment plant operation, as learned by a number of operators of treatment works at military establishments. It appears logical, in general, to assume that if laundering were done entirely in homes there would be no question about the propriety of admitting the laundry water to the sewers, in spite of the heavy Monday load. Large commercial laundries, however, particularly in small communities, may discharge intermittently such large quantities of wastes, heavy with soap, that sensitive sewage treatment processes may be seriously disrupted. Institutional laundries are notorious for their effect on sewage treatment plant operation. It is well to remember that laundry wastes are considerably higher in pollutional characteristics than is the average dye house waste.

Preliminary Treatment of Industrial Wastes

In spite of the many difficulties involved in the acceptance of industrial wastes in the public sewer system the practice is, in general, the best method of handling the problem. Certain wastes having objectionable characteristics, however, must be given preliminary treatment at the source to eliminate or minimize their harmful effects. In addition, the few wastes which are incompatible and incapable of satisfactory treatment by available sewage treatment processes must be excluded from the sewers. The usual methods applicable to the preliminary treatment and control of industrial wastes follow:

Regulated Discharge: It is obvious that if a waste normally discharged in 8 hours is uniformly distributed over 24 hours its effect should be reduced to one-third. This applies not only to volume but also to organic load and temperature. Holding tanks or basins with orifice box control of discharge are practical for this purpose and may be supplemented by aeration to prevent odors of decomposition during the storage period.

Screening: Excessive solids can be retained by passage through screens of suitable fineness. Mechanical screens of both the vibrating and rotary type are in common use and are much more satisfactory than manually cleaned screens which are too often neglected.

Plain Sedimentation: Heavy settleable solids, such as grit and other mineral matter, can be retained in grit chambers or properly designed sedimentation tanks. Similar treatment may sometimes be justifiable for removal of excessive organic solids such as from meat packing plants and vegetable canneries.

Chemical Coagulation and Sedimentation: In addition to plain sedimentation, chemical coagulation may be resorted to for removal of fine suspended solids and colloidal matter if such matter proves troublesome.

Flotation: Removal of oil and grease by flotation in units known as separators or grease traps is standard practice and the value of the reclaimed material often pays for the cost of its recovery. Application of diffused air or chlorine adds to the effectiveness of such treatment.

Acid Cracking: Grease and oils in emulsified form are not separable by plain flotation and must sometimes be subjected to acidification to break the emulsion and cause the grease or oil to float.

Neutralization: Acid wastes may be neutralized by properly controlled application of alkaline agents but it may be necessary to supplement this with sedimentation to prevent admission of resultant sludge to the sewer system.

Modification of Manufacturing Processes: It may be justifiable and even necessary in extreme cases to reduce or eliminate particularly objectionable waste water characteristics by effecting major changes in plant operations or processes. Careful studies to this end undertaken by plant managements will often reveal needless extravagance in use of water, waste of soap or chemicals and failure to recover materials which may become valuable by-products.

Heat Exchange: Reduction in temperature of waste waters may be reduced, often with substantial savings in fuel, by the installation of heat-exchange apparatus.

Chlorination: Rapidly decomposable material may be treated with chlorine before discharge to suspend decomposition and thereby control objectionable odors from sewer manholes and prevent production of destructive compounds until the waste waters become sufficiently diluted farther down in the sewer to establish a safe balance.

A few examples of typical methods of preliminary treatment follow:

1. *Abattoirs and Packing Plants:* Segregation and salvage of blood, paunch manure, etc., screening and salvage of fleshings, sedimentation of fine solids, flotation and recovery of grease (possibly with addition of chlorine or air) and carefully planned economy in use of water.
2. *Acid Pickle Liquor:* Neutralization and sedimentation.
3. *Breweries:* Screening of spent grain for use as cattle feed and, sometimes, regulated discharge of aging vat lees, bottle wash and keg wash. In large breweries conversion of vat lees to foodstuff of high vitamin and pro-

tein content might be profitable or at least justifiable if exclusion from the sewer system is necessary to prevent disturbance of sewage treatment processes.

4. *Gas Works:* Exclude entirely from sewers.
5. *Paper Mills:* Generally to be excluded from sewers but sometimes admissible if the volume is reduced to a minimum by recirculating or closed system, including an efficient "save-all" for retention of settleable or flotable solids.
6. *Vegetable Canneries:* Screening through 30- or 40-mesh wires, correction of reaction if a low pH is troublesome and possible regulated discharge. Relatively clean cooling water should be excluded from the sewers.
7. *Milk Plants:* Minimize milk losses from can washing by installation of drip savers and pre-rinse jets and prevent losses from evaporators by the installation of entrainment separators. Positively prevent the discard of skim milk to sewers. Regulated discharge is sometimes advisable because of peak high loads and aeration of waste holding tanks is desirable to prevent septic action and local nuisance.
8. *Textile Mills:* Screening and regulated discharge may suffice but chemical coagulation and sedimentation may be necessary in some cases. Regulated discharge is sometimes important to prevent bulking in activated sludge plants. Color, in itself, is ordinarily not important, particularly if the sewage treatment process includes oxidation. If sulfur dyes are present special treatment may be necessary. Wool scouring wastes usually require special treatment for removal of grease.
9. *Distilleries:* All distillery slop should be screened for recovery of spent grain, which is valuable as stock feed, and the screened slop should be completely evaporated to produce material of high vitamin and protein content for fortification of foodstuffs. Large volumes of barometric condenser water should be excluded from the sewer system.

Inspection and Control

The problem is not solved merely by the installation of properly designed works for preliminary treatment of objectionable waste waters. Routine inspection by municipal authorities and tests of efficiency of such works must be made to insure their proper operation and maintenance. Industrial managements are too likely to forget their responsibilities in matters which do not produce a profit but which, on the contrary, usually cost in proportion to their effectiveness.

An essential feature in a program for control of sewage treatment difficulties due to industrial wastes is an orderly system of recognizing trouble when it occurs, identifying its source and setting in motion the machinery for correction at the source. Following is an outline of procedure applicable to an average situation:

1. Operator observes and records difficulties—date, time of day, appearance, effect, etc.
2. Operator reports to superintendent or engineer.
3. Superintendent or engineer makes survey to identify source of harmful waste.
4. Superintendent or engineer reports conclusions to department head or council.
5. Municipal authorities negotiate with management of responsible establishment for adoption of suitable preliminary treatment or elimination of harmful discharge.
6. Careful study of plans for preliminary treatment by the engineer and approval of treatment by municipal authorities only if the proposal is fully satisfactory and then subject to suitable conditions and stipulations.

Conclusion

The operator who merely grumbles, speculates and struggles to combat the effects of industrial wastes on his plant is likely to cultivate an unpleasant disposition while the condition steadily becomes worse. Alertness to unusual difficulties and a systematic procedure toward correction are necessary to keep plant ailments from becoming chronic.

The best efforts of a plant operator are of little avail if he is not supported by superiors who are willing to help him in his difficulties and who have proper legal control over the use of the sewerage system. Every municipality should have a comprehensive ordinance, prepared by experts, specifically regulating industrial waste discharges to the sewer system. Moreover, although this is perhaps beyond the intended scope of this paper, the writer is of the firm opinion that an equitable and rigidly administered fee or rental system for admission of industrial wastes to the public sewer system not only places the burden of expense where it belongs, but is an important element in establishing the proper responsibility to prevent abuse of sewage works.

USE OF EFFLUENT WATER IN SEWAGE TREATMENT PLANTS *

By Robert Burrell

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The proper use of water in any sewage treatment plant is an important factor in the economy of plant operation. If plant effluent water can be used as a substitute for the public water supply in operations where potable water is not absolutely essential, a yearly saving can be realized which may pay off the cost of the original investment in two or three years. At West Haven, use of the public supply has not been abandoned, but it is reserved for necessary services only. In cities or towns where the watersheds are in a constant source of danger from drought and evaporation the saving of public water by the local sewage treatment plant might well be an obligation which should not be overlooked.

An effluent water pumping system is used successfully at West Haven. The raw sewage at the plant is settled in three plain sedimentation tanks, each 100 ft. long, 12 ft. wide, and having an average water depth of 8 ft. Raw sludge is collected in hoppers at one end of the tanks. This raw sludge is filtered through two vacuum filters. Before discharge to Long Island Sound the settled sewage is disinfected with chlorine. The town population is 30,000; the sewerage system serves 25,000. The remaining 5,000 people are served by private septic tanks and cesspools.

In 1940 Mr. Robert J. Hodge, president of the American Buckle Company and a member of the local Board of Finance, criticized the yearly plant bill for public water which amounted to $1,300. He said that his company used a well-point system with pressure tank and air compressor, which supplied them with all the water required at a good saving in plant operation. He suggested that this system be investigated and, if found practical, that a similar one be installed at the sewage treatment plant.

Well-point tests made at the plant indicated a fine sand infiltration at depths down to 50 ft. This method was abandoned and studies were made by John F. Lynch, Town Engineer, to

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determine the use of effluent water pumped through a pressure system. It was decided that a basement storeroom 12 ft. square in the main operating building would serve as a pump room. Effluent water could be taken by gravity from the effluent channel to the pump. The difference in elevation allowed a minimum 6-ft. head of water above the center line of the pump inlet.

The project, as installed, will be discussed in this paper under the following five divisions: (1) construction, (2) maintenance, (3) uses and advantages, (4) disadvantages and (5) cost and savings.

Construction

A pump, motor, pressure tank, Nu-Matic tank and pressure regulator were brought from the Fairbanks-Morse Co. These items comprise the pumping system and are described in detail as follows:

One 1½-in. centrifugal pump. Figure Number 5870 NE, with a speed of 3,450 r.p.m. This pump is capable of discharging 100 g.p.m. at 60 p.s.i.

One 7.5-h.p. Type QS Fairbanks-Morse ball bearing motor, 3,600 r.p.m., 3 phase, 60 cycles, 220 volts.

One 525-gal. capacity black iron pneumatic pressure tank, 10 ft. long and 3 ft. in diameter. The working pressure is 75 p.s.i. This tank is equipped with a manhole and cover on one end and with water gauge glass, valve and drain cock fittings.

One Cutler-Hammer diaphragm pressure regulator, set to operate between 50 and 70 p.s.i.

One Nu-Matic water and air control tank manufactured by the Clayton Manufacturing Company of Alhambra, California.

The price of all the above equipment was $415 with freight allowed to West Haven, Conn. These prices were at pre-war levels. The equipment was installed with plant labor and engineering but electrical and plumbing work was done by contract.

It was suggested that a small air compressor be installed as a standby unit in case of an emergency breakdown, which unit would have cost $100. This was not purchased but a broken connection was installed in order to use the public water service if required. This has been a safety factor and it has been necessary to use it several times in five years. Each time the effluent water system was restored to service as soon as possible.

During construction work the pump house was by-passed and the flow of water diverted from the effluent channel to Oldfield Creek, which flows to New Haven harbor.

About 80 ft. of 4-in. feeder pipe was installed from the effluent channel to the pump inlet in the pump room. This run of pipe required holes to be broken in three concrete walls and the last 2 ft. of excavation was in mud. A sump pit dug lower than the trench floor helped the pumping operations considerably. All piping laid in trenches was supported with 12 in. of stone ballast, which covered the floor of the trench. All piping of 2-in. or over was lined inside with bitumastic and the outside was covered with bitumastic and wrapped in felt.

It is necessary to strain the effluent water before it enters the pumping system (Figure 1). A standard piece of 4-in. pipe, 4 ft. long, was drilled with 6 rows of ½-in. diameter holes spaced 4 in. on centers. This strainer is capped at one end and the other end is connected to a 4-in. gate valve.

Another strainer made of fine wire mesh was built to enclose the perforated pipe. The protection of both strainers allows nothing but the finest silt or grease to flow through to the pumping system. There are occasions, however, when tomato seeds pass through the strainers. This strainer system is located in the effluent channel of the settling tanks and a 6-in. baffle was built ahead of the strainer to insure submergence at the hours of least flow. This bulkhead is open at the bottom for the full width of the channel to prevent sedimentation and to allow a steady flow. The strainer pipe was laid so that the pipe invert is 2 in. above the concrete channel floor. This clearance allows the fine screen to be telescoped over the coarse strainer.

At the pump room end of the suction pipe, just ahead of the pump, was installed a 4-in. gate valve and a 1-in. drain with valve, so that the suction could be cleaned. This drain pipe was carried into a pit in the pump room and piped to the sump servicing the main building.

The 2-in. discharge from the pump is connected to the underside of the 525-gal. pressure tank. In this pipe was installed a 4-in. standpipe, 4 ft. long, to act as an air chamber, a 2 in. check valve and then a 2-in. gate valve (Figure 2).

From the discharge outlet of the pressure tank is extended a 2½-in. pipe which feeds two 2-in. pipes, one serving the two chlorinators on the operating floor and the other of which extends to a yard manhole near the three settling tanks. There is a valve control in this manhole and a system of 1½-in. piping and hoses. This system is used to wash down the settling tanks and break down the scum and heavy sludge in the sludge storage basin.

A 2-in. valve was installed at the pressure tank outlet in order to empty the tank for cleaning purposes.

The line serving the chlorinators contains a strainer system which is connected directly to the discharge pipe of the pressure tank. It is constructed similarly to the by-pass piping in a water meter pit. The single 2-in. discharge is separated into two 2-in. by-pass lines by means of tees, elbows and nipples. Each by-pass line contains gate valves set on either side of a combined strainer and sediment trap, which trap has a removable cover and a drain plug. It also contains a strainer screen with fine mesh of about 200 perforations per sq. in. This system allows each strainer to be cleaned separately without shutting down the operation of the pumping system.

A soft silt or grease will collect in the pressure tank even though the effluent water may seem clear. These fine mesh strainers will prevent such sediment from reaching the chlorina-

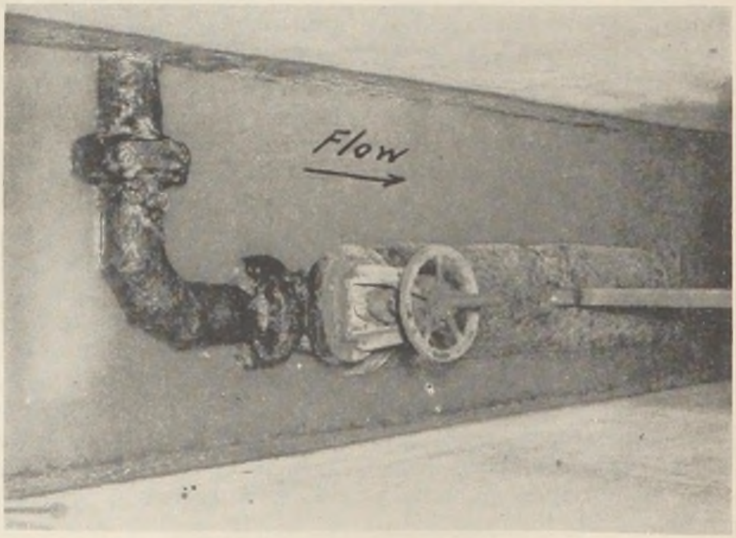

FIGURE 1.—Strainer at suction intake in effluent channel of sedimentation tank.

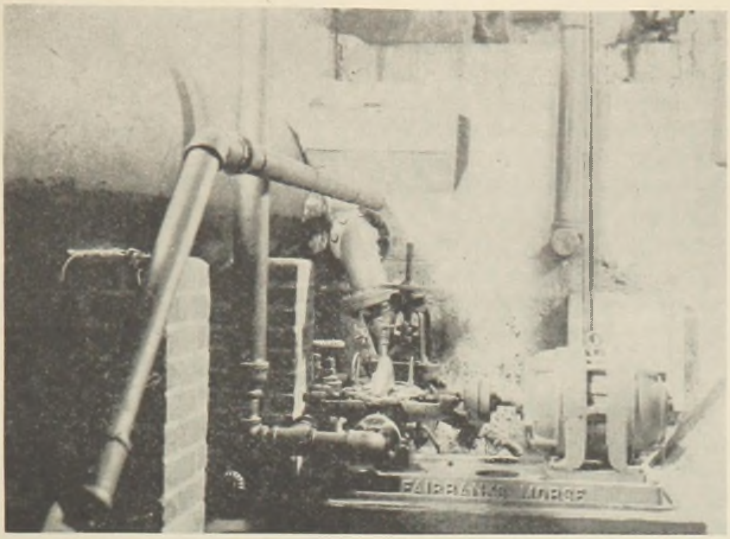

FIGURE 2.—Pump, pressure tank and piping used in effluent water system.

tors and fouling their delicate mechanisms.

Rubber chlorine hose lines, $1\frac{1}{2}$ in. in diameter, extend from the two chlorinators to a valve control board directly behind the machines. From here they extend to pre- and post-chlorination points. There is only one break in each hose line, that being a hard rubber drain valve installed at the lowest point. These chlorine hoses have free open outlets extending into the lowest depths of the screening pit and the outfall pump house pit.

The Nu-Matic water and air control is really the heart of the system. If this fails all operation stops. This device is a small tank $8\frac{1}{2}$ in. in diameter and 28 in. long. It has two chambers, the upper or float chamber and the lower or compression chamber. A copper water tube extends from the bottom of the Nu-Matic tank to the bottom of the 525-gal. pressure tank. Another copper tube for air extends from the top of the Nu-Matic to the top of the pressure tank. A gauge in the air line indicates the pressure in both tanks. The air tube connects to the Cutler-Hammer regulator which in turn connects to an automatic switch which starts and stops the pump motor.

The Nu-Matic control was originally installed in accordance with the manufacturer's instructions so that a predetermined control water line in the top chamber is on the same level as the required minimum water line in the large pressure tank. The control system continues to operate by means of air and water displacement while there is the slightest head of water in the pressure tank above the control water line. The method of operation is explained as follows:

Water is pumped into the pressure tank until the pressure reaches 70 lb., when the pump motor stops automatically. The water in the pressure tank is above the control water line and this head of water causes a flow from the large pressure tank into the bottom chamber of the small Nu-Matic tank. This bottom chamber is originally filled with air at atmospheric pressure which enters by means of a needle valve in the bottom of the tank.

Approximately three gallons of water flow from the pressure tank into the Nu-Matic and while this occurs there is a ball float arrangement in the pressure chamber which operates a see-saw valve controlling the inlet and outlet water and at the same time controlling an air valve to the upper chamber. While filling the lower chamber the water forces the air from the lower into the upper chamber and from there to the top of the pressure tank. This air passes through a water seal in the upper chamber. At the instant the lower chamber is entirely filled with water three valves operate as follows:

The see-saw valve closes the inlet water line and opens the outlet discharge line. The ball float arrangement raises the inverted copper float in the upper chamber and shuts off the air outlet valve. Now the three gallons of water discharge from the bottom of the Nu-Matic tank, the total time of discharge being about one minute. A vacuum has now been created in the lower chamber because the water has forced out the air and has subsequently drained off. Due to this vacuum, air is now drawn through the air needle valve into the lower chamber. Since there is still a head of water in the pressure tank this cycle is repeated.

In this manner three gallons of water flow from the pressure tank into the Nu-Matic tank and the equivalent amount of air flows from the Nu-Matic to the pressure tank. This displacement of water and air continues during the time there is any head of water in the pressure tank. When the water line of both tanks is the same the proper water level and air volume has been attained and from that time the Nu-Matic operates automatically to check and correct this condition.

Maintenance

Once a week the strainer and sediment trap in the water line between the pressure tank and the Nu-Matic tank are cleaned. Both strainers in the 2-in. by-pass system between the pressure tank and the two chlorinators are cleaned weekly. Each month the bonnet from the 1½-in. centrifugal pump is removed and any foreign matter which might have passed through the screens in the effluent channel is cleaned out. The water seal packing and the discharge tubing which serves the water cooling system is checked at this time. It is necessary to shut down the system for about one hour when the pump bonnet is removed but the strainers can be cleaned without stopping the operation.

The pump and motor bearings are checked once a day but lubrication attention is necessary only once in three months. At least once in three months the system is shut down for a general cleaning of the pressure tank. If necessary, the interior of the tank is dried and repainted with hot bitumastic paint. All exposed piping and the pressure tank exterior is painted once a year with bitumastic paint.

Uses and Advantages

Clarified sewage effluent is used to serve two chlorinators, except for maintenance of the seal at the water trays of the machines, where the public water supply is used. Each chlorinator has a maximum chlorine dosage capacity of 300 lbs. per day. These two machines serve two and sometimes three chlorine hose lines of 1½ in. diameter.

The effluent water is also used from a yard manhole to wash down the three settling tanks daily and for breaking up the sludge stored in a converted Imhoff tank. Since this tank accumulates about nine months of sludge before it is pumped to the auxiliary sludge beds, the scum and top sludge becomes very compact and requires heavy water pressure to make it flow through the sludge pumps.

The total volume of water saved by the above uses is estimated at 4 m.g. per year.

Disadvantages

The effluent water system does develop trouble at times. As stated before, the Nu-Matic tank may be classified as the heart of the system and, like the human heart it has its breakdowns. Most of these breakdowns, however, can be repaired and the system restored to operation relatively quickly.

There is a 1/16-in. rod connecting the upper and lower chambers, which helps to operate the ball float mechanism in the pressure chamber. This rod disintegrates due in part perhaps to the effects of the hydrogen sulfide in the effluent water. When the rod fails, it is necessary to dismount the tank entirely and to replace this rod with the toughest piano steel wire available.

The copper flapper valve which operates the air inlet needle is so delicate that a hinge will break occasionally. The holes through which the effluent water passes to actuate the three internal valves are so small that foreign particles will plug them and interfere with operation. The inverted copper float in the upper chamber develops leaks and requires periodic repair or replacement. During the war these replacements were not available and home-made parts were used in order to keep the system operating.

The pump can also develop trouble. Tomato seeds will find their way through the screens in the effluent channel and when they have swelled they will not pass through the small impeller passages of the pump. Since they cannot pass the impeller they cut down the volume of discharge. They have caused the pump to churn and continue to run without reaching the maximum pressure of the regulator. This will generally cause the system to become water-logged. The remedy is to remove the pump bonnet and clean out the shell with a wire hook.

Cost and Savings

The total cost of installing the effluent water system was $1,400. Of this amount $415 was paid for the pump, motor, Nu-Matic tank, pressure tank and the pressure regulator. Most of the unskilled labor was performed by municipal employees. The electrical work and some of the plumbing was done by contract.

The public water bill for the year 1939, before the installation of this system, was $1,300. The public water bill for 1940, the first year of operation, was $720.

The yearly saving is estimated to be $500 after deducting the cost of operation, which saving has been fairly consistent during the five years of operation of the effluent water system. Thus the cost of the original investment was repaid by savings within the first three years.

BARK FROM THE DAILY LOG

By Walter A. Sperry

Superintendent, Aurora (Illinois) Sanitary District

November 2—There are 24 sewage treatment plants on the Fox River between the Wisconsin line and the mouth of the stream. Every community has a sewage treatment plant except East Dundee and Yorkville and these are planned for post-war construction. The existing plants include those serving two industries, three private institutions and two state institutions. They represent an investment of about $3,700,000 and serve some 150,000 persons. The State Sanitary Water Board considers the Fox River program to be one of the most successful pollution abatement campaigns in the U. S.

Rumor has it that soon all these plants will be required to provide effluent chlorination during the summer season—a delightful anticipation for the many recreation camps located along the river banks. The Aurora chlorinator, with equipment to handle ton containers, is ready.

If proof were needed that the Fox River is much improved over 20 years ago, old Mr. Wormley can supply it. The other day, while making some river tests, we found him fishing from a nearby bridge. To our amazement he showed us a diary in which he had recorded his catch since August 9. It recorded a total of 196 bass of legal size and 60 catfish. Upon relating this at a Board meeting, one of the trustees told of a friend who had caught six bass one Sunday while fishing from the river bank in his own back yard!

November 5—Here is an idea we think worth passing along. We have a roadway passing between two sets of sludge beds. Originally a 10-in. insert pipe with Dresser couplings was provided; this was lifted and bolted in place and laid aside again as needed to convey sludge across the road. The operation required several men an hour of time. We finally bolted the pipe in place, wrapped and wired it with heavy roofing paper and bedded it in concrete in such a way that it could be removed if necessary. We then reshaped the roadway over it with gravel from our own pit.

This job required a cubic yard of concrete. We have so little need for concrete that we do not own a mixer and had no desire to mix such a quantity by hand, so we sent the truck downtown and bought a yard of mixed concrete from a cement block plant. This stunt saved considerable time as well as a lot of hard work.

November 7—Today we received the Annual Report of the City Engineer, Dr. E. J. Hamlin, of the city of Johannesberg, South Africa, for the year 1943–44. This has been our annual privilege ever since Dr. Hamlin's visit here some years ago. We have exchanged reports and an occasional letter ever since.

One can well appreciate the modern and metropolitan air of this city of near 400,000 population when examining these reports. There is always something to arouse wonder and stimulate interest.

Some two years ago we wondered whether it might not be possible to make methyl alcohol from our waste gas, so we studied up a bit in our old organic chemistry and talked it over with the chemistry professor of the local college. Imagine our interested surprise to read in this Johannesberg report that the Department of Commerce and Industry had requested the City Council to co-operate in the development of a process for converting the unused digester gas into methyl alcohol and formalin solution! Complying with this request, the City Council voted 5,000 pounds for the erection of a commercial scale pilot plant. At this writing the plant is partly constructed.

Our hats are off with admiring respect for this sort of initiative!

November 14—Some days the work around a plant is so uneventful that the silence is broken only by the normal hum of the engines. The next day may be a "three-ringed circus," popping off with an urgent telephone ring as one comes in the door.

