# SEWAGE WORKS JOURNAL

VOL. XVI | NOVEMBER, 1944 | NO. 6

## *Special Features*

Digestion of Grease—Rudolfs

Postwar Planning in New York—Devendorf

Industrial Wastes Disposal in California—Symposium

Sewage Treatment in Maryland—Kaltenbach and Wolman

Annual Index

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# SEWAGE WORKS JOURNAL

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Crushing Strengths:
A.S.T.M. 3-edge bearing test method

| Pipe size inches | Class 1 | Lb. per linear ft. Class 2 | Class 3 | Class 4 |
|---|---|---|---|---|
| 4 | 4125 | .... | .... | .... |
| 5 | 3350 | .... | .... | .... |
| 6 | 2880 | .... | .... | .... |
| 8 | 3100 | .... | .... | .... |
| 10 | 2580 | 3690 | 4920 | .... |
| 12 | 2370 | 3850 | 5100 | .... |
| 14 | 2200 | 3920 | 5150 | .... |
| 16 | 2120 | 4050 | 5280 | .... |
| 18 | 2030 | 4140 | 5360 | 6340 |
| 20 | 2290 | 4280 | 5850 | 7100 |
| 24 | 2340 | 4550 | 7050 | 8600 |
| 30 | 2980 | 5000 | 8180 | 10450 |
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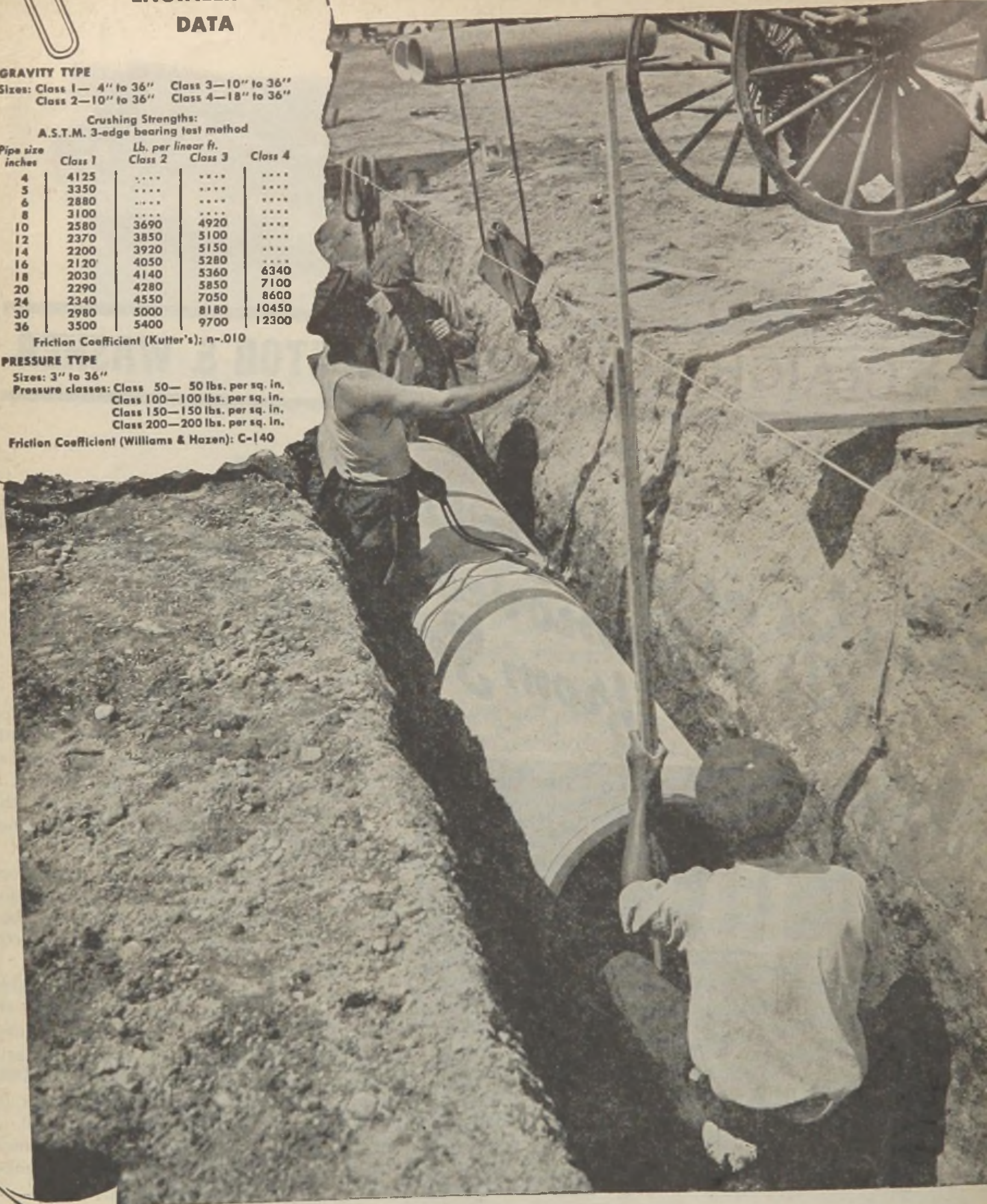

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# Plant Operation

## OILS AND GREASES AS THEY AFFECT SEWAGE TREATMENT PLANTS *

By Frederick G. Nelson and W. N. Lauer

*Engineers, The Dorr Company*

War conditions have focused the attention of operators and engineers on the problems encountered in sewage treatment resulting from the presence of large quantities of grease. It often constitutes one of the most abundant single ingredients found in sewage, particularly at army, navy and marine camps, or at cities where a considerable amount of war activity is in progress.

Its chief significance is in its effect upon the efficiency of established methods of sewage treatment. It materially lowers the efficiency of plants using biological methods of treatment, such as activated sludge and trickling filters. Grease carrying over from primary clarifiers onto trickling filters has a tendency to coat the filter stone or possibly the biological gel, causing not only a lowering in the efficiency, but resulting in the production of odors. The effect on the operation of activated sludge plants seems to be still more marked and may be due either to coating of the sludge solids, or because a much longer detention is required to oxidize the grease. The effect of grease on activated sludge has been covered in considerable detail by Heukelekian (1).

Generally speaking, greases encountered in sewage treatment are of the saponifiable and non-saponifiable types. Insofar as removal is concerned, they may be considered as being in the same category, but the subsequent disposal presents different problems. From the operator's point of view, the principal difference in these two types of grease is that saponifiable grease can be readily disposed of by digestion in properly designed and operated digesters, while non-saponifiable grease cannot be digested and must be disposed of in some other manner. However, this subject will be discussed in more detail later on in this paper.

The chief sources of grease in sewage are from restaurants, military kitchens and commercial establishments such as meat packing plants, creameries, machine shops, garages, and many others. The amount to be expected from any of these sources may vary through wide limits, making it difficult to predict the quantity to be expected.

It is becoming generally recognized that grease can be most effectively removed near the source of pollution. Considerable effort has

* Presented at 18th Annual Ohio Conference on Sewage Treatment, Marion, June 21–22, 1944.

been made to accomplish this, resulting in the development of various grease trap devices and the passage of ordinances and regulations for governing the discharge of greasy wastes into sewers. A review of recent literature describes fully the thought and effort that have been given to this phase of the problem. Keefer (2) has described Baltimore practice in eliminating waste oil from its sewers. He gives figures on cost to the city and the quantities of grease and oil which have been collected for the years 1927 to 1943 inclusive.

Dawson and Kalinske (3) have discussed the design, operation and efficiency of grease traps from work carried out under laboratory conditions at the Iowa Institute of Hydraulic Research. Their paper covers both the design and operation of grease traps for best efficiency under various conditions.

Kessler and Norgaard (4) make mention of the operation of grease traps for army kitchens and cite figures on the recovery of grease from them.

It is shown from these various papers that large quantities of grease can be intercepted at the source provided regulations are rigidly enforced and grease traps properly operated. Along with enforcement, education must go hand in hand because it is difficult for the public to appreciate the problem unless fully informed of the consequences of misuse of sewers.

While grease can best be separated near the source, it is not practical nor desirable to carry this method of control too far. Even the best operated grease traps probably will not remove more than 90 per cent, which means in many instances there are still large quantities of grease discharging to the sewers.

It is highly questionable whether an attempt should be made to intercept kitchen greases from private residences. Cohn (5) states that in his experience he has not seen many serious stoppages in sewers serving truly domestic areas. He also gives figures, which he believes to be reasonably accurate, showing that most towns under 50,000 population do not have grease intercepting devices and that 50 to 60 per cent of cities over 50,000 population do have some form of regulation. The cost of maintenance for individual intercepting devices and the nuisance created for the individual property owner would appear to the writer to more than offset the advantages to be gained by the community as a whole. It is better to spend money to educate home owners to keep free grease out of kitchen drains rather than to try to intercept it after it has been discharged.

Continuation after the war of salvaging cooking fats may be found to be practical even though the reclaimed value drops considerably. The housewife does not dump fats into the kitchen drains because she prefers that method of disposal, but rather because she has no other convenient means of getting rid of them. It is entirely possible that if suitable containers are devised and means of collection systematized, it will be found economically feasible for salvage companies to collect waste kitchen fats.

Regardless of efforts made to keep grease out of sewage, there is still likely to be sufficient present to require special consideration. Methods which have been employed for removing grease at sewage treatment plants may be listed as:

1. Sedimentation tanks, with or without chemical precipitation.
2. Aeration, either of the mechanical or diffused air type.
3. Aero-chlorination.
4. Vacuum flotation.

Eliassen and Schulhoff (6) report results from laboratory and field tests on army sewage. Various methods of grease removal were tried out and the results compared with plain skimming tanks. Their general conclusions were that there was little to be gained by the various methods investigated over plain skimming tanks.

This subject needs a great deal more study, preferably under actual field conditions. There is a surprising lack of information on the efficiency of various grease removal devices, which in part may be due to the many difficulties in obtaining reliable data. Some of these difficulties may be listed as:

1. The grease content of the raw sewage often fluctuates through wide limits, not only due to its intermittent discharge to the sewers, but because of being trapped in manholes, wet wells and similar points.

2. It is difficult to get a representative sample unless it can be caught as the sewage falls over a short weir, or where considerable agitation is present.

3. A portion of the grease may adhere to the surfaces of the sampling container.

4. Analytical determinations are often inaccurate as evidenced by the difficulties in checking analyses. Recognizing this fact, many operators have devised their own methods of making grease analyses. From a casual observance of some of these methods, it would appear that some are superior to the present standard methods, while others are questionable.

The above difficulties, together with the labor involved, may account for the reason that few plant operators run routine grease analyses. Such data would be valuable in plant operation, and it is hoped that the method can be simplified so that reliable routine determinations can be made.

It is difficult to evaluate grease removal. While it is generally reported as percentage removal, or parts per million remaining, possibly these figures are not altogether significant. It is known that a certain amount of grease will adhere to other suspended solids, and it is reasonable to assume that at least a portion will continue to adhere throughout the secondary treatment process. These may not be a factor in coating filter stone or interfering with the activated sludge process. Possibly if the ratio of grease remaining to suspended solids remaining does not exceed a certain value, trouble will not be experienced in the secondary treatment process.

Grease probably appears in three forms: free, that which is attached to other solids, and semi-colloidal. Free grease will float and presents no serious problem of removal, but the other two forms are difficult to get rid of. When grease attaches to other solids, it lowers their specific gravity, resulting in the flotation of some, while others will either settle or remain suspended in the liquid. It is probably the latter, together with the colloidal grease, which is likely to cause trouble in the secondary treatment process.

There is very little information in the literature as to whether or not grease appears in colloidal form in domestic sewage. There is evidence that grease in meat packing wastes and certain other industrial wastes is present in the form of colloids.

The various methods of grease removal will not be described here because there is ample literature on each and, as stated above, removals to be expected from them are given by Eliassen and Schulhoff (6). However, a brief description of vacuum flotation may be in order.

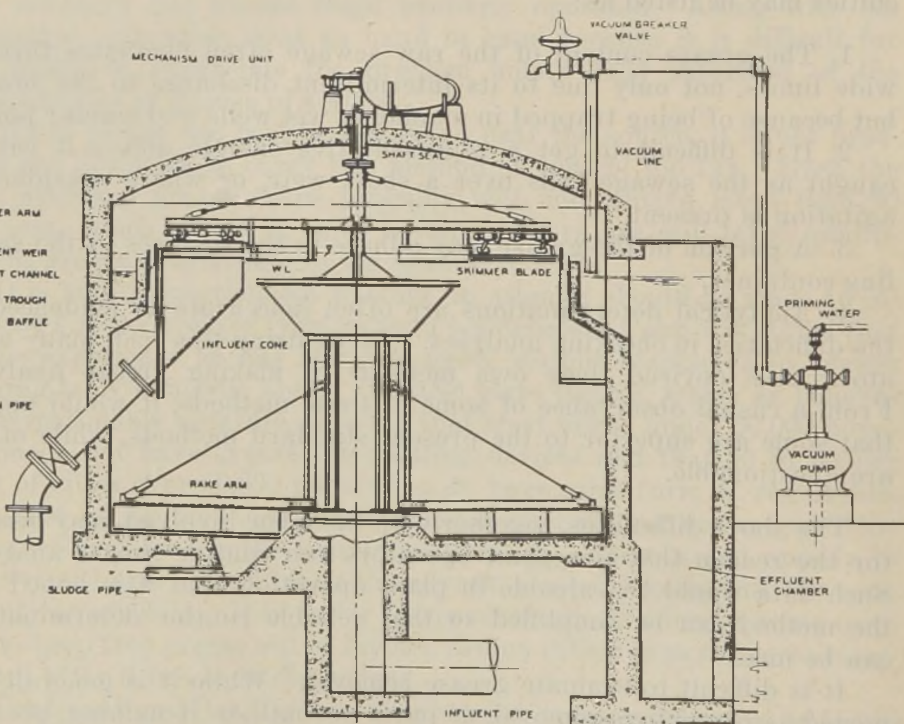


Fig. 1.—Sectional elevation of Dorrco Vacuator.

The Vacuator is shown in Fig. 1. The process consists of aeration, deaeration, and the application of vacuum for the flotation of scum. It relies upon small air bubbles attaching themselves to the suspended solids to cause flotation when the sewage is subjected to vacuum. For that reason, the sewage is aerated for a short period of time with from 0.025 to 0.05 cubic feet of air per gallon in order to introduce a reasonable amount of dissolved and entrained air. This step is accomplished either with mechanical or compressed air aeration.

A short period of deaeration is necessary to release free air bubbles which otherwise, due to their high rate of rise, would cause agitation within the Vacuator.

The sewage passes from the deaeration chamber directly to the Vacuator, which is continuously under a vacuum of approximately 10 inches of mercury. The unit is not designed on a detention basis but rather on overflow rates of 5,000 to 10,000 gallons per square foot per day. Lower or higher rates than these can be used. As the rates are lowered, the percentage of suspended solids removed increases, while there is a lowering in the efficiency of suspended solids removal as the rates increase.

The Vacuator gives a three-way separation made up of floating solids, settling solids and the effluent. The floating solids, or scum, are removed from the tank by an automatic continuous skimmer causing the material to discharge through a barometric leg into a pit. This material is low in moisture, being about the consistency of good primary clarifier sludge. At some plants the moisture content has been found to be so low that it was necessary to dilute it to cause it to flow readily.

The underflow consists of the faster settling sewage solids and grit. If there is sufficient grit in the sewage to warrant removal, the material is passed through a cleaning mechanism for washing, while the organic solids are returned to the tank effluent, passing into the primary clarifier.

## Disposal of Grease

Considerable thought, particularly during the war period, has been given to the disposal of grease removed at sewage treatment plants. Whether it can be recovered depends upon the size of the plant and the amount of grease present. It is general practice at most of the smaller, and many medium sized plants, to pump scum directly to sludge digesters. If properly operated, and if the grease is of the saponifiable type, this is a satisfactory means of disposal. Its success, however, depends upon the care with which the digester is operated. There is a tendency to pump too much water when transferring scum, resulting in dilution and cooling of the digester sludge. Unless properly mixed with the seeded sludge, a thick surface scum is likely to form, interfering with proper digestion and preventing the free passage of gas. Grease digests readily, producing a large volume of gas, if the temperature is maintained at 90 to 95° F.

If there is a considerable amount of mineral oil present, digestion is not satisfactory, as the oil remains in the digester, inducing scum formation and fouling the supernatant liquor. Plants having this type of grease should look to some other method of scum disposal.

Under present conditions, many large cities find it economical to sell skimmings. Since the middle of 1943, New York City's plants have sold an average of about 90,000 lbs. of scum per month to a vendor at a rate of 0.8¢ per pound, f.o.b. sewage plant. This is equivalent to about $9,000 per year. One hundred lbs. of scum, as it was put into the buyer's cans, contained approximately 53 lbs. of water, 37 lbs. of ether soluble material and 10 lbs. of impurities. An analysis of the scum shows an average of approximately 46 per cent solids of which about 80 per cent is ether soluble (7).

It should be remembered that the New York plants did not provide special equipment for scum collection, nor did they add any additional labor to their crews. The scum is removed from scum pits by the operators with hand dippers and placed in the vendor's cans.

The Sanitary District of Chicago sells scum from the Southwest plant and Racine Avenue pumping station. At the Southwest plant the operators remove the scum from the tank, putting it into a separate tank from which it is drawn by the vendor. The scum analyses about 50 per cent grease on a wet basis, of which 15 per cent is non-saponifiable. About five tons of scum per day is sold at a price of 0.6¢ per pound.

At the Racine Avenue Pumping Station, the non-saponifiable grease is much lower, resulting in a contract price of 1.1¢ per pound. About 400 tons, on a wet basis, were sold from January 1, 1944 to March 31, 1944.

The City of Fort Dodge, Iowa, sells grease recovered from the skimming tank. At first it was rendered in an improvised rendering tank, and a total of 8,092 pounds was sold for a price of 7¢ per pound. Their contract now provides for selling the scum direct. The vendor furnishes empty drums and picks up the full ones. The plant operators dip the skimmings from the tank onto a platform where they drain for twenty-four hours before placing in the drums.

Analysis of the scum shows 46 per cent grease with a yield of 28 per cent. The price received for the scum, on a wet basis, is 2¢ per pound. From July 1942 to April 1944, total receipts have amounted to $4,834.04.

## Conclusions

1. The presence of large quantities of grease in sewage interferes with plant operation and lowers the efficiency of biological treatment methods.

2. Grease can be removed most effectively at the source.

3. Simpler and more reliable methods should be devised for making analyses for oils and greases.

4. Plant operators should keep more complete records on quantities of grease and its removal in the plant.

5. There is a need for more study to determine the efficiency of various devices for removing grease from sewage.

6. Saponifiable grease can be digested in properly operated digesters.

7. Under present conditions grease from many treatment plants can be salvaged at a profit.

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# SLUDGE DISPOSAL AT CLEVELAND'S SOUTHERLY SEWAGE TREATMENT PLANT *

By G. E. Flower

*Superintendent, Southerly Sewage Treatment Plant, Cleveland, Ohio*

Cleveland's Southerly sewage treatment plant has two types of digested sludge: (*a*) fresh solids from which coarse screenings and grit have been removed, which are digested in Imhoff tanks, and (*b*) fresh solids with grit removed, mixed with comminuted screenings, grease, skimmings and excess activated sludge, which are digested in heated separate digestion tanks.

The digested sludge is disposed of in three ways:

1. Drying under glass-covered sludge beds.
2. Lagooning.
3. Vacuum filtration after conditioning with chemicals.

In the first method, there are eight glass covered beds, with a sand area of 32,250 square feet, all of them being underdrained. Each bed has an industrial track laid on top of the sand, extending the entire length of the bed. Small, industrial, side dump cars, manually loaded, and propelled by a gasoline driven locomotive, are used for transporting the partially dewatered sludge to the dump or into trucks to be used on the grounds, or given away to agriculturists as a soil conditioner.

The number of fillings per bed per year for eleven years' average was 12.2 times. The eleven-year average for pounds of dry solids per square foot of sand bed area was 58.5. The number of fillings will vary with the weather conditions, the depth or thickness of the wet sludge discharged to the beds, the amount of moisture in the sludge applied, and the necessary manpower available to remove sludge cake.

The eleven-year average per cent of moisture in the wet digested sludge applied to the beds was 92.1, and the per cent of moisture in the sludge removed from the beds was 63.1.

Clean washed sand, free from loam and grit taken from the grit chambers, is used for replacing the sand lost from the beds.

In the second method, lagooning was practiced when the plant was first started and continued until January 31, 1943, after which date it was discontinued.

In the third method, more than 90 per cent of the sludge produced from the Imhoff tanks and separate digestion tanks was dewatered by the vacuum filters. There are eight vacuum filters of the rotary drum type providing a string discharge for removal of the sludge cake. Each filter has an effective area of 320 square feet. Iron wire screen is used

* Presented at 18th Annual Ohio Conference on Sewage Treatment, Marion, June 21–22, 1944.

for the backing of the filter cloth, instead of phosphor-bronze wire, due to inability to obtain corrosion resistant wire during the present war.

There is continuous maintenance work required for keeping the screens free from the lime deposit. Two methods have been tried for removing the lime deposits: first, by washing with diluted muriatic acid and an inhibitor; second, by removing the screens and cleaning them by sand blasting.

The cloths used on the filters that have been found satisfactory are an unbleached cotton drill, with a thread count of 68 threads per inch in the warp, and 40 threads per inch in the filter. The weight of the fabric is 2.75 square yards per pound. The filter cloth life varies from 162 hours to 239 hours.

The chemicals used for conditioning the sludge are ferric chloride and lime. The ferric chloride is received in rubber-lined cars as a solution containing about forty per cent of anhydrous ferric chloride, and stored in three rubber-lined steel tanks. It is then forced by air pressure to rubber-lined steel dilution tanks, where it is made into a solution containing one pound of ferric chloride to the gallon.

The lime used is an unslaked pebble lime, averaging about 88 per cent calcium oxide. The lime is received in box cars or hopper bottom cars, for which we have a special attachment for unloading. All the lime is unloaded by a pneumatic vacuum system at a rate of 5 tons per hour and stored in bins. The lime is then fed into slaking tanks by automatic weighing, dry feed machines.

The digested sludge is drawn from a sludge well by bucket elevators to a mixing tank and mixed with the chemicals by wooden paddles.

The following table gives a four-year average of tons of dry solids filtered, per cent of dry solids in the wet sludge, per cent of moisture in the filter cake, per cent of chemicals, and cost of chemicals per ton of dry solids.

| Per Cent Dry Solids Wet Sludge | Tons Dry Solids Filtered | Per Cent Moisture Filter Cake | Per Cent Lime per Pound Dry Solids | Per Cent CaO per Pound Dry Solids | Per Cent $FeCl_3$ per Pound Dry Solids | Cost Lime per Ton Dry Solids | Cost $FeCl_3$ per Ton Dry Solids |
|---|---|---|---|---|---|---|---|
| 6.5 | 13,045 | 72.0 | 14.2 | 12.5 | 4.3 | $1.20 | $1.49 |

The filter cake is conveyed by synthetic rubber belt conveyors to four multiple hearth (eight hearths each) incinerators. Each incinerator has a rated capacity of one hundred tons of wet filter cake per twenty-four hours.

Formerly, fuel oil was the only source of supply for extra fuel in the incinerators, but during the last year sewage gas has been used almost entirely.

Samples taken on the first five hearths showed the following moisture contents in the filter cake:

| Sample | Per Cent Moisture |
|---|---|
| Applied Filter Cake | 70.9 |
| Hearth No. 1 | 70.2 |
| Hearth No. 2 | 67.1 |
| Hearth No. 3 | 65.0 |
| Hearth No. 4 | 33.7 |
| Hearth No. 5 | 21.0 |

The cake on No. 5 hearth was not burning, but on hearth No. 6 it was burning rather vigorously. The temperatures on the various hearths when moisture samples were taken are as follows:

| Hearth | Temp., Deg. F. |
|---|---|
| 1 | 500 |
| 2 | 680 |
| 3 | 740 |
| 4 | 1000 |
| 5 | 1250 |
| 6 | 1310 |
| 7 | 1220 |
| 8 | 920 |

If the rate of feed is above the designed capacity, the moisture content in the cake on the various hearths will be greater than shown above. A light load on the incinerators will cause the temperatures to rise on the upper hearths. An increase in the volatile content of the filter cake requires less added fuel, thereby increasing the temperatures on the hearths. This means that the optimum period of digestion should be possible in order to maintain a uniform content of burnable matter in the filter cake to be incinerated.

The residue, or ash, is removed by a pneumatic vacuum system and stored in bins. Most of the ash is used as a fill, except a small amount which is sold. At the present time, we have no other use for this material.

# EXPERIENCES IN OPERATION OF ARMY SEWAGE TREATMENT PLANTS *

By Arthur D. Caster

*Sanitary Engineer, Repairs and Utilities Branch, Fifth Service Command*

Stations in the Fifth Service Command have many varied types of sewage treatment plants, all designed to protect the health of army personnel and the ultimate consumer of water from the receiving streams and to maintain the prewar standards of stream conditions promulgated by State Departments of Health, State Departments of Conservation and related groups. In most instances, plants were designed with due regard to the requirements set forth by the four State Boards of Health involved, namely, Indiana, Ohio, Kentucky, and West Virginia. The plants are of many types, such as septic tanks with sand filters; Imhoff tanks, affording primary treatment only; complete treatment plants comprising Imhoff or separate sedimentation tanks followed by trickling filters or activated sludge; portable chemical tanks for small training areas; and chlorination, with its wide range of adaptability, has been utilized with all types of treatment. It has been found that trickling filters for secondary treatment at the army sewage treatment plants in this service command provide the most advantageous and economical treatment because of their flexibility, low cost of operation, low cost of maintenance, and simplicity of operation.

## Grease Problems

Grease in the influent at military sewage treatment plants has been one of the major operation problems. Because of large quantities of meat and many fried foods consumed by army personnel and irregularity of cleaning of grease traps by mess personnel, the grease content at army sewage treatment plants is considerably higher than the normal municipal sewage of 25 to 90 parts per million. Grease in army sewage will average from 75 to 300 parts per million with unusual loads of over 1,000 parts per million. At one station where secondary treatment is by activated sludge, the heavy grease carried over from the primary tanks causes the activated sludge to be very light. The sludge was constantly bulking in the final tanks, causing high suspended solids to carry over in the effluent. At a station with filters, the grease balls clog the nozzles of the rotary distributors, and by installing a screen in a manhole between the primaries and the dosing tank, the grease balls were removed. At a third station, during heavy flows, large cakes of grease which had solidified on the sides of the sewers will break loose and enter the sewage plant, clogging the slots of the comminutor. This would cause a loss of head through the comminutor

* Presented at 1944 Annual Meeting, Indiana Sewage Works Association, Anderson, July 19, 1944.

and the backing up of sewage in the sewer. Where grease collected from the primary tanks has been placed in the digesters, heavy scum ranging from 6 inches to 5 feet in depth has collected on top of the digesters. This Branch has been constantly on the watch to forestall excessive accumulation of grease in digesters by breaking up of scum before the layer becomes too thick or too hard. Several stations are placing the grease in lagoons or burning it at the incinerators. The problem of accumulation of grease and resulting scum at one station is reported by the superintendent-chemist as follows:

"Inspection of the primary digester on June 18th disclosed approximately 5 feet of grease on the top of the digester. This scum was of such a consistency that a 6-foot steel wrecking bar could not be forced through it and the digester floating cover was riding on the surface of the scum instead of the liquid, causing the loss of gas, which fact led to the inspection of the digester surface.

"This digester is a 55-foot diameter by 30-foot depth tank with a floating cover and is heated by six heating cells. All skimmings from the primaries had been pumped to this tank along with all the sludge from the primaries. Humus sludge from the finals is discharged to the preaeration tank. Later laboratory determinations showed the primary sludge to be extremely high in ether soluble matter, sometimes being as high as 40 per cent. This fact caused the digester to become overloaded with grease and it was unable to digest a large portion of it with the result that it accumulated on the surface. No mechanical stirrers are present in this digester, but it is doubtful that they could have prevented this condition had they been installed.

"Several means were tried to remove this grease. The surface of the contents was lowered and it was attempted to pump the grease to the drying bed through the sludge discharge lines. This was not successful. A 2-inch hose was then connected to the supernatant lines and final effluent from the centrifugal pumps discharged on the top of the grease. This succeeded in cutting a small hole through the grease at one spot only. The surface of the contents was further lowered by pumping to the drying beds and sludge was discharged on top of the scum. This also was of no value. The digester was then lowered as far as possible and the gas collection tower removed with a crane. The gas piping lost its support and fell to the bottom of the digester. A ¾-yard cement bucket was attached to the crane and it was attempted to bucket out the grease through the center. The bucket removed the grease in one place only as the scum refused to slide to the middle and this procedure was abandoned. The skimmings during this period were placed in cans and incinerated. Sludge was pumped to the secondary digester which showed no evidence of scum.

"Construction of a lagoon was then begun on June 22 and completed on July 1. This lagoon when completed was 125 feet $\times$ 250 feet $\times$ 4 feet deep. A V-shaped wooden trough, metal lined, was connected from the sludge discharge trough to the lagoon and the digester pumped out as far as the pumps would work. After pumping about 6 feet of liquid, grit and grease still remained in the digester. A booster pump mounted on a truck was then obtained from the Fire Department to attempt to break up the grease under pressure. The suction side of the pump was placed in the final settling tanks and approximately 300 feet of 3-inch pressure hose strung to the top of the digester. A T-shaped iron pipe was lowered through the center of the cover and anchored through the bolt holes so the pipe could be rocked. The hose was then attached to this pipe by ropes and the nozzles placed about 3 feet above the scum. The booster pump was then started on July 5, using a nozzle pressure of 210 pounds. The pump was operated about 20 minutes out of the hour so as to prevent as much wear on the pump and motor as possible. Two men were needed to rock the pipe to which the hose was attached. The pumping under pressure was continued until July 11, pumping only during the day shift. The sludge pumps were run continuously during this period and it was sometimes necessary to shut down the booster pump to allow the sludge to catch up. The excess water accumulated during the daytime was pumped out on the night shifts. On the eleventh, definite signs of success were noted as the grease began to break up or emulsify. The nozzle pressure was then cut down to 50 pounds and the pumping intervals lengthened as volume was of more importance than pressure at this point. The grease was discharged in such quantities that the concrete and wooden troughs could not carry it and it spilled out on the ground. The resultant mess was later cleaned and three truck loads were hauled away. On July 15, the grease was all removed and the hose was removed from the support pipe and carried down into the digester. The pressure was cut down so that the hose could be managed by hand and the entire walls and roof of the digester were thoroughly cleaned. About 6 inches of grit on the floor was also hosed to the middle and pumped out. Inspection of the heating coils showed them to be in excellent shape with no evidence of corrosion or electrolysis.

"New gas collection piping was installed and the tower lifted back in place by means of a winch. The digester was back in service on July 17 and the cover floated the next day by means of water from the final settling tanks. The primary was seeded in a 1 to 7 ratio from the secondary digester and sixteen sacks of lime were added to maintain the pH above 6.8. Gas production was normal in thirty days.

"The digester was out of service for twenty-six days. Actual cleaning required only ten days. Cost of the lagoon was $606 and extra labor involved was $69.43. Labor cost of the men furnished by the Fire Department to operate the booster pumps was not estimated.

"All skimmings from the primary settling tanks are now discharged to the lagoon and only a 3-inch light scum is now present on the digester. This scum will be broken up next summer by water under pressure and forced back under the cover. No further digester trouble is contemplated as long as the primary skimmings are lagooned."

Reduction of the high grease content has been the result of many directives from Office of the Chief of Engineers in Washington and from this headquarters. Training of the mess officers and mess sergeants in ''robbing'' grease traps has become a function of the Post Engineer. Constant training and watching is helping to overcome the grease problem. Grease contents of the sewage have been lowered and the operators are aware of troubles that may result if care is not taken in removing the grease before secondary treatment. Further information on grease problems at army stations may be found in an article entitled ''Grease Removal at Army Sewage Treatment Plants'' by Eliassen and Schulhoff, *This Journal,* 16, 296 (March, 1944).

High variation of flows at army sewage treatment plants, caused by routine schedules of all personnel at the stations, has given the operators trouble with shock loads every day. At the time of the heavy flow, the sewage is very high in B.O.D. and suspended solids, the primary tanks are reduced in detention time, causing a carry-over of solids to the secondary treatment units. Constant attention of the operator resulted in minimizing this problem at many stations. Operators came to know when to expect these shock loads and learned to have the bar screens cleaned or comminutor running; they have also learned to have sludge pumped from primaries and to remove the grease and scum often so as to reduce carry-over of solids to secondary treatment units.

Personnel at the sewage treatment plants were, in a large number of instances, men who had been at the sewage plant during construction, or men without sewage treatment experience. Although many had not had previous operation experience, knowledge of maintenance of equipment pulled them through until they were trained by this headquarters. The turnover of operators has been great because industries have offered higher wages or they became part of the army or navy. This necessitated a constant training program by this headquarters and Post Engineers at the plants. By training lower graded men to carry on operation, upgrading resulted for many operators. Although the plant may have and did suffer in some cases because of poor operation, as the men became proficient, the operation results have shown fine improvement. The experience gained by the operators will be beneficial in future positions in private or municipal work after the war. Operators who have operated army sewage treatment plants, in the opinion of the writer, will prove very resourceful in handling municipal plants because they have learned to operate without frills and to do without many common pieces of equipment normally found in municipal plants. In other words, they have learned to do without.

The sewage plant operating forces have been reduced to a bare minimum and at several plants are manned only eight hours or sixteen hours per day. This is in line with War Department policy of conservation of manpower. The more lightly manned plants may not be turning out 95 per cent reductions, but are still producing satisfactory effluents.

Many operators were permitting the laboratory to run them and the plant, instead of the operators using the laboratory to guide them in plant control. In other words, the time consumed by the operator in running control tests did not give him time to attend properly to other duties. By reducing the sampling schedule from a daily to an alternate daily basis, the operators were able to give adequate time to necessary routine work. Thus, ample laboratory data were made available for plant control and sufficient time was left to apply the information properly.

Based on operating logs at four large stations, the following data have been summarized from 24-hour composite samples:

| | |
|---|---|
| Average 5-day B.O.D. | 382 parts per million |
| Average suspended solids | 351 parts per million |
| Percentage removal B.O.D. | 93.4 per cent |
| Percentage removal suspended solids | 92.9 per cent |

These four stations were designed for a B.O.D. of 0.20 pounds and suspended solids of 0.27 pounds per capita per day. Averages of actual data at the four stations shows a B.O.D. loading of 0.199 pounds and suspended solids of 0.189 pounds per capita per day.

Further studies of operation results in relation to design at army installations may be reviewed in an article entitled "Sewage Treatment at Military Installations" by Lt. Col. B. F. Hatch, *This Journal*, **15**, 839 (September, 1943).

### Operation Costs

The operating costs of army sewage treatment plants are in line with costs of operating municipal plants, taking into consideration the slightly higher wage scale set up for the operators of these plants over municipal operators. The annual costs of treating sewage at one large station at which the flow varied from an average daily maximum of 2.6 m.g.d. for one month to a minimum of 1.2 m.g.d. for another month, and with an average daily flow of 1.91 m.g.d., are as follows:

| Flow | Labor per Million Gals. | Total Cost per Million Gals. | Cost per Capita per Year | Cost per 1,000 Lbs. B.O.D. Removed |
|---|---|---|---|---|
| High | \$21.26 | \$24.90 | 0.786 | \$10.12 |
| Low | \$43.20 | \$47.60 | 1.800 | \$35.61 |
| Average | \$29.43 | \$34.15 | 1.012 | \$18.56 |

## Summary

An operator of an army sewage treatment plant must produce at a low cost the best effluent possible with his type of plant so that in the surrounding communities the health of the population will not be jeopardized. Studies are being made at this headquarters as to how to shut down various units of the sewage treatment plants in the Command as the loads at the plants are reduced because of reduction in the training of soldiers or deactivation of the stations, keeping in mind each station's responsibility to maintain a good effluent so as not to lower the quality of the receiving stream.

# GAS UTILIZATION AND INSTALLATION OF NEW GAS ENGINE DRIVEN PUMPING UNIT AT THE MUNCIE SEWAGE PLANT *

By Paul R. White

*Superintendent of Sewage Treatment, Muncie, Indiana*

When the Muncie sewage treatment plant was designed, estimates of the expected gas production were conservative and facilities for its utilization were provided accordingly. The plant was equipped with a 90 h.p. gas engine directly connected to a Roots-Connersville blower, two gas burning boilers for heating the digesters, and the laboratory was equipped for using sewage gas. No other provisions were made for utilization of the gas. The cooling or jacket water from the engine as well as the heat from the exhaust gases (by means of a heat exchanger) is utilized for heating the digesters. During the cold winter months, all the heat available from the engine, plus one gas fired boiler, are required to heat the digesters. During the fall and spring months the engine with the heat exchanger is sufficient and during the warm summer months the proper digester temperatures are maintained by using only the cooling or jacket water. After the digesters became filled and their operation had leveled off to more or less routine, it soon became apparent that more provisions should be made to use the gas that was being wasted. The plant was producing more gas than was anticipated. At the end of 1942 the gas production records for the year showed that the plant had produced an average of 60,000 cu. ft. per day, 40,000 of which was utilized and 20,000 wasted. Sufficient records were now available on which to base designs for additional gas utilization equipment.

In the meantime, after the first year of operation, a gas burner was installed in one of the two steam boilers for heating the plant. Since that time, coal has not been used.

The raw sewage flows through the system of intercepters by gravity and discharges into a wet well at the sewage plant, from which it is lifted by pumps a vertical distance of 20 to 25 feet to the primary tanks. This pumping was done by a battery of three electric driven centrifugal pumps. These pumps have capacities of 3, 5, and 7 m.g.d. They are driven by single speed motors and operate automatically by a float control, in various combinations to conform with the variation in the sewage flow.

From a study of the raw sewage pumping requirements and the sewage gas available it was decided to install the following equipment:

A 50 h.p. gas engine having arrangements for variable speed, directly connected to a 16-inch centrifugal pump. By proper float control the speed of the engine may be varied, depending upon the rate of pumpage required, thereby increasing or decreasing the capacity of

* Presented at Conference of Indiana Sewage Works Association, Anderson, July 19, 1944.

the pump. This variation in speed effects a pumping capacity range of from approximately four m.g.d. to ten m.g.d. Pumping requirements above the capacity of this engine driven unit are met by the original electric driven pumps, operating automatically.

The new pumping unit was installed by our regular plant employees except for a small amount of special work.

Because of the special fittings required and the difficulty in buying cast iron pipe and fittings at this time, steel pipe and fittings were used in connecting the pump. The straight pipe (16-inch) and flange fittings and suction bell were made locally. "Tube Turn" bends were used and these were welded direct to the straight pipe.

The suction pipe extends through an 18-inch reinforced concrete wall into the wet well. Compressed air equipment was used to cut the hole through this wall and the pipe was fastened in place with lead. The lead was poured in place and calked.

The pump discharges through a 16-inch steel pipe into a 30-inch cast iron pipe header. The discharge pipe, which connects to the pipe header at an angle of 45 degrees, was cut to fit on the outside of the header. The opening in the header was made with ¼-inch electric drills. These ¼-inch holes were drilled as close together as possible and after the opening in the header was made, the pipe edge around the opening was made smooth by chisels and an emery wheel. The steel discharge pipe was then set in place and was joined to the cast iron pipe by brazing.

The base of the engine is approximately 20 feet below the grade elevation around the main building. Approximately 65 feet of 4-inch pipe was used to conduct the exhaust gases out of the building. A Maxim silencer was used on the extreme end of the exhaust pipe. The cooling or jacket water is connected in parallel with the cooling water from our other engine which, as stated above, circulates through the heating coils in the digesters. Heat from the exhaust gases can also be utilized for heating the digesters by means of a heat exchanger. The heat exchanger was installed on a by-pass line from the 4-inch exhaust pipe, so that it can be used or not used in accordance with our digester heat requirements. Except during the extreme cold winter weather the two engines furnish sufficient heat for the digesters without using the boilers.

Because of the length and elevation of the exhaust pipe, a trap was installed at the low point in the line to collect the condensate. However, the requirements for this purpose were underestimated and it was necessary to provide additional facilities. The engine was started at the last of October and no difficulties were encountered until the weather became cold. At one time, when the engine was stopped, an accumulation of water in the exhaust pipe ran back and filled the engine. Water continuously discharging from the exhaust pipe, trickled down on the outside of the pipe onto the silencer and was blown onto the building by the wind. The silencer and side of the building were kept continuously wet and discolored.

To overcome this condensation trouble, drain pipes were connected to both the lower and upper compartment of the silencer. Also, a small lip or dam was installed at the outlet end of the exhaust pipe which stops or collects the water and a drain pipe conducts it (the water) to the ground. The exhaust pipe was tapped at the points between the silencer and engine where the water seemed to collect, and ½-inch pipes were connected and extended down to the floor where, by

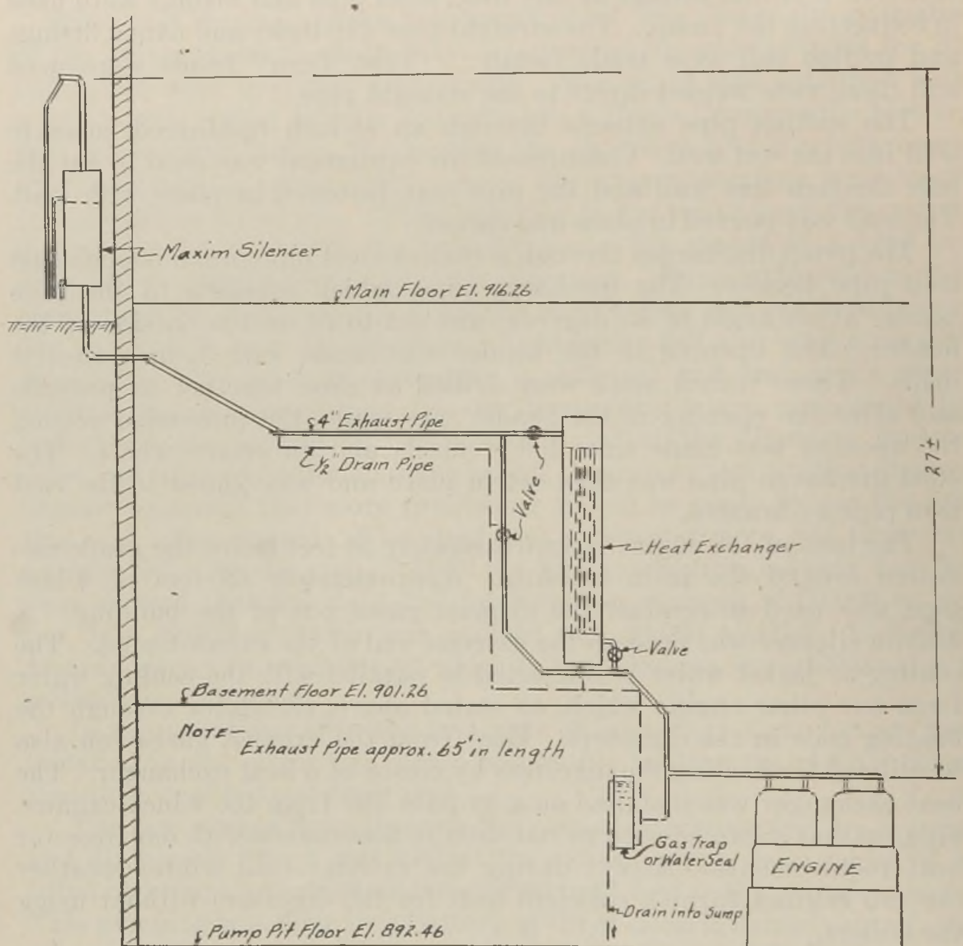


FIG. 1.—Diagrammatical sketch showing arrangement of gas engine exhaust pipe at Muncie, Indiana.

opening valves the water could be drained out. This required too frequent attention from the operator and it was soon found that a drain to operate continuously would be necessary for satisfactory operation. To accomplish this the drain pipes were all connected into one pipe which ran underneath and paralleling the exhaust pipe, draining into a sump below. To seal out the exhaust gases, a water seal or trap was installed in the drain line. This was constructed as shown by Fig. 1, and the depth of sealing water was determined experimentally by immersing the discharge end of the drain pipe in a water container and increasing the depth of immersion to a point where the back pressure from the engine would not blow out through the water. This depth was found to be approximately 18 inches. The trap was made of 8-inch steel pipe, cutting it the proper length and welding on steel plate ends. We have had no trouble from exhaust condensation since this drainage system was installed.

This trouble from exhaust gas condensation might have been prevented by covering the exhaust pipe with an insulating material. However, this was not done for the reason that the location of the pipe made

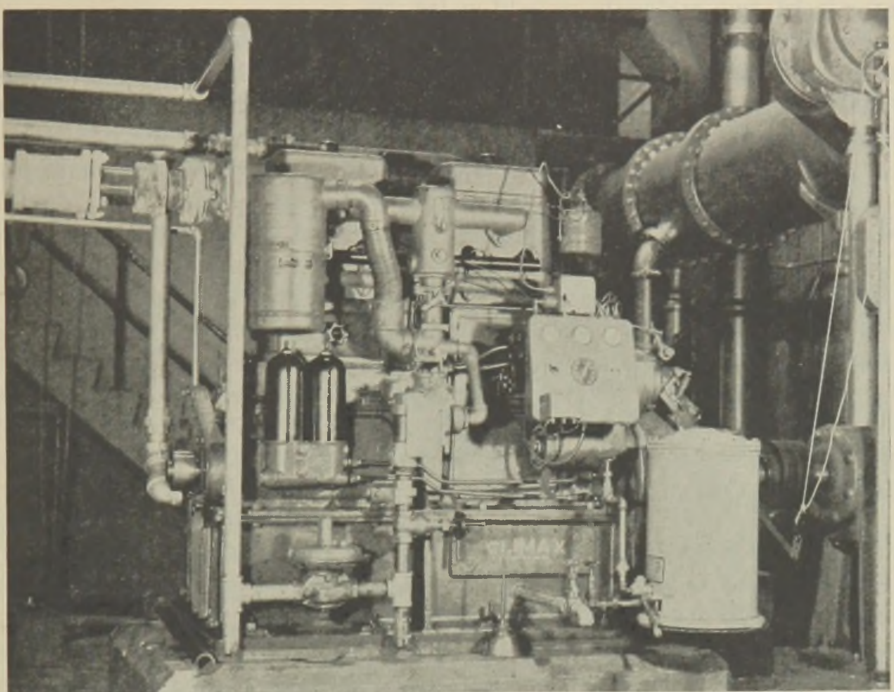

FIG. 2.—Gas engine installation at Muncie, Indiana.

it rather difficult to accomplish and also because it was intended to utilize the heat for heating the building.

The engine uses approximately 20,000 cu. ft. of gas per 24 hours. Assuming this gas to be 60 per cent methane ($CH_4$) this would be 12,000 cu. ft. of methane per 24 hours.

From calculations using chemical combustion equation $CH_4 + 2\ O_2 = CO_2 + 2\ H_2O$, approximately 145 gallons of water would be produced per 24 hours.

Following is an indication of the calculations involved in arriving at this figure:

A volume of 22.4 liters of any gas at 0° Centigrade and at one atmosphere pressure, weighs its molecular weight in grams (22.4 liters carbon dioxide ($CO_2$) would weigh 44 grams). This figure of 22.4 is a standard figure used by all chemists in much the same way as we accept 16 ounces as being one pound.

It is a marked coincidence that the number of liters in a cubic foot and the number of grams in an ounce are the same, namely 28.3. This enables use of the more direct relation that a volume of 22.4 cu. ft. of any gas weighs its molecular weight in ounces (22.4 cu. ft. of carbon dioxide would weigh 44 ounces, since 44 is the molecular weight of carbon dioxide).

In the equation $CH_4 + 2\ O_2 = CO_2 + 2\ H_2O$, there is one molecule of methane and 2 molecules of water. Since the molecular weight of water is 18, two molecules would weigh 36.

For every 22.4 cu. ft. of methane burned there would be produced 36 ounces of water. By the direct proportion, $22.4 : 12{,}000 = 36 : x$, we get 19,300 ounces or 145 gallons of water produced in the complete burning of 12,000 cu. ft. methane.

# Sewage Research

## DECOMPOSITION OF GREASE DURING DIGESTION, ITS EFFECT ON GAS PRODUCTION AND FUEL VALUE OF SLUDGES *

By Willem Rudolfs

*Chief, Department of Water and Sewage Research*

The general relationship between the quantities of grease in sewage sludge and gas production is well known. Some definite results from plant and laboratory experiments are available to indicate what may be expected under certain conditions when excessive quantities of grease are present, but these results have not been generally utilized for practical purposes. Emphasis has been placed more on the difficulties encountered than on the benefits derived from grease as far as gas production and the composition of the gas are concerned.

Many plant and laboratory data are available on the overall destruction of grease and oil during sludge digestion. Some laboratory experiments have been published on the anaerobic decomposition of pure fats and fatty acids, but little information appears available to indicate the rate of grease and oil decomposition during digestion. The actual changes taking place in the nature of the fatty substances during digestion, and the effect of different types of grease and oil on digestion require further elucidation.

To obtain basic information on the rate of decomposition of grease normally present in settled sewage solids, its relation to the total quantities and character of the gas produced, and its relation to other organic substances present in sewage solids, a series of experiments were made with fresh solids subjected to anaerobic digestion. To determine the rate of grease destruction and the changes in grease composition during normal digestion, experiments were made with mixtures of fresh solids and ripe sludge. To determine the effect of grease and oils on the rate of digestion, gas production and gas composition, quantities of sewage grease and mineral oils were added to digesting mixtures. To determine the effect of different types of fats on the rate of digestion, various materials were added to digesting fresh-solids ripe-sludge mixtures.

It is well known that effective and normal sludge digestion is dependent upon rather definite relationships between the carbon and nitrogen present in the sludge. For an adequate presentation of results and proper conclusions to be drawn, it is therefore essential to have available the quantities of nitrogen as well as the grease content of the sludge. Special attention has been paid to the carbon-nitrogen ratios present in

* Journal Series Paper of the New Jersey Agricultural Experiment Station, Department of Water and Sewage Research, Rutgers University, New Brunswick, New Jersey.

the fresh solids used to obtain basic information on digestion, particularly when additional quantities of grease were used.

The fuel value of various sludges of greases found in fresh solids, and of residual grease in digested sludges, form a part of the entire problem.

As a basis for gauging the importance of grease in sewage and sludge treatment the following figures have been compiled from data in our files:

| | Number of Plants | Number Samples* | Maximum | Minimum | Average |
|---|---|---|---|---|---|
| Raw Sewage, p.p.m. | 87 | 470 | 220.8 | 8.4 | 68.2 |
| Effluent, p.p.m., Settled | 36 | 197 | 198.0 | 11.0 | 64.5 |
| Trickling filter | 26 | 86 | 146.8 | 7.0 | 46.1 |
| Activated sludge | 17 | 44 | 69.0 | 1.6 | 35.2 |
| Screenings, per cent | 10 | 37 | 21.4 | 1.8 | 5.3 |
| Humus Sludges, per cent | 7 | 16 | 4.5 | 1.5 | 3.6 |
| Fresh Solids, per cent | 56 | 138 | 44.0 | 5.7 | 13.1 |
| Activated Sludge, per cent | 19 | 122 | 11.9 | 2.8 | 6.3 |
| Digested Sludge, per cent | 64 | 141 | 14.1 | 2.0 | 7.7 |

* Several annual average results considered as one sample from one plant.

## 1. Decomposition of Grease in Fresh Solids

Fresh solids collected from domestic sewage, known to contain appreciable quantities of grease, showed the following characteristics on analysis:

| | |
|---|---|
| Total solids | 4.92 per cent |
| Ash | 22.80 per cent |
| Fats in solids | 32.22 per cent |
| Nitrogen in solids | 3.57 per cent |

The fresh solids were incubated at 70° F., rather complete analyses were made at frequent intervals, gas was collected and recorded daily, and the composition of the gas was determined.

The progress of digestion as illustrated by the actual volatile solids and grease present at intervals, expressed in grams per liter of sludge, is shown in condensed form in Table I. The percentage grease reduc-

Table I.—*Reduction of Volatile Solids and Fats (grams per liter sludge) with Corresponding Gas Production*

| Days Digestion | Vol. Solids | Fats | Org. N Per Cent of V. M. | Cc. Gas per gm. V. M. | pH |
|---|---|---|---|---|---|
| 0 | 38.7 | 14.10 | 4.42 | 0 | 6.0 |
| 72 | 30.7 | 11.40 | 4.50 | 200 | 5.1 |
| 124 | 25.4 | 8.97 | 4.48 | 229 | 5.3 |
| 166 | 19.4 | 6.80 | 4.43 | 385 | 5.7 |
| 222 | 18.0 | 5.87 | 4.25 | 493 | 7.3 |
| 257 | 16.4 | 4.20 | 4.20 | 601 | 7.7 |
| Per Cent Red. | 57.4 | 70.2 | 5.0 | — | — |

tion at the end of the experiment was materially higher than the percentage total volatile solids destruction. The same table shows also the percentage of organic nitrogen in the volatile matter present. The percentage organic nitrogen remained almost constant, indicating that its destruction progressed at virtually the same rate as the reduction in total volatile matter. Total gas production was directly related with the total volatile matter and grease decomposition. The relationship is more effectively shown in Fig. 1, where the percentages of volatile

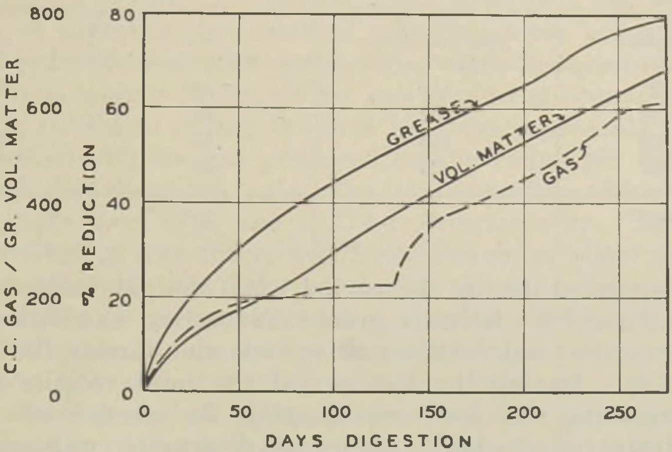


FIG. 1.—Relation between volatile matter and grease reduction and gas production.

matter and grease reduction recorded are compared with the gas produced per gram volatile matter present at closer intervals than in the table. Volatile matter and grease destruction appear to progress simultaneously throughout the period of digestion. Calculations showing the relative percentage decomposition indicate, however, that the rate of destruction of the total organic matter as compared with grease was not constant throughout the period of digestion (Table II). The percentage

TABLE II.—*Relative Destruction of Volatile Matter and Grease*

| Days Digestion | Vol. Matter, Grams | Grease, Grams | Vol. Matter less Grease, Grams | Original V. M. less Grease Decomposed, Per Cent | Grease Decomposed, Per Cent |
|---|---|---|---|---|---|
| 72 | 8.0 | 2.70 | 5.30 | 21.5 | 19.0 |
| 52 | 5.3 | 2.43 | 2.87 | 11.7 | 17.0 |
| 42 | 6.0 | 2.17 | 3.83 | 15.5 | 14.4 |
| 56 | 1.4 | 0.93 | 0.47 | 2.3 | 6.6 |
| 35 | 1.6 | 1.67 | 0.0 | 0.0 | 11.8 |

grease as well as total volatile matter decomposition during the first 166 days, that is, the period when the pH values recorded, indicated the acid phase of digestion, was fairly constant. Thereafter, a sharp drop in total volatile matter destruction was recorded, with a smaller reduction in grease. This would seem to indicate that certain volatile substances including fats are easily destroyed, whereas others are more resistant and must be reduced to less complex materials before conversion into gases.