Take today for instance. The phone was ringing when Williard came in—a lady wanted a sewer location immediately. Then we were tied up downtown for an hour getting petitions signed requesting the

City Election Commission to put the question of a Municipal Retirement Fund for our plant employees on the ballot next spring. En route to the plant again, we passed a car from Saskatchewan, Canada, and wondered where they were going, only to find twenty minutes later, while catching up on the day's laboratory chores, that they were coming to see us. Our guests were Mr. J. G. Schaeffer, Divisional Director of Sanitation for the Province of Saskatchewan and Mr. R. W. Allen, City Engineer of Regina—two delightful gentlemen on an inspection tour. Dropped all and sundry routines and spent the morning talking shop.

They were so interested in the new screen and screenings grinder that we have on order that we took them to visit the American Well Works Co. and, of course, they took us all to lunch.

Back to the plant and another hurried trip to town with pick, shovel hammer, rod and tape to locate a manhole buried under six inches of tough tar and gravel, so that another lady might be assured of a sewer connection. Out to the plant again to find that the tractor had side slipped into a swamp while leveling grit and that a neighbor boy had arrived with his "Farmall" to help pull it out. A $5 bill made him willing to come again, if and when. Then we ran gas tests for the week, took advantage of the warm sun to start a crew at painting some of the filter wall copings and called up a local garage to hurry our truck repairs so that we could make the already delayed pumping station inspections. Then it was five o'clock and the excitement had finally subsided.

November 23—A telephone message this afternoon from the Fire Department indicates not only an on-the-job alertness and thoughtfulness but emphasizes the problem of sewage plant hazards as well. A moving van had overturned in a traffic accident downtown, and had spilled 50 gallons of gasoline in the street. The Fire Department flushed it into a nearby catch basin and immediately called us. Fortunately nothing happened.

Had a similar warning been given the sewage plant workers at Grand Rapids, Mich., some years ago, when a large tank truck of gasoline was overturned, serious explosion damage would have been averted at the large screening station and the lives of two men would have been saved. This item needs no further comment.

November 28—We were in the middle of a paint discussion this afternoon when a large refrigerator truck drove up. The strapping big boy that drove it said the boss had sent him down and could he unload a ton of spoiled cottage cheese? We promptly said "No" and the boy looked crestfallen—evidently he was not expected to return with his cargo. We volunteered help and called the garbage disposal plant. Their reply was also negative but they suggested a nearby pig farm and that was that! One of our men who raised pigs at home took 200 pounds and it disappeared almost before he could empty the containers. Later the boy's boss thanked us sincerely.

Reminds us of our funniest near tragedy. One morning a coupe bearing a young man and his wife drove up. They had a hogshead of night soil resting on the back bumper and tied with a light clothesline. It was so heavy that the rear end of the car sagged dangerously. They had been driving around in puzzled helplessness, wondering what to do. We took one look and decided we did not dare let them drive back uphill to the highway, for fear of the worst! After promising to do the unloading themselves and to clean up afterward, they were permitted to empty the barrel into an open channel back of the screen house. They did a good job and departed—a relieved and grateful couple.

December 3—A dog has his fleas and a sewage plant has its hydrogen sulfide. About a year ago we boasted just a little in this **Log** about the fine ball bearings that we had installed at the rebuilt sludge meter. They were a complete failure.

Almost before we realized what had happened the felt protecting rings between the meter body and the bearings had practically "digested" away. The brass ball retainer rings all but disappeared; only a fragment was found, and all the balls were lost. All that remained were the ball races and the frame. After a thorough post mortem with the bearing designer, the verdict was "misapplication due to the corrosive effects of sewage and hydrogen sulfide."

The bearing frames were bored out and brass bushed iron cores were tapscrewed into the old frames. This made a fine salvage job with prospects of a long life, thanks to our helpful friend the machine shop man.

December 12—The accompanying picture shows Williard, our trusted assistant, and one of the operators as they inspect our latest gadget. It is a handy little tool to hook rags that sometimes escape the screen and are caught on the clarifier wiers. During storm periods they can be quite annoying. If not caught on the weirs they later foul the valves of the sludge pumps and give more trouble.

The blacksmith made this tool for us from a six-tined pitchfork, by cutting the tines to about four inches in length, sharpening them and then bending them over at right angles. The handle was shortened to about three feet with a hole in the end for a loop of sash cord to pass over the hand, while in use, as a safeguard against losing it in the clarifier.

December 20—Received an eight-sheet set of plans from District Engineer Walter E. Deuchler today, completely detailing the new building plans which the trustees hope to offer for bids next spring. We sincerely hope they can.

One new room in this plan is set aside as a classroom for the instruction of visiting groups. This week, on Tuesday, we had an eager eyed class of fourteen Girl Scouts and three mothers. Then on Thursday we had a group of 25 nurses from the training class at St. Joseph's Hospital.

FIGURE 1.—"Rag Picker" gadget for removing accumulations from clarifier weirs.

We take great care with the nursing classes, of which we usually have four each year. An hour and a half is spent in a general review of the sanitary engineering field, with special emphasis on water supply and sewage treatment, before taking them through the plant. Now, a set of painted planks are placed on trestles in the laboratory for such classes. A set of typical Imhoff cones, together with framed diagrams and an easel for displaying lecture charts completes the arrangements.

Last year, due to the gasoline shortage, this class hiked out and we took them home in the plant truck. This was a truckload of pulchritude and a merry ride!

December 23—Spent the afternoon looking over the plans for the largest wallpaper printing plant in the U. S. It is to be built partly over our main interceptor and just across the tracks from our plant. The building is impressive, being 1,200 ft. long, 400 ft. wide and five stories high.

This brings us another interesting waste problem that involves 350-mesh clay, color and a fairly high B.O.D. caused by the protein and casein used in the process. Laboratory studies made on the wastes from the Chicago and Joliet, Ill., plants of the company indicate that the clay does not settle readily but that it is sharply responsive to coagulants, and that the coagulated and settled liquor has a greatly reduced B.O.D.

Looks like a good story or two ahead to share with the readers of this **Log.**

INTERESTING EXTRACTS FROM OPERATION REPORTS

Conducted by LeRoy W. Van Kleeck

The world is interested in the
result, not the work behind it.
—The Sphinx

Report on the Administration, Operation and Maintenance of the Division of Sewage Disposal, Department of Public Utilities, Cleveland, Ohio, for the Year 1943 *

By J. W. Ellms, *Commissioner*

When a city spends nearly a million dollars yearly for the administration, maintenance and operation of its sewage treatment and disposal facilities, the report on the operation of those facilities should be received with considerable interest by sewage plant superintendents and sanitary engineers. While this abstractor will attempt to review here the highlights of the 1943 report of the city of Cleveland, may I urge all who can possibly do so to visit Messrs. Wirts, Gerdel and Flower at their respective Easterly, Westerly and Southerly plants where the attractiveness, variety of processes and capabilities of the superintendents in charge of these plants will result in a most profitable day.

Table 1 summarizes the operation and maintenance costs of all the sewage plants and one ejector station:

* For previous extracts see: *This Journal,* 12, 625 (May, 1940); 15, 99 (Jan., 1943).

TABLE 1.—Summary of 1943 Operating Data, Cleveland, Ohio
Operation and Maintenance Costs—All Plants and One Ejector Station

Operation Items	Easterly	Southerly	Westerly	Ejector Station	Total
Supervision and labor	$113,038.88	$161,730.62	$ 87,414.95		$362,184.45
Chlorine	9,755.35		6,384.43		16,139.78
Power and lighting	123,051.51	28,085.61	8,666.99	$2,397.37	162,201.48
Coal and fuel oil	4,072.02	3,932.82			8,004.84
Lime and ferric chloride	4.70	27,322.63	5,951.58		33,278.91
General supplies and expense	3,349.48	4,669.45	2,165.13		10,184.96
Total operation costs	$253,271.94	$225,741.13	$110,583.08	$2,397.37	$591,993.52
Maintenance Items	**Easterly**	**Southerly**	**Westerly**	**Ejector Station**	**Total**
Labor	$ 54,383.74	$ 68,635.95*	$ 15,959.29	$ 498.82	$139,477.80*
Materials	27,261.50	69,475.73*	6,861.57	380.00	103,978.80*
Total maintenance costs	81,645.24	138,111.68*	22,820.86	878.82	243,456.60*
Total plant costs	$334,917.18	$363,852.81	$133,403.94	$3,276.19	$835,450.12

* Included in the maintenance labor and material figures were costs incurred during 1942, for the rebuilding of incinerators at the Southerly plant. These charges were $8,198.80 for labor, and $36,098.38 for materials. The 1943 costs to complete, which are also included in the above figures, were $10,878.56 for labor and $2,679.03 for materials.

Following are the total adjusted costs for administration, operation and maintenance:

	Easterly	Westerly	Southerly
Plant costs	$580,761.91	$133,403.94	$121,284.27
Administrative costs	80,856.87	26,194.07	26,862.29
Total	$661,348.78	$159,598.01	$148,146.56
Cost per m.g.	$ 18.04	$ 13.38	$ 12.14

The average for all costs is $15.94 per million gallons, based upon a measured flow of 60,782 millions of gallons of sewage, and a total cost of $969,093.35. The plant costs averaged $13.74 per million gallons, and the administrative costs, $2.20 per million gallons.

Report on the Operation and Maintenance of the Easterly Sewage Treatment Plant

By John J. Wirts, *Supt.*

Comminutors

The four 54-in. comminutors are the first and only comminutors built to handle 60 to 70 m.g.d. of raw sewage. They have given good service over a considerable period of time. They should now be replaced with improved machines.

Detritors

All grit is now dumped as fill in the lagoon at the north side of the plant. The possibility of using all of the fill for shore erosion and thereby creating an additional boat harbor should be investigated.

Grease Flocculation

The grease flocculation unit was not in service during 1943, due to the failure of the cast aluminum plate holders as noted in the 1942 report. A small amount of air, about 0.007 cubic feet per million gallons of sewage, was fed to the raw sewage in the central channel leading to the pre-settling tanks. During a trial period it was found that this small amount of air aided in the separation of grease from the sludge, and that without this air, particles of sludge appeared to adhere to particles of grease so that the combination floated to the surface causing an offensive odor. The amount of this material to be removed and its consistency was such that it was necessary to skim by hand, as the automatic skimming devices were unable to remove the combination of sludge and grease.

Pre-Settling Tanks

Excess activated sludge was pumped to the pre-settling tanks during the week ends in January and February. It was then discontinued for the remainder of the year because of the recycling of the finer activated sludge solids to the aeration process.

Southerly Sludge Pumps and Force Main

All of the excess sludge produced at the Easterly plant is pumped to the Southerly plant for digestion and final disposal.

In November, about 5.1 miles of the 13 mile, 12-in. cast iron force main were cleaned. A typical rate test comparison taken before and after this partial cleaning showed a slight increase in pump discharge, a corresponding rise in amperage and a drop in pressure as follows:

Time of Test	Pump Group	M.G.D.	Amperes	Pressure (P.S.I.)
Before cleaning.	North	0.93	121	141
After cleaning. .	North	0.98	127	139

A study of the sludge pumping problem led to several changes in operation; some of these were effected and some are still being contemplated as follows:

Excess activated sludge was mixed in the Southerly pump sump with primary sludge from the pre-settling tanks prior to pumping to the Southerly plant. This insured a much more nearly uniform pumping mixture by diluting the often times extremely heavy primary sludge.

Experiments with the concentration of excess activated sludge were conducted, and one of the Dorr final clarifiers was used for this purpose with slight alterations.

A pipe line cleaning machine was leased for use in the 12-in. cast iron force main. Plans were completed for the construction of junction chambers at both the Easterly and Southerly sites for the insertion and removal of the cleaning machine.

In the concentration process, the pumpage of concentrated activated sludge was substituted for the pumpage of the excess activated sludge. A comparison of sludge pumpages during the month of December in 1942 and 1943 shows the effect of the concentration process on the volume of sludge pumped:

	Daily Ave. Total Sludge Pumped (M.G.)	Ave. Dry Solids (Per Cent)	Total Lbs. Dry Solids Pumped	Total Raw Sewage Flow (M.G.)
Dec., 1942	0.96	1.7	4,972,000	3,163.9
Dec., 1943	0.64	3.0	4,230,000	2,659.6

Aeration Tanks

A contract with the Wailes Dove-Hermiston Corp. was entered into for coating the cast aluminum plate holders in the aeration tanks with Bitumastic No. 70. At the close of the year, coated plate holders had been installed in aeration tanks Nos. 4 and 5 and the plate holders in Nos. 9, 13 and 16 were being prepared for coating.

Chlorination

Chlorine was used in three stages of treatment during 1943. Post-chlorination to protect the bathing beaches was practiced for a total of 103 days from June 3 through Sept. 13. At an average dosage rate of 4.4 p.p.m., 360,104 pounds of chlorine were fed to the effluent before entering Lake Erie. After a contact period of five minutes, an average residual chlorine content of 0.5 p.p.m. was maintained.

For a period of 33 days in August and September, 59,540 pounds of chlorine were used for prechlorination at an average rate of 2.4 p.p.m. Prechlorination was practiced in an effort to separate the particles of sludge adhering to floated grease during the period when the feeding of air in the central sewage channel leading to the presettling tanks was shut off. This matter was previously mentioned in the paragraph on "Grease Flocculation." The feeding of chlorine without air did not remedy the situation appreciably; but when air was fed in conjunction with chlorine a marked improvement was noted.

For a period of 21 days in late September and early October, chlorination of the return sludge was practiced in one battery as a test to determine the effect of chlorine on controlling the sludge index of return activated sludge. A brief summary of this test follows:

	Sludge Index	
	Unchlorinated Batteries	Chlorinated Batteries
One day before chlorination	91	100
Ave. during chlorination	102	89
Ten days after chlorination	123	80

The average dosage of chlorine was at the rate of 8.0 p.p.m. based on the metered volume of return sludge.

Boilers

The use of one boiler for an entire heating season has been made possible by treating the boiler feed water with sodium hexametaphosphate. An inspection of the boiler tubes in the summer of 1943 showed that considerably less scale had formed and this was easily removed. This is the first time that one boiler has been used for the entire heating season.

Industrial Wastes

Industrial wastes have continued to be received and the detriment to plant processes and equipment continues. With the heavier loading caused by increased flow of raw sewage, the treatment of industrial wastes becomes more difficult and their effects become more pronounced.

Table 2 is a summary of the 1943 operating data:

TABLE 2.—Summary of 1943 Operating Data, Easterly Plant, Cleveland, Ohio

Item	Average
Sewage flow, m.g.d.	101.2
Settled sewage flow given complete treatment, m.g.d.	91.3
Mixed liquor flow, m.g.d.	108.4
Return sludge flow, m.g.d.	19.1
Per cent return sludge	20.9
Air applied, cu. ft. per gal.	1.1
Grit, cu. ft. per m.g.	3.91
Screenings, cu. ft. per m.g.	0.47
Analytical data:	
Suspended solids:	
Raw, p.p.m.	239.0
Settled, p.p.m.	165.0
Per cent removal by settling	31.0
Final effluent, p.p.m.	12.0
Per cent removal	95.0
Total iron:	
Raw, p.p.m.	14.1
Settled, p.p.m.	12.0
Per cent removal	14.9
Final effluent, p.p.m.	0.9
Per cent removal	93.6
pH:	
Raw	7.0
Settled	7.2
Final effluent	7.5
5-Day B.O.D.:	
Raw, p.p.m.	148.0
Settled, p.p.m.	106.0
Per cent removal	28.4
Final effluent, p.p.m.	13.4
Per cent removal	90.9
Dissolved oxygen, p.p.m.:	
Pre-settled sewage	1.8
Aerator influent (mixed liquor)	1.5
Aerator effluent (mixed liquor)	3.8
Activated sludge:	
Total solids, p.p.m.	11,600.0
Volatile solids, per cent	61.4
Suspended solids, p.p.m.	11,130.0
Mixed liquor, suspended solids, p.p.m.	2,240.0
Sludge index	74.0

Report of the Operation and Maintenance of the Westerly Sewage Treatment Plant

By Walter E. Gerdel, *Supt.*

Grit

Continued difficulty was experienced with some grit passing through the grit chambers and settling out in the Imhoff tanks, causing stoppages in the sludge withdrawal piping serving the sludge hoppers. In an effort to overcome this difficulty, the maximum permissible rate of flow in the individual grit chambers was changed on August 30 from 20 m.g. to 18 m.g. During 1942, the maximum rate of flow in the grit chambers had been changed from 25 m.g. to 20 m.g.

Imhoff Tanks

The Imhoff tanks were again operated as primary settling tanks, with the digestion of sludge being accomplished as much as possible in the separate digestion tanks. The raw sludge settled out in the Imhoff tanks averaged 68.0 per cent volatile, while the sludge removed averaged 60.6 per cent volatile, indicating that considerable digestion did take place in the Imhoff tanks, despite efforts to remove the sludge as fresh as possible. The raw sludge removed, averaged 6.86 per cent total solids.

Gas vent foaming nuisance caused considerable trouble the early part of the summer and the tank surfaces were very difficult to keep clean.

The practice of pumping down the Imhoff tanks and cleaning out the flowing-through compartments was again followed during the greater portion of the year. The end tanks especially are very prone to block up at the slots connecting the flowing through chambers to the sludge chambers.

It is believed that considerable quantities of grit must be in the sludge hoppers of the Imhoff tanks and remain there as an inert material which interferes with and delays the withdrawal of raw sludge until it becomes partially digested. The delayed removal of the raw sludge also tends to allow gas borne particles to rise into the gas vents causing difficulties with gas vent foaming. In an effort to determine the quantity of grit present in the sludge hoppers, No. 4 Imhoff tank was pumped down and cleaned out completely, using a sand water injector. The work took about a month and was finished November 5. A large quantity of grit was found in the sludge hoppers, the worst hoppers being those that serve the inlet side of the tank. There was also removed a considerable quantity of broken concrete and other material which had gotten into the tank in the course of repairs and alterations. The sludge hopper water spray piping was found in fairly good shape and was replaced where necessary. The spray holes were redrilled where they were found to be blocked up. The tank was put back into operation and for the remainder of the year all of the sludge hoppers of the tank were drawn from each day. This method of operating the tank was continued throughout 1944 in an effort to observe the operation of the tank in comparison to the others. At this time it is felt that all of the remaining Imhoff tanks should be cleaned out completely in a similar manner. The lack of personnel, however, prevents this program from being started at the present time.

Sewage Chlorination

Prechlorination was practiced for 109.4 days, while post-chlorination took place 83.0 days during the summer. Prechlorination dosages averaged 7.10 p.p.m., while post-chlorination dosages averaged 4.89 p.p.m. It was possible to maintain residual chlorine in the sewage effluent 73 per cent of the time. The starch-iodine method for determining residual chlorine was again used, and control tests were run every two hours when operators were on duty.

The liquid chlorine evaporator cylinder failed on August 9, discharging chlorine into the chlorinator room. Upon inspection it was found that the lower inside portion of the evaporator cylinder was severely corroded and had decreased the wall thickness until failure resulted.

Separate Sludge Digestion

All of the digesters were again operated as primary digestion tanks and practically all of the resulting digested sludge was pumped to the sludge storage tank for storage and concentration.

Two of the digesters were pumped down and cleaned out in the fall due to excessively thick layers of scum that had accumulated and which interfered with normal withdrawals of supernatant. In both digesters the heating coils were also found badly caked up with sludge scale which prevented normal heat transfer to the sludge. A 2-inch water line terminating in a spray nozzle ejecting into the outlet sludge piping was installed in one of the tanks to facilitate future cleaning out operations on this tank.

Sludge Vacuum Filtration

The 30-in. width elevator conveyor belt was replaced April 15 by a synthetic oil and grease resistant belt. The old belt had given 4 years and 7½ months of service, and contained 8 splices with 3 more splices immediately necessary if it had been continued in service. The original 48-in. width horizontal conveyor belt continued in service the remainder of the year.

Several lime slides occurred from the lime storage bins where the lime had hung up and bridged over. An electric vibrator was installed to overcome this difficulty.

Filter Cake Incineration

Some fuel oil was used during the year, with most of it being consumed during the winter months when the plant gas supply was not adequate for all needs.

No. 2 incinerator was put into service November 1, 1942, and was not taken out of service until October 16, 1943, a continuous period of 11½ months, which is the longest continuous period an incinerator was ever operated at the Westerly plant. Maintenance work on the incinerators and auxiliary equipment was about normal.

Considerable difficulty was had with ash dust escaping from the bottom seal of No. 1 incinerator into the building. This condition was helped somewhat by emptying the seal of sand and allowing air to enter at this point and keep the ash from escaping.

Miscellaneous Improvements

A portable ventilating blower fan unit having a capacity of 5,000 c.f.m. was constructed from available equipment. This equipment was designed principally to ventilate the digesters when they are being pumped down and cleaned out.

Table 3 summarizes the operating data at this plant for the year 1943:

TABLE 3.—Summary of 1943 Operating Data, Westerly Plant, Cleveland, Ohio

Item	Average
Sewage flow, m.g.d.	32.7
Overflow and by-pass operated, hrs. per month	30.0
Grit, cu. ft. per month	3,584.0
Cu. ft. per m.g.	3.61
Volatile matter, per cent	20.5
Analytical data:	
Suspended solids:	
Raw, p.p.m.	256.0
Imhoff tank effluent, p.p.m.	150.0
Per cent reduction	41.6
5-Day B.O.D.:	
Raw, p.p.m.	244.0
Imhoff tank effluent, p.p.m.	187.0
Per cent reduction	23.3
Total iron:	
Raw, p.p.m.	8.0
Imhoff tank effluent, p.p.m.	6.0
Per cent reduction	25.0
Pre-chlorine dosage (June–Sept.), p.p.m.	7.1
Post-chlorine dosage (June–Sept.), p.p.m.	4.89
Separate sludge digestion data:	
Gals. sludge added during year	20,102,500.
Lbs. dry solids added during year	11,729,700.
Lbs. volatile solids added during year	7,114,300.
Gals. digested sludge drawn, year	12,582,100.
Lbs. dry digested solids drawn, year	8,293,700.
Lbs. volatile solids drawn, year	3,907,900.
Per cent digestion loss, total dry solids, yr.	24.49
Per cent digestion loss, volatile solids, yr.	41.44
Cu. ft. gas:	
Per pound total solids added	5.03
Per pound volatile solids added	8.29
Per pound total solids destroyed	20.53
Per pound volatile solids destroyed	20.0
Circulating water for digesters, °F.:	
In	142.0
Out	119.0
Gas utilization, per cent of total:	
To digester heaters	20.3
For building heat and misc.	16.9
For incinerators (sludge)	15.4
Wasted	47.4
Digested sludge for vacuum filtration:	
Total gallons, year	8,217,300.
Total solids, per cent	7.66
Volatile solids, per cent	46.7
Total dry solids, lbs., year	5,410,400.
pH	7.4
Alkalinity as $CaCO_3$, p.p.m.	2,960.0
Ferric chloride dose, per cent	2.68
Lime dose, per cent	14.7
Calcium oxide dose, per cent	13.1
Sludge filtration:	
Filter hours, year	11,733.0
Filter cake, tons, year	10,092.0
Filter cake moisture, per cent	68.1
Filter cake volatile solids, per cent	38.0
Filter cake dry solids, tons, year	3,219.0
Lbs. dry solids, per sq. ft. per hr.	3.32
Filter cloth life, hours	272.0
Filtrate, total solids, p.p.m.	3,991.0
Filtrate, suspended solids, p.p.m.	300.0
Filtrate, alkalinity, p.p.m.	2,530.0
Sludge cake incineration:	
Total tons incinerated, year	8,006.0
Dry solids incinerated, year	2,557.0
Tons cake per incinerator hour	1.57
Fuel oil per ton cake incinerated	0.48
Fuel oil per ton dry solids incinerated	1.51
Gas per ton cake incinerated, cu. ft.	360.0
Gas per ton dry solids incinerated, cu. ft.	1,129.0

Operation and Maintenance of the Southerly Sewage Treatment Plant

By G. E. Flower, *Supt.*

Sewage Flows

A total metered flow of 12,204.1 m.g. of raw sewage was treated during the year of 1943. This volume included 70.6 million gallons of concentration tank supernatant. The average daily flow for the year was 33.4 m.g. The raw sewage overflowed 27 per cent of the time during the entire year, 42 per cent of the time before August 21, and 6 per cent of the time after that date.

Imhoff Tanks

The tanks were all foaming intermittently up to August 1, and from then on they functioned normally. The suspended solids were reduced 43 per cent and the B.O.D. 50 per cent.

Abbreviated Aeration Unit

This unit treated 2,954.2 m.g. of Imhoff tank effluent, in addition to 153.7 m.g. of digester supernatant liquor, up to September 1. For the balance of the year, the aeration unit treated 1,700.7 m.g. of Imhoff tank effluent without any digester supernatant liquor.

A total of 24,573,300 lb. of dry solids was removed by the aeration unit, of which 12,507,200 lb. were pumped to the lagoon, and 12,066,100 lb. to the concentration tanks. There was no sludge pumped from the aeration unit to the lagoon after August 31.

The suspended solids were reduced 93.1 per cent and the B.O.D. 89.6 per cent by this unit.

There were 856 cu. yd. of gritty material removed from the two aeration tanks during September and October. This material analyzed 23.8 per cent volatile matter, with 22 per cent passing a 50-mesh screen.

Trickling and Magnetite Filters

The trickling filters treated a combined flow of Dorr clarifier effluent and Imhoff tank effluent from January 1 to August 1 and from December 15 to December 21. The balance of the time —from August 1 to December 15— they treated Imhoff tank effluent only. The Dorr tank effluent flowed directly to the magnetite filters, by-passing the trickling filters, during the period from August 1 to December 15. The trickling filters treated 3,323.8 m.g. of Imhoff and Dorr tank effluents and the magnetite filters treated 5,623.6 m.g. of trickling filter and Dorr tank effluents. It was decided to discontinue the operation of the magnetite filters because of the high maintenance costs. The work of bricking up the influent conduit openings to the magnetite filters was started on December 16 and completed December 28.

Sludge Drying Beds

The drying beds dewatered 2,907,-800 gal. of Imhoff tank sludge, containing 2,133,000 lb. of dry solids, which was 24.6 per cent of all the sludge removed from the Imhoff tanks. The moisture content of the sludge pumped to the drying beds was 91.4 per cent, and was reduced by the sand beds to 64 per cent.

Sludge was applied to the beds 85 times, or an average of 10.6 times per bed per year. It was necessary to add 314.5 cu. yd. of sand or washed grit, equivalent to 3.2 in. per bed, in order to replace the sand lost in removing the dried sludge.

Separate Sludge Digestion Tanks

All the digesters were operated as primary digestion tanks up to April 23, when two of them were used as secondary tanks.

The digester supernatant liquor averaged 11,945 p.p.m. of total solids and 6,672 p.p.m. of volatile solids. The digester supernatant liquor was pumped to the influent of the aeration tanks up to September 1, after which date it was discharged directly into the main plant outfall which empties into the river.

There were 241,521,100 cu. ft. of gas produced, figured for standard conditions, or 5.61 cu. ft. per lb. of volatile solids added, compared with 7.37 cu. ft. per lb. of volatile solids added in 1942.

Sludge Vacuum Filtration

During the year, 47,466,900 gal. of digester and Imhoff tank sludges, containing 12,622.1 tons of dry solids, were conditioned and partially dewatered. This process required 601 tons of anhydrous ferric chloride and 1,845 tons of lime, as received, or 1,598 tons of calcium oxide for conditioning the sludge. The dose of chemicals on the basis of dry solids averaged 4.8 per cent for ferric chloride, 14.6 per cent for lime or 12.7 per cent of calcium oxide.

Table 4 summarizes the operating data for this plant for the year 1943:

TABLE 4.—Summary of 1943 Operating Data Southerly Plant, Cleveland, Ohio

Item	Average	Item	Average
Sewage flow, m.g.d.	33.4	Aeration tank influent	6.9
Screenings, cu. yds. per m.g.	0.022	Dorr tank effluent	7.1
Grit, cu. yds. total from grit chambers	786.0	Trickling filter effluent	7.1
From Imhoff tanks, cu. yds.	5.0	Magnetite filter effluent	7.1
From aeration tanks, cu. yds.	856.0	Suspended solids, mixed liquor, p.p.m.	2,720.0
Total cu. yds.	1,647.0	Digested Imhoff tank sludge:	
Imhoff tank sludge, gals. × 1,000, total	11,834.7	Total solids, per cent	8.6
Sludge from drying beds, cu. yds. total	4,431.7	Volatile solids, per cent	47.1
Aeration data:		pH	6.7
Settled sewage treated, m.g. per month	400.7	Alkalinity, p.p.m.	1,570.0
Air, cu. ft. per gal.	0.45	Drying beds, sludge cake, moist. %	64.0
Return sludge, per cent	11.1	Fresh solids:	
Sewage flow to trickling filters, m.g. per month	277.0	pH	5.9
Sewage flow to magnetite filters, m.g. per month	468.6	Volatile solids, per cent	58.4
Analytical data:		Grit, volatile solids, per cent	28.7
Suspended solids, p.p.m.:		Vacuum filtrate:	
Raw	212.0	Total solids, p.p.m.	5,266.0
Imhoff effluent	120.0	Suspended solids, p.p.m.	240.0
Aeration tank influent	582.0	pH	11.9
Dorr tank effluent	40.0	Alkalinity, p.p.m.	2,010.0
Trickling filter effluent	57.0	Digester supernatant:	
Magnetite filter effluent	24.0	Total solids, p.p.m.	11,915.0
5-Day B.O.D., p.p.m.:		Alkalinity, p.p.m.	1,530.0
Raw	163.0	pH	6.8
Imhoff effluent	82.0	Digester sludge:	
Aeration tank influent	241.0	Solids, per cent	6.4
Dorr tank effluent	25.0	Volatile solids, per cent	51.3
Trickling filter effluent	26.0	Alkalinity, p.p.m.	1,910.0
Magnetite filter effluent	20.0	pH	6.9
River above plant	9.0	Circulating water for digesters, ° F.:	
River below plant	23.0	In	126.0
Dissolved oxygen, p.p.m.:		Out	113.0
Raw	4.7	Sludge gas utilization, per cent total:	
Imhoff effluent	1.8	Wasted	37.7
Dorr tank effluent	3.0	To digester heaters	23.7
Trickling filter effluent	7.1	For sludge incineration	9.4
Magnetite filter effluent	6.1	For gas engines	17.6
River above plant	9.4	For building heat and misc.	11.5
River below plant	7.7	Sludge filtration:	
pH:		Filter cake produced, tons total	62,346.0
Raw	6.7	Filter cake dry solids, tons total	18,231.0
Imhoff effluent	6.8	Ferric chloride, per cent	4.8
		Lime, per cent	14.6
		Calcium oxide, per cent	12.7
		Filter cake moisture, per cent	70.7
		Filter rate, lbs. per sq. ft. per hr.	3.6
		Cloth life, hrs.	239.0

TIPS AND QUIPS

Data from Denver, where the Rocky Mountain Sewage Works Association met for its Twelfth Annual Meeting on September 20, 1945 . . . a very favorable registration of about 75 . . . and not a 10-gallon hat or pair of spurs in the crowd! . . . stream sanitation in its highest sense as a water conservation measure, in a region in which water is a *scarce* resource—not to be wasted . . . a report by retiring State Sanitary Engineer B. V. Howe (who announced at this meeting that he was leaving the employ of the State to engage in private practice as a consulting engineer) that about 70 Colorado municipalities had been ordered to build new sewage treatment plants or improve existing ones . . . the quip by President-elect John T. Franks, while presiding over the forum on postwar problems—"Is there any other pessimist who cares to say anything?" . . . which just about completely summarizes the present situation on labor, construction and equipment . . . a detailed visit to both of Denver's modern sewage treatment plants, where Supt. C. P. Gunson is a man of ideas with the energy and courage to apply them . . . and saw how fresh sludge return to the raw sewage flocculation tanks effects remarkable removals of B.O.D. and solids in primary sedimentation units . . . in addition to an unique arrangement for heating a digester and recirculating sludge therein by means of a steam injector . . . true western hospitality typified by the many personal courtesies of Dana Kepner, Carroll Coberly, Chas. A. Davis, et al. . . . climaxed by the resolution adopted by the Association inviting the Federation to hold its annual convention at Denver in 1947!

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Improved supernatant can be secured at over-active sludge digestion tanks by raising the temperature 3 or 4 degrees above the normal value, then cutting off all heat and allowing the unit to settle for a few days, during which time stratification will occur. This tip originates with Glen Cary and Fred Knollman of the plant at Fort Logan, Colorado.

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The opportunity to greet those returning to civilian pursuits after their periods of military service brings added enjoyment to the attendance of technical meetings these days. The list of those who are resuming the wearing of a vest as part of their apparel is increasing so rapidly at present that any attempt to give names is out of the question. Each day brings more good news, as we hear of those who are en route to home and jobs after having contributed so magnificently to the Great Victory.

There will undoubtedly be considerable readjustment and changing of employment in the next few months, although most of our military people appear to be returning to their prewar places. Stabilization will come in due course, and when it does, the huge task of overcoming the wartime moratorium on stream pollution abatement will accelerate in pace.

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Another group of war workers that is deserving of the everlasting gratitude of the armed services, the public and the sanitary engineering profession is that little band of civilian technicians who rendered such sterling service in the R. and U. Division of the office of the Chief of Engineers. The return of E. F. Eldridge of Michigan, L. H. Kessler of Wisconsin and others to their peacetime pursuits gives reminder of the tangible accomplishments of this group of men. Much will yet be heard of their work as certain reports, studies and accumulations of data are released for publication, and there can be assurance that this material will be intensely interesting and of great permanent benefit to the profession.

Prof. E. F. Eldridge, who took leave from Michigan State College to serve for eighteen months in the R. and U. office of the Ninth Service Command, gives an interesting cross section of the work done in these offices in a recent letter. Extracts follow:

"We have all kinds of country out here, from northern states of Washington and Montana to the deserts of Arizona and southern California. We also encounter all types and kinds of water supply, from Washington's soft waters to Arizona's hard Colorado River water.

"Our Sanitary Engineering Section is charged with the supervision of water supply and sewage treatment and disposal at all Army installations in these eight western states. This is a sizeable job. The quantity of water delivered for consumption during the past quarters (3 months period) was between 5 and 6 billion gallons. On an average, the quantity of sewage disposed of from these installations averages about 60 per cent of the water supplied. The percentage is low because of the irrigation requirements.

"A considerable portion of the supply is from government owned sources, although some is purchased from municipal and private sources. Much is from run-off of mountainous areas and is accumulated and held in large reservoirs often high in the mountains and many miles from the post. A few of the supplies, especially in the north, are from streams. Streams are dry in the south for much of the year. In some cases, water is delivered to the distribution system by gravity without the need for pumping. Fort Douglas supply is an example of this condition, water being impounded above the post.

"Many supplies are from wells. I was surprised to find Arizona posts with ground water supplies. All of the water is, of course, chlorinated to the Army standard of 0.4 p.p.m. after 30 minutes.

"We have only 8 filtration plants in the Command, two of which practice complete softening using lime-soda. Perhaps the most interesting problem has been scale and corrosion control. We have about 45 installations at which either sodium metaphosphate or sodium silicate is being added on a postwide basis. Two p.p.m. metaphosphate is usually sufficient to effectively control scale formation in hot water systems. About 0.5 p.p.m. at the hot water installations (heater or storage tanks) is necessary. Because of long storage in lines and reservoirs, the amount added must be regulated by a phosphate test at various points on the water system.

"Corrosion control is much more difficult. Sodium silicate has been effective in the soft water of the northwest, but is not effective in the harder waters of other areas. Ten parts of sodium metaphosphate has given partial control in the latter cases.

"There are about 90 sewage treatment plants under our supervision. These range from septic tank and drainage fields to complete biofiltration plants. There are no activated sludge plants or Hayes process plants in the Command. In a great many posts, the sewage is completely disposed of on the reservation, since state laws will not allow discharge to water courses. Oxidation and percolation beds are used following secondary treatment to dispose of the water. Chlorination is necessary if the effluent goes to irrigation channels.

"You can believe that this has all been an experience well worth any personal inconvenience I have experienced. Some of our trips have been rather rugged, but I have enjoyed them."

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Jotted at Jefferson City, while the Missouri Water and Sewerage Conference met in its 21st Annual Meeting on October 22–23, 1945 . . . the final registration of 147 considered most satisfactory . . . the enlightening impromptu comparison of sanitary engineering practices in the U. S. with those he observed in Germany, by Maj. Warwick Doll . . . pleasure in presenting Geo. S. Russell, staunch supporter of the Conference for many years, with the Federation's Kenneth Allen Award . . . the impassioned plea by Secretary W. A. Kramer for members of the Conference to exert themselves to the end that the organization may expand its scope of influence to municipalities not now represented . . . adoption of a voluntary certification program for sewage works operators . . . and the approval of a plan whereby the Conference becomes a joint sponsor of correspondence courses to be given for water and sewage works operators by the U. of Missouri, credit for these courses to be applied to advancement in certification grade . . . which, we believe, inaugurates something new in operator's training activity . . . and back to headquarters, with the firm conviction that the development of sewage and industrial waste treatment in Missouri is in good hands!

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Plenty of money floating around Denver these days!

During one week recently, exactly $50 in 10- and 20-dollar bills was salvaged from the screenings at the main sewage treatment plant. Although attendance to the mechanical screens here is not the most pleasant job imaginable, Supt. Gunson reports that he always has plenty of volunteers for the assignment!

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F. M. Veatch, Jr., well-known consulting engineer and a man who likes to reconcile his facts, has been disturbed ever since the 1944 convention of the Federation at Pittsburgh, where W. M. (Bill) Piatt was honored with a birthday cake on what Mr. Piatt modestly announced as his 51st birthday. Upon checking his data, as does every good consulting engineer, Mr. Veatch finds that the records of the Quarter Century Operators Club show that Bill began his service as an operator at the Winston-Salem, N. C., sewage treatment plant in 1903, when he would have been just ten years old!

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Just in case some of those whose primary interest lies in trickling filters may feel somewhat slighted by the November *Journal,* which was almost entirely devoted to the activated sludge process, we are pleased to report that some good trickling filter papers are on the way. A "summary of experience" on trickling filter operation is in preparation by D. E. Dreier and has been tentatively scheduled for the May issue. Moreover, not one but *two* authoritative papers on the use of DDT in filter fly control are in the process of clearing Army channels en route to us!

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"**Bargain Day,**" for municipal departments engaged in sewage and water works, sanitation and other public health activities, should be at hand as this issue of the *Journal* achieves distribution. At this writing, late in 1945, spadework is under way toward the distribution of surplus war property to municipalities that can demonstrate a public health need for the available items—at extremely favorable prices. The Federation, together with A.W.W.A. and A.P.H.A., is being given a voice in the early development of the program through a joint advisory committee serving the Surplus Property Board, the Federal Security Agency and the U.S.P.H.S., the three agencies involved in the distribution of goods to be used for public health purposes.

Wherever and whenever possible, the Federation will assist in the furtherance of this worthwhile service. It is expected that the field offices and personnel of the U.S.P.H.S. will process and clear applications for purchases, under the general direction of Engineers Carl E. Schwob and V. G. MacKenzie in Washington. Further detailed and specific information will be broadcast as it is made available.

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On the heels of the bulletin containing the papers presented at the First Industrial Waste Conference held at Purdue University in November, 1944, comes a notice from Prof. Don E. Bloodgood advising that the second conference has been scheduled tentatively for January 10–11, 1946. The program of the first conference, incidentally, was the finest symposium on industrial waste problems as yet arranged, and the published *Proceedings* is indeed a significant reference volume. The program of the 1946 conference was not available at this writing.

Prof. Bloodgood and Purdue University are rendering a valuable service by their sponsorship of this activity.

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"Glamorized" bond issue campaigns, even where they are part of a sewage works project, have the best chances for success. In addressing the Missouri Water and Sewerage Conference recently, R. M. McDonnell, prominent consulting engineer, related the story of the bond issue that financed the sewer system at Glendale, Calif., some years ago, on which occasion a 2-mile parade of unusual outhouses was staged. This truly "carried the problem to the voters" and the referendum was successful by a 10 to 1 majority!

Mr. McDonnell did *not* refer to participation in the parade by any bevy of comely cinema starlets, such as is usually prominent in California public relations activities!

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Editorials

THE MODERNIZED FORMAT

By the time this page is reached, readers and users of the *Journal* will have formed their first opinions in regard to the new two-column format. Some of these impressions may be unfavorable to the departure from the old arrangement, because there is a natural aversion to changes in things to which we have become accustomed and in which we may find satisfaction as they are. But there has been progress in the arts of typography and printing composition, just as there has been advancement in the science of sewage treatment. The two-column page initiated in the text section of this issue represents an important step ahead and is not founded on a mere whim or a desire to try something different. As a matter of fact, the writer confesses to an entrenched personal satisfaction with the former full measure page and to some reluctance toward the adoption of this modification, yet he is firmly convinced that the advantages of the two-column page are manifold and compelling.

As early as 1904, psychologists investigated printed line arrangement and length with respect to motor habits and eye movements in reading. In his book "Investigations in the Hygiene of Reading," Blackhurst refers to the research of Dr. W. F. Dearborn, who concluded as follows: "These (desirable) motor habits are most easily acquired in the shorter lines and aid materially the rapidity of reading. Length of text lines is mainly important in its effect upon the formation of motor habits. The rate of reading depends upon the ease with which a regular rythmical movement is established. Lines should be from 75 to 85 mm. in length." In 1911, a committee of the American School Hygiene Assn. included the following in its recommendations covering the format of textbooks: "The eye moves by a succession of movements and stops and makes a long backward sweep to the beginning of the next line. Fatigue is markedly increased by the difficulty of the backward movements and in locating the beginning of the next line, if the line is too long. The maximum of safety is 90 mm. and 60 to 80 mm. is better." It is pertinent here to note that the text line length in the new format is 62 mm., as compared to 127 mm. in the former single column page.

In response to a direct inquiry, Mr. Andrew J. Farr of the Graphic Arts Association of Illinois advises that "A line containing about forty characters and spaces has always been considered an ideal easy reading measure." The new two-column page fulfills this specification almost exactly.

So much for the advantage to the reader.*

By using the shorter line, it is possible to use a smaller type face and thus to produce a more compact volume. The new format reduces space (and paper) requirements about 13 per cent and results in a slight reduction in printing costs. This reduction will also be reflected in the cost of reprints.

The two-column arrangement permits better placement of figures and tables in that "white space" is eliminated where the full page width is not required. A further improvement, from the aesthetic standpoint, is the use of bold-face type in the captions

* The article "How Well Do You Read" on page 102 of the November, 1945, issue of *Reader's Digest* may be of further interest in this connection.

and in the titles of tables and cuts. This gives a pleasing contrast that eliminates the monotony of a solid page of uniform type.

To summarize, the new "streamlined" version of the *Journal* is easier to read, less bulky, improved in appearance and, withal, less expensive to produce. These facts should be taken into account by the reader before he passes final judgment on the change.

W. H. W.

IT WILL BE THE NINETEENTH ANNUAL MEETING AT TORONTO

In the course of the Board of Control sessions at Pittsburgh in 1944, objection was raised to the designation of that conference as the "Fifth Annual Meeting," because such numerical designation connoted a false impression of the age of the Federation, even though it correctly stated the number of conventions of the membership-at-large that had been held. Accordingly, the Board acted officially to establish the Pittsburgh conference as the "Sixteenth Annual Meeting," with the intention that the annual gatherings of the Board of Control from 1928 to 1941 would thus be duly recognized, and properly so. This action was promptly recorded in the minutes.

Several months later there was a disconcerting discovery. While assembling data on past annual meetings for the 1945 directory it was found that the Board of Control meeting at Pittsburgh was not the sixteenth but the *seventeenth* annual conclave of that august body!

The very first item of business at the 1945 meeting of the Board was to rectify the omission of the lost anniversary and to correct the minutes of the Pittsburgh meeting. All is now serene in the counting room and a vigilant watch will be maintained henceforth to make certain that no more birthdays go astray!

W. H. W.

Proceedings of Member Associations

MISSOURI WATER AND SEWERAGE CONFERENCE

21st Annual Meeting

Jefferson City, Mo., October 22–23, 1945

The twenty-first Annual Meeting of the Missouri Water and Sewerage Conference was held at the Missouri Hotel, Jefferson City, on October 22–23, 1945. Total registration was 147.

The Water and Sewage Divisions met in joint session to open the conference, with President J. F. Sanders presiding. Papers presented were "Flood Control and Its Relation to Water Supplies," by J. A. Short of the Water Division of the Missouri Department of Resources and Development, and "Labor Relations," by W. V. Weir, Supt., St. Louis County Water Company.

The Sewage Division met in separate session in the afternoon of the first day, the following program being presented with G. L. Loelkes presiding: "Milk Waste Products," by H. E. Trebler, National Dairy Product Corp., Baltimore, Md.; "Infiltration," by Dewey Welch, City Engineer, Columbia, Mo.; and "Fly Control with DDT," by Robert Sikorsky, U. S. P. H. S., Jefferson City, Mo.

At the business meeting held in the evening of October 22, important actions included a by-laws amendment by which the Conference becomes a sponsor of the water and sewage works correspondence courses offered by the University of Missouri and the adoption of a voluntary certification program for sewage works operators. George S. Russell, faithful supporter of Conference activities for many years, was honored with the Federation's Kenneth Allen Award, the certificate being presented by W. H. Wisely, Executive Secretary-Editor of the Federation. Officers elected to serve the Conference for the year 1945–46 were:

Chairman: Roscoe R. Howard. Slater
Vice-Chairman: V. P. Opie, Paris
Secretary-Treasurer: W. A. Kramer, Jefferson City

Another general session was held on the morning of October 24 at which the papers presented included: "Legislation Applying to Water and Sewerage Utilities Under New Constitution," by R. E. McDonnell of Kansas City; "Federal Works Agency Program," by C. W. Anderson of the Kansas City District Office of FWA; and "Pensions, Retirement Plan and Social Security as Applied to Water Works Employees," by D. L. Maffitt. Des Moines, Ia. A short informal talk by Maj. Warwick Doll on his observations of sanitary engineering works in Germany was an added feature of this session.

In the afternoon, separate meetings of the Water and Sewage Divisions were again held, the program of the latter comprising two papers: "Garbage Disposal," by L. E. Ordelheide, Missouri State Board of Health, and "Flow Measurements in Sewerage Systems," by Prof. H. W. Wood, University of Missouri.

The twenty-first Annual Meeting closed with the Annual Dinner in the evening of October 23. W. E. Ralls, Supt. of Light and Water at Trenton, Mo., was presented at this function with the Annual Award of the Conference.

WARREN A. KRAMER,
Secretary-Treasurer

OHIO CONFERENCE ON SEWAGE TREATMENT

Nineteenth Annual Meeting

Columbus, Ohio, October 31–November 1, 1945

The Nineteenth Annual Meeting of the Ohio Conference on Sewage Treatment was held at the Hotel Fort Hayes, Columbus, on October 31 and November 1, 1945. Ninety members and guests were registered.

The conference opened with the annual business meeting, at which Chairman J. R. Turner presided. The following officers were elected to serve for 1945–46:

Chairman: D. D. Heffelfinger, Alliance
Vice-Chairman: L. C. Hoffman, Dayton
Secretary-Treasurer: L. B. Barnes, Bowling Green

F. H. Waring, Chief Engineer of the State Department of Health, was honored for his past service to the conference when he was presented with the Kenneth Allen Award of the Federation of Sewage Works Associations. Presentation of the certificate of Award to Mr. Waring was made by W. H. Wisely, Executive Secretary of the Federation.

The program at the annual dinner offered dual attractions. The address "Legislative Problems in Ohio" by the Hon. Roscoe R. Walcutt, State Senator from the Twelfth District, was both amusing and instructive. The second feature of this function was the travelogue, illustrated with slides, given by Dr. A. J. Fischer of the Dorr Co., Inc., in which Dr. Fischer presented scenes he encountered in Germany during the course of his government mission during the past summer.

Technical papers presented at the Conference were:

"Sewage Practice Encountered Overseas" by E. E. Smith, General Superintendent, Department of Water and Sewage Treatment at Lima, Ohio.

"A Study of Wastes from the Synthetic Rubber Industry" by C. C. Ruchhoft, Principal Chemist, U. S. P. H. S., Cincinnati.

"Modern Trends in the Sewage Works Field" by W. H. Wisely, Executive Secretary-Editor of F. S. W. A.

"Treatment of Supernatant Liquor" by Ming Lee, Sanitary Engineering Department of the University of Illinois at Urbana.

"Experience of a Sanitary Engineer in Persia" by Lt. Col. F. D. Stewart, Chief of the Sanitary Branch Headquarters, Fifth Service Command at Columbus.

"Report on the Pilot Plant Operation of the Dorr Company Vacuator" by John J. Wirts and Dr. A. J. Fischer, Superintendent, Easterly Sewage Treatment Plant, Cleveland, and Research Engineer of the Dorr Company, Inc., New York City, respectively.

"Planning Sewage Treatment Improvements for the Post War Era" by F. H. Waring.

"Progress in Waste Pickle Liquor Treatment" by Richard D. Hoak, Senior Fellow, Mellon Institute of Industrial Research at Pittsburgh.

"Sanitary Engineering at an Ordnance Depot" by L. T. Hagerty, Associate Sanitary Engineer, Blue Grass Ordnance Depot, Richmond, Ky.

A series of round table discussions included:

"Activated Sludge" by J. R. Collier, Superintendent of Sewage Treatment, Elyria, Ohio.

"Sewage Filtration" by Earl F. Wittmer, Chemical Engineer, Floyd G. Browne and Associates, Marion, Ohio.

"Sludge Digestion and Disposal" by Walter E. Gerdel, Superintendent of Westerly Sewage Treatment Plant, Cleveland.

"Standardizing Laboratory Practice" by T. C. Schaetzle, Engineer-

Chemist, Sewage Treatment Plant at Akron.

"Sewage Plant Maintenance" by R. F. Snyder, Sanitary Engineer, Sewage Treatment Plant at Massillon, Ohio.

At the close of the program those interested made an inspection trip to the Columbus Sewage Treatment Plant.

L. B. Barnes,
Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Texas Sewage Section	College Station, Texas	Feb. 11–13
New Jersey Sewage Works Association	Stacy-Trent Hotel, Trenton, New Jersey	March 20–22
Montana Sewage Works Association	Finlen Hotel, Butte, Montana	April 11–12
New England Sewage Works Association	Hotel Pickwick Arms, Greenwich, Conn.	May 17
Pacific Northwest Sewage Works Association	————	May 22–24
Central States Sewage Works Association	Purdue University, Lafayette, Ind.	June 13–14

Federation Affairs

MINUTES OF MEETING OF 1945 BOARD OF CONTROL

October 17, 1945

The Annual Meeting of the Board of Control of the Federation of Sewage Works Associations was called to order by President A. E. Berry in the Hotel Stevens, Chicago, Ill., at 10:45 A.M., October 17, 1945.