In order to determine the variations in the rate of volatile matter and grease destruction, when the materials were digesting in different pH ranges, the relative units of materials decomposed per day were calculated (Table III). It is evident that the greatest rate of daily destruction occurred during the period when the pH values were rising between 5.3 and 7.3. Relative grease destruction was higher, however, than the relative total volatile-matter reduction during the acid period (pH 5.1–5.3). During the last period the total volatile matter and grease remaining was low; consequently, the number of units which could be destroyed was lower, but grease destruction was comparatively greater than total volatile-matter destruction. As a matter of fact, all of the material destroyed during the last period can be accounted for by fats or their degradation products.

TABLE III.—*Relative Rate of Volatile Matter and Grease Destruction (Units per Day)*

| Days Digestion | Total Vol. Matter | Fats | pH Range |
|---|---|---|---|
| 0–72 | 114 | 38 | 6.0–5.1 |
| 73–124 | 102 | 48 | 5.1–5.3 |
| 125–166 | 143 | .52 | 5.3–7.3 |
| 167–257 | 30 | 28 | 7.3–7.7 |
| 0–257 | 86 | 54 | — |

The amounts of gas produced per liter of sludge and the quantities of volatile matter and grease destroyed during the different periods were calculated in an effort to determine possible relationships (Table IV). The total amount of gas produced per gram volatile matter destroyed amounted to 917 cc. On the basis of percentage total volatile-matter and grease destruction, it appears that the volatile matter without grease produced, on the average, 280 cc. of gas as compared with 378 cc. for the total volatile matter (including grease), or nearly 25 per cent less. This would indicate that the grease had about 25 per cent greater

TABLE IV.—*Relation Between Volatile Matter and Grease Destruction and Gas Production*

| Days Digestion | Gas per Gram Vol. Matter Destroyed, cc. | Gas for Each Per Cent Destroyed | | Gas per Liter Sludge, cc. |
|---|---|---|---|---|
| | | Total Vol. Matter, cc. | Vol. Matter less Grease. cc. | |
| 72 | 962 | 357 | 405 | 7,700 |
| 124 | 211 | 95 | 66 | 1,116 |
| 166 | 984 | 384 | 412 | 5,906 |
| 222 | 3,048 | 2,843 | 647 | 4,268 |
| Average | 917 | 378 | 280 | 18,990 |

gas producing value than the other decomposible volatile matter present. During the acid stages of digestion (dropping and stationary pH) considerable amounts of volatile matter were destroyed (liquefied), but gas production was relatively low. During the period of rising pH values and alkaline digestion, gas production for each per cent volatile matter destroyed was higher and the highest relative gas production occurred while the material was alkaline. Calculations show that during this period the weight of gas was greater than the apparent amounts of volatile matter destroyed. It is evident, therefore, that during the acid stages of digestion the mass of materials were not actually destroyed but reduced to simpler compounds, which in turn produced gas when conditions became favorable for gas-producing organisms.

If the gas produced during the first 124 days represents the period of acid digestion and the gas produced during rising pH values (5.7–7.7) as the alkaline digestion period, the total quantities of gas produced in these periods were 8816 and 10,174 cc. respectively. The average daily gas production was, therefore, 71 and 104 cc., or about 45 per cent more during alkaline digestion than during the acid digestion period.

Decomposition of grease takes place simultaneously with other organic substances present in sewage sludge during digestion. The rate of destruction of grease and other volatile substances is not the same during the entire period of digestion. Grease decomposes in the acid stages of digestion, but gasification and methane production is greater during the alkaline stage. Studies made by Neave and Buswell (1) substantiate the results obtained. These authors, studying the acid stage of digestion, concluded that "in the acid type of sludge digestion a rapid destruction of fats and soaps occurs with the production of lower fatty acids. Some of the fatty acids ferment further to give methane." The breakdown of fats and soaps into lower fatty acids results in an accumulation of part of these intermediate decomposition products. The accumulation of intermediate decomposition products in turn results in lowering of pH values and may hinder proteolysis. Carrying the digestion through the alkaline stage showed that more gas is produced during this stage of digestion than in the acid stage as a result of accumulation of degradation products. Since the percentage grease destruction during digestion is greater than the percentage total volatile matter destruction, it follows that the more grease and soaps which are present in the sludge the higher will be the relative gas production. Greases removed from sewage by various devices should be returned to the digesters if maximum amounts of gas are desired.

Although gas production during the first stages of digestion was relatively high, the percentage combustibles in the gas was rather low. Apparent grease destruction was comparatively high under acid conditions and the relative grease destruction as compared with total volatile matter reduction remained fairly constant during the entire period of digestion. There appears to be a closer direct relationship between the percentages of combustibles in the gas produced and the percentage of fat destruction than between combustibles and total volatile matter destruction (Table V). During the acid stage of digestion, the carbon dioxide content of the gas was materially higher than the combustible content.

TABLE V.—*Relation Between Volatile Solids and Fat Decomposition and Composition of Gas Produced*

| Days Digestion | Vol. Matter Reduction, Per Cent | Fat Reduction, Per Cent | Composition of Gas | |
|---|---|---|---|---|
| | | | $CO_2$, Per Cent | Combustibles, Per Cent |
| 0 | (38.7) | (14.1) | — | — |
| 70 | 20.6 | 19.6 | 52.0 | 27.2 |
| 124 | 34.8 | 36.4 | 49.0 | 38.6 |
| 166 | 48.8 | 51.8 | 34.4 | 56.4 |
| 222 | 53.5 | 58.3 | 29.1 | 59.0 |
| 257 | 57.4 | 70.2 | 21.1 | 69.8 |

The results as a whole suggest that fats are not only hydrolyzed during the acid digestion period, but also reduced to gas. The preponderance of the gas produced is $CO_2$ rather than methane. The main difference between the acid and alkaline stages of digestion appears to be not in liquefaction and gasification, or primarily in the quantities of gas produced or the rate of fat destruction, but essentially in the type of gas produced. Grease and other volatile matter produce relatively more $CO_2$ during the acid stage of digestion and relatively more methane during the alkaline stage of digestion.

The rate of decomposition of fats and soaps during digestion of unseeded material is undoubtedly lower than in properly seeded mixtures. With proper seeding no appreciable accumulation of grease degradation products should occur and the composition of the gas should be more uniform. Changes in the uniformity of the gas composition would indicate changes in the rate of decomposition. Fats are important sources of methane gas, and a high carbon dioxide content of the gas would indicate either unbalanced relationships between the various constituents in the sludge solids or incomplete digestion.

TABLE VI.—*Relation Between Organic and Ammonia Nitrogen*

| Days Digestion | Org.-N, P.p.m. | $NH_3$-N, P.p.m. | Total N, P.p.m. |
|---|---|---|---|
| 0 | 1,710 | 73 | 1,785 |
| 70 | 1,380 | 450 | 1,830 |
| 124 | 1,142 | 650 | 1,792 |
| 166 | 862 | 860 | 1,722 |
| 222 | 766 | 920 | 1,696 |

Changes in the nature of the greases and fats present in fresh solids during the first period of digestion are illustrated in Table VII. The total fat content of the fresh solids was high, showing a rapid percentage decrease during the first 35 days of digestion. On the other hand, both the titration for fatty acids and the percentage unsaponifiable fats in the grease extracted show an increase. The determination of fatty acids and saponifiable fats by titration is inaccurate, on account of the color in the solution. Nevertheless, the general and progressive increase in fatty acids and unsaponifiable fats in the fats remaining is suggestive.

TABLE VII.—*Comparison of Fat Content, Fatty Acids and Saponifiable Fats During Digestion of Fresh Solids*

| Days Digestion | Total Fats in Sludge, Per Cent | N/10 NaOH, cc. | Unsap. in Fats, Per Cent |
|---|---|---|---|
| 0 | 32.5 | 22.0 | 18.3 |
| 7 | 30.8 | 25.5 | 22.1 |
| 14 | 25.3 | 33.7 | 27.2 |
| 21 | 23.9 | 38.7 | 30.1 |
| 35 | 20.0 | 41.2 | 38.7 |

The increase of 20 per cent in the unsaponifiables is the result of the difference in the rate of decomposition of total fats and unsaponifiable fat. Decomposition of unsaponifiable or mineral fats is slow in comparison with animal or vegetable fats. The actual quantities amounted to 6.0 grams per 100 grams dry solids, as compared to 7.63 grams after 35 days digestion. The destruction of total fats amounted to 20 grams, whereas the increase in unsaponifiable fat amounted to 1.63 grams.

The NaOH values given in Table VII, show a gradual increase in fatty acid content of the material during the acid period of digestion. As will be shown later, the fatty acid content of the sludge decreases rapidly during the alkaline phase of digestion, indicating that any fatty acids accumulated are eventually destroyed.

In a paper pertaining to sewage sludge as a fertilizer (3), the average results of a number of sludge analyses from various plants in the country showed that the percentage nitrogen in the fresh solids was materially higher than in ripe sludge. Carefully controlled laboratory experiments made on the carbon and nitrogen transformation during digestion (4) showed that there is no reduction in the total nitrogen content in a given volume of digesting sludge. Some years later Buswell and Neave (2), using pure nitrogenous compounds, showed that proteins and peptones are good sources of gas and concluded that the digestion process effects merely a remobilization of nitrogen, during which not over 5 per cent of that present is lost as gaseous nitrogen. Recently Snell (5) again found that organic nitrogen is not lost during anaerobic digestion. The results reported in Table I show that the percentage organic nitrogen of the total volatile matter remains constant. Since the total volatile solids were reduced about 57 per cent and the organic nitrogen remained practically constant in the remaining volatile matter, it is evident that the form of nitrogen was changed. The results obtained substantiate this, as shown by the figures in Table

VI. The difference in total nitrogen at the beginning and after 222 days of digestion is small, amounting to about 5 per cent, and may have been caused by errors in sampling or analytical methods employed.

The results show that the organic nitrogen decomposed about 60 per cent after 222 days as compared with about 59 per cent grease and about 53 per cent total volatile solids. It is evident, therefore, that the nitrogenous substances decomposed at about the same rate as the grease and at a higher rate than the other volatile material subject to decomposition. The ammonia nitrogen increases rapidly during the acid stage of digestion, gradually slowing up until a fairly constant level is reached during the alkaline phase of digestion. It is clear that more and more ammonia becomes available, changing to ammonium bicarbonates, which makes the environment suitable for methane organisms and acts as buffer agent. The rapid increase in ammonia suggests that during normal digestion of domestic sewage solids more than sufficient ammonia nitrogen is available for biological resynthesis and activities.

## 2. Decomposition of Grease during Normal Digestion

Transformation and decomposition of grease in properly seeded mixtures or under normal operating conditions should proceed at a higher rate than if fresh solids alone are digested. An increased rate of grease transformation is not necessarily accompanied, however, by a greater degree of destruction. The rate of destruction is primarily dependent upon the proper organisms present and environmental conditions such as optimum temperature, reaction, and possibly concentration.

Results obtained with seeded mixtures are reported briefly in the form of a few laboratory experiments, large-scale experimentation with different sludges, and results from actual plant operation.

### *Laboratory Experiments*

Laboratory results obtained on the decomposition of grease in properly seeded mixtures may be illustrated briefly by two examples. One of the examples chosen shows the percentage grease destruction with a low grease concentration and the other with a relatively high grease content in the original mixtures.

Thoroughly ripe sludge was mixed with fresh solids and digested at 70° F. until gasification was practically completed. Gas production amounted to 594 cc. per gram volatile matter added. The percentages total solids and grease of the mixtures at the beginning and end of the experiment were:

| | Beginning | End |
|---|---|---|
| Total Solids, per cent | 6.32 | 5.38 |
| Grease in Solids, per cent | 13.10 | 5.36 |

Assuming no further destruction of the volatile matter and grease present in the original ripe sludge, the total solids reduction of the fresh solids amounted to 30 per cent and the reduction of grease to 81.6 per cent.

Similar experiments with fresh solids-ripe sludge mixtures, but with higher concentrations of grease in the fresh solids, showed the following percentages decrease in grease:

| Mixture | Beginning | | End | |
|---|---|---|---|---|
| | A | B | A | B |
| Fresh Solids | 34.2 | 25.8 | — | — |
| Ripe Sludge | 7.3 | 7.1 | — | — |
| Mixture | 20.1 | 16.5 | 7.3 | 7.1 |
| Reduction Mixture | — | — | 63.5 | 57.0 |
| Reduction Fresh Solids | — | — | 78.7 | 72.7 |

It appears that with complete digestion of settled fresh solids as ordinarily practiced, i.e., when gasification is at least 90 per cent completed, grease reduction of from 70 to 80 per cent might be expected.

*Plant Operation Results*

The total quantities of grease, oil, and fats present in fresh solids and ripe sludge vary from place to place. Under normal conditions, when no large amounts of mineral oils are present, the variations in grease content are greater in fresh solids received at different plants than the total grease in the residual ripe sludge. These variations are illustrated in results shown in Table VIII. The percentages total grease in the ripe sludge are rather uniformly low irrespective of the quantities of grease present in the fresh solids. These figures represent the grease content in fresh solids and ripe sludges obtained at the same time from the plants and are not strictly comparable. Samples of fresh solids and ripe sludge obtained from 10 different plants showed the following percentages total grease content on a dry solids basis:

TABLE VIII.—*Grease Content of Fresh Solids and Ripe Sludge* (*Per Cent of Dry Matter*)

| Source | Total Grease | | Unsaponifiable | |
|---|---|---|---|---|
| | F.S. | R.S. | F.S. | R.S. |
| Plainfield | 33.4 | 7.2 | 5.5 | 4.9 |
| Freehold | 25.7 | 7.1 | 5.4 | 3.5 |
| New Brunswick | 32.2 | 7.6 | 6.4 | 5.8 |
| Highland Park | 22.4 | 6.3 | 5.7 | 4.8 |
| Rahway | 18.6 | 7.6 | 5.9 | 2.8 |

| | Maximum | Minimum | Average |
|---|---|---|---|
| Fresh Solids | 35.1 | 18.6 | 27.4 |
| Ripe Sludge | 9.2 | 6.3 | 7.3 |

The fact that the total grease in the ripe sludge in all cases varied within narrow limits indicates that the digestible grease has been destroyed to a high degree, leaving only a small percentage of resistant grease or oil in the ripe sludge. Most of the grease present in the ripe sludge was unsaponifiable, in other words, in the form of mineral oils. As stated before, the ripe sludges used for analyses are not the residues of the fresh solids and, therefore, the results show only the general destruction of grease in fresh solids; it is nevertheless of interest to compare the percentages unsaponifiables present in the fresh solids with those found in the ripe sludge. In all cases the percentages of unsaponifiable fats were lower in the ripe sludge than in the fresh solids. This may be coincidence, but as is shown elsewhere, mineral oils may be subject to slow decomposition during digestion. The average of unsaponifiable fats in the ripe sludges was about 20 per cent less than in the fresh solids samples.

Of more interest is, perhaps, to compare the percentages of unsaponifiables in the total grease present in the fresh solids and ripe sludge (Table IX). With the exception of the Rahway fresh solids,

Table IX.—*Comparison of Per Cent Unsaponifiable Fats in Total Grease Present in Fresh Solids and Ripe Sludge*

| Source | Per Cent Unsaponifiable Fats Fresh Solids | Per Cent Unsaponifiable Fats Ripe Sludge |
|---|---|---|
| Plainfield | 16.5 | 67.2 |
| Freehold | 21.2 | 64.6 |
| New Brunswick | 19.9 | 75.4 |
| Highland Park | 26.5 | 75.5 |
| Rahway | 31.6 | 37.0 |

which showed a relatively low total grease content and a comparatively high grease content in the ripe sludge, the apparent changes check well with results presented in Section 5, where different types of materials have been added to digesting mixtures.

If it is assumed that these examples are representative of the actual changes taking place in treatment plants, the average reduction in grease content for all 10 plants amounted to about 73 per cent. This reduction is of the same magnitude as found for unseeded and seeded solids digested under laboratory conditions.

*Large-Scale Experimentation*

In the course of several years considerable data have been accumulated in conducting large-scale experiments. Some of the material has been published incidental to other work, but not with particular emphasis on grease decomposition, and other results are still awaiting publication. Pertinent portions of the data collected are used in this paper to illustrate the degree of grease destruction and its effect on gas production and decomposition of the gas produced. For convenience and ease of illustration the results are presented under subheadings.

*Fresh Solids.*—An experimental sludge digestion tank, with capacity to take care of sludge produced by 450 persons, was operated for a period of 166 days. Ripe sludge obtained from an efficiently operating digester was used for seed. The daily loading was kept approximately constant by adding 5 per cent fresh solids on a dry solids basis. The temperature of the digester was kept within the limits of 79° to 86° F. The gas produced was metered and the total recorded daily. During the entire period no fresh solids were added on Sundays and, therefore, the actual average loading per day was 1/7 less than the average daily 5 per cent additions recorded. The 5 per cent additions were made on the basis of the original amount of sludge present; with increasing quantities of ripe sludge produced, the relationship between fresh solids and ripe sludge changed.

TABLE X.—*Summary of Results of Fresh Solids Digestion*

| | Max. | Min. | Ave. |
|---|---|---|---|
| Daily Additions—F. S. to R. S., per cent | 6.2 | 4.6 | 4.96 |
| Total Solids, per cent | 6.90 | 4.82 | 5.24 |
| Ash of Solids, per cent | 32.1 | 20.2 | 24.2 |
| Liquid Removed: | | | |
| Total Solids, per cent | 0.26 | 0.10 | 0.14 |
| Ash, per cent | 42.1 | 52.3 | 48.7 |
| Ripe Sludge: | | | |
| Total Solids, per cent | — | — | 5.02 |
| Ash, per cent | — | — | 49.2 |
| Volatile Matter Red., per cent | — | — | 62.2 |
| Grease in Fresh Solids, per cent | 26.2 | 22.2 | 24.1 |
| Grease in Ripe Sludge, per cent | — | — | 7.2 |
| Grease Reduction, per cent | — | — | 70.0 |
| Gas per lb. Vol. Matter Added, cu. ft. | 7.72 | 11.20 | 8.78 |
| Gas per lb. Vol. Matter Destroyed, cut. ft. | — | — | 12.11 |

A summary of the results obtained is shown in Table X. Total volatile matter reduction on the basis of total pounds material added amounted to 62 per cent, and grease reduction was 70 per cent. Total gas production amounted to 551 cc. per gram volatile matter added. It is probable that, as in plant operation, a small percentage of the gas produced escaped and that part of the carbon dioxide was dissolved in the discarded supernatant liquor.

*Sreenings.*—Experiments utilizing a small tank having a gross capacity of 260 gallons (6) were conducted for a total period of 290 days. The experiments consisted of two parts (*a*) batch addition and (*b*) daily addition. To an initial quantity of 60 gallons of ripe sludge used for seeding, 140 gallons of screenings were added. The materials used have the following composition:

| | Per Cent Total Solids | Per Cent Ash | Per Cent Total N as $NH_3$ |
|---|---|---|---|
| Ripe Sludge | 3.54 | 41.4 | 3.28 |
| Screenings | 8.40 | 8.9 | 4.66 |
| Mixture | 3.45 | 18.1 | 3.23 |

The high volatile matter content of the screenings resulted in a volatile matter relation between ripe sludge and screenings of 1:12. The batch experiment was continued for a period of 102 days, after which daily additions were made of 5 gallons of screenings for a period of 188 days. A temperature of 81° F. was maintained throughout the digestion period. A summary of the pertinent results is shown in Table XI.

TABLE XI.—*Summary of Small Tank Screenings Digestion*

| | Max. | Min. | Ave. |
|---|---|---|---|
| Solids Added: | | | |
| Total Solids, per cent | 8.40 | 4.15 | 5.33 |
| Ash, per cent | 13.62 | 4.64 | 7.90 |
| Solids Drawn: | | | |
| Total Solids, per cent | 4.47 | 1.88 | 3.50 |
| Ash, per cent | 27.6 | 15.8 | 20.9 |
| Liquid Drawn: | | | |
| Total Solids, per cent | 0.21 | 0.11 | 0.16 |
| Ash, per cent | 49.7 | 36.1 | 44.4 |
| N as $NH_3$: | | | |
| Screenings, per cent | 3.54 | 2.35 | 3.23 |
| Sludge, per cent | 3.66 | 2.68 | 3.11 |
| Liquid, per cent | 5.13 | 3.05 | 4.21 |
| Grease: | | | |
| Screenings, per cent | 78.60 | 4.98 | 13.40 |
| Sludge, per cent | 5.25 | 1.58 | 4.03 |
| Gas per lb. Dry Screenings, cu. ft. | 7.28 | 2.14 | 5.30 |
| B.O.D. Sludge | 1760 | 440 | 890 |

The screenings were digested on a calculated 40-day schedule, and the amount of screenings represented the waste of about 205 persons. After 40 days the screenings appeared to be thoroughly digested, as indicated by the drainability of the sludge (dried on sand beds and spadable in 4 days with a moisture content of 69.4 per cent), the absence of odor, and a low B.O.D. of the sludge.

The quantities of material added during the entire period of digestion and the sludge left were as follows:

| | | |
|---|---|---|
| Dry Ripe Sludge | 19.5 | lbs. |
| Dry Screenings Added | 464.6 | lbs. |
| Dry Solids Drawn and Left | 178.4 | lbs. |
| Solids Reduction | 61.6 | per cent |
| Volatile Matter Reduction | 66.8 | per cent |
| Nitrogen Reduction | 59.5 | per cent |
| Grease Reduction | 70.7 | per cent |
| Gas per lb. Dry Screenings Added | 5.3 | cu. ft. |
| Gas per lb. Screenings Destroyed | 9.0 | cu. ft. |

Decomposition of 274.5 pounds volatile matter with the production of 9.0 cubic feet of gas per pound volatile matter was less than that obtained in carefully controlled laboratory experiments with the same material. The grease content of the screenings varied materially, indicating a reduction of 70.7 per cent, or somewhat more than the percentage total volatile matter reduction. This is about in line with the results obtained for fresh solids digestion.

Experiments with large tanks, 18 feet square and 20 feet 9 inches deep and having an effective digestion capacity of 3500 cubic feet, gave

TABLE XII.—*Summary of Large Scale Screenings Digestion*

| | Min. | Max. | Ave. |
|---|---|---|---|
| Screenings Added: | | | |
| Total Solids, per cent | 7.3 | 9.7 | 8.52 |
| Ash, per cent | 7.6 | 20.8 | 10.10 |
| N as $NH_3$, per cent | 2.66 | 3.84 | 3.24 |
| Grease, per cent | 7.01 | 18.60 | 11.80 |
| Liquid Drawn: | | | |
| Total Solids, per cent | 0.12 | 0.41 | 0.26 |
| Ash, per cent | 41.6 | 55.7 | 48.6 |
| Sludge Drawn: | | | |
| Total Solids, per cent | 3.00 | 9.59 | 6.25 |
| Ash, per cent | 41.1 | 56.0 | 47.0 |
| B.O.D., p.p.m. | 210 | 1590 | 780 |
| Total Nitrogen, per cent | 2.01 | 2.74 | 2.44 |
| Grease, per cent | 2.18 | 5.10 | 3.47 |
| Gas, Cu. Ft. per Lb. Dry Solids | 2.48 | 14.30 | 6.26 |

further information regarding the relation between gas production and decomposition of grease in screenings. The total operating time during which grease analyses were made amounted to 214 days. A summary of the pertinent data obtained is shown in Table XII. A total of 58,843 pounds of dry screenings were added and digested at

TABLE XIII.—*Weekly Averages of Grease Reduction and Composition of Gas*

| Date | Per Cent Grease in Screenings | Per Cent $CO_2$ | Per Cent Combustibles | Per Cent Grease in Sludge | Per Cent Grease Destroyed |
|---|---|---|---|---|---|
| 3/9 –3/16 | 9.54 | 37.6 | 57.7 | 3.10 | 67.8 |
| 3/17–3/23 | 10.00 | 37.0 | 52.0 | 3.28 | 67.2 |
| 3/24–3/30 | 13.66 | 35.0 | 49.9 | 4.69 | 65.8 |
| 3/31–4/6 | 11.72 | 36.7 | 51.3 | 3.64 | 68.8 |
| 4/7 –4/13 | 13.35 | 36.8 | 53.4 | 3.38 | 74.8 |
| 4/14–4/20 | 11.21 | 36.3 | 47.4 | 3.68 | 67.4 |
| 4/21–4/27 | 13.90 | 37.9 | 55.4 | 4.87 | 65.2 |
| 4/28–5/4 | 14.58 | 33.5 | 50.9 | 3.83 | 73.8 |
| 5/5 –5/11 | 17.00 | 35.7 | 52.6 | 5.10 | 70.6 |
| 5/12–5/18 | 17.50 | 38.6 | 52.5 | 4.75 | 72.8 |
| 5/19–5/25 | 18.14 | 39.4 | 51.6 | 4.56 | 74.8 |
| 5/26–6/1 | 18.60 | 38.4 | 57.4 | 3.35 | 82.3 |
| 6/2 –6/8 | 9.77 | 38.2 | 50.1 | 3.35 | 65.5 |
| 6/9 –6/15 | 12.77 | 35.5 | 51.0 | 4.94 | 61.6 |
| 6/16–6/22 | 15.35 | 39.0 | 46.8 | 5.01 | 67.7 |
| 6/23–6/29 | 13.46 | 35.4 | 52.6 | 4.39 | 67.4 |
| 6/30–7/6 | 14.37 | 30.1 | 56.5 | 4.37 | 69.6 |
| 7/7 –7/13 | 14.65 | 35.3 | 52.2 | 5.25 | 64.3 |
| Averages | 13.85 | 35.9 | 52.3 | 4.19 | 69.8 |

an average temperature of 84° F. For seed sludge 13,180 pounds dry solids were used. During the digestion period 6,993 pounds of grease were added. On the basis of volatile matter added and withdrawn the average reduction of volatile matter amounted to 60.2 per cent and the grease reduction to 70.3 per cent.