Roll call was as follows, a quorum being represented:

PRESENT IN PERSON

Affiliate or Office Represented	*Represented by*
President	A. E. Berry
Vice President	J. K. Hoskins
Treasurer	W. W. DeBerard
California Sewage Works Assn.	C. C. Kennedy
Federal Sewage Research Assn.	M. LeBosquet, Jr.
Florida Sewage Works Assn.	F. A. Eidsness
Georgia Water and Sewage Assn.	H. A. Wyckoff
Iowa Wastes Disposal Assn.	J. W. Pray
Kansas Water and Sewage Works Assn.	P. D. Haney
Maryland-Delaware Water and Sewage Assn.	A. L. Genter
Missouri Water and Sewerage Conference	W. Q. Kehr
New England Sewage Works Assn.	J. H. Brooks, Jr.
Pennsylvania Sewage Works Assn.	F. S. Friel
Rocky Mountain Sewage Works Assn.	D. E. Kepner
Texas Sewage Works Section	W. S. Mahlie
Canadian Inst. on Sewage and Sanitation	Stanley Shupe
Director-at-Large	F. W. Mohlman
Director-at-Large	C. A. Emerson
Water and Sewage Works Mfgrs. Assn.	L. H. Enslow
Water and Sewage Works Mfgrs. Assn.	W. B. Marshall
Water and Sewage Works Mfgrs. Assn.	F. W. Lovett
Organization Committee	Earnest Boyce
Publications Committee	F. W. Gilcreas
Sewage Works Practice Committee	M. M. Cohn

PRESENT IN PERSON, ACTING BY PROXY

Affiliate or Office Represented	*Represented by*
Past President	G. J. Schroepfer (for A. M. Rawn)
Dakota Water and Sewage Works Conf.	Kenneth Piper (for K. C. Lauster)
Michigan Sewage Works Assn.	G. S. Russell (for W. F. Shephard)
New Jersey Sewage Works Assn.	M. S. Kachorsky (for E. P. Molitor)
New York State Sewage Works Assn.	E. J. Smith (for C. G. Andersen)
Ohio Sewage Works Conf.	A. H. Niles (for C. D. McGuire)
Oklahoma Water and Sewage Conf.	V. P. Enloe (for E. R. Stapley)
Pacific Northwest Sewage Works Assn.	R. E. Fuhrman (for M. S. Campbell)
Argentina Society of Engineers	W. D. Hatfield (for E. B. Besselievre)
Director-at-Large	O. T. Birkeness (for W. J. Orchard)

Executive Secretary-Editor W. H. Wisely was also present.

The Executive Secretary directed attention to an error in the minutes of the meeting of the 1945 Board, held on October 14, 1944, wherein the annual meeting in 1944 was designated as the Sixteenth Annual Meeting. The 1944 meeting should have been designated as the Seventeenth Annual Meeting. It was moved, seconded and carried that the minutes of the Board of Control meetings held at Pittsburgh on October 11 and 14, 1944, be approved with the above correction and otherwise as published in SEWAGE WORKS JOURNAL, 17, 1, 158 (January, 1945).

President Berry presented the following as his report:

"The past year has been an abnormal one because of the effect of the war on the activities of the Federation. Restrictions on transportation made it necessary to cancel the annual convention scheduled for Toronto on October 1–3. Many Member Association conventions have likewise had to be cancelled or held on a reduced scale. In spite of this there has been an ever increasing interest in the work of the Federation, and the membership has risen by 228 over that of a year ago.

"Committee activities have continued most energetically. All are making splendid progress. The first manual of practice has been published and more are to follow at an early date. The Federation has played a prominent part in the preparation of the Ninth Edition of *Standard Methods of Water and Sewage Analysis*, soon to be released.

"The close of the war has opened up new opportunities for service by the Federation. The Water and Sewage Works Development Committee, on which this organization has been represented, has stimulated planning and blueprinting, with the result that the work already planned has now exceeded a billion dollars. As materials and labor become available it is anticipated these projects will reach the construction stage rapidly.

"The past year has been a prosperous one for the Federation, both in membership and in finances.

"While it was not possible to hold the usual convention, your Publications Committee has secured papers in much the same way as for an annual meeting. Some of these have already appeared in the JOURNAL and others will be published very shortly. This will be most helpful to all members. Similarly, the loss resulting from the lack of exhibits is being offset by the Water and Sewage Works Manufacturers Assn. through the publication of a brochure or 'Convention in Print.' This will be distributed to all members as a most helpful contribution to these times.

"The details of the year's activities will be presented in the reports of the secretary and the various committees. The co-operation of all officers of the Federation, members of the Board of Control and committees has been greatly appreciated, and my thanks to them are tendered herewith."

The Executive Secretary-Editor presented his report * for the year ended September 30, 1945. Reference was made to the gains in membership and financial position and to the expansion of current functions and services. The report was accepted, by motion, seconded and carried.

Treasurer W. W. DeBerard presented his report for the year ended September 30, 1945. The unencumbered total balance in banks at the close of the year was given as $17,830.03, distributed as follows:

	Balance, Sept. 30, 1945
First National (Champaign) . .	$ 7,830.03
Busey's State (Urbana)	5,000.00
Continental-Illinois (Chicago) .	5,000.00
Total	$17,830.03

It was pointed out that the above bank balances are in agreement with those stated in the financial report of the Executive Secretary and with the corresponding bank statements. It was also reported that, in accordance with the authorization of the Board and instructions of the Finance Advisory Committee, $5,000 was invested in 1945 in registered U. S. Treasury Bonds and $2,733.03 in registered Dominion of Canada Bonds. These securities are held in the safety deposit box of the Federation in the First National Bank

* See page 144.

of Champaign. By motion, seconded and carried, the report was accepted subject to the annual audit.

The report of the Executive Committee was presented by President Berry and referred to the 1946 Board by motion, seconded and carried.

The report of the General Policy Committee offered a recommendation "that the Federation sponsor a Fellowship for the study of some particularly perplexing problem in sewage research." It was ordered that the report be placed on file.

The report of the Publications Committee, containing the following recommendations, was presented by Chairman Gilcreas:

"In 1941, the Board of Control, on recommendation of the Publications Committee, established rules and regulations relative to the publication of papers presented at meetings of the Federation and Member Associations. Regulation 1 states that 'All papers presented before the meetings of the Federation or before any of its Member Associations become the property of the Federation, and publication of these in any but the Federation publications can be made only with specific permission from the Publications Committee.' Reconsideration of this regulation was made by the Committee to determine if the policy should be liberalized in any way to permit publication in journals other than SEWAGE WORKS JOURNAL of papers presented at meetings of the Federation or of Member Associations. The concensus of opinion of the Committee was that the present regulation should remain unchanged but that the Chairman of the Publications Committee and the Editor of the JOURNAL should be permitted to act for the full committee to determine in specific instances if simultaneous publication in a journal other than SEWAGE WORKS JOURNAL should be permitted. The Committee, therefore, recommends that there be no change made in the present rules and regulations.

"The Editor of the JOURNAL requested the opinion of the Publications Committee regarding a change in the format of the JOURNAL which would provide for a two-column page in place of the single-column page in use since the establishment of the JOURNAL. The Committee unanimously recommends that the two-column format be adopted for SEWAGE WORKS JOURNAL.

"Since it was anticipated that the glossary of sewage works terms would be presented for approval in the near future, the Publications Committee was circularized to determine if they would permit the Chairman of the Committee to act for them in passing upon this glossary since copies of the galley proof would not be available for all members. The Committe unanimously delegated this responsibility to the Chairman.

"The Sewage Works Practice Committee has submitted to the Publications Committee the first draft of Manual No. 2, 'Utilization of Sewage Sludge as Fertilizer.' Copies have been sent to all members of the Committee, who have given their tentative approval and have agreed that the final approval of the Manual may be delegated to the Editor and Advisory Editor."

By motion, seconded and carried, the recommendations of the committee were adopted, with instructions to the Editor to institute the format change with the January, 1946, issue of the JOURNAL.

Chairman Boyce presented the report of the Organization Committee, as follows:

"In order that the reports of this Committee will provide a complete record of organizational activity, note is made of the application of the Montana Sewage Works Association. The revised Constitution and By-Laws of the Montana association were submitted to and approved by the members of the Organization Committee subsequent to the completion of the 1944 report, but before the Annual Meeting of the Board of Control held October 11, 1944. Note is therefore made of the approval given by the Board to the Montana association at this meeting.

"Note is also made of the action taken at the 1944 Board of Control meeting with reference to the Georgia Water and Sewage Association Constitution and By-Laws, as amended in September, 1944. The Board action was to give approval 'subject to the review of the Organization Committee.' Committee approval was subsequently indicated to the Executive Secretary in a letter dated November 21, 1944.

"In September, 1943, the Organization Committee made certain constitution revision recommendations to the Pacific Northwest Sewage Works Association. The recommendations were subsequently incorporated in an amended Constitution and By-Laws and adopted by that association on May 11, 1944. Knowledge of this action did not reach the Committee until after the 1944 Board meeting. The Committee recommends to the Board of Control the approval of the revised Constitution and By-Laws of the Pacific Northwest Sewage Works Association.

"The Constitution and By-Laws of the Pennsylvania Sewage Works Association were amended in September, 1941. The Organization Committee in 1942 made certain recommendations with regard to additional amendments that would more definitely provide for the affiliation of the association with the Federation and for the election of a Director to represent the association on the Federation Board of Control. The matter has now been reopened, and it is anticipated that in the near future it will be possible for the Organization Committee to submit a favorable report to the Board of Control with regard to this association.

"The Iowa Wastes Disposal Association is now in the process of reorganization and, with the approval of its membership, will become the Iowa Sewage Works Association. The proposed Constitution and By-Laws of the new organization have been submitted for prior approval by this committee. Certain revisions and clarifications have been made as the result of this preliminary review, and the Organization Committee recommends to the Board of Control the approval of the new Constitution and By-Laws of the Iowa Sewage Works Association, contingent upon the completion of the reorganization of the association, as now proposed.

"The Louisiana Conference on Water Supply and Sewerage has expressed a desire to revise its Constitution and By-Laws to provide for a Sewage Works Section. The advice of the Executive Secretary and the Organization Committee has been requested in the preparation of the proposed amendments. It is anticipated that within the year that appropriate action will have been taken by the Louisiana association to provide for affiliation with the Federation.

"The Committee continues its recommendation that, pending the resumption of more normal conditions with regard to the activities of Member Associations, the Board of Control continue the affiliation of the following associations, which have not as yet submitted revised Constitutions and By-Laws, as nominal members of the Federation for the ensuing year:

Arizona Maryland-Delaware Oklahoma

"A check of the areas covered by the various Member Associations discloses that the following states are not officially included in any sewage works association that is now or may soon become a member of the Federation:

Alabama	South Carolina
Arkansas	Tennessee
Kentucky	Utah
Mississippi	Virginia
Nebraska	West Virginia
Nevada	

"The Committee recommends that a definite campaign be instituted through the office of the Executive Secretary, assisted by such committee or committees as may be helpful, to stimulate organizational interest in those states or areas not now represented by local sewage works associations; and to aid in providing complete coverage by the Federation of all states by securing the organization of local associations in those areas not now covered.

"Suggestions from Federation members residing in the states listed, or others, with regard to the possibility of extending organizational activity into these states would be appreciated."

By motion, seconded and carried, the report was accepted and all recommendations approved, with commendation to the committee and with the suggestion that existing Member Associations could be helpful in developing interest in adjacent states not now represented in the Federation by inviting to their technical meetings any individuals who are engaged in sewage works activity in such non-member states. The Constitution and By-Laws of the Iowa Sewage Works Association (replacing the Iowa Wastes Disposal Association) were approved subject to adoption by the membership of the association.

Chairman Cohn presented a detailed progress report * on the activities of the Sewage Works Practice Committee, referring to gratifying activity in the development of several new manuals of practice. The report was accepted by motion, seconded and carried. Mr. Enslow suggested that the committee give consideration to the production of a manual on sewage works cost accounting and Mr. Emerson suggested that the Executive Secretary investigate the purchase of a supply of standard ring binders for filing manuals of practice, such binders to be distributed by sale after the second or third manual is published. Mr. Niles suggested that future manuals be punched for such a binder before distribution. The Executive Secretary was authorized to extend a 15 per cent discount on all purchases of 300 or more copies of manuals of practice.

It was moved, seconded and carried that publication of Manual of Practice No. 2, entitled "Utilization of Sewage Sludge as Fertilizer," is authorized subject to final editing by Langdon Pearse, the Advisory Editor and the Editor.

The report of the Research Committee was presented by the Executive Secretary for Chairman Heukelekian. This was a statement of activity for the year and contained no recommendations. The report was accepted, by motion, seconded and carried.

Chairman Hatfield presented the report of the Committee on Standard Methods of Sewage Analysis, in which progress in the production of the Ninth Edition of the laboratory manual *Standard Methods of Water and Sewage Analysis* was cited. Distribution of the new edition is anticipated by late 1945 or early 1946. A Subcommittee on Industrial Waste Analyses has been created to fill a current need for special study. The report was accepted, by motion, seconded and carried.

The Executive Secretary presented the report of the Committee on Sewage Works Nomenclature for Chairman Velz. The report cited progress in the production of the Glossary of Water and Sewage Control Engineering, a joint project of A.S.C.E., A.P.H.A., A.W.W.A. and the Federation. Several details of production were explained and it was stated that C. L. Bogert, Editor of the glossary, had delivered the edited manuscript to A.S.C.E. on October 2, 1945. The report was approved, by motion, seconded and carried.

It was moved, seconded and carried that the Secretary advise the chairmen of the collaborating joint glossary committees that it is the desire of the Federation that the term "sewage works" be designated as the comprehensive term including all structures used for the collection, treatment and disposal of sewage.

The report * of the Committee on Operation Reports was presented by the Executive Secretary for Chairman Babbitt. Creation of an annual operation award, to be known as the William D. Hatfield Award, was recommended and the mechanics of determination of the recipient each year were set forth. By motion, seconded and carried, the recommendations of the report were adopted, with instructions to the committee to initiate the program immediately.

The report † of the Committee on Qualifications of Sewage Treatment Plant Operators was presented by the Secretary for Chairman Van Kleeck. This report, several years in development, sets forth an analysis of existing plans for certification and registration of operators with detailed recommendations for the guidance of the field in establishing new programs and in improving those now in operation. With several minor amendments, the report was adopted by motion, seconded and carried, the committee to be continued to activate the provisions of the report.

Chairman Mohlman presented a verbal report for the Industrial Wastes Committee, advising that functions to date have been mainly organizational except for the arrangement for several technical program and JOURNAL contributions. The committee plans to bend its efforts toward the development of interest in industrial waste problems in the Member Associations as

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* See page 155.

* See page 157.

† See page 147.

well as on a national basis. The report was accepted, by motion, seconded and carried, with the suggestion that this aspect of Federation activity be given the greatest possible emphasis and that such activity be aimed toward achievement of maximum co-operation between the interests concerned with industrial pollution.

President Berry presented the report of the Finance Advisory Committee for Chairman Orchard, who was unable to be in attendance because of illness. The verbal presentation referred to the services of the committee in carrying out the prior instructions of the Board in regard to the 1944 audit, the investment of funds referred to in the report of the Treasurer and in the determination of financial details of the 1945 membership contest. The committee also developed the 1946 budget, as presented by the Executive Committee. The report was accepted, by motion, seconded and carried, and the Executive Secretary was instructed to extend the regrets of the Board to Chairman Orchard at his inability to attend this meeting, with best wishes for his early and complete recovery.

Mr. Emerson, senior representative of the Federation on the Joint Committee on Water and Sewage Works Development, presented a verbal report for that committee. He reviewed past accomplishments and outlined current activities, pointing out that the original objectives of the committee have been largely realized. Present work is on a limited scale and is being conducted from the headquarters of the W.&S.W.M.A. By motion, seconded and carried, the report was approved.

Chairman Emerson presented the report * of the Committee on Honorary Membership, which report recommended that Dr. Willem Rudolfs be elected to the rank of Honorary Member. A motion to adopt the recommendation was seconded and carried and the election of Dr. Rudolfs to honorary membership was so ordered.

The report * of the Awards Committee was next presented, with recommendations that the 1945 awards be conferred as follows:

Award	*Recipient*
Harrison Prescott Eddy	Lloyd R. Setter
George Bradley Gascoigne	John D. McDonald
Charles Alvin Emerson	Harold Warner Streeter
Kenneth Allen:	
Florida Sewage Works Assn.	Joe Williamson, Jr.
Kansas Water and Sewage Works Assn.	Murray Alderson Wilson
Missouri Water and Sewerage Conf.	George S. Russell
Ohio Sewage Works Conf.	Frederick Holman Waring
Pennsylvania Sewage Works Assn.	Howard Eugene Moses
Arizona Sewage and Water Works Assn.	Dario Travaini

By motion, seconded and carried, the recommended awards were authorized, and the Executive Secretary was instructed to secure cost and other data concerning the production of suitable emblems to be presented to recipients of past and future awards, his report to be cleared through the Awards Committee and referred to the Executive Committee for recommendation to the Board of Control at the next annual meeting.

The Executive Secretary presented the following applications for membership in the Federation in the grade of Associate Member:

American Concrete Pipe Assn., Chicago, Ill.

Climax Engineering Co., Chicago, Ill.

Josam Manufacturing Co., Cleveland, Ohio

McNulty Engineering Co., South Boston, Mass.

By motion, seconded and carried, the above applications were approved.

President Berry suggested that action of the Board was desirable in regard to authorization for the reimbursement of members of the Board in attendance at this meeting for their hotel expenses while in Chicago. It was pointed out that many of those present had attended at personal expense. It was moved, seconded and car-

* See page 159.

* See page 159.

ried that the Treasurer and Executive Secretary be authorized to reimburse each member of the Board who had been required to spend two nights in Chicago to the amount of $10 and each member who had been required to spend but one night in Chicago to the amount of $6, this expense to be charged to the administration and convention expense accounts.

Mr. Friel inquired as to the procedure that would be required to make it possible for an Active or Corporate Member of any Member Association to claim direct membership in the Federation. General discussion brought out that such a change would involve a complete revision of the basic structure of the Federation. No action was taken.

President Berry issued a call for a meeting of the Election Committee to follow immediately the adjournment of this session.

The meeting adjourned *sine die* at 3:55 P.M.

(Signed) W. H. WISELY,
Executive Secretary

Approved:
(Signed) A. E. BERRY, *President*

MINUTES OF MEETING OF 1945 ELECTION COMMITTEE

October 17, 1945

The regular meeting of the 1945 Election Committee of the Federation of Sewage Works Associations was brought to order by President A. E. Berry at 4:10 P.M., October 17, 1945, in the Hotel Stevens, Chicago, Ill.

Roll call of Directors representing Member Associations was as follows:

PRESENT IN PERSON

Member Association Represented	*Director*
California Sewage Works Assn.	C. C. Kennedy
Federal Sewage Research Assn.	M. LeBosquet, Jr.
Florida Sewage Works Assn.	F. A. Eidsness
Georgia Water and Sewage Assn.	H. A. Wyckoff
Iowa Wastes Disposal Assn.	J. W. Pray
Kansas Water and Sewage Works Assn.	P. D. Haney
Maryland-Delaware Water and Sewage Assn.	A. L. Genter
Missouri Water and Sewerage Conf.	W. Q. Kehr
New England Sewage Works Assn.	J. H. Brooks, Jr.
Pennsylvania Sewage Works Assn.	F. S. Friel
Rocky Mountain Sewage Works Assn.	D. E. Kepner
Texas Sewage Works Section	W. S. Mahlie
Canadian Institute on Sewage and Sanitation	Stanley Shupe

PRESENT IN PERSON, ACTING BY PROXY

Member Association Represented	*Represented by*
Central States Sewage Works Assn.	C. C. Larson (for B. A. Poole)
Dakota Water and Sewage Works Conf.	Kenneth Piper (for K. C. Lauster)
Michigan Sewage Works Assn.	G. S. Russell (for W. F. Shephard)
New Jersey Sewage Works Assn.	M. S. Kachorsky (for E. P. Molitor)
New York State Sewage Works Assn.	E. J. Smith (for C. G. Andersen)
Ohio Sewage Works Conference	A. H. Niles (for C. D. McGuire)
Oklahoma Water and Sewage Conf.	V. P. Enloe (for E. R. Stapley)
Pacific Northwest Sewage Works Assn.	G. J. Schroepfer (for M. S. Campbell)
Argentina Society of Engineers	R. E. Fuhrman (for E. B. Besselievre)

The above representation constituted a quorum. Executive Secretary W. H. Wisely was also present.

President Berry called for nominations to the office of President for the year 1945–46 and the name of J. K. Hoskins (Federal) was presented by Mr. LeBosquet. There were no further nominations and a motion to close was seconded and carried. The election of Mr. Hoskins as President was confirmed by *viva voce* vote and so declared.

Upon call for nominations to the office of Vice-President for the year 1945–46, the name of F. S. Friel (Pennsylvania) was presented by Mr. Genter. There being no further nominations, a motion to close was seconded and carried. The election of Mr. Friel to the office of Vice-President was confirmed by *viva voce* vote and so declared.

A request for nominations to the office of Treasurer for the year 1945–46 brought a renomination of W. W. DeBerard (Central States) by Mr. Brooks. No other names were offered and a motion to close the nominations was seconded and carried. Re-election of Mr. DeBerard was confirmed by *viva voce* vote and so declared.

Nominations for the office of Director-at-Large for a three-year term ending in October, 1948, were requested. The name of Harold F. Gray (California) was presented by Mr. Kennedy. There were no further nominations and motion to close was seconded and carried. By *viva voce* vote, the election of Mr. Gray to the office of Director-at-Large was confirmed and so declared.

There being no further business, the meeting adjourned *sine die* at 4:25 P.M.

(Signed) W. H. Wisely,
Executive Secretary

Approved:
(Signed) A. E. Berry, *President*

MINUTES OF MEETING OF 1946 BOARD OF CONTROL

October 17–18, 1945

The organization meeting of the 1946 Board of Control of the Federation of Sewage Works Associations was called to order by retiring President A. E. Berry, at 4:30 P.M., October 17, 1945, in the Hotel Stevens, Chicago, Ill.

Roll call was as follows, a quorum being represented:

Present in Person

Affiliate or Office Represented	*Represented by*
President-elect	J. K. Hoskins
Past President	A. E. Berry
Vice President-elect	F. S. Friel
California Sewage Works Assn.	C. C. Kennedy
Central States Sewage Works Assn.	C. C. Larson
Federal Sewage Research Assn.	M. LeBosquet, Jr.
Florida Sewage Works Assn.	F. A. Eidsness
Georgia Water and Sewage Assn.	H. A. Wyckoff
Iowa Wastes Disposal Assn.	J. W. Pray
Maryland-Delaware Water and Sewage Assn.	R. E. Fuhrman
Missouri Water and Sewerage Conf.	G. S. Russell
New York State Sewage Works Assn.	E. J. Smith
Ohio Sewage Works Conf.	A. H. Niles
Pennsylvania Sewage Works Assn.	F. S. Friel
Texas Sewage Works Section	W. S. Mahlie
Canadian Institute on Sewage and Sanitation	Stanley Shupe
Director-at-Large	C. A. Emerson
Director-at-Large	F. W. Mohlman
Water and Sewage Works Mfgrs. Assn.	L. H. Enslow
Water and Sewage Works Mfgrs. Assn.	F. W. Lovett
Organization Committee	Earnest Boyce
Publications Committee	F. W. Gilcreas
Sewage Works Practice Committee	Morris M. Cohn

PRESENT IN PERSON, ACTING BY PROXY

Affiliate or Office Represented	*Represented by*
Treasurer	O. T. Birkeness (for W. W. DeBerard)
Dakota Water and Sewage Works Conf.	Kenneth Piper (for K. C. Lauster)
Kansas Water and Sewage Works Assn.	P. D. Haney (for P. E. Kaler)
Michigan Sewage Works Assn.	W. Q. Kehr (for W. F. Shephard)
New England Sewage Works Assn.	J. H. Brooks, Jr. (for L. W. Van Kleeck)
New Jersey Sewage Works Assn.	M. S. Kachorsky (for E. P. Molitor)
Oklahoma Water and Sewage Conf.	V. P. Enloe (for E. R. Stapley)
Pacific Northwest Sewage Works Assn.	G. J. Schroepfer (for M. S. Campbell)
Rocky Mountain Sewage Works Assn.	D. E. Kepner (for W. V. Leonard)
Argentina Society of Engineers	W. D. Hatfield (for E. B. Besselievre)
Water and Sewage Works Mfgrs. Assn.	W. B. Marshall (for Linden Stuart)

Executive Secretary-Editor W. H. Wisely was also present.

The Executive Secretary presented the report of the Election Committee, which listed the following new officers for the terms indicated: J. K. Hoskins, President; F. S. Friel, Vice-President; W. W. DeBerard, Treasurer (all to serve until October, 1946) and H. F. Gray, Director-at-Large (to serve until October, 1948).

In relinquishing the chair to President-elect Hoskins, Dr. Berry repeated his earlier acknowledgment of the co-operation he had received during the past year and spoke of the many pleasant associations he had enjoyed during his term as President. He tendered his continuing interest and aid toward the progress of the Federation.

It was moved, seconded and carried that Past President Berry be given a rising vote of thanks for his energetic and progressive leadership in the course of his term as President. Dr. Berry was so acclaimed.

Assuming the chair, President Hoskins thanked the Board for the confidence placed in him and gave assurance that he would serve the Federation to the best of his ability. He closed his brief remarks with a plea for the wholehearted support of the Board and of all officers and committee personnel, to the end that the Federation may meet more than adequately its growing responsibilities.

The Executive Secretary presented the matter of the continuation of the membership contest in 1946 and requested authorization for the prizes if the contest is to be conducted, which item of business was referred from the 1945 Board. It was moved and seconded that a membership contest be conducted in 1946 on the same basis as in 1945, except that the two prizes be awarded to the winning Member Associations for allocation as each may choose, the amounts of the prizes to be $100 for the Member Association showing the greatest numerical increase and $50 to the Member Association showing the greatest percentage increase in membership during the period of the contest. The motion was carried with one vote dissenting.

Past President Berry presented the budget for the fiscal year of 1946, as developed by the Finance Advisory Committee and recommended by the Executive Committee. Minor adjustments were agreed upon in discussion and the following 1946 budget was adopted by motion, seconded and carried:

Receipts	*1946 Budget*
Membership Dues:	
Active	$ 9,000
Corporate	150
Associate	1,400
Non-Member Subscriptions	2,000
Advertising (Net)	13,000
Sale of Miscellaneous Publications (Net)	1,200
W.&S.W.M.A. Contribution	5,000
Miscellaneous Income	500
	$32,250
Expenses	
Printing and Mailing of Publications	$14,300
Executive Secretary—Salary	7,000
Office Salaries	5,400
Office Rent	720
Office Expense	1,300
Travel Expense	1,000
Editorial Expense	900
Administration Expense	300
Committee Expense	200
Convention Expense	500
Contingencies	630
	$32,250

The next item of business was the appointment of an Executive Secretary-Editor, in accordance with Section 3 of Article IV of the By-Laws. It was moved, seconded and carried that W. H. Wisely be re-appointed as Executive Secretary-Editor for the fiscal years of 1946 and 1947, at a salary of $7,000 for the fiscal year of 1946, and that the Board commends the services of the Executive Secretary-Editor for his services in his current term of office.

At this point (5:05 P.M.) President Hoskins declared the meeting to be in recess until 9:00 A.M., October 18, 1945.

The meeting was called to order for resumption of business at 9:10 A.M., October 18, 1945. There were no changes in roll call.

It was moved, seconded and carried that Dr. F. W. Mohlman be commended for his service as Advisory Editor during the past two years and that he be re-appointed to this position for the fiscal years of 1946 and 1947.

President Hoskins presented a tentative schedule of 1946 committee appointments, as compiled by himself and Past President Berry for the guidance of the Board. He proposed the following constitutional committee appointments, which were approved by motion, seconded and carried:

Executive Committee

(President and four Directors)

J. K. Hoskins, *Chairman*

F. W. Lovett (W.&S.W.M.A.)
F. S. Friel (Pennsylvania)
C. C. Kennedy (California)
C. A. Emerson (Director-at-Large)

General Policy Committee

(Latest living Past President as chairman, three Members-at-Large, three Directors. Three of total to be operators. Three-year terms)

A. E. Berry, *Chairman*

A. H. Niles, 1948 (Director, Operator)
J. H. Brooks, Jr., 1946 (Member-at-Large, Operator)
A. S. Bedell, 1946 (Member-at-Large)
R. E. Fuhrman, 1948 (Director, Operator)
M. LeBosquet, Jr., 1947 (Director)
D. E. Bloodgood, 1947 (Member-at-Large)

Publications Committee

(Editor and at least four Members-at-Large)

F. W. Gilcreas, *Chairman* (New England)

W. H. Wisely (Editor)
F. W. Mohlman (Advisory Editor)
Rolf Eliassen (New York)
Carl E. Green (Pacific Northwest)
F. M. Veatch (Rocky Mountain)
C. C. Larson (Central States)

Organization Committee

(Three Members-at-Large)

Earnest Boyce, *Chairman* (Michigan)

C. R. Compton (California)
R. H. Suttie (New England)

Sewage Works Practice Committee

(Editor and at least four Members-at-Large)

Morris M. Cohn, *Chairman* (New York)

W. H. Wisely (Editor)
F. W. Mohlman (Advisory Editor)
C. E. Keefer (Md.-Del.)
G. P. Edwards (New York)
H. F. Gray (California)
J. J. Wirts (Ohio)
J. R. Downes (New Jersey)
A. H. Niles (Ohio)
Langdon Pearse (Central States)
L. W. Van Kleeck (New England)
F. W. Gilcreas (New England)
R. F. Brown (California)
K. V. Hill (Central States)
D. E. Bloodgood (Central States)

Research Committee

(At least four Members-at-Large appointed by Chairman, President concurring)

Willem Rudolfs, *Chairman*

President Hoskins then proposed the following special committee appointments for 1946, which were approved by motion, seconded and carried:

JOINT COMMITTEES

Committee on Sewage Works Nomenclature

C. J. Velz, *Chairman* (New York)

C. A. Emerson (Honorary)
C. E. Keefer (Maryland-Delaware)

Committee on Standard Methods of Sewage Analysis

W. D. Hatfield, *Chairman* (Central States)

G. E. Symons (New York)
S. E. Coburn (New England)
A. J. Fischer (New York)
G. P. Edwards (New York)
E. W. Moore (New England)
D. E. Bloodgood (Central States)
F. W. Gilcreas (New England)
E. F. Hurwitz (Central States)
Keeno Fraschino (California)
W. S. Mahlie (Texas)
M. Starr Nichols (Central States)
Richard Pomeroy (California)
C. C. Ruchhoft (Federal)
Willem Rudolfs (New Jersey)
H. W. Gehm (New Jersey)
H. Heukelekian (New Jersey)
R. D. Hoak (Pennsylvania)
R. F. Weston (Pennsylvania)
T. C. Schaetzle (Ohio)

Committee on Water and Sewage Works Development

(Two representatives of Federation)

C. A. Emerson
G. J. Schroepfer

SPECIAL CONVENTION COMMITTEES

Meeting Place Committee

(President, Vice-President, Past President and Secretary of Federation; President, Chairman of Sewage Works Div. and Secretary-Manager of W.&S.W.M.A.)

J. K. Hoskins, *Chairman* (President, F.S.W.A.)

F. S. Friel (Vice Pres., F.S.W.A.)
A. E. Berry (Past Pres., F.S.W.A.)
W. H. Wisely (Secretary, F.S.W.A.)
W. C. Sherwood (Pres., W.&S.W.M.A.)
F. W. Lovett (Chmn. Sew. Wks., Div., W.&S.W.M.A.)
A. T. Clark (Secy.-Mgr., W.&S.W.M.A.)

Publicity and Attendance Committee

L. H. Enslow, *Chairman*

E. J. Cleary
M. M. Cohn
W. S. Foster
A. Prescott Folwell
J. P. Russell
J. A. Daly

Convention Management Committee

(Three Federation and two W.&S.W.M.A. representatives)

A. E. Berry, *Chairman* (F.S.W.A.)

W. H. Wisely (F.S.W.A.)
Stanley Shupe (F.S.W.A.)
Arthur T. Clark (W.&S.W.M.A.)
W. J. Orchard (W.&S.W.M.A.)

OTHER SPECIAL COMMITTEES

Awards Committee

L. F. Warrick, *Chairman* (Central States)

E. S. Chase (New England)
G. M. Ridenour (Michigan)
H. W. Streeter (Federal)

Operation Reports Committee

H. E. Babbitt, *Chairman* (Central States)

W. A. Allen (California) W. F. Shephard (Michigan)

Finance Advisory Committee

W. J. Orchard, *Chairman*

J. K. Hoskins (President) A. E. Berry (Past President)

Industrial Wastes Committee

F. W. Mohlman, *Chairman* (Honorary)

D. E. Bloodgood (Central States) H. W. Gehm (New Jersey)

L. F. Oeming (Michigan)

Honorary Membership Committee

(President and four living Past Presidents, senior Past President as chairman)

A. S. Bedell, *Chairman*

G. J. Schroepfer A. E. Berry

A. M. Rawn J. K. Hoskins

Mr. Cohn called attention to the many important legislative matters concerning Federation interests and activities that are currently under consideration. He moved that there be created a special Legislative Analysis Committee comprising five or more members appointed by the President, said committee to study legislation pertinent to the interests of the Federation and to serve the Board in advisory capacity. The motion was seconded and carried.

The next item of business was the selection of an auditing firm to perform the annual audit of Federation accounts as of December 31, 1945. It was moved, seconded and carried that the Finance Advisory Committee be empowered to select auditors for the above purpose.

The following depositories for Federation funds for the fiscal year of 1946 were approved:

First National Bank of Champaign, Ill.
Busey's State Bank of Urbana, Ill.
Continental-Illinois National Bank and Trust Co. of Chicago, Ill.

The Executive Secretary presented the report of the Meeting Place Committee, in which it was recommended that the Nineteenth Annual Meeting of the Federation be held at Toronto, Canada, on October 7–9, 1946. It was pointed out that this recommendation was supported by the Executive Committee and by the 1945 Board of Control, at the time action was taken to postpone the 1945 annual meeting. By motion, seconded and carried, staging of the Nineteenth Annual Meeting at Toronto was approved, the dates of October 7–9, 1946, being tentatively approved subject to change, if necessary, by the Executive Committee.

It was moved that the requirement of Associate membership in the Federation be waived at the Nineteenth Annual Meeting in the case of members in good standing of the Canadian Water and Sewage Equipment Manufacturers Assn. who may wish to participate in the exhibits at that meeting. The motion was seconded and carried.

The Executive Secretary presented correspondence he had received from Secretary-Manager Arthur T. Clark of the W.&S.W.M.A., in regard to the conduct of entertainment at meetings of the Federation and of its Member Associations. This correspondence included a report dated May 24, 1945, of the Board of Governors of W.&S.W.M.A. in which the following statement of policy of the American Water Works Assn. was commended and urged as basis for a similar statement of policy to be adopted by the Federation and its Member Associations:

"1. The registration fees at Sectional Meetings shall provide funds sufficient to cover all entertainment. Expenditures for allotments received by local Sections from the Association may be made for the Approved Uses of A.W.W.A. Funds allocated to local Sections, as are directed by the Section officers.

"2. Registration fees at Section meetings may be uniform for all grades of members or may be upon a graduated basis designed to provide through recorded channels funds to cover the requirements of Section 1, provided, that the maximum fee for such purposes shall not exceed $10.00 for any class of member.

"3. Representatives of manufacturers who are not Associate Members of A.W.W.A. shall be charged a registration fee double that charged the representatives of manufacturers who are Associate Members.

"4. The Water and Sewage Works Manufacturers Association shall establish its own rulings as to exhibiting at Section meetings, except that no firm or person shall be allowed to exhibit at any convention or Section meeting unless he be an Associate Member of A.W.W.A."

It was moved, seconded and carried that the above statement of policy be transmitted to all Member Association secretaries, with the explanation that it applies only to sections of A.W.W.A. as written and that the Board has directed its transmittal only for the information and consideration of the Member Associations.

The above report of the Board of Governors of W.&S.W.M.A. also included a recommendation that the "Club Room" type of entertainment be adopted, on a trial basis, at all water and sewage meetings, this type of entertainment being designed to prevent and replace undesirable private room entertainment. The report included detailed rules and procedures for presenting such "Club Room" entertainment. It was moved that the "Club Room" type of entertainment be endorsed to the Member Associations and adopted for future meetings of the Federation, and that the Executive Secretary so advise the Secretary-Manager of W.&S.W.M.A. The motion was seconded and carried.

Mr. Niles suggested that the Federation should present each of its retiring presidents with a suitable certificate to commemorate his service in that capacity. It was moved, seconded and carried that the Executive Secretary, under the direction of the Executive Committee, develop a certificate to be presented to each Past President at the Nineteenth Annual Meeting and that such a certificate be presented to each retiring President in the future.

Mr. Emerson referred to the growing strength and responsibilities of the Federation and suggested that the time may be approaching for consideration to the publication of SEWAGE WORKS JOURNAL on a monthly schedule. He moved that the Publications Committee, together with a representative to be appointed by the W.&S.W.M.A., be instructed to study costs, availability of material, advertising revenue and other data pertinent to the production of a monthly JOURNAL, and that a report be made to the Executive Committee by May 31, 1946, for review and recommendation by that committee to the Board of Control at the 1946 annual meeting. The motion was seconded and carried.

Mr. Schroepfer directed attention to the amended Spence Bill (H.R. 4070), as recently introduced into the 79th Congress. An earlier draft of this bill was considered by the 1945 Board and a resolution concerning it was distributed to members of the Congress early in 1945. It was moved, seconded and carried that the Board reaffirm its endorsement of the principles of the Spence Bill (H.R. 4070) and the companion measure in the Senate, and that the Executive Secretary so inform the membership of the House Rivers and Harbors Committee and the Senate Commerce Committee.

Mr. Cohn suggested similar consideration of the Bailey Bill (H.R. 3972), which would permit an industry to charge all costs of construction of waste treatment works to current expenses instead of capital investment, thus making such expenditures deductible in the computation of taxes. He moved that the principles of the Bailey Bill be endorsed by the Board and that the Executive Secretary so advise the proper clearing committees of the House and Senate, with the explanation that the interest of the Federation is prompted by the probable favorable influence of the legislation on the abatement of industrial stream pollution. The motion was seconded and, when the *viva voce* vote was divided, President Hoskins asked for a showing of hands. Results of the ballot were: 17 ayes; 11 nays; 5 not voting.

President Hoskins declared the motion carried.

It was moved, seconded and carried that the previous action of the Board in regard to the 1946 membership contest be reconsidered. Mr. Enloe then moved that the prize to be offered to the Member Association showing the greatest percentage increase be made the same as that to be given to the association recording the greatest numerical increase, *i.e.,* $100. The motion was seconded and carried.

Adjournment of the Eighteenth Annual Meeting to the next annual meeting or upon call of the President was moved, seconded and carried at 11:35 A.M.

(Signed) W. H. Wisely,
Executive Secretary

Approved:
(Signed) J. K. Hoskins, *President*

REPORT OF EXECUTIVE SECRETARY–EDITOR

Year Ended September 30, 1945

This report covers a 12-month period which began with the war at its peak, during which total victory was won, and ending in the early stages of the reconversion to peace time activity. Despite the instability and uncertainty of these hectic times the Federation has continued its gratifying gains of recent years and today enjoys the strongest position in its history, by every measure. The extraordinary current interest in sewage works construction, as evidenced by planning estimates, foretells a period of accelerated growth and responsibility.

PUBLICATIONS

Sewage Works Journal

Curtailment of Member Association meetings, with consequent reduction in available Journal material, necessitated extra effort in gathering contributed papers. The 1945 volume of the Journal will, however, maintain the same high standard of quality and quantity of subject matter as those preceding.

Unavoidable delays in the establishment of our printer and in connection with the assembly of advertising copy made it impossible to effect distribution of the Journal on its regular schedule, but no 1945 issue was distributed more than one week following the scheduled month of issue. Production difficulties should be eased as wartime obstacles disappear. Restrictions on paper stock have already been lifted and it is expected that use of the original 60-lb. text paper will be resumed early in 1946, replacing the 45-lb. stock used in accordance with WPB requirements since March, 1944.

Attention is directed to the effort made to improve the Annual Directory as contained in the March, 1945, issue. It is planned to follow the same general form in developing the directory henceforth.

Interest in the advertising facilities offered by the Journal continues to increase, the paid space used in the six issues of November, 1944, to September, 1945, inclusive, aggregating 256 11/24 pages. A comparison of advertising space used in recent years follows:

Year	*Paid Advtg. (Pages)*	*Per Cent Increase Over Previous Year*
1942	183⅙	——
1943	202¾	10.6
1944	220⅙	8.6
1945	262⅚	19.1

A substantial increase was again recorded in paid circulation of the Journal, this figure being 3,805 on September 30, 1945, including 3,292 member and 513 non-member subscriptions. The gain in paid circulation for the year was 8.2 per cent.

Back Numbers

A marked increase in the sale of single copies of back issues of the Journal resulted from an effort to aid various technical libraries to assemble complete files. A total of 381 single copies were sold during the year. According to the running inventory kept by Lancaster Press, Inc., about 8,900 back numbers are in storage.

Modern Sewage Disposal

Only 22 copies of the Federation's Tenth Anniversary Book "Modern Sewage Disposal" remain to be sold. This item will undoubtedly be closed out during the next year.

Manuals of Practice

A new and valuable service by the Federation was initiated in January, 1945, by distribution of Manual of Sewage Works Practice No. 1, "Occupational Hazards in the Operation of Sewage Works." Distribution data follow:

Total copies printed		7,227
Copies distributed to Sept. 30, 1945:		
Free to members	3,172	
Sold to members at 25¢ rate	540	
Sold to non-members at 50¢ rate	2,067	
Complimentary and replacement	89	5,868
Inventory, Sept. 30, 1945		1,359

The first manual, an outstanding technical accomplishment, was a complete financial success by virtue of the heavy demand for extra copies. Gross revenue to date is $1,168.28, as compared to the production cost of $871.20.

MEMBER ASSOCIATION ACTIVITY

Every effort was made to co-operate with the officers of Member Associations in matters of administration and development. The Executive Secretary visited and participated in the following meetings during the year:

Association	*Place and Date of Meeting*
Pennsylvania S.W.A.	Pittsburgh, Oct. 12–14, 1944
Canadian Institute	Toronto, Nov. 1–2, 1944
New York S.S.W.A.	New York City, Jan. 19, 1945
Montana S.W.A.	Lewistown, April 12–13, 1945
Rocky Mountain S.W.A.	Denver, Sept. 20, 1945

Other meetings at which the Federation was similarly represented were the Illinois Sewage Works Operators Conference at Springfield (Nov. 29, 1944); the Purdue Industrial Wastes Conference at Lafayette, Ind. (Nov. 30, 1944); the Illinois Sewage Works Short Course at Urbana (March 26–30, 1945); the Louisiana Water and Sewerage Conference at Baton Rouge (June 27–28, 1945) and the Indiana Sewage Works Assn. at Indianapolis (Aug. 17, 1945).

At the meeting of the Louisiana Conference listed above, plans were discussed in regard to the creation of a new Member Association of the Federation. Necessary constitutional revisions are now under consideration.

MEMBERSHIP

The Montana Sewage Works Association officially became a Member Association of the Federation on January 1, bringing the total of affiliated associations to 27.

Fears early in the year that the cancellation of many Member Association meetings would seriously curtail their membership proved entirely unfounded. All credit for the satisfying increase in the aggregate membership in these associations to a new all-time high of 3,216 must go to the zealous efforts of the Member Association secretaries and their membership committees. The above total represents a gain of 228 members or 7.6 per cent during the year ended Sept. 30, 1945. A detailed tabulation of membership is made a part of this report; it will be noted that only four Member Associations failed to equal or exceed their membership during the year.

In accordance with the rules of the annual membership contest (see March, 1945, JOURNAL, p. 392), the Arizona Sewage and Water Works Association and the Canadian Institute on Sewage and Sanitation have earned the privilege of naming the individuals from their membership who shall receive the 1945 prizes. The prize (one $100 Series E bond or equivalent) for percentage increase in membership will be assigned by the Arizona unit, the increase from 10 to 24 members representing a gain of 140 per cent—the highest recorded. The Canadian Institute, by increasing its membership by 72 members during the contest, will assign a similar prize to one or more of its members.

Membership in the Associate class also continues to increase. Associate Members now number 76 as compared to 72 on September 30, 1944.

FINANCIAL

Each member of the Board of Control was furnished statements of receipts and disbursements as of December 31, 1944, March 31, 1945, and June 30, 1945, as is required under Section 5, Article IV of the By-Laws. The December 31, 1944, statement, with the balance sheet of that date, were taken from the annual audit, as performed by the Bresee-Warner Systems of Champaign.

Financial progress of the Federation in recent years is shown by the following:

Date	*Net Worth*
December 31, 1940	$ 3,075.78
December 31, 1941	7,089.54
December 31, 1942	13,489.73
December 31, 1943	21,981.73
December 31, 1944	25,863.52
September 30, 1945	33,778.65

MISCELLANEOUS

The Executive Secretary extended all possible assistance to Federation committees in the performance of their functions. There having been no convention, the time ordinarily required for service in the convention management committees was used to good advantage in the promotion of advertising, membership and sale of publications.

Of particular satisfaction to the Executive Secretary has been the increasing demand upon the headquarters office for technical service. A total of 54 technical inquiries were received and answered during the year, and a number of gratifying responses have resulted. In addition, 21 inquiries pertaining to personnel placement were received and handled, with successful results in several cases.

ACKNOWLEDGMENTS

The splendid co-operation of all officers, committee chairmen, Member Association secretaries and many individuals is gratefully acknowledged.

Respectfully submitted,

W. H. Wisely,
Executive Secretary

SUMMARY OF MEMBERSHIP

As of September 30, 1945

Federation Members

Honorary	7
Associate	76
Member Associations	27
Active Members	3,166
Alternate Active Members	30
Corporate Members	20

Net Membership of Member Associations

Member Association	Total Active, Alt. Active and Corporate Members*		Numerical Increase	Per Cent Increase
	Sept. 30, 1944	Sept. 30, 1945	1944–1945	1944–1945
Arizona	10	24	14	140.0
California	299	300	1	0.3
Canadian Inst.	151	223	72	47.7
Central States	538	563	25	4.7
Dakota	41	45	4	9.8
Federal	102	98	−4	——
Florida	61	70	9	14.7
Georgia	53	65	12	22.7
I.S.E. (England)	32	34	2	6.3
I.S.P. (England)	97	106	9	9.2
Iowa	43	43	—	——
Kansas	19	28	9	47.5
Maryland-Delaware	27	29	2	7.4
Michigan	120	127	.7	5.8
Missouri	37	41	4	10.8
Montana**	—	31	31	——
New England	160	172	12	7.5
New Jersey	82	87	5	6.1
New York	488	493	5	1.0
North Carolina	58	50	−8	——
Ohio	105	108	3	2.8
Oklahoma	5	10	5	100.0
Pacific Northwest	100	101	1	1.0
Pennsylvania	216	216	—	——
Rocky Mountain	71	61	−10	——
San. Eng. Div. (Argentina)	10	6	−4	——
Texas	63	85	22	35.0
Totals	2,988	3,216	228	7.6

* Dual Members, *i.e.*, those belonging to more than one Member Association, credited only to "home" association.

** New member association. Admitted to Federation in October, 1944.

QUALIFICATIONS OF SEWAGE TREATMENT PLANT OPERATORS

Final Report of the Special Committee Authorized by the Board of Control on October 11, 1941, Approved October 17, 1945

COMMITTEE

L. W. VAN KLEECK, *Chairman*
W. A. ALLEN
E. P. MOLITOR

INTRODUCTION

This committee has reviewed the existing rules and regulations governing the certification, approval and licensing of sewage plant operators in the United States in states where either a voluntary or compulsory plan is now in effect. The plans in use have been drawn upon freely by the committee in formulating recommendations for national guidance.

In 1940 the states of Connecticut, New Jersey, New York and Ohio were the only states having required certification plans in effect; that is, having plans with legal status. A summary of these plans will be found under Section X of this report.

Voluntary plans are in use in the states of Arizona, Arkansas, California, Georgia, Illinois, Michigan, North Dakota, Oklahoma, South Dakota, Texas, and West Virginia. In many of these states the plan is administered by the local sewage works association, but in a few cases the agency is the state department of health. A summary of these plans may be found in the March, 1942, issue of *Sewage Works Engineering* based on data compiled by Charles C. Agar.

It is generally agreed that the postwar era will see an expanded program of all public works projects, one of the most important of which will be the construction of new sewage treatment plants and the modernization and enlargement of many existing plants. Large expenditures for these plants will be utterly wasted funds unless the plants are competently operated. The committee therefore feels that the establishment of definite qualifications with legal status for plant operators is an important part of the postwar sanitation program, without which the entire movement may be seriously handicapped.

COMMITTEE STANDARDS

If the standards as set up in this report seem arbitrary, the committee wishes to point out that anything short of a specific set of standards tends to "let down the bars" with resulting circumventing and waiving of the rules. The members of the committee, through personal contacts with plant operating personnel, feel that the standards as herewith suggested are reasonable and just to the operator and local community, and will meet all needs with minor modifications by the state supervising agency.

SECTIONS IN THIS REPORT

I. General policies on certification recommended by the committee.
II. Advantages of certification.
III. Classification of operators.
IV. Qualifications for operators.
V. Means for providing special training of operators.
VI. Examinations for operators.
VII. Suggestions for a "Model Law" for state agencies charged with enforcement of operators' qualifications.
VIII. A suggested application form for operators' certification.
IX. A suggested "Certificate of Qualification" form.
X. An appendix giving a summary of regulations governing certification or licensing of sewage plant operators in Connecticut, New Jersey, New York and Ohio.

SECTION I

GENERAL POLICIES ON CERTIFICATION RECOMMENDED BY THIS COMMITTEE

1. Passing on the qualifications of sewage treatment plant operators should be vested primarily in the state agency having supervision of plant operation. The personnel of the supervising agency might well be augmented by a leading educator in sanitary or civil engineering within the state and by a recognized leader in sewage treatment operation in the state, preferably a superintendent of a sewage plant chosen by majority vote of the existing operators in the state.

2. State regulations on qualifications of plant operators should be compulsory—not voluntary.

3. Operators should be certified or licensed. Certification or licensing should continue in effect as long as the person certified is rendering satisfactory service as an operator, or as long as the certifying agency is satisfied that such person is entitled to certification; certification, however, should be issued subject to cancellation by the certifying agency for just cause after a hearing.

4. Certain chief operators and chemists, as well as superintendents, should be subject to classification and approval of qualifications as set forth in Section III of this report.

5. The best classification for operators requires at least three classes, with laboratory technicians making another.

6. Where short school or university training courses are not available to unqualified operators, provision should be made for temporary waiving of the "special training" requirements of the recommended regulations. Following home study or other special training arrangements, such operators should be subject to a written or oral examination, or both, to be held at least yearly.

SECTION II

ADVANTAGES OF CERTIFICATION

Certification of operators is advantageous to the public, to local officials, the state supervising agency, and the operator.

The public should and usually will support a sound certification plan for operators as a good business proposition to protect the community's investment and to secure the best operating results possible from the plant.