It is evident from the low average B.O.D. of the ripe sludge that digestion had progressed satisfactorily. The amount of gas produced was relatively high for screenings, but rather low if compared with gas production from fresh solids. The composition of the gas also was somewhat different from that produced by fresh solids. The $CO_2$ content was high and, consequently, the percentage combustibles low. As an example the results obtained over an eighteen-week period, when the addition of screenings was practically constant, are shown in Table XIII. The average $CO_2$ content of the gas was 35.9 per cent with an average destruction of grease of 69.8 per cent. The high $CO_2$ content of the gas was apparently not caused by the magnitude of the grease content or the degree of decomposition of the grease. Grouping the results on the basis of grease content in the screenings we find:

| No. Days | Per Cent Grease in Screenings | Per Cent $CO_2$ in Gas | Per Cent Grease Destroyed |
|---|---|---|---|
| 42 | . 10.83 | 36.7 | 66.4 |
| 49 | 14.00 | 34.8 | 69.0 |
| 28 | 17.81 | 38.0 | 75.1 |

With increasing percentages of grease present in the raw screenings, the $CO_2$ did not progressively increase, in spite of the fact that a greater percentage of grease was destroyed in the screenings with the higher grease content. Evidently another factor was responsible for the higher $CO_2$ content of the gas.

The higher $CO_2$ content of the gas was apparently not caused by a low pH value, since the average pH during the entire period of digestion was 7.4, varying between 7.2 and 7.8. There may be a possibility that the comparatively low total nitrogen content of about 2.0 per cent as compared with the total nitrogen content in fresh solids (4–5 per cent) played a role, but it is more likely that far less $CO_2$ was dissolved in the discarded supernatant liquor than is ordinarily the case in fresh solids digestion. The concentration of screenings added amounted to 8.5 per cent as compared with about 5 per cent fresh solids. The volume of liquor introduced into the tank was, therefore, some 60 per cent less, and presumably less $CO_2$ was removed from the gases in passage. Unreported laboratory experiments have shown that the $CO_2$ content of the gas produced increases with increasing concentration of solids. In this respect it should be remembered that the total gas production amounted to only 427 cc. per gram volatile matter in the screenings, or about one-third less than might be expected from fresh solids. The lower total gas production was, however, probably due to the larger quantities of resistant fibrous material present in the screenings.

*Activated Sludge.*—A small covered tank, with a capacity of 215 gallons, was used for digestion of activated sludge. After seeding with ripe sludge, activated sludge was added daily and, after operation for 5 months, the quantities of grease in the ripe sludge present and the activated sludge added daily were determined for a period of 120 days. The tank was kept at an average temperature of 81° F. An attempt to measure gas production was made, but the apparatus available made it difficult to obtain accurate readings. The gases evolved were analyzed at weekly intervals.

TABLE XIV.—*Summary of Results of Activated Sludge Digestion*

| | Min. | Max. | Ave. |
|---|---|---|---|
| Total Solids Added, per cent | 1.96 | 4.83 | 2.40 |
| Ash of Solids, per cent | 26.6 | 36.5 | 31.2 |
| Sludge Drawn, Solids, per cent | 3.10 | 5.69 | 4.52 |
| Ash, per cent | 36.3 | 48.6 | 42.9 |
| Liquid Drawn, Solids, per cent | 0.11 | 0.22 | 0.13 |
| Ash, per cent | 38.5 | 52.9 | 45.4 |
| Total Nitrogen, Activated, per cent | 4.81 | 6.40 | 5.56 |
| Total Nitrogen, Sludge Drawn, per cent | 2.69 | 5.83 | 3.48 |
| Grease, Activated, per cent | 4.60 | 8.28 | 6.29 |
| Grease, Sludge, per cent | 3.75 | 5.96 | 5.09 |
| $CO_2$ in Gas, per cent | 17.2 | 35.3 | 27.3 |

A summary of the analytical results is shown in Table XIV. During the period under consideration, the quantities of material added and drawn as ripe sludge or supernatant liquor were as follows:

| | Added | Drawn | Per Cent Reduction |
|---|---|---|---|
| Total Solids, lbs. | 255.8 | 220.4 | 14.0 |
| Volatile Matter, lbs. | 205.0 | 110.7 | 46.2 |
| Grease, lbs. | 17.6 | 11.2 | 36.2 |
| Total Nitrogen, lbs. | 20.04 | 13.60 | 32.0 |

During the aeration processes a considerable percentage of volatile matter is oxidized and gasified. Hence, the volatile matter content of activated sludge is lower than of fresh solids. It would seem that the grease present in the raw sewage, particularly is destroyed, as indicated by the low average percentage (6.29) in the activated sludge. This is as low as that found in well digested sludge obtained from fresh solids. Further decomposition of volatile matter and particularly of grease under anaerobic conditions must be limited. Of the total quantity of volatile matter added, about 94 pounds were destroyed during digestion, whereas only 6.4 pounds of grease, or about 36 per cent of the total, were destroyed. It is not probable that the composition of the gas produced would be greatly influenced by the relatively small percentage of grease present, which was only 14 per cent of the volatile matter added. Nevertheless, the average $CO_2$ content of the gas was rather high. As a matter of fact, the $CO_2$ content was as high as the percentage $CO_2$ found in the gas when properly seeded fresh solids are digested. On the other hand, when the $CO_2$ content in the gas produced from digesting screenings having a low initial grease content is considered, the $CO_2$ content of the gas from activated sludge was comparatively low. The solids concentration of the activated sludge averaged only 2.40 per cent, or about half the fresh solids and less than one-third of the screenings concentration, with corresponding larger volumes of water for the solution of $CO_2$. The results seem to indicate that grease is not only a good source of gas, but that the combustibles or heat value of the gas obtained from grease is greater than from other types of volatile matter.

### 3. Aerobic Decomposition of Grease

Considerable unpublished work on aerobic decomposition of fresh solids at various temperatures has included some studies on the fate of grease. A few figures from data obtained at higher temperatures show the relation between total volatile matter destruction and grease decomposition. Fresh solids with 23.1 per cent ash and 29.2 per cent grease were aerated for 350 hours at different temperatures. The losses in total volatile matter and grease were as follows:

| Temperature °C. | Per Cent Volatile Matter Reduction | Per Cent Grease Reduction |
|---|---|---|
| 40 | 14.5 | 4.6 |
| 45 | 24.4 | 12.0 |
| 50 | 24.8 | 14.2 |
| 55 | 27.0 | 20.1 |
| 60 | 18.3 | 6.2 |

In general, the percentage total volatile matter reduction at the various temperatures recorded was greater than the percentage grease destroyed. Under anaerobic conditions the degree of destruction would be the reverse. Transformation and oxidation of grease in sewage treated by the activated sludge process have been discussed by Heukelekian (9). He concludes that oxidation and destruction of adsorbed grease proceed slowly in the beginning of aeration, but accelerate rapidly on continued aeration. In the presence of activated sludge, the percentage grease destroyed during 6 hours' aeration amounted to about 54 per cent and increased to 86 per cent on continued aeration for 24 hours. On repeated addition of sewage to the same activated sludge, the grease content of the sludge remains constant, unless excessive quantities of grease are added or more sewage is applied before the adsorbed grease is destroyed (overloading). It is evident, therefore, that aerobic organisms responsible for the decomposition of grease are present in sludge, but time is required to produce a sufficiently high concentration of enzymes, or "active" sludge must be added, to obtain rapid results. Incidentally, the rate of volatile matter and grease destruction under anaerobic conditions reaches a maximum at 55° C.

Studies on the grease content of the film present in bio-filters and standard filters show that from the top down to the lower levels of the filters considerable destruction of grease takes place. Humus tank sludge usually contains less than half the grease content of settled fresh solids. The destruction of grease during aeration, resulting in a low grease content of the sludge, is corroborating evidence for the relatively slow rate of grease decomposition when activated sludge is anaerobically digested.

### 4. Grease Additions

Solids deposited in different parts of a settling tank contain various quantities of grease (7). Seeded fresh solids were digested anaerobically for 47 days at 70° F. Some condensed results obtained showed the following:

| | A | B |
|---|---|---|
| Grease in Volatile Matter, per cent | 32.0 | 52.8 |
| Nitrogen in Volatile Matter, per cent | 3.20 | 3.84 |
| Volatile Matter Reduction, per cent | 46.4 | 47.4 |
| Gas per Gram Volatile Matter, cc. | 817 | 855 |

The variation in grease content obtained by settling did not cause a material difference in the percentage reduction of volatile matter. The solids with the higher grease content produced more gas than the solids with the lower percentage grease. It took a somewhat longer time, however, to reach the peak of gas production, indicating some retarding action during the first few days of digestion.

Another method of grease enrichment, by aerating fresh solids for a period of 15 minutes and mixing the grease skimmings with a portion of the same fresh solids, has been used to determine the effect of a change in composition of the solids on the rate of digestion and gas production (8). The grease and nitrogen content of the fresh solids and skimmings were as follows:

| | Fresh Solids | Skimmings | Residue |
|---|---|---|---|
| Total Solids, per cent | 6.35 | 11.7 | 4.9 |
| Ash, per cent | 23.0 | 18.9 | 24.4 |
| Grease in Dry Solids, per cent | 35.3 | 46.1 | 32.1 |
| Nitrogen in Dry Solids, per cent | 4.1 | 3.1 | 4.4 |

If the composition of solids has influence on the course of digestion and the quantity and character of gas produced, differences should be noticeable when fresh solids are used mixed with skimmings produced by mechanical means. Portions of the materials were seeded with ripe sludge to yield a ratio of 2:1 on a fresh-solids and ripe-sludge volatile matter basis. The materials were digested at 80° F.

Daily gas production showed that digestion was completed first in the ripe-sludge and residue mixture, followed by the ripe-sludge and fresh-solids mixture and considerably later in the skimmings and ripe-sludge mixtures. Condensed results obtained at the completion of digestion were as follows:

| | Fresh Solids | Skimmings | Residue |
|---|---|---|---|
| Volatile Matter Reduction, per cent | 40.4 | 47.0 | 44.5 |
| Gas per Gram Vol. Mat. Added, cc. | 625 | 1,030 | 580 |
| Gas per Gram Vol. Mat. Destroyed, cc. | 1,030 | 1,450 | 855 |
| $CO_2$, per cent | 19.7 | 17.4 | 14.2 |
| Combustibles, per cent | 66.5 | 68.6 | 77.1 |
| Gasification Complete, days | 24 | 40 | 20 |

Note: Gasification complete = more than 90 per cent possible gas.

Aeration of fresh solids for the short time of 15 minutes had no effect on digestion as indicated by separate experiments aerated for ½ hour, except that the aerated mixture appeared to digest at a slightly faster rate.

Volatile matter reduction and gas production were materially higher with the mixtures containing the greater grease content, but the time required was increased. Of particular interest is that the amounts of gas produced per gram volatile matter destroyed increased with the increase in grease content, indicating again that grease is a good source of gas. Further, the heat value of the gas was not decreased with the higher grease content. It would appear that the rate of grease decomposition and its products of hydrolysis determine in general the rate of digestion of the sludge.

## 5. Oil Additions

*Mineral Oil*

The addition of small quantities of mineral oils (gasoline, crank case oil) does not materially affect the digestion or gas production of seeded fresh solids. Larger quantities retard digestion (10). Gasoline added in quantities varying from 0.2 to 1 per cent by volume (on the basis of fresh solids) showed the following after 30 days' digestion:

| Per Cent Gasoline Added | Per Cent Volatile Matter Reduction | Gas per Gram Volatile Matter Added, cc. | Per Cent Grease Reduction |
|---|---|---|---|
| 0 | 34.4 | 461 | 54.2 |
| 0.19 | 30.8 | 453 | 49.8 |
| 0.94 | 8.2 | 153 | 19.2 |

Addition of crank case oil to fresh solids-ripe sludge mixtures digested for a period of 35 days at 80° F., showed that waste oil added in quantities up to 2.5 per cent by volume to the fresh solids had no detrimental effect on digestion as far as gasification is concerned. Some condensed results illustrate this point:

| Per Cent Oil Added | Per Cent Total Vol. Matter Reduction | Gas per Gram Vol. Matter Added, cc. | Per Cent Total Grease and Oil Reduction | Per Cent Grease Reduction |
|---|---|---|---|---|
| 0 | 33.9 | 693 | 61.5 | 61.5 |
| 1 | 29.2 | 727 | 29.2 | 57.0 |
| 2.5 | 17.6 | 710 | 15.0 | 40.5 |

Notwithstanding a reduced destruction of volatile matter in the fresh solids and smaller reduction of the grease present, the quantities of gas produced per gram volatile matter added (as fresh solids) were not less with the oil additions. Similarly, the composition of the gas was not changed, as indicated by analyses made after various periods of digestion:

| Per Cent Oil Added | Per Cent $CO_2$ | | | Per Cent Combustibles | | |
|---|---|---|---|---|---|---|
| | 10 Days | 17 Days | 26 Days | 10 Days | 17 Days | 26 Days |
| 0 | 18.6 | 15.1 | 18.2 | 74.5 | 82.2 | 80.2 |
| 1 | 17.6 | 15.2 | 13.0 | 77.6 | 78.7 | 82.6 |
| 2.5 | 18.6 | 15.7 | 13.5 | 73.9 | 81.8 | 85.1 |

The percentages of total grease and oil, and the non-saponifiable and saponifiable fats present at the beginning and end of the experiment would seem to indicate that little, if any, of the oil was destroyed. This is shown by the following results, calculated on a dry solids basis:

| Oil Added cc. per Liter | Beginning | | | End | | |
|---|---|---|---|---|---|---|
| | Per Cent Total | Per Cent Saponif. | Per Cent Non-Sap. | Per Cent Total | Per Cent Saponif. | Per Cent Non-Sap. |
| 0 | 24.8 | 20.6 | 4.0 | 14.4 | 9.7 | 5.6 |
| 10.6 | 32.3 | 21.1 | 11.7 | 26.8 | 10.1 | 15.6 |
| 25.6 | 49.2 | 20.1 | 29.1 | 44.7 | 9.4 | 35.3 |

The total amount of volatile matter and grease destroyed in grams per liter of wet sludge, and the amount of gas produced on the basis of total volatile matter and grease destruction only, were as follows:

| Per Cent Oil Added | Total V. M. Destr., Grams | Grease Destr., Grams | Gas per Gram V. M. Destr. | Gas per Gram Grease Destr. |
|---|---|---|---|---|
| 0 | 10.4 | 5.4 | 1,260 | 2,190 |
| 1 | 6.0 | 5.8 | 2,780 | 2,870 |
| 2.5 | 5.2 | 4.8 | 3,120 | 3,390 |

Although total gas production was not affected by the addition of oil, the total volatile matter destruction was materially less, but there seemed to be no interference with the decomposition of the grease present in the sludge, unless it should be assumed that appreciable amounts of gas were produced from the mineral oil. In effect, the amount of gas produced per gram of grease destroyed increased with increasing quantities of oil added.

The results in general seem to show that mineral oil present in sufficient quantities may materially change the relationship between volatile matter and grease decomposition without detriment to the quantity and composition of the gas produced, but with the production of increased quantities of residue.

*Vegetable Oil*

Fats and greases appear to produce considerable portions of the gases evolved during anaerobic digestion. Mineral oils may affect gas production and change the relationship between volatile matter and grease decomposition. Small quantities of vegetable oils aid in gas formation. In the course of studies pertaining to the effect of vegetable fats on digestion and the changes of fats during digestion, larger quantities of material were added. Fats in various stages of unsaturation were selected for the purpose. For illustration, some results obtained with linseed oil (unsaturated) and coconut oil (saturated) are presented. To fresh solids—ripe sludge mixtures (2:1 basis), one gram of oil was added for each 3.16 grams volatile matter in the mixtures. After 42 days' digestion the percentages volatile matter and grease destroyed were as follows:

| Mixture | Per Cent Volatile Matter Destroyed | Per Cent Grease Destroyed | Gas per Gram V. M. Added, cc. |
|---|---|---|---|
| F + R | 29.8 | 70.0 | 507 |
| F + R + Linseed Oil | 16.7 | 14.6 | 287 |
| F + R + Coconut Oil | 12.5 | 6.5 | 30 |

It is evident that large quantities of vegetable oil retard digestion. Examination of the detailed gas production curves and grease destruction figures shows that most of the fat was destroyed at the height of gasification. The saturated oil added in large quantities was more detrimental to digestion than the unsaturated oil. The quantities of volatile matter destroyed decreased with the addition of oil as well as did the actual total quantities of grease present and added. The relationship between volatile matter and grease destroyed changed, as may be seen from the following figures showing the grams volatile matter and grease destroyed per liter of sludge:

| Mixture | V. M. Destroyed | Grease Destroyed | Ratio V. M. : Grease |
|---|---|---|---|
| F + R | 9.42 | 4.41 | 2.13:1 |
| F + R + Linseed | 6.07 | 2.38 | 2.55:1 |
| F + R + Coconut | 5.20 | 1.06 | 4.90:1 |

*Animal Grease*

Additions of various types of wastes containing animal fats and greases to digesting mixtures have shown a tendency to decompose at a high rate and to a greater extent than the gross volatile substances found in sludge. As an example is cited the addition of different quantities of wool scouring wastes to properly seeded mixtures of fresh solids and ripe sludge. The solids, ash, and grease content of the materials used were:

| | Per Cent Solids | Per Cent Ash | Per Cent Grease |
|---|---|---|---|
| Fresh Solids | 6.5 | 21.9 | 19.3 |
| Ripe Sludge | 2.5 | 40.1 | 7.28 |
| Wool Waste | 2.86 | 35.3 | 40.8 |

The total grease in the wool waste contained 9.6 per cent soaps. Fresh solids were seeded with ripe sludge on a 2:1 volatile matter basis. To the mixtures were added 10 and 20 per cent of wool scouring waste on a wet basis. After 30 days' digestion the percentages volatile matter and grease destroyed and the gas produced amounted to:

| Mixture | V. M. Destroyed | Grease Destroyed | Gas per Gram V. M. Added | Gas per Gram V. M. Destroyed |
|---|---|---|---|---|
| R + F | 42.0 | 61.0 | 490 | 1,140 |
| R + F + 10% Waste | 41.3 | 59.2 | 504 | 1,215 |
| R + F + 20% Waste | 41.5 | 54.8 | 484 | 1,163 |

The percentage volatile matter destroyed remained constant with the addition of wool scouring waste. The percentage grease destroyed appeared to decrease. In effect, the actual quantities of grease destroyed were greater in the mixtures with the wool wastes added. Calculations show that 6.5 and 12.8 per cent more volatile matter were destroyed in the various mixtures with wool waste than in the control mixture. The total gas production was greater with the wool waste added, amounting to 10.3 and 13.0 per cent, respectively, but the quantities of gas produced per gram volatile matter destroyed were about the same. It appears, therefore, that the animal grease was destroyed to about the same degree as the total volatile matter and that approximately the same amounts of gas were produced from the animal grease as from the mixture without additional grease.

The composition of the gas produced was similar for all the mixtures, with somewhat higher percentages of combustibles in the gas produced from the mixtures with wool wastes:

| | Per Cent Combustibles | Per Cent $CO_2$ |
|---|---|---|
| Control | 72.7 | 25.0 |
| 10% Wool Waste | 76.2 | 21.4 |
| 20% Wool Waste | 76.3 | 21.2 |

The supposition that grease present in the sludge may be responsible for high percentages of carbon dioxide in the gas does not seem to be tenable.

## 6. Fuel Values of Sludge and Grease

An empirical relationship between fuel value and loss of ignition of sewage sludges has been presented by Fair and Moore (11). They found that the fuel value per unit weight of volatile matter decreases sharply with the percentage volatile matter content of the sludge. Since the volatile matter content of sewage solids decreases during digestion, they concluded "that it is the organic matter of the highest calorific power, probably grease, carbohydrates and proteins," which is responsible for the fuel value. Although it is known that sludges obtained from various sources may have the same volatile matter content and still differ in fuel value, no information appears to be available on the specific fuel value of sewage greases or the relation between grease content and total volatile matter and fuel value of sludges.

### *Fresh Solids*

A series of fresh solids samples were collected from a number of sewage treatment plants and the volatile matter, grease content, and fuel values determined. The results obtained (Table XV) show that,

Table XV.—*Percentage Volatile Matter and Grease and B.T.U. Values of Fresh Solids*

| Source | Vol. Matter | Grease | B.T.U. per Lb. Dry Solids | B.T.U. per Lb. Vol. Matter |
|---|---|---|---|---|
| R. | 60.1 | 22.0 | 7,600 | 12,600 |
| N. B. | 64.0 | 32.1 | 8,600 | 13,440 |
| H. P. | 73.9 | 20.6 | 7,990 | 10,800 |
| S. R. | 68.0 | 28.9 | 7,950 | 11,740 |
| H. | 75.0 | 20.6 | 8,500 | 11,230 |
| S. | 74.1 | 26.7 | 8,420 | 11,260 |
| B. B. | 74.0 | 26.8 | 8,510 | 11,500 |
| M. | 51.2 | 18.3 | 5,800 | 11,230 |
| B. | 70.1 | 19.4 | 7,100 | 10,120 |
| E. | 77.0 | 25.3 | 8,890 | 11,660 |
| C. | 62.2 | 22.6 | 6,510 | 10,500 |
| P. | 79.0 | 33.4 | 8,900 | 11,050 |
| Rah. | 61.9 | 23.9 | 8,100 | 13,040 |
| S. L. | 79.0 | 35.1 | 9,745 | 12,200 |
| V. H. | 70.0 | 27.4 | 8,200 | 11,720 |
| Ave. | 69.0 | 25.5 | 8,050 | 11,660 |

in general, the fuel value per pound dry solids increases with the increase in the percentage grease present. Calculation of the fuel value per pound of total volatile matter shows a relatively closer relationship. The variations in B.T.U.'s, however, do not seem to be correlated directly with the grease content. The fuel value of the volatile matter in fresh solids is not materially and uniformly affected by the percentage grease content; probably the differences in total grease content of the various samples are relatively small and are masked by the variations in total volatile matter content.

### *Digested Sludge*

Digestion reduces the total volatile matter and grease content, with the result that the fuel value is decreased. The average B.T.U. per pound dry digested solids of a number of samples obtained from various sources was found to be 4,610 as compared with an average for fresh solids of 8,050. Perusal of Table XVI shows that there is a fairly close

TABLE XVI.—*Percentage Volatile Matter and Grease and B.T.U. Values of Digested Sludges*

| Source | Per Cent Vol. Matter | Per Cent Grease | B.T.U. per Lb. Dry Solids | B.T.U. per Lb. Vol. Matter |
|---|---|---|---|---|
| S. A. | 55 | 7.1 | 5,410 | 9,820 |
| B. B. | 50 | 6.9 | 4,500 | 9,000 |
| N. B. | 47 | 7.5 | 4,600 | 9,680 |
| Mo. | 38 | 4.1 | 3,780 | 9,950 |
| Hill. | 51 | 9.6 | 4,950 | 9,900 |
| Rid. | 49 | 9.8 | 4,920 | 10,000 |
| Rah. | 36 | 7.6 | 3,070 | 8,520 |
| Mid. | 41 | — | 3,690 | 9,000 |
| H. P. | 50 | 6.3 | 5,090 | 10,250 |
| P. | 49 | 7.2 | 5,510 | 11,250 |
| M. | 37 | — | 3,800 | 10,260 |
| H. | 46 | 6.0 | 4,300 | 9,350 |
| J. | 24 | 4.1 | 2,360 | 9,870 |
| M. | 51 | — | 4,850 | 8,380 |
| Wood. | 38 | — | 3,350 | 8,810 |
| F. | 57 | 7.2 | 5,810 | 10,200 |
| C. | 50 | 6.4 | 5,520 | 11,020 |
| A. | 43 | 5.3 | 3,290 | 7,670 |
| Ma. | 51 | 8.6 | 4,950 | 9,700 |
| Ca. | 38 | 4.1 | 4,110 | 10,800 |
| W. | 60 | 14.1 | 6,260 | 10,420 |
| F. W. | 49 | 4.0 | 4,390 | 8,950 |
| L. | 61 | 6.8 | 7,080 | 11,600 |
| B. | 47 | 5.3 | 4,850 | 10,360 |
| M. A. | 54 | 10.2 | 4,400 | 8,150 |
| S. P. | 47 | 9.2 | 5,100 | 10,610 |
| Ave. | 47 | 7.3 | 4,610 | 9,830 |

relationship between the percentage volatile matter and the B.T.U. values of the dry solids. Calculation of the fuel value of the digested sludge on a volatile matter basis shows variations which do not seem to be related to the grease content of the sludges.

The digested sludges were in no instance the residue of the fresh solids analyzed and in a number of cases were not even obtained from the same plants. Nevertheless, some observations are pertinent and of general interest. From laboratory experiments it was shown that the grease reduction during digestion amounted to some 70 per cent. A comparison of the fresh solids and digested sludge results shows an average difference of 71.5 per cent in the grease content. A comparison of other results shows:

| | Fresh Solids | Digested Sludge | Per Cent Difference |
|---|---|---|---|
| Volatile Matter, per cent | 69 | 47 | 32.0 |
| Grease, per cent | 25.5 | 7.3 | 71.5 |
| B.T.U. per Lb. Dry Solids | 8,050 | 4,610 | 42.8 |
| B.T.U. per Lb. Volatile Matter | 11,660 | 9,830 | 15.7 |

It appears that there is no direct relation between the percentage destruction of grease or total volatile matter, but that digestion has destroyed particularly material with high fuel values. The residue remaining after digestion has a decidedly lower fuel value, even on the basis of volatile matter.

### *Filter Cake*

The substances destroyed by digestion are assumed to be the most putrescible. Addition of chemicals to the sludge should reduce the fuel value of the dry solids in approximately the same proportion as the chemical addition or increase in ash content. Some samples of filter

TABLE XVII.—*B.T.U. Values of Filter Cakes*

| Source | Per Cent Vol. Matter | B.T.U. per Lb. Dry Solids | B.T.U. per Lb. Vol. Solids |
|---|---|---|---|
| N. B. | 56 | 5,070 | 9,060 |
| Sa. | 67 | 7,000 | 10,450 |
| R. | 57 | 6,510 | 11,320 |
| S. R. | 52 | 6,360 | 12,230 |
| S. | 57 | 5,300 | 9,300 |
| So. | 63 | 6,590 | 10,460 |
| Ave. | — | 6,140 | 10,470 |

cake (Table XVII) show that to be the case. A comparison of the average results obtained on the different types of sludge is of interest:

| Material | Per Cent Volatile Matter | B.T.U. per Lb. Solids | B.T.U. per Lb. Volatile Matter |
|---|---|---|---|
| Fresh Solids | 69 | 8,050 | 11,660 |
| Filter Cake | 59 | 6,140 | 10,460 |
| Digested Sludge | 47 | 4,610 | 9,830 |

The fuel value of the dry solids appears to vary with the amount of ash, and there is also a reduction in the fuel value of the volatile matter remaining. In the case of digested sludge the greatly reduced grease content may be considered of principal importance. The reduction in fuel value of the volatile matter, due to chemical treatment and digestion, appears to be about 10 and 15 per cent, respectively, as compared with 25 and 40 per cent on a total dry solids basis.