Local officials should support certification by the state since the standards set up are a desirable guide to the appointing authorities. Political pressure for turnovers in operating personnel with changes in administration can be circumvented because of state requirements. This means that trained men remain at the plant, resulting in better operation at lower cost to the municipality. Local officials can likewise anticipate a higher class of men to be attracted to enter and remain in the field.

From the state standpoint, certification of operators means improvement in operation as well as better public health protection, and facilitates state control of treatment plants. State supervision of operation is also simplified since qualified operators once trained are generally retained by municipalities and there is, therefore, much time saved in training new men and in supervising plants upset by personnel changes.

The operator has much to gain under certification or licensing. Under certification operators receive a professional rating, and improvements in status, resulting inevitably in better salaries. Plant operation is taken out of the category of political appointments, and tenure of office by the alert and progressive operator is generally assured.

Where an effective and well managed system of civil service is in operation or can be instituted, the committee recognizes the value and advantages of the same and would not discourage regulation of operator qualifications through civil service procedures. If such civil service system is well managed and effective, however, it will provide proper co-ordination between civil service and the agency administering the certification system as recommended herein to the end that operator qualifications established through civil service will be the same or equal to those recommended in this report. Such co-ordination exists, for example, in New York between the State Civil Service Commission and the State Department of Health. Under existing laws the State Civil Service Commission administers civil service in most of the municipalities of the state and the State Health Department has received excellent co-operation in having the requirements of the State Sanitary Code relating to operators incorporated in the requirements for operator positions as established under civil service procedures. Civil service, if honestly and intelligently administered, through the encouragement given to the establishment of adequate salary scales and retirement arrangements, offers some advantages which a simple certification system does not afford. Civil service should not, however, be regarded as a substitute for but rather as an adjunct to a certification system.

The distinction between certification and licensing may appear to be finely drawn, yet it is none the less important. Licensing in the true sense requires an official listing of available personnel from which communities within a state must pick a candidate. The certification method involves approval of local men and permits home rule. Charles C. Agar * in a paper entitled "Licensing of Sewage Plant Operators," presented before the Federation on October 4, 1940, stated in this connection:

"Even though so-called political expendiency may enter into the appointment of sewage plant operators, the state should not use this as a principal argument for compulsory licensing and control of the hiring and firing of municipal employees. Centralization of authority is, of course, a trend of the times, but this writer feels that the principle of home rule, with only sufficient restraint or guidance by the state to assure a reasonable measure or standard for an appointment, is for the best interests of the municipality and the state.

"A plant, in order to operate effectively, must not only have a competent operator, but also must be supplied with the wherewithal to accomplish satisfactory results. This means that an operator must be able to work with and secure from the municipal authorities what is needed. His relations, therefore, in order to be successful must be in harmony with the local administration. It is conceivable, therefore, that with the operator responsible primarily to the state under a statutory license plan, relations between the operator and the municipality might at times become strained, resulting in defeat of the principal object of the licensing; namely, betterment of plant operation."

Warren J. Scott in discussing a paper on "Administration of New York State Requirements Relative to Qualifications of Sewage Treatment Plant Operators" by A. F. Dappert,† has said along the same lines:

"Neither the New York law nor the Connecticut law definitely guarantees tenure of office for sewage plant operators. However, as already mentioned, the fact that replacements must be made from the ranks of qualified men tends to promote a degree of civil service. The fact must not be lost sight of, that while the state has a very definite interest in seeing that plant operating results are satisfactory, the plant is municipally owned and it is absolutely necessary that there be co-operation between the sewage plant operator and the municipal government. The most qualified operator in the world cannot do a first-class job in the face of constant lack of co-operation by the municipal finance body and other municipal agencies."

SECTION III

CLASSIFICATION OF OPERATORS

The term "operator" shall apply to any person having active field supervision of a sewage treatment plant. It shall not apply to a city engineer, public works superintendent or other similar official who exercises only general supervision. Classes for superintendents, based on the size and type of sewage treatment plant to be operated, are recommended.

Chief operators in responsible charge of scheduled shifts at all plants having 24-hour operating supervision, or at all plants serving more than 50,000 population or equivalent sewage flow, should at least possess qualifications for the class below that of the superintendent under whom they serve.

Chief chemists at plants serving more than 50,000 population, or equivalent sewage flow, or at any plant employing activated sludge or chemical precipitation of sewage should be approved as such. Applicants for such a position should possess a college degree in engineering or chemistry, which has included acceptable courses in sanitary science, or other satisfactory educational and practical experience.

Plants should be classed according to population served, or sewage flow handled, and type of plant.

The following is suggested as a method of classification on the basis of population (or equivalent sewage flow) and type of plant.

Class A Plants

1. Plants serving more than 50,000 population.
2. Plants serving 20,000 to 50,000 population, employing activated sludge, separate sludge digestion with gas collection, biological oxidation, chemical precipitation or mechanical dewater-

* "Licensing of Sewage Plant Operators," Charles C. Agar, S. W. J., 13, 1, 89 (Jan., 1941).

† "Administration of New York State Requirement Relative to Qualifications of Sewage Treatment Plant Operators," A. F. Dappert, S. W. J., 10, 6, 988 (Nov., 1938).

ing and incineration of sludge, or other highly mechanized or specialized methods of sewage treatment.

Class B Plants

1. Plants serving 20,000 to 50,000 population, not designated as Class A.
2. Plants serving 10,000 to 20,000 employing secondary treatment other than sand filters, separate sludge digestion with gas collection and burning, chemical precipitation, mechanical dewatering or incineration of sludge.
3. Plants serving less than 10,000, employing the activated sludge process, chemical precipitation, separate sludge digestion with gas collection, or mechanical dewatering with incineration of sludge.

Class C Plants

1. Plants serving less than 20,000, not designated as Class B.

SECTION IV

QUALIFICATIONS FOR OPERATORS

In addition to the requirements below for the specific classes, all operators of sewage treatment plants should possess a sufficient degree of application, initiative and judgment so as to enable them in practice to secure satisfactory plant operating results. Operators should be sufficiently familiar with the end to be accomplished in plant processes so as to recognize faulty operating conditions and, where such conditions exist, to overcome them if practicable. Ability and experience in handling men is frequently as important as specialized knowledge, and for this reason, an operator's experience qualifications should be given careful review and heavy weight.

Class A

General: All applicants shall be in good physical condition, read and write the English language, submit satisfactory evidence of at least two years of responsible administrative experience in sewage treatment works operation or an acceptable industrial field and pass a written examination to be given within one year of provisional approval by the state supervising agency, and

1. Possess a college degree in sanitary, chemical, civil or mechanical engineering; or
2. Possess a college degree in engineering or chemistry which has included acceptable courses in sanitary science; or
3. Be a high school graduate possessing special mechanical experience, with a minimum of five years responsible administrative experience in sewage treatment works operation or in an acceptable industrial field (instead of the two years minimum required under "General") and who completes within one year a special course of training (short school or university extension course) or other home training course approved by the state supervising agency, or
4. Submit any combination of education, training and experience which in the opinion of the state supervising agency is the equivalent of the above qualifications.

Class B

General: All applicants shall be in good physical condition, read and write the English language, submit satisfactory evidence of at least one year of responsible administrative experience in sewage treatment works operation or an acceptable industrial field, pass a written or oral examination to be given within one year of provisional approval by the state supervising agency, and,

1. Be a high school graduate possessing acceptable mechanical or chemical experience, and complete within one year a special course of training [see Class A, (3)] approved by the state supervising agency, or
2. Submit any combination of education, training and experience which in the opinion of the state supervising agency is the equivalent of the above qualifications.

Class C

General: All applicants shall be in good physical condition, read and write the English language, pass an oral examination given by the state supervising agency and,

1. Be a grammar school graduate and possess acceptable experience for the work required.

In all classes, the reviewing authority may in specific cases accept the qualifications of an applicant without examination when it is satisfied that such examination is unnecessary.

Operators should be permitted to apply for, and be granted on request, certification by the supervising agency for a class higher than required for the plant being operated. In this way Class B or C operators may improve their status and become qualified to operate plants requiring a more advanced operator. Applicants initially possessing the required qualifications should also be granted, on request, a class higher than that required for the plant to be operated.

SECTION V

MEANS FOR PROVIDING SPECIAL TRAINING OF OPERATORS

The requirement of special training for Grades A and B operators brings up the question of how such training can best be provided. The committee reviews below the facilities which are now available, together with suggestions for the future.

In some states, for example, New York and New Jersey, special short course schools, lasting one to three weeks are sponsored by the state department of health. These schools, in some cases open to out-of-state residents, offer studies leading to qualifications for operating different types of plants. Operators may frequently improve their status and qualifications by attendance at subsequent sessions. Such training is generally offered once or twice yearly.

The committee recommends that more short-time courses be made available to operators in the various states, lasting from one to five days. This enables the small plant operator to get away for a limited period and provides a study course that can be adequately retained by the operator.

Another means of training operators is at colleges and universities offering special courses for either limited periods or at night. Such training has, for example, been available at New York University. The nature and coverage of the course would determine the type of plant for which the graduate might be qualified.

In some states having sufficient sanitary engineering personnel, operators tentatively approved on their past industrial experience and basic education can be trained by such personnel in the fundamentals of sewage treatment practice, at least for their own plants, together with occasional informal conferences called by the state supervising agency for instruction in the theory of sewage treatment and in laboratory procedures. Passage of an examination within one year of tentative approval would be evidence that the operator had acquired the necessary fundamentals.

Technical supervision of plant operation as well as the training of new operators can sometimes be secured by arrangements with experienced personnel at the larger sewage treatment plants. Under some conditions laboratory training can also be obtained in this manner.

In many communities, especially the larger, consulting sanitary engineers, state sanitary engineers, teachers and other qualified persons are sometimes available for private tutoring or consultation. Some home study courses in sewage treatment operation are also available from mail training schools. The contents of such courses should be approved by the state supervising agency before being undertaken as a training course. There is a way for the ambitious and determined man.

Not the least of the available means for providing special training for operators are the books and manuals which have been published. The data in various published material might well serve as a special home course of study. Following is a list of some of these publications that are especially suitable:

List for New Operators

1. "Sewage Plant Operation," published by *Sewage Works Engineering*, 24 West 40th Street, New York City.
2. "The Operation of Sewage Treatment Plants," published by *Public Works*, 310 East 45th Street, New York City.
3. Pamphlet on "Operation and Control of Sewage Treatment Plants," New York State Department of Health, Bureau of Sanitary Engineering, Albany, New York.
4. A Laboratory Manual for "The Chemical Analysis of Water and Sewage," by Theroux, Eldridge and Mallmann.

McGraw-Hill Book Company, Inc., New York City.
5. "Principles of Sewage Treatment," by Dr. Willem Rudolfs, National Lime Association, Washington, D. C.
6. "Questions and Answers on Sewage Plant Operation," Vols. I and II. *Sewage Works Engineering,* 24 West 40th Street, New York City.
7. "Laboratory Control of Sewage Treatment Plants." *Sewage Works Engineering,* 24 West 40th Street, New York City.
8. Annual Reference and Data Issue, *Water Works and Sewerage,* 155 E. 44th St., New York City.

List for More Advanced Study

1. "American Sewerage Practice," Vol. 3, "Sewage Treatment" (1935), by Metcalf and Eddy. McGraw-Hill Book Company, Inc., 310 Seventh Avenue, New York City.
2. "Sewage Treatment" by Karl Imhoff and Gordon M. Fair. John Wiley and Sons, Inc., New York City.
3. "Standard Methods for the Examination of Water and Sewage," published by American Public Health Association.
4. "Sewage Treatment Works," by C. E. Keefer. McGraw-Hill Book Company, Inc., New York City.
5. "Industrial Waste Treatment Practice," by E. F. Eldridge. McGraw-Hill Book Company, Inc., New York City.

The committee feels that the "Manuals of Sewage Works Practice" being prepared by the Federation's Committee on Sewage Works Practice will be excellent study and reference books for new operators and recommends their use for this purpose.

SECTION VI

EXAMINATIONS FOR OPERATORS

Whenever the supervising agency deems an examination necessary for approval of plant operation, as will be true in the majority of cases, the following specifications and procedures are suggested.

Examinations should be held at least yearly at places designated by the state agency and all operators tentatively approved on their basic education and experience should be required to take this examination for final approval of their qualifications. Operators having less than one year's experience in sewage treatment may have such examination postponed upon request.

Operators failing to pass the examination should be entitled to re-examination, preferably within six months.

The committee believes that these examinations should be straightforward, that the questions should require only brief answers and that the subject matter should pertain specifically to sewage works operation and the fundamental theories of treatment.

We further believe that operators should be advised in advance of the character of the material to be covered in the examination for their grade. The purpose of an examination should be to determine in a fair manner whether an operator has acquired the necessary fundamental knowledge required to operate his plant. It should also measure, where required, an operator's mechanical aptitude and manual dexterity. Much confusion and unnecessary worry can be avoided by informing operators of the character of the subject matter upon which they will be examined.

The following general guide is suggested for the guidance of state supervising agencies:

Class A Operators

1. A knowledge of the purpose, operating details and common difficulties of all standard designs of sewage treatment units, such as grit chambers, screens, comminutors, settling tanks, digestion tanks, sludge drying equipment, gas utilization facilities, chlorinators, chemical feeding apparatus, pumps, etc.
2. A knowledge of all the standard laboratory tests in use for determining sewage solids removal; sludge quality; nitrogen; moisture and solids content of screenings, sludge cake, grit; procedures for B.O.D. tests, chlorine residual tests, gas analyses and bacteriological analyses, and ability to interpret the results of such tests.

Class B Operators

1. See (1) under Class A. Questions should permit a choice, so that the operator in this class may answer

and be graded on those devices in use at his plant.

2. Only the simpler laboratory control tests should be required, including pH, chlorine residual tests (if chlorination is being practiced), settleable solids, relative stability test and total and volatile solids.

Class C Operators

1. See (1) under Class B.
2. Knowledge of laboratory tests should be limited to those required for control of a plant which a Class C operator is qualified to operate. Examinations in this grade being oral, they should be conducted on as informal a basis as possible.

SECTION VII

SUGGESTIONS FOR A "MODEL LAW" FOR STATE AGENCIES CHARGED WITH ENFORCEMENT OF OPERATORS' QUALIFICATIONS

ENFORCEMENT OF OPERATORS' QUALIFICATIONS

The essential provisions to be incorporated in such a law should include:

1. All public institutions, cities, towns, boroughs, counties or other municipal districts or subdivisions, or any person, firm, institution or corporation operating a sewage treatment plant should be subject to the regulations.
2. A statement that such treatment works shall be under the supervision of trained individuals whose qualifications to perform the duties required shall have been approved by the department. Penalties for non-conformity should be included.
3. The agency should have the authority to classify sewage treatment plants according to their type and the population served, or the type and flow capacity; to classify the operators in charge of such plants according to the skill, knowledge, experience, and character necessary for them to operate such plants successfully; and to adopt rules and regulations for the classification of such plants and the approval of their operators, and to make provision for the issue of "certificates of qualification" for approved operators in the classes indicated by their qualifications.

SECTION VIII

A SUGGESTED APPLICATION FORM FOR OPERATORS' CERTIFICATION

(Data to be submitted by persons desiring to qualify as sewage treatment plant operators)

Date ....

Location at which you are applying for position ....

Name of plant owner ....

Your name ....

Address ....
(street and town)

Date of birth .... Place of birth ....

Ht. .... Wt. .... Are you color blind?.................

Do you suffer from any chronic ailment or do you have any physical impairment? ......

If so, give details ....

....

....

Experience during the past 10 years, listing present position first:

Dates of Employment	*Name and Address of Employer*	*Wages*	*Type of Work*	*From*	*To*	*Total Years*

If any of the above positions were with reference to operation of a sewage treatment plant, please state which ....

Are you in your opinion qualified to carry out repairs on mechanical equipment? ......

....

EDUCATION

	Circle the last grade completed	*City and State*	*Did you Graduate?*	*Give date of leaving or graduation*
(a) Last common school	1 2 3 4 5 6 7 8 ..	....	....	....
(b) Last junior high school (if any)	7 8 9	....	....	....
(c) Last high school (if any)	1 2 3 4	....	....	....
(d) College or university	1 2 3 4 5 6 7	....	....	....
(e) Operators' schools attended	....	....	....	....

(f) Give any other education or training you had: business college, correspondence courses, etc. ....

Have you ever studied sewage chemistry? ....

If so, where? ....

Have you ever studied sanitary, mechanical, civil or electrical engineering? ....

If so, which course and where? ....

Have you ever carried out any laboratory tests? .... If so, have you had laboratory training? .... Where and what kind of training? ....

Give reference to three of your previous employers:

Names .... Adresses ....

....

Signed

Please give any additional data on separate sheet, or on back page, particularly with regard to training and experience.

SECTION IX

A SUGGESTED "CERTIFICATE OF QUALIFICATION" FORM

No. .... Date issued ....

CERTIFICATE OF SEWAGE TREATMENT

PLANT OPERATOR

State of ....

Be it known that .... having submitted acceptable evidence of his qualifications by education, training, and experience, and having passed the required examination, is hereby granted this Class ...... certificate as Sewage Treatment Plant Operator.

(SEAL)

Commissioner of Health

Director, Bureau of Sanitary Engineering

SECTION X

Summary of State Sewage Plant Operators' Certification and Licensing Plans Having Legal Status

State	Date Started	Re-newal	Revo-cable?	"Grand-father" Clause?	Agency Adminis-tering	No. of Classes	Examina-tions	General Features
Con-necticut	1933	None	Yes	Yes	State Dept. of Health	None	Usually none; oral may be given	Regulations require an operator for plants serving 1000 or more persons, or lesser numbers when necessary in department's opinion. Operators must submit evidence satisfactory to department that they are qualified to operate a specific plant. A certification plan.
New Jersey	1919	1 year	Yes	Yes	State Dept. of Health	8	Written and oral	Regulations set up various combinations of training and experience for operators of plants of different types and connected sewage flows. Operators can qualify on basis of sufficient experience without special training. Yearly license fee of $5.00 charged operators. A licensing plan.
New York	1937	None	Yes	Yes	State Dept. of Health	3	None by agency (1)	Combinations of training and experience set up for operators of plants of different types and connected population. Experience alone can not qualify operators for certification, thus differing from New Jersey requirements. A certification plan.
Ohio †	1937	None	Yes	Yes	State Dept. of Health	4	Oral and/or written	Grade required is specified for particular plant. Combinations of training and experience qualify operators for grades. A certification plan.

* All states have printed regulations available.

(1) If educational and experience requirements are met for the grade requested, no examinations are required, but applicants lacking these may take approved special courses through the Municipal Training Institute, at which passage of an examination is a requisite for successful completion of the course.

† Provisional approvals in effect during war emergency.

REPORT OF SEWAGE WORKS PRACTICE COMMITTEE

September 15, 1945

Herewith is presented the report of the activities of the Sewage Works Practice Committee for the past year. It will serve the dual purpose of placing on record the accomplishments of the committee, and expressing the indebtedness of the Federation to those members of the committee who have been engaged in the preparation of manuals of sewage works practice.

The primary work of the committee was

the continuation of work on manuals which were in progress at the time of the last annual meeting, and to initiate work on additional manuals covering pertinent phases of sewage works practice.

MANUAL ON EMERGENCY AND DISASTER PRACTICES

At the meeting of the Board of Control in October, 1944, the Sewage Works Practice Committee was requested to explore the desirability of preparing a Manual on "Sanitation Practices in Times of Emergency or Disaster." As a result of a poll of the committee, and repeated correspondence, it appeared that there was grave doubt whether the committee should handle such an assignment, since it was a task which might well be handled through joint action of a number of technical organizations. This decision was transmitted to the Secretary and President and the committee was instructed to discontinue action on this matter.

MANUAL ON OCCUPATIONAL HAZARDS

During the year the committee's first manual of practice, "Occupational Hazards in the Operation of Sewage Works," under the chairmanship of L. W. Van Kleeck, was completed, published and distributed. This manual has met with complete acclaim and has reached the distribution of nearly 6,000. It symbolizes the services which the Federation can render in standardizing practice and points the way towards better public health services through the control of sewage works. Full credit should be given to this sub-committee for its initiatory action.

MANUAL ON SLUDGE FERTILIZER

The manual "Utilization of Sewage Sludge as Fertilizer" has been under production for some time. Preliminary work was done under the chairmanship of A. H. Niles and, during the course of the year, the task of revising, editing and collating this important manual was accomplished by Langdon Pearse. Mr. Pearse has devoted himself untiringly to this time-consuming task and the first draft of the manual is completed and is now being processed through the personnel of the various committees responsible for its approval for publication. Considerable work must be done to make this voluminous document a valuable, practical tool in the hands of sewage works men, but Manual No. 2 should soon be ready for publication and distribution. This will mark another milepost of service of the Federation to the profession.

MANUAL ON SEWAGE CHLORINATION

During the year, work was started on the preparation of the manual "The Use of Chlorine in Sewage Treatment," under the chairmanship of F. W. Gilcreas. Work is progressing favorably on this manual and its completion is assured during the coming year. The publication of this material will serve as a valuable guide in the use of chlorine for the control and improvement of various phases of sewer system and sewage treatment plant operation.

MANUAL ON TRICKLING FILTERS

Work has been initiated on the manual "Trickling Filters—Their Characteristics and Loadings," under the chairmanship of Kenneth V. Hill. The publication of this work will be a contribution to the fund of knowledge on the behavior of various types of coarse-grained filters, under varying conditions of loading, distribution, design characteristics, etc.

MANUAL ON REPORTING RESULTS

At the last Board of Control meeting, decision was made to designate a Sub-Committee on Standardization of Reporting Units for the purpose of arriving at sensible standard units of measure in determining the efficiencies and loadings in sewage treatment units. Work on this new manual is underway, under the chairmanship of Dr. Willem Rudolfs. This searching study will serve to clarify a troublesome and disconcerting problem.

MANUAL ON SEWAGE AERATION

Progress on the manual "Aeration of Sewage" has been impeded, due to the impact of the war on several sub-committee members. However, the group, under the chairmanship of John J. Wirts, has continued its discussions and, with the cessation of the global conflict, work on this manual should be resumed. It is hoped the publication of this material can be scheduled in about a year.

MANUAL ON SEWER MAINTENANCE

The manual "Maintenance of Sewers and Sewer Appurtenances" has been under preparation for some time. During the year, John H. Brooks, Jr., found it necessary to relinquish the chairmanship of this sub-committee and Reuben F. Brown has accepted the assignment to head the work. It is hoped that this work will be completed and ready for publication and distribution during the coming year.

MODEL SEWER ORDINANCE

The Federation has received numerous requests from municipalities for guidance in the control and operation of sewer systems. It appears that there is serious need for a so-called standard or model ordinance regulating the nature of the material receivable into the sewer system and setting forth methods of control. Don E. Bloodgood has accepted the chairmanship of this sub-committee and it is hoped that this valuable guide can be prepared and published within the coming year.

SPECIAL MANUAL

When the Glossary of Water and Sewage Control Engineering is completed, through the joint efforts of committees representing the Federation and other organizations, it will be cleared through the Sewage Works Practice Committee before publication. The Executive Secretary and the Chairman of the Sewage Works Practice Committee have reached an agreement on the method by which this Glossary will be presented as a special Manual of Practice of the Federation.

FUTURE WORK

Now that the war is over and the coming year will see a stabilization of sewage works personnel throughout the country, it will be possible to initiate work on a number of other sewage works practice topics, in order that there may be an unbroken program of study and manual preparation underway. Among the topics suggested are: Vacuum Filtration; Grit and Screenings—Their Handling and Disposal; Laboratory Design; Sludge Incineration; Grease and Oil Handling; Sedimentation; Odor Control; Dual Disposal of Sewage and Garbage; and Cross Connections in Sewage Works.

The Sewage Works Practice Committee invites suggestions on personnel to handle these assignments, as well as suggestions on other manual subjects.

The unstinting co-operation of all members of the committee, and of the Executive Secretary is acknowledged by the Chairman.

Respectfully submitted,
Morris M. Cohn, *Chairman*
John H. Brooks, Jr.
Reuben Brown
John R. Downs
G. P. Edwards
F. W. Gilcreas
Harold F. Gray
Kenneth V. Hill
C. E. Keefer
F. W. Mohlman
A. H. Niles
Langdon Pearse
Willem Rudolfs
L. W. Van Kleeck
J. J. Wirts
W. H. Wisely

REPORT OF THE COMMITTEE ON OPERATION REPORTS

October, 1945

In accordance with the action of the Board of Control in accepting the 1944 Report of the Committee on Operation Reports as a satisfactory statement of progress, the committee has reviewed and supplemented its previous recommendations. In approaching its functions, the committee has given cognizance to the desire of the Board that the final report include recommendations for the complete mechanics of an Operation Reports Award.

The recommendations of the committee follow:

1. That an annual award be made by the Federation of Sewage Works Associations for the outstanding sewage works operation report of the previous year.

The annual Operation Reports Award shall be designated as the WILLIAM D. HATFIELD AWARD.

2. Each Member Association of the Federation shall be eligible to submit one entry for the WILLIAM D. HATFIELD AWARD. Such entry shall be selected by a duly authorized committee of the Member Association from among all of the reports submitted by members of that association.

3. The Secretary of each Member Association shall submit to the Executive Secretary of the Federation, on or before June 30 of each year, five copies of the operation report which has been selected as the entry of the Member Association. Four copies of each report thus entered for the award shall be transmitted by the Executive Secretary of the Federation to the Chairman of the Committee on Operation Reports on or before July 1 of each year.