### *Activated Sludge*

During aeration of sewage, some of the volatile substances are oxidized. It is logical, therefore, that the fuel value of activated sludge should be lower than the fuel value of fresh solids. Average results of a number of activated sludge samples with a volatile content of 78.3 per cent indicated B.T.U.'s of 8,010 per pound dry solids and 10,250 per pound volatile solids. It is of significance that the B.T.U. values of activated sludge having a considerably higher percentage of volatile matter were found to be virtually the same as those of fresh solids; but on a volatile matter basis the B.T.U. values of activated sludge appeared to be lower. If it is kept in mind that during aeration the grease is reduced greatly (the grease content of activated sludge is approximately the same as that of digested fresh solids), it is clear that the reduction in fuel value is mainly due to the destruction of grease.

### *Grease and Residue*

To determine the fuel value of grease in fresh solids and ripe sludge, several samples were extracted with petroleum ether (regular method, with 12 hours' extraction). The fuel values of the sludges, grease and residues, determined together with the volatile matter and total grease

Table XVIII.—*B.T.U. Values of Sludge Grease and Residues*

| Source | Per Cent Vol. Matter | Per Cent Grease | B.T.U. per Lb. Dry Solids | B.T.U. per Lb. Vol. Sol. | B.T.U. per Lb. Grease Extracted | B.T.U. per Lb. Residue |
|---|---|---|---|---|---|---|
| | | | Fresh Solids | | | |
| El. | 77.0 | 25.3 | 9,340 | 11,950 | 17,270 | 5,995 |
| S. L. | 78.9 | 35.1 | 9,745 | 12,230 | 17,340 | 5,690 |
| Pl. | 79.0 | 33.4 | 9,345 | 11,800 | 17,170 | 6,330 |
| V. H. | 70.2 | 27.4 | 8,615 | 12,260 | 17,795 | 5,825 |
| H. P. | 75.0 | 20.6 | 8,500 | 11,310 | 17,100 | 5,675 |
| Ave. | 76.0 | 28.4 | 9,110 | 11,960 | 17,135 | 5,905 |
| | | | Digested Sludge | | | |
| S. L. | 46.7 | 9.2 | 5,380 | 11,520 | 18,080 | 3,195 |
| Pl. | 49.0 | 7.2 | 5,510 | 11,240 | 17,205 | 3,090 |
| H. P. | 46.0 | 6.3 | 5,090 | 11,060 | 17,510 | 2,880 |
| R. | 36.0 | 7.6 | 5,135 | 14,230 | 17,975 | 2,905 |
| F. | 57.0 | 7.2 | 5,810 | 10,180 | 17,780 | 2,935 |
| Ave. | 46.9 | 7.5 | 5,385 | 11,645 | 17,710 | 3,000 |

content of the sludges, given in Table XVIII, show that the values for grease are materially higher than those of the total volatile matter. It will be noted that the fuel value of the grease extracted from digested sludge is about the same as that of grease extracted from fresh solids. This would indicate that the portion of grease which is destroyed anaerobically during digestion has similar B.T.U. values to those of the unsaponifiable or mineral oils present in the residue. Crude oils, furnace oils, and kerosene have B.T.U. values varying between 18,900 and 19,800. In general, the fuel value of grease present in sludge is not materially affected by digestion, but the quantities of grease are less; hence the B.T.U. value of sludge decreases with the decrease in percentage grease. A comparison of the average fuel values of volatile matter in the fresh solids and digested sludge with fuel values of the volatile matter in the residues (fresh solids 66.5 per cent, digested sludge 42.6 per cent) shows the following:

| | |
|---|---|
| Volatile Matter of Fresh Solids | 11,960 B.T.U. per lb. |
| Volatile Matter of Digested Sludge | 10,660 B.T.U. per lb. |
| Volatile Matter of Fresh Solids Residue | 8,880 B.T.U. per lb. |
| Volatile Matter of Digested Sludge Residue | 7,050 B.T.U. per lb. |

The fuel values of the volatile matter in the fresh solids and digested sludge differ about 10 per cent, but the difference between their residues is about 25 per cent. This leads to the conclusion that the fuel value of the volatile substances other than grease decreases during digestion, or in other words, the substances decomposed, grease as well as other carbonaceous matter, produce the largest quantities of potential heat. In this respect, it is of interest to note that the fuel value of the volatile matter in the digested sludge residue was 4595 B.T.U. per lb. lower than that of the volatile matter of the digested sludge containing 16.0 per cent grease. This compared with a decreased value of 3030 B.T.U. per lb. for the volatile matter of fresh solids residue as against the fresh solids volatile matter containing 36.9 per cent grease.

## General Discussion

The digestion of fresh solids shows that greases are rapidly reduced and destroyed with the formation of combustible gases. The percentage destruction of grease is greater than the percentage destruction of total volatile matter. In the process a definite relationship between carbon and organic nitrogen is maintained. Nitrogenous substances are decomposed producing increasing quantities of ammonia nitrogen. Carefully controlled experiments showed that with a destruction of 57 per cent total volatile matter about 50 per cent of the organic nitrogen was changed to ammonia.

Destruction of volatile matter during anaerobic digestion is usually lower than the percentage destruction of grease. This is illustrated by a comparison of reduction in volatile matter and grease obtained under laboratory and large-scale experimentation.

| | Per Cent Red. Grease | Per Cent Red. Volatile Matter |
|---|---|---|
| Laboratory | | |
| Fresh Solids | 70–80 | 54–57.2 |
| Seeded Solids | 70–80 | 51–52 |
| Small Tank Exp. | | |
| Fresh Solids | 70 | 62.2 |
| Screenings | 70.7 | 66.8 |
| Activated Sludge | 36.2 | 46.2 |
| Large Scale Exp. | | |
| Screenings | 70.3 | 60.2 |

The reverse is true, however, in digesting activated sludge. This is not caused by the relatively low initial grease content of the activated sludge, because when fresh solids are aerated for a period of two weeks, without the aid of activated sludge, the percentage volatile matter destruction is also greater than the percentage grease destroyed.

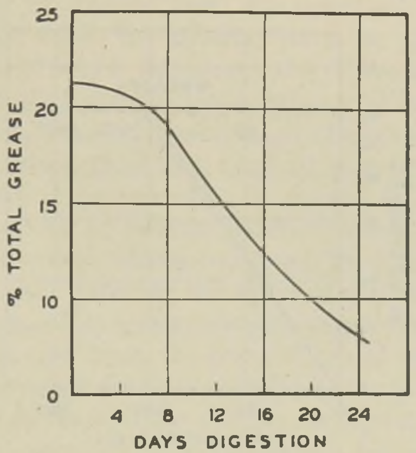


FIG. 2.—Rate of decomposition of grease on digestion of seeded mixtures.

In general, grease destruction during anaerobic digestion of seeded mixtures, proceeds at a high rate (Fig. 2), whereas the rate of grease destruction under aerobic conditions is relatively low. The rate of grease and volatile matter destruction, in unseeded materials under anaerobic conditions is not constant during the digestion process. This is indicated when the percentage destruction of grease and volatile matter remaining is plotted logarithmically (Fig. 3). The break in the curve occurs when the pH values begin to rise. The relative rate of grease destruction remained greater than the relative rate of volatile matter destruction through both the acid and alkaline digestion periods.

It would seem that the destruction of grease under aerobic conditions is dissimilar to the decomposition of grease under anaerobic conditions. Under anaerobic conditions the fats and greases are reduced to various fatty acids, which in turn are gasified in the form of combustible gases (principally methane) and carbon dioxide, whereas under aerobic conditions the end product is virtually all $CO_2$. The mode of grease decomposition under anaerobic conditions as compared with grease destruction under aerobic conditions will be discussed in another paper.

Excessive quantities of sewage grease added to fresh solids retard digestion, but the degree of volatile matter destruction is increased. Grease skimmings produced about 40 per cent more gas than the fresh solids and nearly double the quantity of gas produced by the residue from which a portion of the grease had been removed. The gas produced per unit quantity of volatile matter destroyed was of the same order and nearly of the same magnitude. It has been assumed that the $CO_2$ content of the gas is primarily determined by the grease content of the sludge. The higher the grease content, the lower the percentage combustibles. The detailed studies do not bear out this assumption. With larger quantities of grease the percentage of $CO_2$ was slightly higher, but with excessive quantities of grease no increase in the percentage $CO_2$ was noted. This would indicate that it is not the type of carbonaceous material, but the quantity, that determines the amount of combustible gas produced, unless the type has a retarding or inhibitory action.

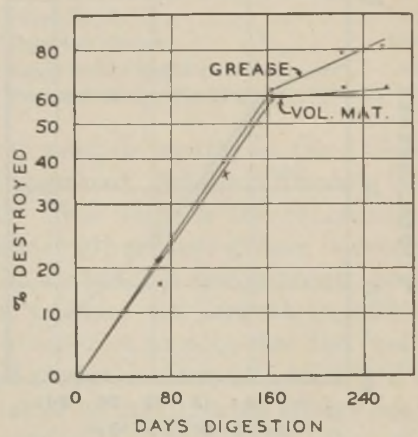


FIG. 3.—Percentage destruction of grease and volatile matter remaining.

Large quantities of grease added to digesting mixtures may result in a rapid accumulation of fatty acids (lower pH values). Acidic conditions in turn retard methane producing organisms, but do not affect $CO_2$ production. The gas produced under these conditions would contain a higher percentage $CO_2$.

Sewage grease contains animal and vegetable fats, soaps and mineral oils. The relation between quantities of animal and vegetable fats is not known, but the percentage of unsaponifiables of the total grease in fresh solids is usually within the range of 15–25 per cent. After digestion, the unsaponifiables in the grease increase to 65–70 per cent.

Soaps decompose at a rapid rate and are excellent sources of gas. There is no danger of producing undesirable acidic conditions, but nitrogen must be available from other sources for proper biological activities.

Limited amounts of mineral oils do not effect total volatile matter and sewage grease decomposition or gas production, but the nature of the oil appears to have influence. For instance, one per cent of gasoline retards digestion materially, whereas a similar percentage of crank case oil has little effect. Decomposition of mineral oil undoubtedly takes place, but at a slow rate, so that in modern heated digesters the reduction of mineral oil may amount to only 10–15 per cent. The bulk of the grease in sewage is vegetable and animal fat and soaps. Small quantities of vegetable oils aid digestion. It would be expected that unsaturated vegetable oils decompose more rapidly than saturated oils. Large quantities of vegetable oil retard digestion, particularly larger quantities of saturated vegetable oils. Gas production from grease appears to depend mainly on animal fats and soaps. The latter products decompose to a greater extent than other volatile substances. The quantities of gas produced per unit sludge mixture destroyed, containing increasing quantities of animal fats, are constant. The quantities of animal fats in sewage solids are greater than the amounts of vegetable oils and, therefore, in practice, the larger the percentage (animal) grease in fresh solids, the higher the gas production. With increasing quantities of animal grease, the composition of the gas remains the same, which is further evidence that this type of grease is of advantage as far as gas production is concerned and should be returned to the digesters if removed before or during sedimentation.

The fuel value of grease extracted from fresh solids or ripe sludge is the same, but the fuel value of the extracted grease is nearly double the fuel value of fresh solids and more than three times the fuel value of ripe sludge. During digestion, the percentage of carbon in the volatile matter doubles. The apparent percentage increase in carbon is due to the reduction of part of the volatile matter and not to addition of carbon. This means that the percentage of carbon in ripe sludge is about the same as the percentage carbon in the fresh solids. During digestion the grease, consisting of carbon, hydrogen, and oxygen, decreases about 70 per cent, whereas the percentage of nitrogen decreases about 50 per cent. If all the carbon present in the fresh solids had about equal fuel values, the fuel value of the volatile solids in the ripe sludge should be about equal to the fuel value of the volatile solids in the original fresh solids. Analyses and calculation show that the fuel value of the volatile matter in the fresh solids is about 10 to 15 per cent higher than that of the volatile matter in the ripe sludge. Hence, the grease has higher fuel values and a reduction in volatile matter caused by digestion is not proportional to the amount of grease destroyed. When the grease is destroyed by oxidation (activated sludge) the heat value of the remaining volatile matter is also lower and compares with digested sludge. Oxidation of organic matter and grease in trickling filters progresses downward in the filter, with the result that the heat values of humus tank sludges are lower than the heat values of fresh solids.

The results show that gas production is dependent upon the degree of volatile matter destruction and is affected by the amounts of grease decomposed. The resulting gas should have about the same heat value as the volatile matter destroyed. Analyses of two different batches of fresh solids digested in the laboratory, containing 14.1 and 24.1 per cent grease, showed that the gas produced has respectively 10,850 and 11,345 B.T.U. per pound volatile matter destroyed. Most of the organic carbon is converted to gases ($CH_4$, $CO_2$, CO, etc.). Part of the carbon dioxide is dissolved in the liquor and is discarded with the supernatant, while another part combines with the ammonia produced by the decomposition of organic nitrogen to form ammonium carbonates. The ammonium carbonate acts as a buffer and is also lost on discharge of the supernatant liquor. The heat values of the gases evolved can be expected to be of about the same magnitude, but somewhat lower than those found for the loss of fuel value in the sludges during digestion.

TABLE XIX.—*Ratios Between Volatile Solids and Grease and Composition of Gas*

| Days | V. M. : Grease Ratio | Composition of Gas | |
|---|---|---|---|
| | | $CO_2$ | Combustibles |
| 0 | 2.28:1 | — | — |
| 72 | 2.64:1 | 52.0 | 27.2 |
| 124 | 2.86:1 | 49.0 | 38.6 |
| 165 | 2.85:1 | 34.4 | 56.4 |
| 222 | 3.06:1 | 29.1 | 59.0 |
| 257 | 8.60:1 | 21.1 | 69.8 |

Not only the volume of gas produced, but the character of the gas, changes progressively with the increase in destruction of grease. This is clearly illustrated in Table XIX. While the ratio of volatile matter to grease increases, the percentage $CO_2$ in the gas decreases, but the percentage combustibles increases. Since most of the gas is produced during the time when the volatile matter grease ratio changes the most (rising pH values), the composition of the bulk of the gas is fairly constant. From the evidence presented, it follows that when fresh solids are properly seeded and digested under constant temperature conditions the heat value of the gas remains fairly constant, regardless of whether appreciable fluctuations in grease content occur. The higher the grease content, the greater the volume of gas produced. Fuel values of the residual sludge will vary with original quantities of grease and the degree of digestion.

## SUMMARY

Results obtained from laboratory and pilot plant experiments and full scale plant digestion of various types of sludges have been compared to determine the rate and extent of total volatile matter and grease decomposition. Different types of fats and oils were added to digesting mixtures to determine their effects. The fuel values of greases, sludges and residues have been compared to obtain information regarding the relation of grease content of sludges, gas production, and extent of

grease destruction. Differences between anaerobic and aerobic decomposition of grease were studied.

In general, the rate and the degree of grease decomposition are greater than the destruction of other volatile matters present in sludges. During digestion, a definite relationship between carbon and organic nitrogen is maintained. With the exception of activated sludge, grease reduction amounted to 70–80 per cent and volatile matter reduction to 50–60 per cent. Destruction of grease under anaerobic conditions appears dissimilar from decomposition under aerobic conditions. Limited amounts of grease, fats, and oils do not affect the rate or degree of digestion. The larger the quantities of animal fats present in sludge, the higher the gas production. The volume and character of gases produced change progressively with the increase in destruction of grease; the percentage $CO_2$ in the gas decreases in relation to destruction of grease. The fuel value of sludges varies with the amount of grease present. Only a fraction of the total grease in fresh sewage solids consists of mineral oils. The relation between fuel values of sludge, grease and other volatile matter is indicated by the following average figures, showing the B.T.U. values per pound of dry material:

| | Fresh Solids | Ripe Sludge |
|---|---|---|
| Total Solids | 9,110 | 5,385 |
| Volatile Matter | 11,960 | 11,645 |
| Extracted Grease | 17,135 | 17,710 |
| Residue After Extraction | 5,905 | 3,000 |
| Volatile Matter of Residue | 8,880 | 7,050 |

Under ordinary conditions prevailing during digestion, unsaponifiable fats (mineral oils) are decomposed to a very limited degree.

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# THE TOXICITY THRESHOLDS OF VARIOUS SUBSTANCES FOUND IN INDUSTRIAL WASTES AS DETERMINED BY THE USE OF *DAPHNIA MAGNA* *

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Several investigators have used the microcrustacean, *Daphnia magna,* as a test animal for the biological assay of many materials. Among them Naumann (1933a . . . g, 1934a . . . j) and Ellis (1937) have developed methods for the detection of toxic materials in trade wastes. The use of *Daphnia magna* as an experimental animal for such purposes is advantageous in many respects. Daphnids are small, reaching a maximum size of five mm., so that a great many can be reared in a small space. They have a relatively short life span, which reaches a maximum of about two months when they are reared at 25° C. Daphnids are easy to culture, requiring only water containing bacteria or their equivalent for food. They can be grown individually in small bottles or in mass culture in large aquaria. They mature early, giving birth to young within their first week of life. After the first brood, they give rise to new broods every two or three days throughout the remainder of their lives. An average of twenty or more young may be produced in each brood. Each female who lives to a ripe old age can bear four hundred or more offspring. Again, all the young from any one female are genetically like the mother if produced parthenogenetically, and reproduction can be limited to parthenogenesis if the proper conditions are maintained. Further, daphnids are representatives of a class of animals that serve as food for many fish, especially while the fish are young. Fishes do not remain long in waters where their food supply has been destroyed, even though the fishes may not be affected directly. For these reasons daphnids should prove satisfactory for testing waters for toxic materials.

In employing daphnids as experimental animals various factors must be taken into consideration as pointed out by Anderson and Jenkins (1942). One of these needs further elaboration. Breukelman (1932) found that *Daphnia magna* are most susceptible to mercuric chloride during their first instar (the period between birth and the first molt) and become less so as their age increases. Naumann (loc. cit.) pointed out that their reactions to many substances varied with the age of the animals. However, Naumann apparently made no attempt to secure age uniformity in his experimental animals. Obviously, in order to secure closely reproducible results animals of the same age should be used. Ellis (1937) employed animals four days old (sometimes older).

* A preliminary paper was presented at the meeting of the American Chemical Society in Detroit, 1943.

This requires special culturing of the experimental animals over a four day period. By utilizing animals eight hours old or less the special culturing is avoided, age constancy within narrow limits is secured, and since daphnids are most sensitive to toxic substances during their first instar the threshold concentrations for mortality can be established with greater certainty.

Various end points have been used in determining killing rates. Berger (1929) found that locomotion ceased long before the heart beat stopped in *Daphnia magna* which were subjected to salt solutions. Breukelman and Sarracino (1932) reported that swimming movements stop shortly after the gill movements cease, but that the heart beat and gut movements continue much longer than do the swimming movements and the gill movements in *Daphnia pulex* when they are exposed to dilute solutions of mercuric chloride. Neither Naumann (loc. cit.) nor Ellis (1937) states specifically what criteria they used in determining mortality. Cessation of any one vital activity should be a satisfactory end point as long as all results are based on the same one. Of these end points the cessation of swimming activities, which the writer proposes to call immobilization, can readily be observed with least disturbance to the animals. Immobilization by dilute solutions takes about half the time required for stoppage of the heart beat and of the gut movements; hence significantly less time is necessary for the performance of individual experiments where immobility is the end point. Immobility can be determined without optical aids and without manipulating the animals individually or collectively, other than that of rotating the bottles containing them to make certain that all animals are observed.

## Materials and Methods

A stock of individually reared daphnids, *Daphnia magna* Straus, of a single clone was maintained in a modified manure-soil medium (Banta, 1921). This was made up in batches of five to ten liters in the following proportions: 5 g. air dried horse manure, 25 g. dried sandy muck, and 1 liter tap water. After it had stood for two days the resulting infusion was strained through silk bolting cloth. The filtrate was allowed to stand until the turbidity disappeared, after which it was used. About 100 ml. of the filtrate was poured into each of a series of four-ounce, wide-mouth bottles and one female daphnid was placed in each one. After the first week 2 mg. of dry yeast * was added every other day. This was done by suspending the yeast in water (250 mg. yeast in 125 ml. water) and adding the equivalent amount of the suspension (1 ml.) to each bottle. Water was also added about once a week to replace that lost by evaporation and in the removal of young. Animals reared in this way averaged twenty or more young for each brood. Two mg. yeast for 100 ml. medium every other day appeared to be the optimum quantity. Larger or smaller amounts brought about a reduction in the number of young produced. All the young were removed at least once a day to prevent depletion of the food supply for the mothers.

* "Maca" manufactured by Northwestern Yeast Company, Chicago, Illinois.

In order to test water for toxic materials and to estimate the degree of dilution necessary to render it innocuous, racks with ten four-ounce, wide-mouth bottles were set up. To the first bottle was added 100 ml. of the water to be tested. To the next eight bottles, 100 ml. of successive dilutions of the test water were added. One hundred ml. of the diluent was added to the last bottle to serve as a control. The dilutions were made up in a geometric progression, usually in powers of $\sqrt{2}$, 2, 3, or 5 for each step, *i.e.* the concentration of the original material in any one dilution was $1/\sqrt{2}$, ½, ⅓, or ⅕ that of the bottle immediately preceding, so that dilution ranges of 16, 256, 6,561, and 390,625 times, respectively, were obtained in any one rack. When the results were plotted on a logarithmic basis the concentration values fell at uniform intervals on the graph.

In testing substances used in the experiments, the results of which are given later, centrifuged Lake Erie water was used as the diluent. Lake water was employed so that the various dilutions would represent as nearly as possible the actual conditions as they might be encountered in the lake. The water in western Lake Erie varies considerably from time to time with respect to suspended matter. In order to free the water of most of this suspended material it was run through a Sharples super centrifuge operated at 22,000 r.p.m. with a discharge of twenty-four liters per hour. In this way a more constant water was secured.

Both the stock and the experimental animals were kept at a constant temperature of 25° C. This temperature was used since it is well below the lethal limit for *Daphnia magna* (Brown, 1929), and is fairly easy to maintain throughout most of the year with the simplest of constant temperature equipment.

After the solutions were prepared, ten young daphnids, which were not over eight hours old from the time of release from the mother, were placed in each test bottle. These were first collected in groups of a hundred and washed three times in the diluent (centrifuged lake water) by simply transferring them from one bottle of the diluent to another, allowing about five minutes in each before the final transfer to the test bottles. The animals were observed at definite times, 15 min., 30 min., 1 hr., 2 hr., 8 hr., 16 hr., and 32 hr., after their transfer to the test bottles, the intervals between observations increasing in geometric progression, and note taken of the number of immobilized animals, lying on the bottom or held in the surface film. Immobility was determined directly by placing the rack of bottles containing the animals in front of a lighted translucent screen.

Upon completion of a particular experiment, if the animals in some but not all the dilutions were immobilized, the geometric mean immobilization time for each concentration was calculated. These values were plotted against the concentrations on double logarithmic paper. In addition, the geometric mean immobilization concentration for each observation time was also determined. These values were plotted against time on the same grid. In effect this method is essentially the same as the plotting of both 50 per cent immobilization time against concentration and 50 per cent immobilization concentration against time. Smooth curves were drawn through the plotted points. The curves for different substances vary considerably, as is illustrated in Fig. 1.

The threshold concentration may be defined as the highest concentration which would just fail to immobilize the animals under prolonged (theoretically infinite) exposure (Bliss, 1940). Obviously, practical considerations do not permit infinite exposure so that the true threshold concentrations may not be realized in all instances. In any event the true threshold concentrations would not exceed the values to be presented.

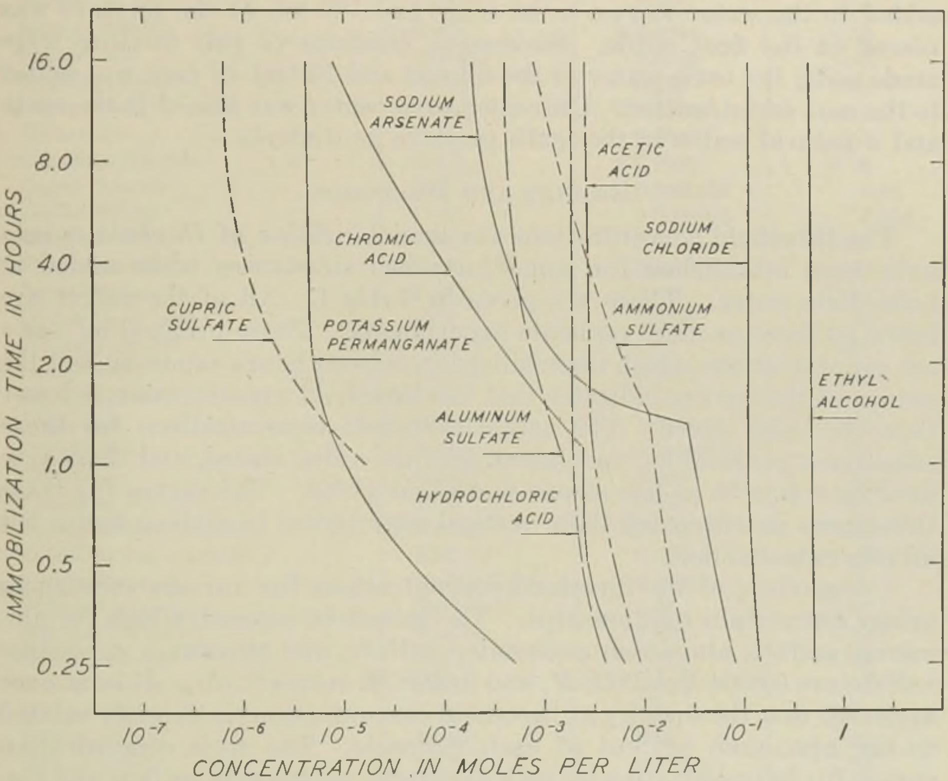


Fig. 1.—Relation of immobilization time to concentration for *Daphnia magna.*

The threshold concentration was estimated graphically as the concentration at which the immobilization curve parallels the ordinate. In Fig. 1 the value is 0.4 *M* for ethyl alcohol, 0.105 *M* for sodium chloride, 0.0025 *M* for acetic acid, 0.0017 *M* for hydrochloric acid, 0.0004 *M* for aluminum sulphate, 0.000,19 *M* for sodium arsenate, 0.000,004 *M* for potassium permanganate, and 0.000,000,6 *M* for cupric sulfate. The threshold concentration can also be determined by equation when it is apparent that the threshold concentration falls below the range of concentrations tested and/or the curve has not reached its vertical asymptote within the time limits of the experiments, as in the cases of chromic acid and ammonium sulfate in Fig. 1. Determined under these latter conditions, the threshold concentration is an extrapolated value. Even though this procedure may be fully justified the author prefers actual experimental determination whenever possible. Ordinarily the threshold concentration was approximated by preliminary experiments with dilutions in large steps. For the final series of experiments the concentration range was adjusted in small steps centered about the approximate threshold concentration.

In order to test the effectiveness of detoxifying agents, such as activated carbon, the procedure outlined above was used except in making up the test solutions. A given quantity of the agent to be tested was added to the water known to be toxic and 100 ml. of the mixture was placed in the first bottle. Successive dilutions of this mixture were made using the toxic water as the diluent and 100 ml. of each was added to the next seven bottles. Untreated toxic water was placed in the ninth and a natural water in the tenth to serve as controls.

## Results and Discussion

The threshold concentrations for immobilization of *Daphnia magna* have been established for some forty-two substances when added to Lake Erie water. These are given in Table I. All of the values are based on three or more replicate experiments. Those prefixed by $<$ or $\ll$ are concentrations which immobilized in sixteen hours exposure, but the nature of the curves indicates that the threshold concentration is lower than the value given. The actual threshold concentrations for those substances prefixed by $<$ are about half the value stated, and those prefixed by $\ll$ may be as low as one-tenth that given. The curves for these substances do not reach their vertical asymptotes in sixteen hours but all others tested do.

Comparison of the threshold concentrations for various substances brings out certain relationships. The threshold concentrations for aluminum sulfate, aluminum ammonium sulfate, and aluminum potassium sulfate are 0.0004 $M$, 0.0008 $M$, and 0.0008 $M$, respectively. It is at once apparent that the toxicity at threshold concentrations is directly related to the aluminum content of each molecule. The time concentration curves for immobilization by both aluminum ammonium sulfate and aluminum potassium sulfate resemble that for aluminum sulfate shown in Fig. 1. In position they fall to the right of the one for aluminum sulfate.

The threshold concentrations of hydrochloric, nitric, and sulfuric acids are 0.0017 $M$, 0.0017 $M$, and 0.0009 $M$, respectively. It is evident that their threshold concentrations of toxicity vary directly with their hydrogen equivalents, as might well be expected if their toxicity is due to acidity alone. The time-concentration curve for hydrochloric acid as shown in Fig. 1 is characteristic of all three of the above acids. That for nitric acid is identical with the one for hydrochloric acid both in shape and position. The curve for sulfuric acid is the same in shape as that for hydrochloric acid but falls to the left of that for the latter acid.

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

| Substance | Formula | Molarity* | P.P.M.* |
|---|---|---|---|
| Acetic acid | $C_2H_4O_2$ | 0.0025 | 150 |
| Acetone | $C_3H_6O$ | 0.16 | 9280 |
| Aluminum sulfate | $Al_2(SO_4)_3$ | 0.0004 | 136 |
| Aluminum ammonium sulfate | $AlNH_4(SO_4)_2$ | 0.0008 | 190 |
| Aluminum potassium sulfate | $AlK(SO_4)_2$ | 0.0008 | 206 |
| Ammonium chloride | $NH_4Cl$ | $<0.0025$ | $<134$ |
| Ammonium hydroxide | $NH_4OH$ | $<0.00025$ | $<8.75$ |
| Ammonium sulfate | $(NH_4)_2SO_4$ | $<0.0008$ | $<106$ |
| Aniline | $C_6H_7N$ | 0.003 | 279 |
| Barium chloride | $BaCl_2$ | $<0.0004$ | $<83$ |
| Benzoic acid | $C_7H_6O_2$ | 0.0015 | 146 |
| Calcium chloride | $CaCl_2$ | 0.012 | 1332 |
| Chromic acid | $CrO_3$ | $\ll 0.000006$ | $\ll 0.6$ |
| Citric acid | $C_6H_8O_7$ | 0.0008 | 153 |
| Cobaltous chloride | $CoCl_2$ | $\ll 0.0002$ | $\ll 26$ |
| Cupric chloride | $CuSO_4$ | 0.0000006 | 0.08 |
| Cupric sulfate | $CuCl_2$ | 0.0000006 | 0.096 |
| Ethyl alcohol | $C_2H_6O$ | 0.4 | 18400 |
| Ferric chloride | $FeCl_3$ | 0.0008 | 130 |
| Ferrous sulfate | $FeSO_4$ | $<0.001$ | $<152$ |
| Hydrochloric acid | $HCl$ | 0.0017 | 62 |
| Iso-amyl alcohol | $C_5H_{12}O$ | 0.01 | 881 |
| Lactic acid | $C_3H_6O_3$ | 0.0027 | 243 |
| Methyl alcohol | $CH_4O$ | 1.0 | 32000 |
| Nitric acid | $HNO_3$ | 0.0017 | 107 |
| Oxalic acid | $C_2H_2O_4$ | 0.00105 | 95 |
| Phenol | $C_6H_6O$ | 0.001 | 94 |
| Potassium chloride | $KCl$ | 0.005 | 373 |
| Potassium dichromate | $K_2Cr_2O_7$ | $\ll 0.000002$ | $\ll 0.6$ |
| Potassium permangante | $KMnO_4$ | 0.000004 | 0.63 |
| Sodium arsenate | $NaH_2AsO_4$ | 0.00019 | 31 |
| Sodium bicarbonate | $NaHCO_3$ | 0.05 | 4200 |
| Sodium carbonate | $Na_2CO_3$ | 0.004 | 424 |
| Sodium chloride | $NaCl$ | 0.105 | 6143 |
| Sodium hydroxide | $NaOH$ | 0.006 | 240 |
| Sodium nitrate | $NaNO_3$ | 0.1 | 8500 |
| Sodium sulfate | $Na_2SO_4$ | 0.05 | 7105 |
| Sodium sulfite | $Na_2SO_3$ | 0.03 | 3784 |
| Sulfuric acid | $H_2SO_4$ | 0.0009 | 88 |
| Tannic acid | $C_{14}H_{10}O_9$ | $\ll 0.00008$ | $\ll 26$ |
| Tartaric acid | $C_4H_6O_6$ | 0.0009 | 135 |
| Zinc sulfate | $ZnSO_4$ | $<0.0003$ | $<48$ |

* On the basis of the formula given.

Oxalic and tartaric acids have nearly the same threshold concentrations as the dibasic sulfuric acid. Acetic, lactic, and citric acids have somewhat higher threshold concentrations than would be expected on the basis of the other acids discussed above. These latter acids seem more likely to be metabolized by the organisms, and if part is absorbed and used by them, less would be available as acid in the medium. This is indicated by the higher pH values for solutions of these three acids compared to solutions of equivalent concentrations of the other acids at the termination of the experiments. Consequently the actual threshold concentrations for these three acids may be lower than those given in the table. The time-concentration curves for citric, lactic, oxalic, and tartaric acids are similar in shape to that for acetic acids shown in Fig. 1. Their positions vary with their threshold concentrations. The curve for benzoic acid differs from that of the other acids but resembles that for ethyl alcohol (Fig. 1). This fact together with the somewhat lower threshold value than that secured for the monobasic mineral acids indicates that the toxicity of benzoic acid may be due to some other factor than acidity.

Chromic and tannic acids have much lower threshold concentrations than the other acids tested. The time-concentration curve for chromic acid is given in Fig. 1. The curve for tannic acid is similar in character to that for chromic acid. The toxicities of these two acids at lower concentrations are due to other factors than acidity.

During July and August, 1943, when these experiments were run, Lake Erie water at Put-in-Bay, Ohio, had a total alkalinity (phenolphthalein plus methyl orange) varying from 97 to 100 p.p.m. as calcium carbonate (determined by Dr. Owen B. Weeks). In terms of molarity this is 0.00097 to 0.001 *M*. This does not mean, however, that one part Lake Erie water will neutralize an equal quantity of 0.00194 to 0.002 *N* acid. The methyl orange end point used in determining alkalinity is approximately pH 4.4. Only about one-fourth as much acid is required to reduce the pH value of the water to 7 as is needed to reduce the pH to 4.4. The pH of the water to which 0.0017 mole monobasic acid is added is approximately 6. With the exception of benzoic, chromic, and tannic acids, all the acids tested were non-toxic as long as they were added in quantities that did not reduce the pH of the water to less than 6.

Cupric chloride and cupric sulfate have the same threshold concentrations when these are considered in terms of molarity. The time-concentration curve for cupric sulfate is shown in Fig. 1. The curve for cupric chloride is identical with that for cupric sulfate in both shape and position.

The threshold concentrations of the three alcohols, methyl, ethyl, and iso-amyl, follow Traube's rule in that the concentration, in terms of molarity, required to narcotize decreases approximately in negative powers of three as the number of carbon atoms in the chain increases. The time-concentration curves for all three alcohols are similar in shape but their positions vary with their threshold concentrations.

The time concentration curves for acetone, aniline, and phenol are similar in shape to those for the alcohols. Their positions vary with their threshold concentrations. Immobilization by these substances, as well as by the alcohols tested, is reversible. Occasionally one or two daphnids which were immobilized after fifteen minutes exposure at threshold concentrations were found swimming actively when later observations were made.

The time-concentration curve for sodium chloride is given in Fig. 1. The curve for sodium nitrate is identical in both shape and position to that for sodium chloride. The curves for sodium bicarbonate, sodium sulfate, and sodium sulfite are the same in shape as that for sodium chloride but differ slightly in position according to their threshold concentrations.

The time-concentration curve for ammonium sulfate is shown in Fig. 1. The curves for ammonium chloride and ammonium hydroxide are roughly similar in shape to that for ammonium sulfate but differ in position.

Many other comparisons might be made. For instance, the effectiveness of various substances that may be used for eliminating microcrustacea from water supplies may be evaluated. These, however, are left to the reader who may find the results of the present investigations applicable to his own problems.

Seven of the substances in Table I, namely ammonium chloride, calcium chloride, cupric sulfate, potassium chloride, sodium carbonate, sodium chloride, and zinc sulfate, were tested by Naumann (1934a, d, h). He presented data on the survival of daphnids in solutions of different concentrations of these substances. From his data one can determine roughly the limits within which the threshold concentrations would fall. In all instances the threshold concentrations for these substances as given in Table I fall within these limits.

How do the threshold concentrations for *daphnia* compare with those for fish? The answer cannot be given in full. Ellis (1937) has summarized most of the literature on the toxicity of over a hundred substances when added to natural, tap, and distilled waters. For the most part the test animals in Ellis's listing have been fish, but other animals, including daphnids, have been employed. The figures which he presents are not always threshold concentrations, but for purposes of discussion they may be so regarded. In many instances the lowest toxic concentrations which he gives are in fair agreement with those presented here for daphnids. In others marked discrepancies are to be found. For instance, Ellis states that 1 p.p.m. sodium chloride in distilled water killed daphnids in one hour. In the present experiments the threshold concentration was found to be 6143 p.p.m. in Lake Erie water. Obviously the difference is due to the diluent. The writer has found that daphnids live three times as long in 200 p.p.m. sodium chloride in double-distilled water as they do in double-distilled water alone.

Many distilled waters appear to be toxic to daphnids. Naumann (1933g) tested distilled waters from many different sources and found that most of them were toxic. Strikingly enough, he found that water distilled from ordinary glass was non-toxic but that from hard glass was toxic. In the author's experience single-distilled waters from each of several different metal stills immobilized first instar young and older daphnids within two hours. He also found that older daphnids survived a week or longer in double-distilled water, the final distillation from Pyrex glass, but that first instar young were immobilized within three hours. Naumann (1933g, 1934e, f) may be consulted for a more complete discussion of distilled waters and their toxicities and for methods of rendering them non-toxic.

From the standpoint of pollution studies experiments in which distilled waters are used seem to be of questionable value since they would not represent actual conditions. If the experiments in which distilled waters were employed as the diluent are eliminated from consideration much better agreement is to be had between the results listed by Ellis (1937) and those of the present work. Even so, outstanding discrepancies are to be found for about a third of the substances given in Table I. For these substances the threshold values presented here are usually lower but some of them are much higher than those presented by Ellis.

The ultimate answer to the question with respect to the threshold concentrations for daphnids in comparison with those for fish must be settled by experiments wherein both types are subjected to the same substances when added to identical diluents. Both for practical and theoretical purposes complete analyses of the diluent waters may be necessary before satisfactory explanations can be reached. Spectrographic analyses of Lake Erie water are now being made at the Franz Theodore Stone Laboratory in connection with limnological investigations. When these become available more complete relationships between the toxicity of various substances may be worked out.

## Summary

The advantages of using the microcrustacean, *Daphnia magna,* as the test animal for the detection of toxic materials in trade wastes are pointed out. Various factors that must be taken into consideration when daphnids are employed as experimental animals are enumerated and discussed.

A method for using daphnids as test animals is described in detail.

The threshold concentrations for immobilization of daphnids by forty-two substances when added to Lake Erie water are given. These are compared and discussed in relation to the results of other investigators for fishes and other animals.

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# Sewage Works Planning

## POSTWAR PLANS FOR SEWERAGE AND SEWAGE DISPOSAL PROJECTS IN NEW YORK STATE *

By Earl Devendorf

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This paper constitutes a discussion of the relationship of plans for sewage treatment and stream pollution abatement to postwar planning in New York State. The subject is of particular importance and interest to all municipal and sewage works officials. To afford a proper appreciation of this relationship, a brief outline is presented of the plans and objectives of the New York State program for meeting the problems of the postwar period.

New York State, while making every possible contribution to aid the national effort in bringing to a successful conclusion the present war, has also given thought to the problems and events which will follow the conclusion of the war. Various measures have been taken toward the prevention of unemployment and for the prompt remedying of any unemployment that may arise. To this end the State has adopted a policy of economy in state expenditures, deferring as much capital expenditure as possible to the postwar period; it is accumulating funds in the state treasury to avoid increased taxes at the close of the war and to make available funds for postwar construction; also, state aid has been authorized to assist municipalities in making plans now for needed projects to be constructed at the close of the war.

In order that a better understanding of the procedures and policies of the New York State Postwar Public Works Planning Commission may be had, it seems desirable to describe briefly the makeup of the Commission and the laws under which it operates. The Commission is comprised of seven members; the chairman being the Director of the State Budget and the other members being heads of other state departments and members of the legislature. The office staff consists of an executive secretary, assistant chief engineer, field consultants, economist and the usual assistants, clerks and stenographers.

### Legislation

Legislation was passed in 1942 carrying an appropriation of one-half million dollars to provide for financing the activities of the Commission. The 1943 Legislature increased the amount of funds available for postwar planning by an additional three million dollars and the 1944 Legislature increased this by another four million.

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*State Legislation*

Chapter 660 of the Laws of 1942 as amended in 1943 created the State Postwar Public Works Planning Commission. It assigned to this body, among other duties, the responsibility of co-ordinating plans for postwar construction by the various state agencies and of allotting funds for the preparation of plans for certain state projects and for assisting municipalities of the State in the preparation of plans for postwar projects. It authorized the Commission to assist municipalities in planning postwar projects to the extent of defraying fifty per cent of the cost of preparing plans, specifications and estimates of approved projects in an amount not exceeding two per cent of the estimated cost of the project upon certification of the fiscal officer of the municipality that a like sum has been made available by the municipality for such purposes. The Commission is not authorized to make any grants for construction.

*Local Legislation*

Chapter 696 of the Laws of 1943 amends the general municipal law and the local finance law in relation to financing of plans for postwar projects. This act authorizes each municipal corporation, school district, or district corporation to issue notes to be denominated "Capital Notes" for expenditures during the fiscal year, for its share in the cost of the preparation of plans for postwar projects, to the extent that such expenditures are not provided for in the annual budget. There is, therefore, no reason for delay in the submission of applications for state grants on the part of the municipalities of the State for the preparation of plans and specifications for worthwhile and needed postwar projects.

## Policy

In considering applications for municipal postwar public works construction projects, the State Commission has declared its intention and desire to co-operate as fully as possible with all our New York State municipalities and districts to the end that the purpose of the act will be carried out, namely, that detailed plans and specifications will be prepared now and be available for use in the postwar period for needed public works projects. The Commission is not authorized to give grants or aid in connection with engineering work already done.

The Commission has adopted the policy of only making grants to municipalities for the preparation of plans for projects, the cost of which does not exceed their borrowing capacity as determined by the State Comptroller. The State Superintendent of Public Works requires that the preliminary plans and estimates of cost be in sufficient detail to permit a check of the estimated cost of the items of work included in the project. The estimated cost of the project as checked by the State Superintendent of Public Works is based on the average 1940 construction costs.

Among the problems that have arisen has been the differences in estimated cost of projects as originally estimated and the costs submitted with the preliminary plans as determined after an engineering study and analysis of the project. The amount of the state grant is determined by the Superintendent of Public Works after an analysis of the preliminary plans and engineering report on projects which have been approved by the Commission; whereas the estimate of cost submitted with the application may more properly be termed a guess estimate as it is arrived at without the benefit of any engineering study or analysis. The Commission has adopted the policy when making the final grant for detailed plans of adding or subtracting, as the case may be, any deficiency or excess in the preliminary grant resulting from differences in these estimates of cost.

### Procedure

A Postwar Public Works Municipal Handbook has been prepared by the New York State Postwar Public Works Planning Commission in conjunction with the New York State Department of Public Works. This gives an outline of procedure to be followed by municipalities and districts when applying for state grants for the preparation of plans of municipal postwar projects. The essential features of the procedure may be briefly summarized as follows:

A limit of two per cent of the estimated construction cost is the maximum amount the Commission is authorized to contribute to municipalities for the cost of design. This sum is to be matched by a similar amount by the municipalities. In addition, the Commission upon recommendation of the State Superintendent of Public Works may, at its discretion, allocate such additional sum or sums as it may deem necessary to pay the cost of test borings or other extraordinary expenditures which it may deem desirable.

In making application to the Commission, a brief description of the proposed project is required with its estimated construction cost and a certified resolution indicating that the locality will provide its share of the cost of the plans. Upon receipt of applications they are reviewed by the Commission and, if deemed desirable, they are referred to the State Superintendent of Public Works who analyzes the reports and submits his recommendation to the Commission. If a favorable recommendation is made by the Superintendent of Public Works he will indicate the allocation that should be made for the State's share of cost for preparing the preliminary plans and estimates. This cannot exceed one-half of one per cent of the estimated construction cost. The Commission then acts upon those projects which have been recommended favorably by the State Superintendent of Public Works. In other words, without the approval of the State Superintendent of Public Works, favorable action by the Commission is precluded.

On approval of the preliminary plans and estimate the Commission will determine the amount of the grant for the final plans and specifications. This amount together with that allowed for preliminary plans cannot exceed two per cent of the revised estimated construction cost.

Payments of grants for both preliminary and final plans in amounts over $1,500 are made in three installments, the first when plans are 50 per cent completed, the second when they are 100 per cent completed, and the balance on their approval by the Commission. In the case of grants less than $1,500 only one payment is made, on approval of the plans by the Commission. One blueprint copy of the preliminary and final plans, specifications, and cost estimate will be filed in the office of the State Superintendent of Public Works.

The Division of Sanitation of the State Department of Health is working in close co-operation with the Postwar Public Works Planning Commission and the State Superintendent of Public Works in the review of applications for postwar sanitary projects submitted to the Commission for consideration.

Recently a review and study of needed sanitary projects in connection with postwar planning has been made by our district engineers and many conferences have been held with local municipal authorities, at which time the submission of applications for financial aid to the State Postwar Public Works Planning Commission for the preparation of plans has been stressed. This has resulted in the preparation of an up-to-date classification of needed sanitary projects, arranged according to their necessity, urgency, and desirability. This information has been furnished to the Postwar Public Works Planning Commission and the State Department of Public Works.

In connection with a review of applications referred by the Commission to the Superintendent of Public Works, the Department of Health has worked out a procedure to assist in this review. This involves a joint field inspection and survey by the district engineer of the State Department of Public Works and the district engineer of the State Department of Health, each of whom separately reports the results of his findings to the respective departments. Based on these reports, recommendations are made to the Commission regarding the necessity, urgency, and desirability of the projects under consideration.

## Sewerage and Sewage Treatment Plant Projects

The writer in 1936 presented before the N. Y. S. S. W. A. an account of the policies and progress in sewage treatment in New York State at that time. Time does not permit a review of the early efforts of the State Department of Health toward control of stream pollution in New York State. This was outlined at length in the previous paper which was published in *This Journal,* **8**, 272 (March, 1936), to which reference may be made if desired.

The importance of sewage treatment becomes apparent when it is considered that the water supplies of about three-quarters of the population of the State are derived from surface sources, some of which only a few years ago were, at times, polluted beyond the ability of safe treatment as based on recognized standards of safe raw water supplies.

Although the abatement of stream pollution has been one of the main functions of the State Department of Health since the passage of the so-called antipollution Law of 1903, the efforts to clean up stream pollution in New York State were greatly intensified beginning in 1930. As a result of this intensified program and the opportunity of obtaining federal aid, more persons are served by sewage treatment plants constructed during the ten-year period from 1930 to 1940 than were served by plants constructed during the previous thirty years. The number of sewage treatment plants increased from 110 in 1927 to 282 in 1940. The great accomplishments in increased sewage treatment already made, will permit no let down in our efforts to complete the problem of elimination of stream pollution, in justice to those communities which have already provided such treatment if for no other reason.

Accordingly, one of the most important types of postwar projects that has been recommended by the State Department of Health is that of sewage treatment plants. This recommendation has been received

TABLE I.—*Postwar Planning in Sewage Disposal and Sanitary Service in New York State—May 31, 1944*

| Community | Project | Est. Const. Cost | Status |
|---|---|---|---|
| Colonie (Tn) | Sewage treatment plant addition | $ 60,000 | A |
| Andover (Vg) | Sewerage system | 200,000 | P |
| Binghamton (Cy) | Sewage disposal plant and intercepting sewer | 2,000,000 | P |
| Dickinson (Tn) | Sanitary sewer and disposal plant | 72,000 | A |
| Fredonia (Vg) | Sanitary sewers—trunk lines | 98,907.65 | A |
| Jamestown (Cy) | Sanitary sewers and improv. of disposal plant | 1,000,000 | A |
| Mayville (Vg) | Sanitary sewer system and plant | 200,000 | P |
| Sherburne (Vg) | New sanitary sewer system and disposal plant | 101,137.50 | A |
| Greenport (Tn) | Sewage treatment plant | 25,000 | P |
| Sidney (Vg) | Sewage disposal plant | 75,000 | P |
| Millerton (Vg) | Sewage disposal plant | 100,000 | P |
| Poughkeepsie (Cy) | 2nd unit intercepter (sanitary sewer) | 153,000 | A |
| Poughkeepsie (Cy) | Sewage disposal plant | 455,000 | A |
| Erie County | Disposal plant, drainage | 15,000 | A |
| West Seneca (Tn) | Sewage treatment plant | 120,000 | P |
| Gloversville (Cy) | Build addition to disposal plant | 150,000 | A |
| Batavia (Cy) | New disposal plant | 751,000 | A |
| LeRoy (Vg) | Sewage system with disposal plant | 300,000 | P |
| Little Falls (Cy) | Disposal plant | 100,000 | A |
| Canastota (Vg) | Sewage disposal plant | 74,030 | A |
| Cazenovia (Vg) | Sewage disposal plant | 50,000 | P |
| Amsterdam (Cy) | Sewage disposal plant | 1,000,000 | P |
| Lawrence (Vg) | Completion of sewer system | 276,000 | P |
| Nassau County | Sanitary sewer and plant | 8,072,000 | A |
| Lewiston (Vg) | Sanitary sewer system and plant | 175,000 | P |
| Wilson (Vg) | Remodeling sewage treatment plant | 30,000 | A |
| Glen Cove (Cy) | Sewage treatment plant improv. | 17,900 | P |
| Vernon (Vg) | Sanitary sewer system and disposal plant | 80,000 | P |
| Fayetteville (Vg) | Sanitary sewer system and disposal plant | 280,000 | P |
| Manlius (Vg) | Sanitary sewers and treatment plant | 170,000 | P |
| N. Syracuse (Vg) | Sanitary sewer system | 225,000 | P |
| Solvay (Vg) | Sewage disposal plant and sewers | 140,000 | P |
| Tully (Vg) | Sewage system and disposal plant | 110,000 | P |
| Victor (Vg) | Sanitary system and disposal plant | 150,000 | P |

TABLE I.—*Continued*

| Community | Project | Est. Const. Cost and Status | |
|---|---|---|---|
| Middletown (Cy) | Improve and enlarge disposal plant | 210,000 | A |
| Monroe (Vg) | Sewer system and disposal plant | 250,000 | P |
| Montgomery (Vg) | Sanitary sewer system and disposal plant | 230,000 | P |
| Wallkill (Tn) | Sanitary sewer system and plant | 250,000 | A |
| Pulaski (Vg) | Complete sewer system | 270,000 | A |
| E. Greenbush (Tn) | Construction of sanitary sewer system | 350,000 | P |
| E. Greenbush (Tn) | Construction of sanitary sewer system | 335,000 | P |
| Ogdensburg (Cy) | Sewage disposal plant | 500,000 | A |
| Ballston Spa (Vg) | Sludge digester installation | 45,000 | P |
| Saratoga Springs (Cy) | Sewage pumping station | 28,000 | A |
| Montour Falls (Vg) | Sanitary sewer system and treatment plant | 225,000 | P |
| Ovid (Vg) | Sanitary sewer system and treatment plant | 180,000 | P |
| Fallsburgh (Tn) | Sewer district extension | 40,000 | P |
| Owego (Vg) | Sewage disposal plant | 400,000 | P |
| Ft. Edward (Vg) | Intercepting sewer and sewage disposal plant | 120,000 | P |
| Sodus (Vg) | Sewage system and disposal plant | 160,000 | P |
| Briarcliff Manor (Vg) | Ext. of sewage system | 75,000 | P |
| Buchanan (Vg) | Drainage and sewage disposal plant | 150,000 | P |
| Croton-on-Hudson (Vg) | Sewage treatment plant | 70,000 | A |
| Eastchester (Tn) | Improve sanitary sewers | 200,000 | A |
| Irvington (Vg) | Sewer improvements | 100,000 | P |
| Larchmont (Vg) | Remodeling sewage treatment plant | 35,000 | A |
| Mt. Pleasant (Tn) | Hawthorne impr. dis. and sanitary sewers | 450,000 | P |
| New Rochelle (Cy) | Disposal plant | 664,400 | P |
| No. Tarrytown (Vg) | Improvements at treatment plant | 20,000 | A |
| Peeksill (Cy) | Intercepting sewers | 200,000 | A |
| Peekskill (Cy) | Outfall sewer and siphon line | 75,000 | A |
| Peekskill (Cy) | Sewage disposal plant | 200,000 | A |
| Port Chester (Vg) | Sanitation improvements | 144,300 | A |
| Arcade (Vg) | Sewer system and disposal plant | 20,000 | P |
| Perry Village (Vg) | Sewage treatment plant | 90,000 | P |
| Suffolk County | County sanitary sewerage program | 10,700,000 | A |
| | | $33,612,675.15 | |

| | |
|---|---|
| P—Pending Commission Action | $ 9,578,300.00 |
| A—Approved by Commission | 24,034,375.15 |
| Total | $33,612,675.15 |

favorably by the Superintendent of Public Works and the Postwar Public Works Planning Commission with the result that many such applications have been approved and allocations of funds made for the preparation of detailed construction plans.

Table 1 is a list of the applications covering municipal sewerage and sewage disposal projects received by the State Postwar Public Works Planning Commission, together with their estimated cost of construction and a record of those approved by the Commission. Sixty-six sanitary sewer and sewage disposal applications with a total estimated cost of $33,612,675 have been received by the Commission. Of these, 28 applications with an estimated cost of construction of $24,034,375 have been approved by the Commission and work is now under way on the preparation of plans for these sanitary sewer and sewage disposal projects. The balance or 38 applications are awaiting action by the Commission.

In addition, 15 applications for combined sewers with a total estimated cost of construction of $2,430,000 have been received by the Commission, 10 of which, having an estimated cost of construction of $1,686,000, have been approved and the remaining 5 are awaiting action by the Commission.

These data were prepared by Mr. Holden Evans, Executive Secretary of the New York State Postwar Public Works Planning Commission, and represent information as of June 1, 1944. These facts and figures reflect the widespread and general co-operation of our New York State municipalities with the State in planning for postwar public works construction as a means of alleviating unemployment in the period immediately following the war.