4. The Committee on Operation Reports shall judge the reports entered by each Member Association and shall submit its report, together with the name of the award winner, to the Executive Secretary of the Federation on or before September 15 of the year in which the award is to be made. Entries will be judged in general compliance with the following rating schedule:

Item	*Maximum Points*
(a) General arrangement and scope	25
(b) Description of facilities	5
(c) Text and tabular coverage of operation procedures, unusual problems, maintenance activities, etc.	25
(d) Presentation and adequacy of analytical data	25
(e) Presentation and adequacy of cost data	10
(f) Presentation and competence of findings and recommendations	10
	100

5. If, in the opinion of the Committee on Operation Reports, no entry is received that is worthy of an award, no award shall be made in that year. No report shall be deemed worthy of the award unless a grade of 75 or higher is earned through application of the above rating schedule.

6. The WILLIAM D. HATFIELD AWARD shall be in the form of a suitable certificate worded as follows and inscribed with the signatures of the President and Executive Secretary of the Federation:

The
WILLIAM D. HATFIELD
AWARD
Presented to

____

By the Federation of Sewage Works Associations

In recognition of his development of the outstanding sewage works operation report for the year 19—, constituting a noteworthy contribution to the technic of sewage works operation and management.

____
Date
(Seal)

________ ____________
President *Executive Secretary*

7. The award shall be presented at the same time and in the same manner as are other awards and prizes of the Federation.

It is the opinion of the committee that the above recommendations should provide adequately for the selection of the outstanding operation report of each year, in compliance with the original intent of the 1941 Executive Committee in its recommendation of this activity. In the event that this report is adopted by the Board of Control prior to November 1, 1945, it is believed that the first presentation of the WILLIAM D. HATFIELD AWARD can be accomplished in 1946.

Respectfully submitted,
H. E. BABBITT, *Chairman*
W. F. SHEPHARD
W. A. ALLEN

REPORT OF COMMITTEE ON AWARDS

August 13, 1945

Following the recommendation of the 1944 Committee on Awards, the two papers on "Modified Sewage Aeration," by Lloyd R. Setter, though published in 1943 and 1944, have been considered as a unit for the Eddy Award.

The recommendations of the 1945 Committee on Awards are:

1. That the *Harrison Prescott Eddy Award* be made to Dr. Lloyd R. Setter for his contributions to SEWAGE WORKS JOURNAL entitled, "Modified Sewage Aeration—Part I" [Vol. 15, No. 4, 629 (July, 1943)] and Part II [Vol. 16, No. 2, 278 (March, 1944)].

2. That the *George Bradley Gascoigne Award* be made to John D. McDonald for his contribution to SEWAGE WORKS JOURNAL entitled, "Sludge Disposal Experiences at Springfield, Mass." [Vol. 16, No. 5, 872 (Sept., 1944)].

3. That the *Charles Alvin Emerson Award* be made to Harold W. Streeter with the following citation:

"The *Charles Alvin Emerson Award* for 1944 is presented to Harold Warner Streeter in recognition of his valuable researches in the fundamental principles of the natural purification of polluted streams; of his service to the Federation especially during its organization and during its formative period and of his continuing loyalty to the well being of the Federation."

4. The committee authorizes presentation of the 1945 *Kenneth Allen Award* to the following, each of whom has been designated by his Member Association as having earned this recognition:

Joe Williamson, Jr. (Florida)
Murray Alderson Wilson (Kansas)
George S. Russell (Missouri)
Frederick Holman Waring (Ohio)
Howard Eugene Moses (Pennsylvania)
Dario Travaini (Arizona)

Respectfully submitted,
GAIL P. EDWARDS, *Chairman*
E. SHERMAN CHASE
G. M. RIDENOUR
LOUIS F. WARRICK

DR. RUDOLFS ELECTED TO HONORARY MEMBERSHIP

Another of the Federation's most loyal and staunch supporters was conferred with the grade of Honorary Member when the Board of Control, in session on October 17, 1945, elected Dr. Willem Rudolfs to such rank. Dr. Rudolfs is the eighth person to achieve this distinction. The honorary membership classification is limited to a maximum of ten living members by the Federation by-laws.

The resolution by which the New Jersey Sewage Works Association nominated Dr. Rudolfs for honorary membership refers briefly to his early and continuing activities in behalf of the Federation:

WHEREAS: Willem Rudolfs, Chief of Water and Sewage Research, New Jersey Agricultural Experiment Station, did in October, 1926, at Buffalo, New York, present a paper before the American Public Health Association stating the need of a journal for sewage research papers; and

WHEREAS: On April 16, 1928, he organized a meeting at St. Louis, Mo., which was instrumental in obtaining a pledge from W. W. Buffum, Manager of the Chemical Foundation, to underwrite and manage the publication SEWAGE WORKS JOURNAL, which has been published continuously since October, 1928; and

WHEREAS: In January of 1929 he was appointed and served as Chairman of an advisory committee to the Chemical Foundation on sewage research, advising in the distribution of funds for research; he was also the organizer and, for many years, Chairman of the New Jersey Conference Group; and

WHEREAS: Since the organization of the Federation in January, 1929, to the present date, he has taken an active part in Federation affairs as a member of the Board of Control since its inception; serving since 1936 as Chairman of the Research

Committee in the preparation of annual summaries and comments on sewage treatment literature published throughout the world; and

WHEREAS: He has, for many years, taken an active part in technical societies, encouraging the friendly exchange of experiences in matters pertaining to sanitation; and, due to his vast scientific knowledge in sewage treatment, he has labored diligently to promote this knowledge; and

WHEREAS: He has been a consistent and valued contributor of articles dealing with research in the sanitation field;

NOW, THEREFORE, BE IT RESOLVED: That the New Jersey Sewage Works Association hereby nominates Willem Rudolf for Honorary Membership in the Federation of Sewage Works Associations, and hereby presents this nomination for consideration by the Board of Control of the Federation at its next scheduled annual meeting.

1945 MEMBERSHIP PRIZES TO CANADIAN AND ARIZONA ASSOCIATIONS

At the close of the 1945 membership contest, as conducted under the rules set forth in THIS JOURNAL, 17, 2, 392 (March, 1945), principal honors went to the Canadian Institute on Sewage and Sanitation and to the Arizona Sewage and Water Works Association. The membership progress during the period of the contest of all Member Associations of the Federation may be observed in the tabulation accompanying the annual report of the Executive Secretary-Editor, published elsewhere in this issue.

In earning the right to assign the prize for greatest numerical increase in membership during the year ended September 30, 1945, the Canadian Institute set an enviable mark in its recorded increase of 72 members. This gain brought the total membership of the Institute to 223 and boosted its position in the Federation from sixth place to the fourth largest Member Association in size. The Executive Committee of the Institute assigned the prize jointly to B. F. Lamson, Chairman of the Membership Committee, and to Dr. A. E. Berry, Secretary-Treasurer of the Institute, both of which zealous workers were unwilling to accept the prize as a personal award. Such assignment was required under the rules of the contest, however, and Mr. Lamson and Dr. Berry have donated the $100 Series E Victory Bond to the Institute, with the recommendation that honorariums be distributed to the members of their respective office staffs who participated in the membership campaign.

By enlarging its roster from 10 to 24 members during the contest, the Arizona Sewage and Water Works Association marked up an increase of 140 per cent, to win the privilege of assigning to one or more of its members the $100 Series E Victory Bond prize for the greatest percentage increase. The accomplishment was entirely creditable to the efforts of Secretary-Treasurer G. W. Marx and the Executive Committee of the Association promptly named Mr. Marx as the sole winner of the prize. The bond was formally awarded at the annual meeting of the association on December 1, 1945, the presentation being made by Federation Past President A. M. Rawn.

Several Member Associations are deserving of honorable mention for their membership activity during the past year. Gratifying gains were made by the Texas Sewage Works Section, the Montana Sewage Works Association, the Kansas Water and Sewage Works Association, the Georgia Water and Sewage Association, the Oklahoma Water and Sewerage Conference, and others. Only four Member Associations failed to increase their membership during the year.

RULES FOR 1946 MEMBERSHIP CONTEST

One of the most important constitutional objectives of the Federation is "the correlation and strengthening of regional and state sewage works associations or conferences." In partial fulfillment of this aim, the Board of Control has authorized a new membership contest for the year ended September 30, 1946, rules for which are given herewith:

1. All Member Associations of the Federation as of September 30, 1945, shall be eligible to compete in the contest. Formal application for entry is not required.

2. The term of the contest shall be from October 1, 1945, to September 30, 1946.

3. Two prizes will be awarded, as follows:

(a) One $100 cash award to the Member Association recording the greatest *percentage increase* in membership during the period of the contest.

(b) One $100 cash award to the Member Association recording the greatest *numerical increase* during the period of the contest.

4. At the termination of the contest on September 30, 1946, the Executive Secretary of the Federation shall determine from his records the Member Associations having recorded the greatest numerical and percentage increases, and shall report his findings to the Board of Control at its next annual meeting. The Board of Control shall confirm the designation of the winning associations.

5. In the determination of membership, only those Active and Corporate Members receiving the publications of the Federation through the Member Association shall be credited to that Member Association, *i.e.,* dual members will be credited only to the association through which they receive the JOURNAL.

6. In the event that one Member Association shall record *both* the greatest *percentage* increase and the greatest *numerical* increase during the period of the contest, such association shall be eligible to receive only one of the prizes. The association recording the second greatest numerical increase during the contest shall be judged the winner of the other prize, in this case.

7. In the event of a tie for either of the prizes, the total amount of the award shall be equally divided among the winning associations.

Reviews and Abstracts*

Conducted by
GLADYS SWOPE
Mellon Institute of Industrial Research,
Pittsburgh 13, Pennsylvania

Getting the Most Out of Sewage Works Data. BY WILLIAM L. HAVENS AND FRANK WOODBURY JONES. *Civil Engineering,* 15, 399–401 (Sept., 1945).

Accurate and complete sewage works data are necessary for the following purposes; to show past performance; to show current results as regards adequacy, economy, and effectiveness of the treatment processes; and to determine the need for extensions and improvements, and to provide a basis of design for such extensions.

It may be seen that all data collected must be accurate and reliable to be of value. Briefly, the following information should be collected and preserved; the number of persons served; the volume of sewage handled; chemical analyses of the sewage; quantities and analyses of screenings, grit, sludges, and other by-products; bacterial analyses; and complete cost data. Additional data should include records as to wind, precipitation, atmospheric and sewage temperature, appearance and odor of sewage, changes in operating procedures, effect of sewage and gases on buildings and equipment, breakdowns, repairs and maintenance, causes of failures, and many apparently trivial matters which when grouped make possible an overall picture.

Reliable records are dependent on several factors, the most important of which is the plant personnel, from the sampler to the plant head. Sampling is of utmost importance and conscientious effort on the part of the sampler is necessary if representative samples are to be obtained. Likewise, careful work is essential in the laboratory if reliable data are to be obtained. Meters and gages should be checked frequently and adjusted as necessary.

T. L. HERRICK

Army Sewerage in Hawaii. BY BELDEN S. TUCKER. *Civil Engineering,* 15, 473–475 (October, 1945).

The Hawaiian Islands were annexed to the United States in 1898, and in 1900 they were organized as a territory. The importance of improving sanitary conditions, particularly in Honolulu, was not realized until 1878. Definite action on a water-carriage sewerage system was taken after the cholera epidemic of 1885. Work was started in 1889 and completed in 1911. The system comprised 58 miles of sewers with 2,600 service connections. In 1911 parts of the system were overloaded and work was started on intercepting sewers.

Before Pearl Harbor the sewerage systems at established Army posts were, in general, adequate. After the outbreak of war, however, established posts were expanded and new camps ranging up to 15,000 men were constructed. There were numerous problems. Areas near the sea necessitated construction in ground water, and provision for protection of beaches against contamination. Inland areas are generally rugged and few streams are suitable for use as receiving bodies for sewage.

At temporary camps pit latrines were used, with separate shower and washing facilities. The pits were made large enough for nine months' continuous use, based on one cu. ft. per capita per month. Where the ground water level was close to the surface or where rock excavation was encountered, the vault type was provided, using water proof concrete construction. Agitators were provided for mixing the sludge. When the maximum sludge level was reached the contents were pumped out and buried. Treatment provided for other

* It will be appreciated if Miss Swope is furnished 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.

wastes from the temporary camps was generally primary settling and chlorination.

Treatment provided at semi-permanent camps depended on local conditions and the degree of treatment required. Where possible, small camps were provided with septic tanks and cesspools or drilled wells for treatment and disposal. Other small camps were provided with complete treatment facilities, including septic tanks, filters, and chlorination.

Since 1941, some 40 treatment plants have been constructed. They ranged in capacity from 300 to 20,000 men. Major plants employed combinations of Imhoff tanks, plain sedimentation tanks, septic tanks, low- and high-rate filters, lath filters, sand filters, contact filters, final sedimentation tanks, chlorine contact tanks, sludge digestion tanks, and sludge beds.

The high rate filters were designed for a B.O.D. loading of 2.0 lb. per cu. yd. of rock and a surface loading of 9.0 m.g.a.d. They were fed from the top, which simplified the center bearing design of the distributor.

The following tabulation shows B.O.D. results at several of the representative plants.

Plant Description	B.O.D. Reduction	Plants in Avg.	Type of Camp
Septic Tank, Contact Filter, Chlorination....	64%	4	(1)
Imhoff Tank, Low-rate Filter, Chlorination....	91%	3	(1)
Septic Tank, Low-rate Filter, Chlorination....	86%	1	(1)
Septic Tank, High-rate Filter, Chlorination....	75%	2	(1)
Sedimentation Tank, Chlorination.........	76%	4	(2)
Septic Tank, Int. Sand Filter, Chlorination....	96%	1	(1)

(1) Semi-permanent camp. (2) Temporary camp.

T. L. Herrick

Post-War Application of Wartime Experience in Sewage Disposal. By Humphrey D. Manning. *The Surveyor,* 104, 379–382 (July 13, 1945).

The design and operation of some 206 sewage disposal works built since 1939 to serve various war-connected establishments is commented upon. The size of plants ranges from those serving twenty to thirty people to those serving several thousands. The author's figures and opinions are based upon analyses of design figures and observations.

Under the heading of "Design" sewage quantities and sewage characteristics, methods of treatment, treatment plant sites, sedimentation and humus tanks, filters, sludge disposal, grease removal, chlorination, and pumping plants are discussed.

Sewage flows varied from 10 gal. per day per head in the case of camps where sullage only was to be treated, up to 50 gal. for hospitals. For workers' hostels the figure assumed was usually 25 or 30 gal. The sewerage was mostly "separate" but allowance for maximum flow rates was four or five times the average. In practice the dry-weather flow usually averaged 30 to 40 gal. per capita per day.

Sewage strengths greater than average were experienced, the B.O.D. ranging from 500 to 700 p.p.m.

Most plants comprised sedimentation tanks, filters, and humus tanks, with simple methods of sludge disposal. Standardized treatment units were prepared and extensively used. Double alternating filtration was successfully employed in one case and activated sludge at another. Sand irrigation with tank effluent was used at a number of camps.

In general sites for treatment plants were selected by others rather than by the designing engineers.

Both horizontal and upward flow tanks were used, the former providing 2.4 hours' displacement and the latter 4 hours, both based on dry-weather flow. Sludge was removed by hydrostatic pressure.

Septic tanks having capacities for 20 to 30 hours' dry-weather flow were provided for 250 persons or less.

Filter depths were generally restricted to 4 ft. 6 in. medium depth. Filter dosage varied from 35 to 90 gal. per cu. yd., based on dry-weather flow. Figures of 90 and 75 gal. per day per cu. yd., proposed by the Ministry of Health, where dry-weather flows of 30 to 20 gal. were expected, proved to be too optimistic. Clinkers was the most popular material used for filter media. Careless handling of the material during installation and medium smaller than 1¼ in. caused difficulties.

Humus tanks were rather generally inadequate and were frequently supplemented by surface irrigation over grassland at the rate of about 1,000 persons per acre.

Sludge disposal in unheated lagoons was successful. A capacity of about 6 cu. ft. per head was provided. Final disposal by land trenching at the rate of 4 to 8 sq. yd. per head was practiced where the land was suitable and on drying beds at 1 sq. yd. for every 4 to 6 persons at other places.

Traps on kitchen drains and scum removal devices on sedimentation tanks were used to remove grease, neither giving too good results.

Chlorination of effluents up to 5 p.p.m. residuals was practiced where necessary to protect the water courses receiving effluent.

Submersible pumps in general caused trouble. Use was made of carefully designed tank sewers to supplement wet wall capacities, provision being made to empty the sewer at each pump operation.

To save lumber for farms, walls were poured between brick facings. Much use was made of mass concrete to avoid use of reinforcing steel.

Shortage of experienced operating personnel was experienced. The author suggests that a more comprehensive organization of visiting inspectors and mobile operating gangs would have been helpful and sees need for such in the post-war period, especially in rural areas.

The author finds little good in the practice of using standardized designs during the war and lists 9 practical limitations and objections to their use in the post-war period, among them variation in characteristics of towns, sewage characteristics, site and soil and ground water conditions, limitations on research and experimentation to develop new methods, and other similar objections. Some standardization of items such as screens, weir blocks, scum-boards, valves, and fittings may be beneficial. One good which may come from the adoption of standardized designs utilized during the war may be the consideration of rural schemes on a comprehensive rather than a piece-meal basis.

In conclusion the author states that few important new treatment processes have been developed; "austerity" methods, limited supervision of construction and lack of skilled labor led to a good deal of second-rate work. The importance of skilled and regular supervision of plant operation was not recognized early enough. Stagnation of design and real economy were lost sight of in chasing the will-o'-wisps of standardization and austerity construction.

K. V. Hill

Sludge Treatment at Small Sewage Works. By L. B. Escritt. *The Surveyor,* 104, 547–548 (July 21, 1945).

The methods of sludge digestion applicable to larger works involve heating, mechanical stirring and closed tanks with arrangements for gas collection; but in small works simple digestion is practicable in open and unheated tanks provided arrangements are made for seeding.

Cold digestion tanks require a large storage capacity. This can be secured most economically by reducing the number of tanks to a minimum, and forming excavation in such a manner that it can be retained by comparatively light concrete walls.

Tanks should not be too long as compared to their breadth and the cross-section should approximate a semi-circle. A simple arrangement is to provide a comparatively flat floor with sides sloping to about 45 degrees, above which are lightly constructed vertical walls of moderate height. The arrangement of inlets should be similar to that of sedimentation tanks but the outlets should be at the lowest part of the tanks farthest from the inlets.

Mechanical stirrers are said merely to rotate the body of the sludge without mixing it. Mixing can be secured by pumping from the outlet to the inlet.

Two-stage digestion with means for seeding the raw sludge at the inlet to the first stage is preferable. Adequate capacities are, first stage 2 to 2½ cu. ft. per head; second stage 1 to 1½ cu. ft. per head.

An effective method of seeding the raw sludge is to couple two pumps to one motor, one pump having 5 times the capacity of the other. The larger pump handles raw sludge and the smaller draws sludge from the bottom of the digestion tanks.

Means should be provided for drawing off water bands from the tanks, either through valves placed at different levels or by adjustable decanting tubes. Supernatant water is near the middle of the first stage digestor and at the top of the second stage digestor. Means for withdrawing the supernatant should be provided, especially from first-stage tanks.

Sludge beds should provide at least 1 sq. yd. for 6 persons. Some means should be provided for decanting top water.

K. V. Hill

Darlington Sewage Works and Farm. By W. Oliver. *The Surveyor,* 104, 567–568 (Sept. 28, 1945).

Darlington has a population of 80,000. Sewerage is mainly on the combined plan. Sewage is discharged directly to a sewage farm located 2 miles south of the town.

The original farm was opened in 1876, and it has been extended several times. A portion of the land was let to a tenant farmer for raising crops and the remainder was used for treating sewage, the corporation providing the labor for distributing the sewage on the land. This system operated for 60 years until 1936, at which time because of the increased volume of sewage, all of the land suitable was taken over for sewage treatment and the agreement with the tenant farmer was terminated.

Continuing increase in sewage flow made necessary the consideration of additional means of treatment. Experiments with activated sludge were carried on over a period of years but finally abandoned and a scheme was proposed to employ trickling filters.

In 1941 a sewage treatment plant was constructed to treat part of the total sewage flow. The works comprised coarse screws, detritus channels, fine screens, storm water tanks, sedimentation tanks, trickling filters, humus tanks and sludge drying beds.

The storm water tanks are three in number and have a capacity equal to 6 hours' dry-weather flow. The tanks are in series and no overflow takes place until all are filled.

The capacity of the sedimentation tanks is equal to 10½ hours' dry-weather flow. They are desludged mechanically.

Each of the twelve trickling filters is 110 ft. in diameter and 5 ft. 6 in. deep. The media is slag, the bottom 2 feet being 3-in. to 4-in. grade, and the remainder 1½ in. grade. Rotary distributors are used.

The humus have a total capacity equal to 4 hours' dry-weather flow. They are 3 ft. deep at the outlet end.

The seven sludge beds have a total area of 2.4 acres.

At first sludge was withdrawn from the sedimentation and humus tanks each day and pumped to the drying beds. This media was unsatisfactory and a sludge digestion tank was developed from the conversation of an old storm water tank. The capacity of the tank when filled to a depth of 6 ft. provides 4 cubic feet per head of population served. Raw sludge is discharged at three points at one end of the tank and the digested sludge may be withdrawn at various levels along the side and opposite end.

The sewage treatment plant handles up to 2,500,000 gal. per day. The remainder of the flow, 1,250,000 gal. per day, are handled at the sewage farm.

Sewage applied to the land may pass through two settling tanks to remove the heavier solids or may pass directly to the land. The farm comprises 317 acres of which 234 acres are used for treating sewage, the remainder being farmed. The quality of the soil varies greatly, 75 acres being loamy sand and gravel, and the remainder fairly heavy soil overlying clay. Broad irrigation is practical and the whole of the land is underdrained. The surface of the land requires constant plowing and subsoiling to keep the surface open and aerated and to control the growth of weeds.

K. V. Hill

Purification of Domestic Sewage by Digestion. By Karl Viehl. *Ges. Ing.,* 65, 394–398 (1942).

Laboratory experiments on the self-purification of sewage showed that with complete exclusion of air and without seeding most of the colloidal substances were flocculated during the first few days, but that the soluble organic content remained the same for several weeks. If air was allowed to enter and the sewage inoocculated with ripe sludge, decomposition proceeded normally. Under these conditions, hydrogen sulfide production was reduced. The digestion period is rather long, but operation is reduced to a minimum. The B.O.D. reduction and H_2S production with unseeded and seeded sewage, seeding and complete exclusion of air, and seeding and surface area exposed, is indicated by the following figures:

	Days	B.O.D. P.P.M.	H_2S P.P.M.
Unseeded, closed bottle . . .	0	264	—
	30	170	90
Seeded, closed bottle	0	268	—
	30	60.5	75
Strictly anaerobic, seeded . .	0	224	—
	21	110	100
Surface exposed, seeded . . .	0	224	—
	21	25	9

The degree of seeding was considered less important than air as indicated by the percentage reduction of soluble organic carbon:

Time, Days	Strictly Anaerobic			Surface Exposed
	Unseeded	Inoculation Light	Inoculation Heavy	Inoculation Light
5	43	43	51	53
10	46	43	55	67
14–15	45	49	61	72
20–21	45	68	67	82

Sewage left a few days under anaerobic conditions should not be placed on biological filters.

W. Rudolfs

A Rational Examination of Stream Pollution Abatement. By Richard D. Hoak. *Science,* 101, 523 (May 25, 1945).

Mr. Hoak's article is written as he says, "in the familiar words of the layman" and of necessity, then, treats the problem of stream pollution abatement from a very general point of view.

Stream Function. By 1942 about 87 per cent of the population of the country living in communities of more than 100 persons was connected to sewers. This development of public sewerage systems resulted in an increase in the volume of domestic and industrial waste discharged to streams.

With increased pollution the relative importance of different stream functions—public health, drainage, navigation, industrial, recreation—arose. While the use of streams for public health purposes such as water supply is of prime importance, its ultimate use can only be determined by an impartial survey which takes into account all pertinent engineering and economic factors and the effect of such use on the population bordering the stream. Such a survey must also take cognizance of legal decisions which in general protect riparian owners against pollution by an industry. The courts may also take into account the principle of reasonableness in handing down a decision. By virtue of this principle they *may* consider it reasonable because of long continued and uniform custom for mill owners and manufacturers to discharge their wastes and refuse into a stream. However the courts do not as a rule allow a defendant to escape liability for pollution of a stream because his industry may be necessary to the economic welfare of a community or because the cost of waste treatment is an economic burden to the industry. These legal considerations must be kept in mind in planning waste disposal plants.

Natural Purification in Streams. The capacity of a stream to purify itself must be considered. Two constituents of natural wastes, important in self-purification of streams are alkalinity which consists principally of bicarbonates of calcium and magnesium, and dissolved oxygen. Alkalinity is effective in neutralizing such acid wastes as acid mine waters thus maintaining a proper reaction necessary to the life cycle of many beneficial flora and fauna of the stream. The presence of sufficient dissolved oxygen permits the biological stabilization of organic pollutants without creating a nuisance.

To preserve a proper oxygen balance in the stream, the organic pollution should not reduce the dissolved oxygen content below 50 per cent saturation. This will permit the proper bacterial population which is necessary to biologic stabilization of organic matter to thrive. If however pollution is allowed to continue to a degree at which the dissolved oxygen is depleted, putrefaction will develop, the stream will become septic and higher animal life will disappear.

Present Extent of Water Pollution. The effect of pollution by industries cannot be evaluated in simple terms for the country at large because of the wide variations in quantity and kind of wastes not only from industry to industry but from day to day in the same industry. The most extensive study of industrial pollution and its effects was recently completed in the Ohio River valley. The Ohio river drainage basin, 204,000 sq. miles, has a population of 19,000,000. Of this population only 8.5 per cent is served by sewers. Thirty-four per cent of the sewage so collected receives treatment before discharge into the stream. The industries in the basin produce sewage equivalent to a population of 10,000,000, 12.5 per cent of which is treated in municipal plants. About one half of the 1604 plants in the basin are making some attempt to reduce the amount or concentration of the wastes discharged to the rivers.