The degree of success of this planning program is necessarily dependent on the co-operation of our municipalities. Unless provisions are made in advance for obtaining any needed land and rights-of-way and for obtaining the needed authorization of funds for their construction, delays will occur and the benefits of advance planning will not be fully realized. It is urged that everyone whose municipalities have such projects under contemplation will make every effort to have all needed action taken by their municipalities to insure against delays in starting work on any needed sewerage and sewage disposal projects as intended under the State Program for Postwar Construction.

This joint planning program of the State and our municipalities is certain to result in a large amount of needed sewerage and sewage disposal construction with the resulting decrease in stream pollution after the close of the war, plans for which have been prepared based on careful engineering studies and which have been reviewed and approved by the state agencies.

# THE NEED FOR SEWAGE TREATMENT IN FLORIDA *

By J. B. Miller

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Insofar as the need for sewage treatment in the State of Florida is concerned, one may indulge in most of the generalities prevailing in other regions of the country in discussing the subject. In broad perspective, of course, sewage treatment is considered as only one of the many factors in the fullest utilization of water by mankind. This broad economy of water use has extensive political and sociological ramifications, and it is of extreme importance that this be borne in mind in considering sewage treatment, this one factor in the water economy structure.

The full economy of water use perhaps is of more importance in regions of the country where comparatively larger numbers of communities will discharge their sewage into a clearly defined natural drainage system such as a big river and its tributaries. Nevertheless, the present generation in Florida has seen a rather astounding population increase which has in turn imposed greater responsibilities, and one of these responsibilities is that of taking a broad view of regional problems involved in design and operation of sewage treatment works. In some regions in the State, no longer can one community rightfully release its sewage into adjacent tidal waters without considering treatment of such with respect to or in terms of its effect on other communities in the same region. The same thing applies to a region about an inland lake or system of lakes: the increasing problem of industrial wastes is rapidly intensifying this consideration. In other words, a community with or without industries should not design a sewage treatment works with the selfish expectation of utilizing a majority of the natural disposal value of the receiving waters. Neither should a community poorly operate a properly designed plant with this expectation. As mentioned before, perhaps the populated drainage regions in Florida are not so clearly defined as to necessitate or make possible establishment of regional authorities to work out each problem on a comprehensive regional basis, but in the absence of such central authorities those of us responsible for the design and operation of sewage treatment works can do so in co-operation with each other in a given region.

It is felt that the tax-paying population will come to a full realization of the need for sewage treatment in Florida with an appreciation of the mutual responsibilities of communities within a drainage or disposal area.

Sewage treatment plant operators and designing engineers over the country look at receiving waters as a part of the treatment and disposal

* Presented at 4th Annual Meeting, Florida Sewage Works Assn., Daytona Beach, May 17–19, 1944.

works, and rightly so. In Florida, however, in many regions we must now consider such waters as the further valuable asset which they are. Visitors to the State as a group pay out huge sums annually for the privilege of recreation, and their recreation almost invariably involves use of our extensive coastal and tidal waters, lakes and streams. When a visitor leaves home for Florida I do not believe he has visions of swimming, boating or fishing in an overgrown cesspool. He expects to find things of this kind pretty well in their natural state. The need for sewage treatment is obvious if Florida's visitors are expected to repeat their experiences, and I believe we are the people who are expected to take a principal part in bringing about desired results.

Although the need for sewage treatment can rather vividly be seen reflected in the economic necessity for preserving our very important recreational attractions, the public health factors are of prime importance. In this connection it is rarely possible to demonstrate dramatically the need as in the case of a somewhat heavily polluted recreational area. We continue, however, to have typhoid fever in the State every year. Back in 1932 there were 266 cases reported. Since then the incidence curve has fluctuated over the years through a range of 94 reported cases to 196 reported cases, with the general trend slightly downward to 68 reported cases last year. Although the incidence rate of this disease has been greatly reduced in this generation, its curve has almost flattened out. Concentrated and direct effort will have to be expended to bring it down to a less disgraceful level. Typhoid fever being one of the filth-borne diseases, its residual largely is kept smouldering in our unsewered communities and in such sections of our bigger cities. Sanitary sewerage is the answer, of course, and this in turn entails sewage treatment.

Further, with respect to the control of filth-borne diseases such as typhoid fever, the dysenteries and hookworm disease, and its relation to the need for sewage treatment, the use of septic tanks and other excreta disposal facilities should be mentioned.

The making of sewer extensions in most localities has nearly become a war casualty because of labor and material shortages. Where war housing has been constructed under the priorities system, developers and underwriters have largely turned to the use of individual septic tanks as means of sewage disposal. Although this has been curtailed in some instances where central sewerage systems were feasible under wartime circumstances, a great many septic tanks have been installed. In a relatively short time, of course, sewer extensions and sewage treatment will have to be provided. I think it cannot be mentioned too often that perhaps a septic tank's principal advantage over the privy may be that it makes possible an inside flush toilet whereas the outhouse does not.

Communities in which sewer extensions need to be made should bear in mind constantly that the septic tanks and other devices in current use may be a real health menace. Of course, approved type pit privies are better than certain other types such as bucket and scavenger devices; a septic tank with flush unit may be better than privies. But it should be kept in mind that, for instance, although there is still a lot to be learned about *Eberthella typhosus,* the etiological agent involved in typhoid fever, the survival of this organism under natural conditions such as in or upon the soil, is certainly not to be taken lightly. Experiments * and investigations carried out under conditions simulating those of septic tanks showed that it took four days for 98 per cent of the typhoid organisms introduced therein to die off, and even after 27 days there were still at least 10 living organisms of typhoid per ml.

I think the allusion is clear. Everyone knows what trouble septic tanks give sooner or later, and more often where installations are made in poorly drained ground and during the rainy seasons. Septic tanks must be cleared out and their drainfields reworked which, in effect, creates an open cesspool in backyards where children are apt to be playing. There are a lot of these in Florida, and I think the hazard is real. Further investigations of the survival of typhoid organisms in nature have shown that the germ lasts surprisingly well. It has been observed to have a period of survival of 50 days in loamy soil during the rainy season. In this same type of soil during the dry season, the organism lived for between 21 and 28 days. Even in sand during the dry season, this organism has survived from 2 to 7 days, depending on humidity and temperature. Obviously, when a typhoid carrier uses a toilet at the time his body is excreting the organisms, and the infected material is flushed into a septic tank and out into the drainfield, there need be but one or two more links in the chain to add to the morbidity statistics. Outhouses and bucket privies, open to the common house fly, and their relation to the possibility of spread of typhoid fever are familiar to most of us. I think it is a good thing to review occasionally these old stories which may be very commonplace. They all point to the need for sewers and sewage treatment in our State. Thus briefly mentioning some of the smaller units that go to make up the composite picture of the need for sewage treatment, we add up what should be done and what is needed in a community. In viewing this we might step back or up onto a more comprehensive viewpoint from which we can see to a point beyond the single community.

The view covers at least 41 towns in the State where sewage treatment is indicated. This number does not embrace the many, many of our smallest communities. These are 41 towns and cities ranging from populations of 3,000 to 200,000 or over, with a lot of them with populations of 10,000 to 25,000.

Some of these towns have fairly good sewer networks, but are badly in need of sewage treatment; the need arises from such conditions as pollution of important recreational areas, pollution of shellfish-growing areas and jeopardizing of water supplies through discharge of sewage into underground waters. Many of these towns have already engaged consulting sanitary engineers who are investigating these problems and developing plans for carrying out the necessary construction upon post-

* "The Survival of Typhoid in Nature"—Paul J. Beard, *A. W. W. A. Journal* (1938).

bellum relaxation of materials control and easing of labor shortages.

Many of the towns in the above population ranges need to make rather wide sewer extensions and to improve their sewage treatment facilities for the purpose of eliminating myriad septic tanks and outhouses in congested areas.

In fairness, it should be mentioned that not a few of our towns have, of course, gone a long way toward a solution of their sewage treatment problems. Some of them, in fact, need only to continue to look after the operation feature of the problem. And that, of course, is a principal purpose of such meetings as this short course.

# Industrial Wastes

## SYMPOSIUM—DISPOSAL OF LIQUID INDUSTRIAL WASTES *

### 1. THE INDUSTRIAL WASTE PROBLEM

By R. F. Goudey

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The general problem of industrial waste disposal is rapidly becoming serious. The National Resources Committee in 1939 reported that $700,000,000 would be required to build treatment plants for industries in the United States now discharging wastes into water-courses. The U. S. Public Health Service recently reported that 1,604 industrial plants are discharging wastes into the Ohio River, equivalent to the sewage from ten million people. The War Production Board in 1943 set an alcohol quota which will produce wastes having an equivalent of nearly thirty million people. It is stated that the brewery wastes in the United States have a population equivalent of twenty-six million people. The Sanitary District of Chicago, serving 300 plants, has a waste disposal problem equivalent to the sewage from a population of 2,700,000. At the present time the industrial load on watercourses is greater than the total load from domestic sewage. These statements go to show that the problem of disposing of liquid industrial wastes has become great.

The viewpoint of industry in the matter of waste disposal is cause for alarm. While some intelligence is used in locating industries having major problems in the matter of waste disposal, there is too often a tendency to locate industries to fit in with availability of raw supplies, transportation facilities, labor conditions, and political arrangements whereby wastes can be disposed of without obligation of the industry itself. Industries discharging wastes into streams have created very serious nuisances and even menaces to health, while with a little study there could have been salvaging, separation of wastes, changing of processes, recirculation of water, regeneration of processes which not only would have minimized the stream pollution problem but in many cases would have netted financial returns. In general, industries have pleaded lack of funds and lack of technical knowledge in the matter of solving their waste disposal problems. Too often industries have sought greater production and economy of operation at the expense of dirtying streams, lowering aesthetic standards, sacrificing recreational facilities and complicating treatment of downstream

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water supplies rather than securing the services of experts to solve their problems. Too often men of inadequate experience with insufficient training are asked to study problems of waste disposal and are not given an opportunity to sell their ideas to management. Even when industry is required to install preliminary treatment works, management appears prone not to co-operate and fails to provide adequate supervision. So long as industry remains in an apathetic attitude, very little can be done in the scientific solution of the waste disposal problem.

To date there has been no standard classification of wastes. Each reporting agency uses different terminology. In this paper wastes are divided into three classes, food, paper and chemical. Table 1 indicates the relative portion of these wastes as reported in different parts of the country.

TABLE I.—*Classification of Wastes—Ratio of Loading*

| | National Resources Comm. (1939) | U.S.P.H.S. (Ohio River) | Sanitary District of Chicago |
|---|---|---|---|
| Food: | | | |
| Including milk, canneries, fisheries, meat packing, cereal, sugar, beverages, and malt liquor | 2.4 | 1.0 | 22.0 |
| Paper and Pulp | 1.2 | 1.3 | 1.0 |
| Chemical: | | | |
| Including alcohol, petroleum, gas-house, and rubber | 1.0 | 3.1 | 2.8 |

It is apparent that there is no uniformity in the geographical distribution of industrial wastes. Food produces the most important waste for the country as a whole, but in the Ohio River basin chemical wastes are three times more important than food waste. In Chicago the waste from food is nearly ten times greater than any other type of waste. This lack of uniformity of geographical distribution is one of the most important factors in finding a regimented solution to the problem for the entire country. The problems vary with each locality and even with similar types of wastes different solutions must be formulated.

Mohlman reports that state boards of health are allowing industries to pollute streams even to the extent of creating odors and nuisances so long as this practice stops just short of creating menaces to health. With the return of peace, there will be an enormous program of waste disposal correction for postwar industry which will be guided largely by experiences gained at the present time. A proper solution of the waste disposal problem involves educating industry, health departments and communities to the duties and responsibilities of each in permitting streams to be used for the disposal of liquid wastes, provided industry or the communities so pretreat their wastes as to provide satisfactory disposal when diluted by streams or watercourses.

## Reduction of Wastes to a Minimum at Their Source

Regardless of how liquid wastes are to be treated or disposed of, it is inherently correct that their volume and strength be reduced to a minimum as near as possible to their sources. Special considerations must be given to each contributing waste as to fluctuations in volume, variations in quality, temperature changes, contained poisons, and the value of recoverable products. It is also necessary to evaluate whether screens, settling basins, biological processes, evaporation or similar treatment should be provided. In this connection the elevation of waste outlets, together with space available for treatment, become important factors and should be anticipated in the design of new plants so that pretreatment can be provided where desirable.

While it is not generally true that all industries could treat their wastes and obtain financial returns to pay for the cost of treatment, nevertheless there are many instances where treatment has more than justified the cost of preliminary treatment works. In some instances the recovery of by-products has been extremely profitable. The literature discloses numerous instances where recoveries have been made, such as:

1. Sulfur, sulfur dioxide, spent acid, solvents, alcohol, metallic salts, pigments, phenol
2. Corn by-products from corn products
3. Glutamic acid and betaine from sugar wastes
4. Activated carbon from sulfite liquor
5. Grease from glue, meat packing and wool scouring plants
6. Fertilizer from heat and fish packing
7. "Ferron" (a building material) from pickling liquor
8. Animal feed from food wastes

Benefits in more economical operation by recirculating condensing, cooling and process waters include savings in power as well as minimizing of liquid wastes.

In a number of instances rather elaborate processes have been developed, such as lanolin recovery from washing of wool, in which calcium chloride is used to produce calcium stearate and fat is recovered from benzene extractions. Free acid has been removed from pickling liquors by acetone, which precipitates copperas which, after centrifuging, is recovered from the loss of water in crystals. There are an untold number of patents dealing with sulfide liquors which are for the most part untried. There is probably no more fertile ground for crackpot, horseback opinions, and untried patents than exists in the industrial waste disposal field.

Certain wastes must be particularly treated to prevent poisoning of surface and underground water supplies. At some ammunition plants, arsenic in the liquid effluent has become a serious problem and in a number of chromium plating plants chromium wastes from aviation industries have endangered underground water supplies. Serious attention must be given to the elimination of poisons, not only from the human standpoint but also because of their effects on fish and plant life in water.

## Pretreatment of Liquid Wastes

Pretreatment is an essential step whether the wastes are to be mixed with sewage or to be treated and disposed of separately. Even though treatment at the source is apt to be sketchy and irresponsible, there are many instances where some pretreatment is necessary to protect pumps, prevent corrosion of pipe lines and to remove the bulk of solids at the source. The simplest types of pretreatment include screening, sedimentation and storage, neutralization by mixing and smoothing out fluctuations in flow and temperature.

## Disposal

The ultimate methods of disposal include discharge into streams, tidewater, on to land, percolation into the ground, spraying into the atmosphere, concentration by evaporation, and entire elimination of any liquid wastes to be discharged from the plant.

When discharged into streams, it is necessary to eliminate suspended solids, B.O.D., poisons and odors up to the point where there will be no overload in the stream into which discharge is made under both peace time and war time conditions. The principles of tidewater disposal involve the removal of enough solids and B.O.D. load to prevent deoxygenation of the diluting body of water and in peace times not to interfere with recreational use. Land disposal depends on the proper isolation and the adaptability of soil, coupled with the proper type of treatment works, so that no underground water supply is spoiled by underground travel of organic pollution or poisons. The disposal of water underground, such as pumping back of salt brines into oil formations, is in many cases the only possible solution. Some types of liquid wastes discharged into underground water supplies result in far-reaching damage; gas wastes travel as much as five miles and food product wastes can be conveyed over a mile through the underground water. There are two cases where wastes have been disposed of by spraying continuously from ponds until evaporated. In a second case, starch wastes have been sprayed as rain on to land for fertilizer value where, otherwise, when discharged into water, they caused death to fish through growths of *Sphaerotilus*. Evaporation by heat has been applied to blood wastes from packing plants and to TNT wastes, resulting in great reduction of the original volume.

## Separate or Public Disposal

No rule can be set regarding whether waste should or should not be placed in public sewers. Certain wastes such as chemical, oil, pickling, and photographic wastes, when pretreated to remove free oil or free acid, may actually be beneficial in sewers due to flushing value and may not interfere with treatment processes. Sludge from water softening plants has been found not to interfere with sludge digestion. Certain wastes, such as meat packing and cannery wastes, do not injure sewers or a sewage treatment plant except to increase the population equivalent. The question as to who pays for the added cost of sewage treatment due to the presence of industrial wastes of this type is a moot point. Other types of wastes should under no circumstances be placed into sewers, such as sugar, molasses, orange pulp and whey. These not only have a high population equivalent but, if discharged into sewers where sulfates are high or aeration is used where lactic acid fermenters are encouraged, trouble ensues. It becomes necessary to study each particular waste to determine whether, with or without treatment, disposal into sewers will create odors, disintegration of structures or added cost of treatment. Other factors which must be taken into account to determine whether separate plants or disposal into public sewers should be provided depend: first, on whether there is a large diluting stream present; second, adequate isolation for local treatment with or without adequate or suitable local land disposal; third, whether a public sewer is available where only preliminary treatment is required; and fourth, if a public sewer is available, what treatment is required for the mixed wastes.

### Los Angeles Regulations

The provisions of the City of Los Angeles in relation to waste disposal govern temperature (less than 100° F.), suspended solids (less than 1,000 p.p.m.), oil (less than 600 p.p.m. by weight), explosive gases (any amounts), and hydrogen ion concentration (limits not lower than 5.5 and not higher than 9.0). It is also required by the City of Los Angeles that all wastes which are odorless and stable (at least for five days at 20° C.) must not be discharged into sanitary sewers. Permits are required for waste disposal connections to the sanitary sewer, manholes for the sampling and measurement of the flow must be available, and special cases must be considered by the Board of Public Works to the end that public health, safety and property be properly safeguarded.

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## 2. THE RESPONSIBILITY OF THE MUNICIPALITY IN THE INDUSTRIAL WASTE PROBLEM

By Harold Farnsworth Gray

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The objectives in the disposal of liquid industrial wastes are quite distinct from the objectives in the disposal of municipal sewage, and there are unusually marked differences in the limiting factors, the economics, the techniques and the attitude of management.

In the first place, industrial wastes have little or no public health significance; that is, they do not contribute to the incidence of communicable disease, as does domestic sewage. Their effects upon water or land are primarily aesthetic or economic. They may render a stream or body of water, or an area adjacent to a land disposal, offensive or unsightly, or they may destroy or greatly decrease the value or usefulness of water or land, but they do not contribute bacteria of human disease to the problem.

Neither federal, state or local health departments have a demonstrable health protective function in relation to the disposal of industrial wastes, in a closely restricted view of public health. Even the physical deterioration of a public water supply by an industrial waste is a matter of economics, or of property rights, rather than a matter of public health. A public nuisance is not necessarily a menace to health. As a rule, no other department of government is as well equipped to handle such problems as is the health department with an engineering staff, but the functions performed lie more in the realm of nuisance than of public health specifically.

An industrial waste is precisely what the name implies—a waste. As such, it represents to industrial management a certain amount of loss—of raw materials and of accessory materials—for which purchase money has been paid. Management is generally interested in reducing such waste when possible, but management's preoccupation of thought is usually on the production and sale of finished products, wherefore these wastes receive but secondary consideration.

Assuming that either through necessity, or an eye to good public relations, industrial management decides to do something about wastes, at least two limiting conditions are usually imposed: (1) the treatment and disposal must be performed within stated limits of installation and operating cost which are somewhat related to the volume of output of product, or net profit, or both; (2) the installation and operation of the waste disposal process cannot be permitted to interfere appreciably with production or with plant arrangement. These factors do not enter into consideration in the disposal of municipal sewage, except as tax limitations or the reluctance of voters to approve bond issues may control.

Still another factor must be considered. Usually the growth of a city is at a fairly steady and determinable rate, and it is possible to design sewage treatment and disposal facilities for a forward period of ten or twenty years with a reasonable prospect of adequacy during such period. An industrial plant, however, may be rather indeterminable even over a period of one year, either as to quantity or wastes or, if processes or products should be changed, as to the characteristics of the wastes. For this reason, industrial management is usually averse to the expenditure of money for fixed and permanent waste treatment and disposal structures and equipment.

Industrial plants are designed, built and operated by men who know (usually) their own field, but are definitely not experts in the complex field of wastes disposal. They give it little consideration—until it is unpleasantly forced upon their attention—and what consideration is given is usually an allotment of a definite sum of money for waste disposal, within which limit disposal must be effected. The plant designer buys such standard equipment (usually on the equipment manufacturer's recommendation) as will fit this budget, hopes for the best, and leaves the rest of the job to the plant superintendent. To the plant superintendent, waste disposal is just another headache, large or small, depending on luck, isolation, the weather and the olfactory insensibility of any adjacent citizenry.

Bearing these various conditions and limitations in mind, it is obvious that the designer of industrial waste disposal plants must operate on a different basis from the designer of plants for the disposal of municipal sewage. His tendency will be to work with standard types of equipment for the removal of settleable or floating solids, by sedimentation and skimming, and he may even go to chemical treatment and vacuum filtration to get a reasonably clarified effluent if it is to be discharged into water. But consideration of the oxygen depleting capacity of the clarified effluent is seldom given, unless a resulting depletion of the dissolved oxygen content of the receiving water produces a condition calling for action by the State Fish and Game Commission or the State Health Department.

It is unfortunate for industry that so frequently the disposal of organic industrial waste is turned over to industrial engineers or managers, who are entirely competent in their own fields, but are not skilled in the field of organic waste disposal. This matter represents a peculiar "blind spot" in the failure of the really competent sanitary engineers to inform industrial managers as to the unique and valuable services they are able to render to industry.

The industrial plant which is located well outside of an incorporated municipality must, as a rule, solve its waste disposal problem by itself. But if the plant is located in a city or sanitary district with a sewer system, a different situation exists. Possibly the volume of liquid waste may overload the adjacent street sewer, and require a separate line to a main sewer of sufficient capacity. This frequently is not discovered until after the plant is in operation, or after an expansion in volume of output. Then there is an argument between the industry and the city as to who is going to pay for the larger sewer. The industry pays taxes, so why shouldn't the city furnish sewer service? Or should it?

Another situation may occur, in a moderate sized city with a sewage treatment plant, adequate for present needs with a reasonable margin of capacity for normal growth. To this city comes a new industry producing large volumes of liquid wastes with high biochemical oxygen demand and a heavy load of suspended solids. No doubt the plant was warmly welcomed by the Chamber of Commerce and the tax collector. But the treatment plant becomes badly overloaded, and trouble ensues. The industry says "Here we are; we pay big taxes; we bring payrolls and business, and anyway it is the city's hard luck if the sewage treatment plant isn't big enough." The city says it hasn't the money to enlarge the plant, and anyway they were getting by comfortably until the industry's wastes sunk them, therefore, the industry must contribute to fixing things up. And so there is an argument, first as to "whether," and second, as to "how much." It may get acrimonious, and may even result in such drastic action by the city as plugging the industry's sewer, or the industry may threaten to leave the city, or there may be a law suit in which nobody benefits but the lawyers and the expert witnesses.

Such situations have occurred, and may occur again, due at least in part to a lack of understanding as to relative responsibilities by city and industry, and to the lack of an acceptable basis of negotiation and agreement.

It would be presumptious to suggest that a brief paper such as this could lay down a definite basis of agreement acceptable in all cases, but it should be possible to suggest certain lines of reasoning which could be pursued in order to arrive at a fair basis of agreement on such disputed matters.

There is no claim made for originality in the following suggested approach to an equitable solution of this problem, though possibly all elements have not heretofore been combined.

1. Municipalities and other governmental agencies furnishing sewerage and sewage treatment and disposal facilities are obligated only to the extent of a normal domestic sewage.

2. Beyond a normal domestic sewage such agencies may:

(*a*) refuse to accept an excess loading on a sewerage system or sewage treatment plant, or
(*b*) may accept such loading after pretreatment by the producing industry, at the cost of the industry, or
(*c*) may accept the industrial waste, without pretreatment at a stipulated or negotiated cost to the industry, or
(*d*) may accept the entire industrial load at the sole cost of the municipality or other agency.

3. A municipality or other governmental agency may adopt one of two financial policies in reference to item 2-*c*:

(*a*) a liberal policy toward industry, in which a relatively substantial part of the cost of treatment of the excess load is borne by the city or agency, or
(*b*) a strict policy wherein the industry bears the entire excess cost as nearly as it may be ascertained.

4. In general, a liberal policy may be anticipated in larger industrial areas and in situations where the costs of sewage treatment and disposal are relatively low. A strict policy may be expected in smaller cities, and where the costs of sewage treatment and disposal are relatively high.

5. For the basis of calculation of excess industrial load, it is first necessary to determine the local normal domestic sewage as to volume, suspended solids and biochemical oxygen demand. It would be definitely *not* advisable to use standards derived from national averages, as cities and regions vary very widely from any national average.

6. With such norms determined for a particular city, they may be equated against assessed valuation so as to determine a series of bases in terms of units of assessed valuation. For example, we find the following approximate and rough average values for the residential areas in cities on the east side of San Francisco Bay:

| | |
|---|---|
| Volume | 44 gallons per capita per day |
| Suspended solids | 0.107 lbs. per capita per day |
| Biochemical oxygen demand (5 day, 20° C.) | 0.114 lbs. per capita per day |
| Assessed valuation | $800 per capita |

Equating these quantities to a basis of $1,000 of assessed valuation, we have the following figures:

| | |
|---|---|
| Volume | 55 gallons per day |
| Suspended solids | 0.134 lbs. per day |
| Biochemical oxygen demand | 0.143 lbs. per day |

7. Assuming that the city intends to make charges for excess costs of sewerage and sewage treatment and disposal (irrespective, for the moment, of whether the city charges for the entire excess cost or for only a percentage of it), then one, or perhaps two, of the foregoing bases may be used as a means of computing the excess charges for particular industrial plants.

8. If no sewage treatment is involved, then the excess cost would probably be apportioned on a measured volumetric basis only. If the sewage treatment consisted only of sedimentation, the apportionment presumably would be on the basis of the suspended solids factor. If secondary (biological oxidation) treatment was involved the basis of computation presumably would be the biochemical oxygen demand factor. In either of the two latter instances, the excess charges might be apportioned partly by volume and partly by either suspended solids or biochemical oxygen demand.

9. The next items to be ascertained would be the local costs of sewerage and sewage treatment and disposal, volumetrically and per pound of suspended solids and per pound of biochemical oxygen demand contributed to the system or to the treatment plant. For a pound of suspended solids or a pound of biochemical oxygen demand these costs may vary so widely that the matter may be more confused than clarified by suggesting average costs.

10. With these costs of treatment, either on a volumetric, pounds of suspended solids, or pounds of biochemical oxygen demand basis, established for a particular situation, then the costs of treatment of the wastes from an industrial plant would then be computed. The difference would be the excess cost to be charged to the industrial plant,

either in its entirety or only in part, according to the policy adopted by the city.

11. In actual practice, however, these calculations would be difficult to prescribe in a municipal ordinance (imagine the mess of verbiage an attorney would use in trying to express these comparatively simple ideas in legal phraseology!). So it is probable that certain standards would be set up, allowing a stated maximum of volume, or suspended solids, or biochemical oxygen demand, per $1,000 of assessed valuation of industrial plant, which would be received and handled by the city without extra charge, and then imposing charges for excesses above such maxima. Such excesses would probably be set up in blocks having upper and lower limits, and using a flat sum between such limits.

If it can be shown clearly that such methods of apportionment of excess costs of treating industrial wastes are based on sound engineering principles, are equitable and are fairly administered, then industry can have little cause for objection, other than the breaking of old precedents which have no other validity than of custom. The experience of Cedar Rapids, Iowa, is illuminating on this point.