The discharge of acid wastes from active and abandoned coal mines is a major source of pollution. The daily discharge into the Ohio river alone amounts to 4,900 tons of 100 per cent acid, about half flowing from abandoned mines and the other half from worked out sections of active mines. Sealing off of these mines resulted in a 25 per cent reduction of acid waste discharged but because of lack of maintenance many of the seals are losing their effectiveness.

Waste pickling liquor is another source of acid waste accounting for 168 tons of free acid daily. The argument is advanced that acid wastes from mines and from steel pickling plants both retards the decomposition of organic matters and acts as a coagulant to clarify the river water to an extent which prevents offensive odors and lifts a great deal of the burden from water treatment plants. The condition at Pittsburgh is cited. However it is admitted that at times of drought, or during spring freshets the bacteriostatic effect of the acid wastes is largely destroyed and intestinal disorders occur in the communities below Pittsburgh which use the Ohio river as a source of water supply.

The Problem of Waste Treatment. There are no standards for treatment of industrial wastes. The changes in volume and character of these wastes are so varied that each industry presents an individual problem. Most industries have become alert to their waste problems and some have established research organizations to develop satisfactory waste treatment processes and, if possible, recover for use some of the wastes.

Very seldom does waste treatment become a profitable enterprise. As a rule it is an added expenditure and manufacturers, particularly those in highly competitive fields, are loathe to add to their cost of production, as they must, if they are to prevent pollution of streams. Nor is it good economy to force such an industry to discontinue operations, thereby unbalancing the domestic economy of a community, in order to preserve a stream for such dubious use as recreation.

Public Attitude Toward Treatment. As soon as personnel becomes available for construction and operation of treatment plants, state sanitary engineers have indicated that they will adopt an aggressive policy toward pollution of surface waters by industrial wastes and will demand that such waste be cleaned up if it is at all economically feasible. Sportsmen and the general public also indicate a desire to eliminate stream pollution, even though in the case of the former they lose tract of the fact that other factors beside industrial wastes may be the cause of disappearance or change in the fauna and flora of a stream.

The Future of Stream Pollution. It has been proposed that streams be divided into three classes according to superior overall function:

1. Those streams which have been preserved in their natural condition. These would serve as sources of water supply and for receational purposes. No pollution would be permitted in them.
2. Those streams which serve for disposal of sewage and industrial waste after treatment and for public water supply after purification. Treatment of wastes discharged into these streams would be adequate to preserve the natural oxygen balance. They would provide recreational facilities and wild life refuges.
3. Streams now so heavily polluted that they are unsuited for public water supply. Into these streams wastes may be discharged after treatment adequate to prevent nuisance.

Just as pollution of streams was increased over a period of years, over a like period of years pollution will gradually be eliminated. It is hoped that this can be brought about through the development of feasible methods for treatment of wastes and perhaps through the discovery of valuable by-products which may be derived from these wastes. Such discoveries would act as an economic stimulus to the treatment of industrial wastes.

E. HURWITZ

Butyl Alcohol by Fermentation of Waste Sulfite Liquor. ANON. *Chemical and Metallurgical Engineering,* 52, 101, No. 6 (June, 1945).

"Development of a process for the production of butyl alcohol by fermentation of waste sulfite liquor was announced in Seattle in mid-April by Dr. Bror L. Grondal, University of Washington professor of forestry, and Major Henry W. Berger, research chemist and fermentologist. . . .

"The discovery, a result of two years of research, may open vast new fields for the pulp industries which for lack of practical use for the sulfite liquor, representing about 50 per cent of every log used to produce chemical pulp, have been forced to dispose of it as waste. Not only would the process provide a means of utilizing almost 100 per cent of the wood, but it would eliminate the source of a long and bitter battle between the Northwest pulp interests and the fisheries, who charge that discarding such liquors into Puget Sound kills fish and oysters."

Waste sulfite liquor contains about 2 per cent fermentable sugar. From 100 lb. of this sugar 22–23 lb. of butyl alcohol may be obtained. The key to the fermentation process is to eliminate inhibiting materials and retain the growth elements necessary for normal development of the Weissman bacillus or Clostridium acetobutylicum. No molasses is needed in this process. The process also produces a 6,000 B.t.u. per lb. fuel. In addition the process would make available large quantities of yeast fodder for livestock. The yeast is described as chemically pure and suitable for baking.

PAUL D. HANEY

Industrial Waste—An Important Factor in Process Planning. ANON. *Chemical and Metallurgical Engineering,* 52, 117–124, No. 8 (August, 1945).

"Waste utilization has long been recognized as an important factor in the economics of the process industries. Waste disposal, on the other hand, has received far too little attention with the consequence that pollution effects of industrial waste have increased tremendously over the years. . . . Simultaneous action on the part of different legislative bodies for the abatement of stream pollution is a sure sign that the common practice of indiscriminately dumping untreated waste material into streams and waterways will eventually be curtailed."

Most government regulation of water pollution has been under authority of state laws. The major objective of most state legislation has been the protection of the public health but some laws include protection of aquatic life, shellfish, industrial water supplies and recreational areas. Certain states are already refusing permission for new plants to start up unless waste treatment is provided. Until recently interstate stream pollution has been the most neglected field since individual state action proved ineffective. Interstate agreements have done much to improve this situation in some cases.

Congressional interest in stream pollution led to the appointment in 1934, of a committee to draft plans for legislative action. In 1938, HR–2711 was passed but was vetoed by the President on technical grounds. This bill provided for state-federal cooperation and for federal assistance in the study and development of plans for pollution abatement and grants-in-aid for treatment works. At present three federal bills are pending. HR–592 is similar in principle to the 1938 bill but eliminates the cause for veto. HR–519 (companion Bill S–535) is sponsored by the Isaak Walton League and provides strict government authority for pollution control. Provision is made for the allowance of no new sources of pollution and definite time limits are set (which may be extended for cause) for abatement action on existing pollution. Enforcement consists of action by the U. S. attorney at the request of a national board only after state and interstate agencies have failed to correct the pollution. HR–587 (companion Bill S–330) is in effect a combination of the two others. This bill places administration under a division of water pollution control of the U. S. Public Health Service. It is almost certain that some kind of organized federal participation in anti-pollution work will be forthcoming.

Many municipalities have built sewage treatment plants and many are planned. Undoubtedly the construction of municipal plants will force industry to clean up its wastes for when public funds are spent to protect streams damage from any other source will be vigorously opposed. A new concept of the importance of this subject must be adopted by management. Waste disposal must be considered as an integral factor of industrial planning and must be accepted as a necessary plant process. The concept that utilization removes all objectionable wastes is erroneous. Few industries can expect to benefit directly from improving the quality of waste discharge from their plants. Industrial waste treatment can not be expected to pay a net return and must be regarded as a charge on the cost of production.

Outstanding in the activity of industrial cooperation for pollution abatement is the National Council for Stream Improvement formed by the pulp, paper and paper board industry. The petroleum, iron and steel, textile, canning, meat packing, dairy and tanning industries have also been more or less active in this field.

Industrial wastes may be classified as organic, toxic, and inert. The effluent from single industrial plants may contain all three. Organic wastes (domestic sewage falls in this class) originate from a number of industries including the dairy, beet and cane sugar, starch, brewery, meat packing, etc., industries. Toxic wastes consist mainly of active chemical compounds such as acids, alkalis, phenol, cyanide, etc., and are derived from metal, wool scouring, dye manufacturing, soap, coke, TNT, oil and other industries. Inert wastes consist of insoluble substances in high concentrations such as culm and silt from coal mines, lime sludge, sawdust, sludges, etc.

Mechanical treatment of industrial wastes involves the use of many common unit operations such as screening, sedimentation, filtration, and centrifuging.

Separation treatment may involve the use of flotation, evaporation, drying and incineration.

Chemical methods of treatment have been found to be quite useful. These involve flocculation and precipitation, neutralization, and oxidation and reduction.

Biological treatment may be applied to certain types of organic industrial wastes; *e.g.*, milk wastes. This type of treatment may involve the use of methods similar to those used in municipal sewage treatment. Trickling filters may be employed for a wide variety of organic wastes.

The job of designing the best, most economical treatment plant requires experience and training in solving this kind of problem and there are certain fundamental aspects of the problem which demand more than straight chemical engineering knowledge. Special knowledge of the sanitary engineer's field is essential.

Paul D. Haney

Tartrates Recovered from Winery Wastes. By Ze'en Halperin. *Chemical and Metallurgical Engineering,* 52, 116–119, No. 9 (September, 1945).

The development of this process has centered around the California wineries where tartrate chemicals are being recovered in substantial quantities. Steps in slop treatment for tartrate recovery involve distillation to strip the wastes of alcohol, settling, pH adjustment with lime, precipitation of calcium tartrate with calcium chloride, and washing and drying of the precipitated tartrate.

Approximately 2,670 lb. of calcium tartrate may be recovered from 100,000 gallons of distilling material slop. This is worth approximately $700.

Paul D. Haney

Stream Pollution in the Marimee River Basin. By Robert W. Heider. *Monthly Bulletin, Indiana State Board of Health,* 48, 91 No. 4 (April, 1945).

Less than one third of this basin is within the State of Indiana. The Indiana portion is located in the northeast corner of the State and contains 22 cities and towns with populations of 300 or more.

Fort Wayne is the largest with a population of 118,410 (1940). The total population of the 22 cities and towns is 148,212. Seventy-three per cent of the population is served by municipal sewage treatment plants providing complete treatment. Municipal and industrial waste treatment at Decatur is the most urgent problem in the basin. Four canneries and five milk plants have waste treatment problems. Plans and specifications for municipal and industrial waste treatment should be prepared now so that treatment can be provided as soon as possible.

PAUL D. HANEY

Stream Pollution in the Whitewater River Basin. BY ROBERT W. HEIDER. *Monthly Bulletin Indiana State Board of Health*, 48, 134, No. 6 (June, 1945).

Approximately 1,350 square miles of this basin lie in Indiana. There are 17 cities and towns with populations above 300 in the Indiana portion of the basin. Richmond is the largest with a 1940 population of 35,147. The total population of the 17 cities is 62,193. Of this total, 44 per cent are served by municipal sewage treatment plants providing complete treatment.

Gross stream pollution occurs below two cities and large numbers of fish are killed by what is believed to be highly toxic industrial wastes.

A total population of 35,680 are served by surface water supplies.

Plans and specifications should be prepared so that treatment facilities needed in this basin can be provided as soon as possible.

PAUL D. HANEY

Stream Pollution in the Blue River Basin. BY ROBERT W. HEIDER. *Monthly Bulletin, Indiana State Board of Health*, 48, 169, No. 7 (July, 1945).

The Blue River basin is the smallest of the fourteen into which the State of Indiana has been divided. It is adjacent to the Ohio River in the central-southern part of the State. The basin is rural in character. Salem with a population of 3,194 (1940) is the only city. The total urban population in the basin is 5,586. Two thousand or 36 per cent of the population are served by a municipal sewage treatment plant located at Salem. At present there are no surface water supplies in this basin but Salem has plans for the development of such a supply. In the past stream pollution has resulted from milk and cannery wastes. This situation has been improved by treating the milk wastes with the Salem municipal sewage and enlargement of the cannery waste lagoons.

PAUL D. HANEY

Cannery Waste Treatment. BY ROBERT W. HEIDER. *Monthly Bulletin, Indiana State Board of Health*, 48, 182, No. 8 (August, 1945).

Approximately 17,000,000 cases of canned goods are packed annually in Indiana. There are a total of 235 canneries in the State and 68 of the 92 counties have at least one cannery. The various cannery wastes are known to range from the equivalent in organic load to as high as ten times that of domestic sewage. Seasonal operation with the peak from August 15 to October 15 (period of low stream discharge) complicates the problem of cannery waste disposal. As far as waste disposal is concerned canneries may be divided into two groups: (1) those which discharge their wastes into the sewers of a municipality, (2) those which must provide their own treatment or disposal facilities.

Of importance in both groups is the practice of preventing the discharge of culls, skins, parings, juices, etc., into the stream of water borne wastes. Also of great importance is the screening of the wastes for the removal of coarse suspended solids. Screening facilities should be located as near the cannery as possible so that the organic matter will have little time to go into solution. Mechanical screens of the revolving and vibrating types equipped with 20- to 40-mesh wire cloth are satisfactory. The process of vacuum flotation may be used instead of screening.

Standard methods of sewage treatment can successfully treat a combination of domestic sewage and cannery waste if the plant units are not overloaded. Municipal plants which are overloaded with cannery wastes may find relief by the application of the following:

1. Additional pretreatment at the cannery including screening or vacuum flotation plus one or a combination of the following:
   (a) Chemical precipitation.
   (b) Biological filtration.
   (c) Discharge to an impounding lagoon or reservoir to regulate the flow to the municipal treatment plant.
   (d) pH adjustment.
   (e) Disposal of part of the waste by lagooning or irrigation.
2. Additional treatment at the municipal plant. An increase in the size of the various treatment units and/or one or a combination of the following:
   (a) Use of chemicals and mixing and coagulating equipment to increase the primary settling efficiency.
   (b) Preaeration. Plain aeration of the combined waste prior to either biological filtration or activated sludge.
   (c) Recirculation of the final effluent.
   (d) Conversion of standard secondary treatment to multiple stage secondary treatment. For example the use of a roughing filter before the biological filter or activated sludge units.
3. Combinations of (1) and (2).

In considering separate treatment of the cannery wastes thought must be given to the location of the cannery, the amount of dilution afforded by the receiving stream, and the extent of operations (whether seasonal or year around operation).

The following methods of cannery waste treatment have been used throughout the country. (1) Chemical precipitation, (2) chemical precipitation followed by biological filtration, (3) absorption lagoons, (4) irrigation fields, (5) impounding lagoons (untreated), (6) impounding lagoons (sodium nitrate treated).

The use of sodium nitrate has been helpful in the operation of lagoons. In order to eliminate an odor nuisance in lagoons it is necessary to use enough sodium nitrate to satisfy 20 per cent of the initial biochemical oxygen demand. This amounts to approximately 200 pounds per 1,000 cases of tomatoes, corn and peas packed.

There appears to be little chance of recovery of valuable materials from the screened liquid wastes at the present time. However, screenings and other solid wastes could yield large quantities of usable byproducts. The average amount of waste for tomato canning is 25 per cent and the amounts for other vegetables range from 12 to 86 per cent.

Eight references.

PAUL D. HANEY

Stream Pollution in the Muscatatuck River Basin. BY ROBERT W. HEIDER. *Monthly Bulletin Indiana State Board of Health,* **48**, 187, No. 8 (August, 1945).

The Muscatatuck River basin is located in the southeastern section of Indiana. There are eight cities and towns with populations of 300 or more in this basin with a combined population of 9,308. Of this total 2,500 are served by a municipal plant providing complete treatment and 2,000 are served by a plant providing primary treatment only.

Public water supplies in this basin are subject to sewage pollution and during dry months stream flow is not sufficient to prevent water shortages for water supply and waste dilution.

The Muscatatuck River basin ranks fifth regarding the extent of sewage treatment in comparison with the thirteen other river basins into which the State has been divided. However, stream pollution resulting from the discharge of a large volume of cannery waste is serious. A research program on cannery waste disposal has been proposed.

PAUL D. HANEY

Operation of Connecticut's Sewage Treatment Plants. BY LEROY W. VAN KLEECK. *Connecticut Health Bulletin,* 183–188 (July, 1945).

This paper was written for the general public and states the various objectives to be obtained by sewage treatment, and gives a brief description of the various methods of treatment.

It is stated that approximately 70 per cent of the 1940 population of the state is served by sewers and 75 per cent of this population is served by sewage treatment plants.

T. L. Herrick

The Corrosion of Concrete. I. The Isolation of a Species of Bacterium Associated with the Corrosion of Concrete Exposed to Atmospheres Containing Hydrogen Sulfide. By C. D. Parker. *The Australian Journal of Experimental Biology and Medical Science,* 23, 81–90 (1945).

Internal corrosion and disintegration of concrete is associated with the production of hydrogen sulfide in the sewer. It occurs only above the water line. In the corrosion products 1–5 per cent of free sulfuric acid is found. Little evidence has been produced as to the method of conversion of hydrogen sulfide to sulfate in the free acid. Some have advanced a non-biological oxidation as an explanation. The work done by the Research Staff of the Sewerage Branch of the Melbourne and Metropolitan Board of Works, of which the present papers are a part, have led to the following conclusions: 1. The direct cause of corrosion is the production of sulfuric acid; and 2. while the conversion of H_2S to free sulfur and the reaction between sulfuric acid and cement constituents can be explained on purely chemical grounds, it is difficult to explain non-biological production of sulfuric acid from sulfur. This paper describes the isolation of a species of bacterium from the corrosion products and its physiological and biochemical properties.

The culture medium used for the isolation consisted of: potassium dihydrogen phosphate, 3 gm.; magnesium chloride, 0.5 gm.; calcium chloride, 0.25 gm.; ammonium chloride, 0.2 gm.; precipitated sulfur, 10 gm.; and distilled water, 1,000 ml. The pH of the medium was 4.5–5.0. Two weeks after inoculation of the above sterilized medium with corroded concrete, the liquid became turbid and developed acidity. Transfers were made into fresh culture media and finally plated on solid agar mineral culture medium used by Waksman for the isolation of *Thiobacillus thiooxidans.* Colonies developed on this agar were identical in appearance. Single colony cultures were obtained from these plates which proved to be pure cultures. Five such cultures were obtained. The numbers of these organisms in different specimens of corroded concrete varied from 50,000 to 5,000,000 per gm. of corroded concrete.

Morphologically, all five strains are similar. They are slender rods 1.5–2.0 μ microns (μ) long by 0.5 μ wide with straight sides and square ends. They are gram negative. Young cultures show a few motile forms but on older cultures no motility is observed. They are non-spore forming organisms.

The organisms do not grow in nutrient broth. In the sulfur medium employed, the sulfur falls to the bottom some days after turbidity appears. The organisms utilize thiosulfate when it replaces the sulfur in the medium. All strains are aerobic and obligate autotrophic. They require carbon dioxide which cannot be replaced by carbonates or bicarbonates. In general, organic carbon as glucose, glycerol and lactate has little influence on low concentrations (50 p.p.m.) in some cases showing a slight stimulative effect and in others slightly inhibitive. Higher concentrations reduce acid formation, in some cases resulting in complete inhibition of growth. With all five strains growth occurs with free sulfur and thiosulfate as a source of sulfur, while no growth occurs when sulfite, sodium sulfide or hydrogen sulfide is used as a source of sulfur. Strain A and E attack thiosulfate slowly and produce small amounts of sulfur but little or no free acid. Strains B, C, and D attack thiosulfate rapidly, but whereas B and D produce little free acid and much free sulfur, strain D produces a considerable amount of free acid and little free sulfur. The five strains are similar in that they can utilize ammonia and nitrate nitrogen equally well. Peptone nitrogen results in a slight decrease in the rate of acid formation and nitrite cannot be used by any strain. Nitrite is toxic as no acid formation occurs even when ammonium nitrogen is present. A 50 p.p.m. concentration of nitrogen appears to be optimal for acid production. The rate of acid formation increases with the nitrogen concentration up to about 50 p.p.m. Above this concentration, there is a slight inhibition. The acid formed is directly proportional to the phosphate content up to a concentration of 0.5 p.p.m. of phosphorus. Beyond this concentration acid formation does not change. All strains develop turbidity and acidity most rapidly at a pH value of 4.0 and can grow and develop acidity at a pH value of 6.0, but not at pH 6.5 or higher. Cultures of strains B and D produced an acidity equal to 10 per cent sulfuric acid in 80 days and the organisms were still viable. The organisms have a temperature optimum of about 30° C.

The five strains belong to the group of sulfur oxidizing bacteria and resemble *Thiobacillus thiooxidans* in that they are strictly autotrophic, they oxidize sulfur to sulfuric acid, they do not utilize H_2S and develop only in acid media. They differ from *Thiobacillus thiooxidans* morphologically and in colony form in thiosulfate agar. They are definitely inhibited while *Thiobacillus thiooxidans* is stimulated by organic carbon compounds. They utilize nitrate as well as ammonium nitrogen while *Thiobacillus thiooxidans* can only utilize ammonium nitrogen. They precipitate sulfur from thiosulfate in some cases producing little or no free acidity, while *Thiobacillus thiooxidans* converts thiosulfate directly to sulfuric acid. These strains are isolated from corroding concrete sewers, while *Thiobacillus thiooxidans* has been isolated from compost of soil, sulfur and rock sulfate.

The name *Thiobacillus concretivorus* is proposed to this species and the five organisms isolated are considered as five separate strains belonging to one species. The activity of this species would explain the production of sulfuric acid in the corrosion process, provided free sulfur or some utilizable form of sulfur is first formed from the hydrogen sulfide.

H. HEUKELEKIAN

The Corrosion of Concrete. II. The Function of *Thiobacillus Concretivorus* (Nov. Spec.) in the Corrosion of Concrete Exposed to Atmospheres Containing Hydrogen Sulfide. BY C. D. PARKER. *The Australian Journal of Experimental Biology and Medical Science,* 23, 91–98 (1945).

The characteristics of internal corrosion of concrete are as follows: (1) It is associated with the presence of hydrogen sulfide in the sewer atmosphere; (2) it occurs above the water line; (3) the result of corrosion is the conversion of concrete to a putty-like mass; (4) test specimens placed in the sewer show a definite lag in the development of corrosion. Concrete is highly alkaline (pH 11–12.5). On exposure to the atmosphere, the calcium hydroxide on the exposed surface is completely converted to calcium carbonate. It is further converted to bicarbonate and at equilibrium, it would attain a pH of 8.4. As corrosion sets in and calcium sulfate is formed as powdery white deposits, the pH value drops to 6–7. Finally when the surface assumes a putty-like consistency and free sulfuric acid is present, the pH value is frequently less than 2.0. The frequent isolation of *Thiobacillus concretivorus* in large numbers from corrosion products, and its ability to produce high concentrations of sulfuric acid, suggest that this organism may play an important part in the process.

The carbon dioxide necessary for the growth of this organism is present in ample quantity as it grows on the surface of the concrete. The pH value is also suitable once the corrosion has progressed sufficiently to produce acid. A typical analysis of corroded concrete is given as follows:

Moisture	40 per cent
Acidity (as H_2SO_4)	1.5 per cent in the moisture
pH	1–4
Ammonium N	675 p.p.m. in the moisture
Nitrate N	12.5 p.p.m. in the moisture
P_2O_5 P	52.6 p.p.m. in the moisture
SO_3	36.7 per cent on dry solids basis
$CaSO_4$	62.4 per cent on dry solids basis
S	.01 per cent on dry solids basis

The ammonia nitrogen in the corrosion products comes from that emitted by the sewage as tests showed .2–.7 p.p.pm. of NH_3–N in the sewer atmosphere. Thus the nutritional requirements of the organism are met and the environmental conditions are favorable for its development. The presence of free sulfur fits with the inability of the organism to utilize H_2S and demonstrates the presence of a utilizable source of sulfur.

The corrosion of concrete under pure culture conditions was attempted experimentally. The culture medium was the one used for the isolation of *Th. concretivorus*. Sterile concrete blocks were placed in it. Sterile sulfur was added and the medium inoculated with a culture of *Th. concretivorus*. It was necessary to readjust the pH value of the medium to 5.0 for a few days because of the solution of lime from concrete. Incubation was continued for 3–4 months. At the end of this period considerable corrosion was evident on the concrete block below the surface of the liquid. The sterile flask showed no signs of corrosion. The conditions in this experiment, however, were not identical with the sewer, so that experiment was repeated by replacing the sulfur with hydrogen sulfide. Through the inoculated cement flask an atmosphere of water vapor, H_2S and ammonia were aspirated. The test atmosphere aspirated through the flask containing the block contained 100 per cent humidity, 1–2 p.p.m. of ammonia, 300 p.p.m. H_2S (higher concentrations than actually found in sewers were used to accelerate the corrosion). Precautions were taken to prevent the contamination of the culture. Corrosion appeared on all inoculated blocks. After 6 weeks' exposure the inoculated specimens all showed whitening of the top surface which eventually spread down the sides of the block. Towards the end of the incubation period, 75 per cent of the hydrogen supplied was removed by the inoculated blocks. By the end of the experiment they displayed all the signs typical of the normal corrosion found in sewers. The whitened portions were soft and could be scraped away. Analyses of the inoculated and uninoculated specimens of block showed that considerable amounts of sulfates had been formed on the inoculated blocks. Under sterile conditions only small amounts of sulfates were formed. Thus, it was concluded that while rapid corrosion and sulfate formation could take place through the activity of *Th. concretivorus*, very small amounts of sulfates can be formed by non-biological means. Free sulfur was formed on both sterile and inoculated blocks. It appears that this sulfur is present as an intermediate compound formed non-biologically and that corrosion can only develop where the sulfur is converted to sulfate by the activity of this organism. The pH of inoculated blocks was lower than that of the sterile ones. Since *Th. concretivorus* has been shown to be unable to use H_2S, it appears that free sulfur or poly-sulfides are formed as intermediate products by chemical action between H_2S and the cement compounds, and the organism utilizes these intermediate products for its oxidative activity. Another difficulty in the theory is the pH of concrete which attains stability at 8.4 and the inability of this organism to grow at such pH values. The author suggests the following explanations: (1) A preliminary stage in which carbonate-bicarbonate-CO_2 equilibrium is destroyed and the pH falls from 8.4 to 6 and 7, and (2) a final stage in which active proliferation and acid formation by this organism takes place. It is suggested that other species of sulfur bacteria are responsible for the preliminary stage of the process.

H. Heukelekian

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