There is a further value to the practice of charging industries for excess costs of sewerage and sewage treatment. It will cause industry to endeavor to minimize the industrial waste load through improvement in plant processes, such as recovery of by-products, reduction of water wastage, the increased use of closed or recirculating systems, the removal of solids and their separate disposal, and the like. In the long run this will accrue to the advantage of industry.

## Discussion

By Harold K. Palmer

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The Los Angeles County Sanitation Districts take the attitude that industries have a right to a proportional use of the sewers and treatment plant, so long as their wastes will not cause damage to the system or unjustified expense to other user. A sewerage system built to handle and treat noxious fluids is more expensive per unit of capacity than a storm drain built to carry surface storm water only, and it is economy to dispose of as many innocuous wastes as possible through the storm drain.

There are acid wastes which would destroy any structure made of cement and such wastes must be neutralized before admission to the sewer. Many methods of sewage treatment depend upon the action of bacteria for their operation and, therefore, any bactericidal substance should be excluded from the treatment plant. Such cases also must apply some treatment before the waste is discharged to the sewer.

In accordance with this principle, the Districts attempt to handle in the sanitary sewers such noxious industrial wastes as cannot be discharged into storm drains, but at the same time take care to see that nothing detrimental to the sewer or the treatment plant is admitted. Despite all efforts, there are times when large slugs of oil or acid find their way to the treatment plant. Nearly always the source of these slugs can be determined and the industry responsible is notified that appropriate action will be taken if it is repeated.

Every industry is required to apply individually to the General Manager for a permit to connect to the sewer and the applicant must furnish an analysis of the waste, state the point of discharge to the sewer, the amount of waste and the quantity and rate at which it will be discharged. In many cases this is referred to the chemist who takes into account the condition and quantity of sewage and considers the effect of this addition. Several years ago a steel plant asked permission to discharge spent pickling wastes. The Districts then were operating an activated sludge plant which was sensitive to low pH, but it was found that at the point of contribution the sewage was sufficiently alkaline and the flow great enough that the sulfuric acid could be admitted if a regulating pond was built so it would enter at a constant rate throughout the 24 hours. There has been very little trouble since the routine was learned. This was possible because of the low ratio of wastes to sewage flow. In a small sewer an equal volume of acid would have been disastrous.

Lately a winery making alcohol has contributed a very odoriferous waste which has made itself obnoxious several miles downstream where there are some drop manholes. There the sewage is stale and the fall releases gases which find their way up through house connections. It was necessary to install gas traps in the house connections and to insist that the waste be chlorinated in the future.

Most wastes are not harmful to the sewer. When one company began discharging copper sulfate it was found to have the same effect as chlorine, and because of this waste it has been possible to close several chlorine dosing plants along the sewer below.

Except for the most harmless wastes, the question of their acceptance should depend upon a report from the chemist, as he is the only one who can predict the effect on the system. The engineer or superintendent can report intelligently only when the volume of wastes may exceed the capacity of the sewer or plant. It has been the rule of the Los Angeles County Sanitation Districts to have the chemist make such reports, and in some cases he makes periodical inspections afterwards, especially if some type of pretreatment is necessary.

Every sewerage system and every treatment plant has its limits in volume of flow and character of sewage, and it is the duty of those in charge to keep these limits in mind, because, to the average citizen, there are no such limits and too often the small community with a new sewage treatment plant will invite a large industry to establish itself in its territory, only to find later that the treatment plant is sorely overloaded and has become a nuisance in its immediate neighborhood.

A large sewerage system may absorb several industries that would swamp a small system. The Los Angeles County Sanitation Districts now serve several establishments that have had to move away from smaller communities for this reason. Had this effect been foreseen the expense of moving and starting over again would have been avoided. In order to assist in foreseeing such contingencies, the Industrial Wastes Committee of the California Sewage Works Association is collecting, as rapidly as possible, certain important facts about many of the industries in this State and filing the data with the Los Angeles City Engineer, where it will be available to all who are interested. Unfortunately, it is difficult to get this information, and usually it can be obtained only when an application is made for service, but it is hoped in time to have enough available data so that any community can predict the effect of a proposed industry on its system and take the necessary steps before the plant is overloaded or damaged. If this information can be obtained from a going concern it may assist a similar concern to establish itself in another community without seriously overloading the sewage treatment plant, or incurring unnecessary expense in pretreatment.

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## 3. SOME EXAMPLES OF LIQUID INDUSTRIAL WASTES TREATMENT IN CALIFORNIA

By Edmund B. Besselievre

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It can be said, without fear of contradiction, that any liquid industrial waste may be so treated as to produce an inodorous, inoffensive and safe effluent. But it is not always economically practicable to do so. The three elements: common sense approach to the subject; treatment to the degree required by the needs of the case; and the development of a simple, economical means of treatment enter into every problem.

There are many different types of liquid wastes found in industry but for the purposes of this meeting we are concerned only with those wastes peculiar to the industrial structure of the State of California. The object of this paper is to present briefly some examples of successful liquid waste treatment.

In California there are a series of wastes that are not common to other sections of the country. These are the citrus packing plant wastes, the winery wastes, the wastes from potato dehydration plants, the oil field and oil well wastes, the fish cannery and packing wastes and several newer ones in this field, such as wastes from steel mills and chemical plants which have come in mainly with wartime developments.

In solving any waste problem there are three basic factors which must be considered. The proper evaluation of these factors requires the co-operation of the owner of the plant, who is to pay the bill; the State Department of Health authorities, who initiate the need for treatment; and the legal and legislative agencies who make the laws that force the owner to comply.

It is not enough to simply advise an industrial plant owner that he must treat his wastes and then to stop there. He must be given assistance in setting a standard of treatment that will not wreck his profit structure or cause him to shut down or move his plant to another locality. An industry usually brings revenue and work to a community and many people derive benefits from its operations. To force arbitrarily such an industry to close down or move to another locality because of indefinite or too stringent requirements for waste treatment results in hardship on many families. A degree of treatment that will meet the needs of the case is all that is required and justified—to demand more is to penalize industry unduly. More careful initial study in this regard will make it possible for many industrialists to comply with the law, where otherwise a too severe requirement would force them out of business or to go to the courts for relief. A long drawn out fight in the courts does no one any good. The average industrial plant owner is a reasonable man and is usually willing and anxious to co-operate. Let us make it possible for him to do so. It is the State Health Department's part to set the minimum limits of treatment that will meet the needs of the case in hand; it is for the consulting and designing engineer to work with both the State Health Department and the plant owner in developing and producing a method of treatment that will meet the requirements at the least cost, both for initial construction and daily operation. Waste treatment is never cheap, and is a daily surcharge on the operations of the plant, but economical methods can usually be worked out. By-product recovery is one way of making a waste treatment plant both a success technically and not a burden financially. This requires close study by experts in this line. Many plant owners and engineers have neglected this phase of the problem.

As California is a relatively young industrial state and its industries are peculiar to it, many of the waste problems presented here have not been attacked or solved elsewhere. Water is scarce in many parts of California and fertilizer is expensive and requisite to proper crop growth. It will be perhaps fitting, therefore, to start the discussion of examples of waste treatment that have tended to conserve water for irrigation and other uses by reciting the details of the plant recently completed at the Kaiser Steel Mill at Fontana for the treatment of their pickling liquors. This plant not only takes care of a troublesome waste problem but enables the company to recirculate the effluent back to the plant for other uses and to use by-product materials recovered in the treatment process to offset the cost of the treatment.

This plant operates as follows: Pickling liquors from the merchant and structural mills and the alloy finishing department amount to approximately 45,000 gallons per day of acid wastes. The plant is designed to operate from 6 to 8 hours per day to handle this normal volume. To assure a steady, uniform flow over the operating period of the waste treatment plant the first unit is a receiving or holding tank which has a volume equal to a day's flow of pickle liquor and rinse water. This tank is 30 feet in diameter, 10 feet deep and is of Douglas fir. The acid liquors discharge into it by gravity. The concentrated wastes are then drawn from this tank over the operating period of the waste treatment plant at a steady rate of from 100 to 125 gallons per minute. The treatment consists of the neutralization of the excess acid by the dosage of powdered limestone and the reaction of the soluble ferrous sulfate in the liquor with the limestone. Calcium sulfate is the precipitated residue from this operation together with ferrous hydroxide. The latter will be oxidized to ferric hydroxide and ferric oxide by air forced through the slurry. The fittings and pumps and valves are of acid resisting materials, including duriron and duramet. The three mixing tanks are each equipped with a 42-inch duplex mixer of the Turbo type.

Limestone of 100-mesh size will be fed into the first tank, and air at the rate of 200 cubic feet per minute will be continuously blown through the slurry in each mixing tank. The slurry in the three tanks will be partially recirculated, 5 parts being pumped from No. 3 tank back to No. 1, and the 6th part will overflow into a thickener in a wood stave tank 35 feet in diameter. The effluent from the thickener flows by gravity to the chlorine contact tank of the adjacent domestic sewage treatment plant, whence it is pumped along with final sewage plant effluent back to the mill for service in the rolling mills. The acid treatment plant includes a 30-ton bin for storage of powdered limestone, which is lifted from a truck dump pit by screw conveyor and bucket elevator. The mixers are fed through a variable gear-driven vane feeder and screw conveyor, the limestone being introduced directly into mixing tank No. 1. The 600 cubic feet of air (200 cubic feet applied in each mixer) will be supplied by a rotary blower and the recirculation of the sludge or slurry will be by means of a slurry pump. The 125 gallon per minute raw wastes pump is so arranged with valves on its suction so as to evacuate completely the acid sewers. Sludge will be sent to drying beds by a diaphragm pump until a demand is created and means provided for reclaiming it as a by-product.

Winery wastes, in view of California's large part in the wine industry of the United States, have become more and more troublesome. High in dissolved solids, B.O.D. and color, but low in volume they are believed to be susceptible to treatment by combinations of biological and chemical methods. Depending upon whether they must be so treated as to be suitable for discharge into streams which are sources of potable water supplies, for man or beast, or whether they are handled on percolation beds or ponds, the treatment may be complex or simple. In cases where they are to be handled on large areas of percolation ponds, which many wineries already have in use, and the seepage through these ponds will not reach local watercourses or underground supplies direct, it has been found that these wastes can be treated adequately by presedimentation to permit as much of the solids to settle as will and then by chemical treatment of the effluent, with proper flocculation and mixing to assume complete and proper contact of the chemicals with the liquid, followed by a period of sedimentation. The sludge obtained from the presedimentation and final sedimentation tanks may be put into digesters. This form of treatment is not expensive and requires a relatively small plant. In those cases where the discharge must be into streams direct and a relatively clear effluent from which most of the B.O.D. and dissolved solids have been removed is required, the treatment is more complex. Here it has been found effective to provide a short period of digestion as the first step in the treatment, to permit some of the delayed fermentations to take place, and to treat the overflow liquor from the digester on biological filters, using recirculation of the effluent to maintain a high rate of dosage. In many wineries the lees from the pressing of the grapes, consisting of skins, seeds, stems, etc., contain much tartrate and this valuable material can be recovered and become a source of considerable revenue. In wineries where alcohol is made from molasses still slops the problem of treatment involves the use of digestion as a primary phase, followed by biological treatment.

The war has brought into being many plants for the dehydration of vegetables for the purpose of conserving space in shipments abroad to our fighting forces. One of the most important of these has been the dehydration of potatoes, and numerous plants have been built in California. While this is not a waste of large volume it is a troublesome one for it contains a high percentage of dissolved solids and is high in B.O.D. It cannot be allowed to remain too long as it begins to exude a disagreeable, sour odor in a short time. The problem here is mainly precipitation of the solids. The larger solids, such as skins, eyes, etc., can be readily removed by a screen. A plant for a potato dehydration plant as designed by Harold Gray was described recently (*This Journal,* **15**, 71 (January, 1943)) and consists of screening the wastes through a 60-mesh shaker screen and the spreading of the effluent on sand beds, one bed being used for the wastes of one day. This method requires the availability of a considerable area of waste land but is effective in those parts of California where such land is cheap. For those cases where these areas of land are not available it has been found that this type of waste may be treated by screening, followed by precipitation with lime, flocculation and a sedimentation period of two hours. This reduces practically all of the solids and substantial proportion of the B.O.D. and renders the wastes suitable for discharge into a city sewer system. Plants of this type must handle a waste containing approximately 960 pounds of B.O.D. for each ton of potatoes handled.

Oil wells are common sights on the landscape of California but the oil field wastes are not so attractive in the streams, covering them with those iridescent oil sleeks which shine so kaleidescopically in the sun. The main problem here is to remove the oil. The plant at Santa Fe Springs is an example of how this has been accomplished. The oily wastes are first put through settling tanks in which the settleable dirt is caught and some of the heavier oil taken off by surface overflows.

The effluents from these tanks still contain much light oil. Further settlement without aid does not remove much of this. At Santa Fe Springs the settling tank effluent is put through two special vertical type Flocculators with magnetite filters on the effluent edge. These remove sufficient of the oil to enable the liquid to be discharged into the tidal waters without presence of sleek. It has been found that by treating the settling tank effluent with aluminum sulfate and silica with proper flocculation and sedimentation, that practically all of the oil and sludge can be removed from these wastes.

Citrus fruit canneries produce a troublesome waste, both because of the large amounts of solids in them and their tendency to produce obnoxious odors, as they sour rapidly. The solids from the canneries or packing plants, consisting of particles of fruit skins, seeds, cores, etc., can be readily removed by screens and the lighter finer solids may possibly be removed to a high degree by a vacuum type of solids removal unit (known as a ''Vacuator'') in which the wastes are preaerated to coat the fine solids with air, causing them to rise rapidly, and then subjected to a vacuum in a closed tank. The pull of the vacuum combined with the buoyancy imparted by the preaeration causes these solids to rise immediately to the surface of the tank, whence they are skimmed off. These solids may be put into digesters for further treatment or buried or burned. The liquid wastes may then be treated by biological means to produce a stable, clarified effluent, or put into the city sewers.

California is also faced with the problem of distillery wastes. These are the wastes contributed by plants which distill grains to produce ethyl alcohol. These wastes have been treated mainly for byproduct recovery by methods including screening, concentration, evaporation and drying. It is believed that they can also be handled by anaerobic fermentation and with treatment of the digester liquors on trickling filters, preferably of the high capacity type with recirculation of effluent. In some cases, the suspended solids can be removed by centrifuging prior to multiple effect evaporation followed by rotary driers. It has been stated that where grains are used in producing alcohol a high grade stock food can be recovered from the wastes, amounting to 16 to 18 pounds per bushel of grain ground.

It is impossible to give a complete story of the proper treatment of industrial wastes in this brief discussion, but primarily it must be understood that there is and can be no universal panacea for all types of wastes, or for any one type. Each problem presents individual conditions that must be studied and evaluated, and an effort must be made to co-ordinate the experience at other places with similar wastes, with the modern technique of treatment of organic and other materials. It is necessary to work out for each case at hand the method of treatment which will solve the present problem with due regard to economy of construction and operation for the plant owner.

# Stream Pollution

## THE EFFECT OF SEWAGE TREATMENT ON MARYLAND STREAMS

By Albert B. Kaltenbach and Abel Wolman

*Engineer, Whitman, Requardt and Associates, Baltimore and Professor of Sanitary Engineering, The Johns Hopkins University, Baltimore, Respectively*

Pollution by domestic and industrial wastes of receiving bodies of water is an ever present problem. Since the reduction of such pollution is one of the primary motives for sewage treatment, it is important to determine whether the money spent for this purpose generally accomplishes the expected results.

Physically objectionable conditions are the most obvious if not the most serious objections to stream pollution. Depreciation of contiguous property values, the ruin of waters for sources of supply, injury to fish life, danger to livestock, in the irrigation of certain vegetables, the quarantining of bathing areas and damage to shipping are effects that justify the expenditure of large sums to keep our rivers and streams clean.

But such expenditures are justifiable only when the desired results are obtained. Such is not always the case. Often small towns build sewage treatment plants and, due to faulty design, construction or operation, the conditions in the stream below the outfall remain objectionable. Inability or lack of desire to pay capable, intelligent and interested operators is a common difficulty of small communities.

It is with the purpose of determining whether the treatment of domestic and industrial wastes is actually alleviating the conditions in the stream to the extent for which the plants were designed, that this study has been made. Four streams, each in the vicinity of a populated area in Maryland, were investigated. Bacteriological and chemical data were obtained from the Maryland State Department of Health. Whenever they were available, the results were reviewed of the examinations of stream samples above and below the outfalls of the sewers and before and after sewage treatment was inaugurated. Two of the towns, Hagerstown and Belair, discharge their sewage into flowing streams, while the other two, Annapolis and Chestertown, discharge into tidal waters. These towns vary greatly in size, in their ability to bear the expense of sewage treatment and in the quality of the receiving waters.

### Hagerstown

Hagerstown, the third largest city in Maryland, has a population of 32,941 (1940 census). It is in Washington County in a broad valley between the Blue Ridge and the Allegheny Mountains. This city had a sewerage system for perhaps 30 years, the raw sewage being discharged into Marsh Run, a very small tributary of Antietam Creek, which bisects Hagerstown. In 1917 a $750,000 sewerage improvement program was carried out, which consisted of many extensions and the construction of an outfall line which carried the sewage to Antietam Creek about two miles from the center of town. Even at this time, however, some domestic sewage was still discharged into Marsh Run, according to a State Department of Health memorandum of July 31, 1922.

In 1924 a treatment plant was built southeast of the city on a 500 acre municipally owned farm. The plant consisted of a coarse bar screen, a fine screen, two grit chambers, two aeration tanks, two final settling tanks, thirteen open sludge drying beds and a service building. The aerators did not operate satisfactorily or economically in spite of much experimentation with the original equipment and later with other types. Because of these difficulties and because of the increase of sewage flow, the city engaged a firm of consulting engineers to remodel the original unit to a complete activated sludge plant. The remodeling was completed in the spring of 1933. It is designed to treat 6 m.g.d. by the activated sludge process or 8 m.g.d. by plain sedimentation (1).

Antietam Creek, with its several tributaries, although relatively small, is put to many diverse uses, from its source in Adams County, Pennsylvania, to its mouth, at the Potomac River. The main stream is about 50 miles long and drains 292 square miles. In Maryland near the source of Little Falls Creek, one of the tributaries of Antietam Creek, a dam impounds water for recreational purposes and for the water supplies of Camp Ritchie, and Camp Louise. These camps discharge their sewage into the same stream farther down. This sewage is given secondary treatment by using prechlorination, sedimentation, separate sludge digestion, sand filtration and chlorination of the effluent. Still further downstream, on the same tributary, the town Rouzerville, Pennsylvania, obtains 48,000 g.p.d. for its water supply, filtering and chlorinating it. Waynesboro, Pennsylvania, with a population of 10,231, takes 2.1 m.g.d. for domestic use from the main stream near its source and chlorinates it, later returning it in the form of secondary treated and chlorinated sewage. The Waynesboro Gas Company discharges approximately 13,000 g.p.d. of scrubbing and wash water. Separators remove the tar before disposal. The Mont Alto Sanitorium (Pennsylvania), uses 200,000 g.p.d. chlorinated, from still another tributary. A small tributary in Maryland, supplies 1.2 m.g.d. to Hagerstown while back on the main stream, at Security, Maryland, two steam power plants use water for condensing and make-up. Security also discharges about 23,000 g.p.d. of untreated sewage into the main stream.

At Hagerstown a steam power station uses water from the creek for condensing and make-up. The city discharges an average of 4 m.g.d. of domestic sewage. Local trade wastes from a dairy and from the Koppers Company, and scrubbing waters treated by separating tanks, settling and filters from the gas company, are all discharged separately into the stream at Hagerstown. Several miles downstream the Roxbury State Penal Farm discharges approximately 8,500 g.p.d. of sewage which receives only primary treatment; and finally before joining the Potomac River the stream is dammed by a 1,022 h.p. hydroelectric power station at Breathedsville. Below Hagerstown three old

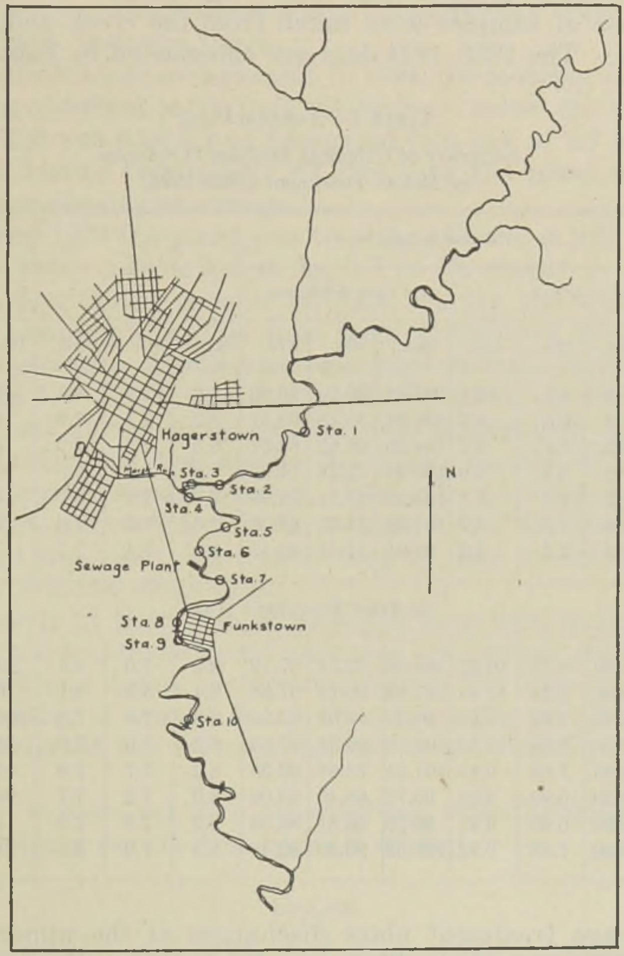


FIG. 1.—Hagerstown and Antietam Creek. 1″ = 2 mi.

mill dams survive, but are no longer in use. Besides these uses, the stream supplies ideal recreation areas for picnicking, fishing and bathing.

Antietam Creek, therefore, supports one hydro-electric plant, furnishes five settlements, and three power stations with over 2 m.g.d. of water and carries away over 5 m.g.d. of domestic and trade wastes from four towns and four industries (2).

The records available on Antietam Creek are rather few in number. A number of stations for sampling were established on the stream above and below Hagerstown. (See Fig. 1.)

From 1922 through 1924, 15 sets of samples were taken. They are monthly from September 1923 on. Only DO, $CO_2$ and pH analyses were run; there are no records of bacteria counts made. Of these samples, six were taken before the Hagerstown sewage was treated, and the remainder after the opening of the plant. In 1938 and 1939, five more sets of samples were taken from the creek and given chemical analysis. The 1922–1924 data are summaried in Table I.

TABLE I.—*Antietam Creek*

Summary of Chemical Analyses of Samples
(*a*) Before Treatment (1922–1924)

| Station | Dissolved Oxygen | | | | | | pH | | | $CO_2$, P.p.m. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P.p.m. | | | Per Cent Saturation | | | | | | | | |
| | Max. | Min. | Ave. | Max. | Min. | Ave. | Max. | Min. | Ave. | Max. | Min. | Ave. |
| 1 | 12.4 | 8.7 | 10.4 | 100.00 | 90.36 | 95.89 | 8.2 | 7.9 | 8.1 | 2.2 | 0.0 | 0.9 |
| 2 | 12.2 | 6.5 | 9.7 | 108.30 | 75.58 | 92.51 | 8.2 | 7.7 | 7.9 | 2.9 | 0.7 | 1.6 |
| 3 | 12.2 | 5.7 | 8.7 | 100.20 | 66.82 | 83.61 | 8.3 | 7.5 | 7.9 | 4.4 | 0.0 | 1.6 |
| 5 | 12.2 | 3.8 | 6.9 | 100.20 | 43.78 | 71.66 | 7.9 | 7.4 | 7.6 | 6.6 | 1.8 | 3.2 |
| 6 | 12.2 | 4.1 | 7.1 | 104.80 | 47.24 | 73.63 | 7.9 | 7.5 | 7.7 | 4.4 | 1.5 | 2.3 |
| 8 | 11.9 | 2.7 | 6.7 | 101.00 | 31.65 | 63.05 | 7.8 | 7.5 | 7.6 | 5.1 | 1.5 | 2.9 |
| 9 | 11.9 | 2.7 | 7.2 | 91.01 | 31.11 | 64.57 | 8.0 | 7.4 | 7.7 | 7.3 | 1.5 | 3.1 |
| (*b*) After Treatment (1924) | | | | | | | | | | | | |
| 1 | 13.80 | 8.73 | 10.52 | 104.60 | 92.74 | 97.19 | 8.3 | 7.6 | 8.1 | 10.0 | 0.0 | 2.4 |
| 2 | 13.80 | 8.39 | 10.49 | 102.89 | 90.12 | 97.68 | 8.4 | 8.3 | 8.1 | 10.0 | 0.6 | 2.9 |
| Marsh Run | 6.43 | 3.87 | 5.24 | 88.35 | 49.05 | 62.25 | 8.3 | 7.6 | 7.8 | 106.0 | 1.0 | 125.0 |
| 3 | 13.50 | 8.20 | 10.33 | 102.16 | 90.51 | 97.68 | 8.2 | 7.6 | 7.9 | 26.0 | 1.0 | 6.4 |
| 5 | 13.85 | 7.03 | 9.85 | 101.91 | 78.64 | 92.55 | 8.2 | 7.7 | 7.9 | 45.0 | 1.0 | 6.9 |
| 6 | 13.20 | 6.89 | 9.34 | 99.73 | 68.46 | 88.09 | 8.0 | 7.3 | 7.7 | 94.0 | 3.0 | 15.5 |
| 8 | 13.20 | 6.66 | 9.21 | 99.73 | 66.81 | 86.54 | 8.2 | 7.6 | 7.9 | 4.0 | 0.0 | 1.8 |
| 9 | 13.80 | 7.83 | 9.82 | 100.63 | 80.39 | 92.49 | 8.3 | 7.9 | 8.1 | 21.0 | 0.0 | 4.2 |

The sewage treatment plant discharges at the upper end of the backwater from the small mill dam at Funkstown. Stations 6, 7 and 8 are in this reach with station 8 just above the dam. Station 9 is just below the dam and station 10 several miles downstream at another small dam at Rose Mill. Stations 3, 4 and 5 are between Marsh Run and the sewage outfall. The other two stations are further upstream.

Two tributaries near Hagerstown have the name of Marsh Run. The larger one joins Antietam Creek north of the town while the smaller one drains a lake in a city park and runs just a short distance before emptying into Antietam Creek just below the Hagerstown Light & Power Company. It is this latter one that is referred to in this report.

This small rivulet is nothing more than an open drain receiving the storm water runoff of the city, some trade wastes and, originally, the sewage of Hagerstown.

Before treatment was provided the samples show a distinct drop in the D.O. content of the river below the outfall sewer and Marsh Run; although on occasion it was quite high—probably due to heavy rains increasing the dilution and turbulence. During this period the river is reported to have been in a very offensive condition and Funkstown threatened an injunction suit to prevent Hagerstown from discharging raw sewage into Antietam Creek.

After treatment was inaugurated in 1924, the monthly samples show a distinct improvement in D.O. at the stations below the outfall. The lowest recorded was 6.66 p.p.m. compared to a low of 2.7 p.p.m. at the same station before treatment. At this time the plant was treating 750,000 gallons per day of sewage.

In 1938 and 1939 the plant was treating about 3 m.g.d. by the activated sludge process from about April 1 to November 1; and only by clarification, because of greater dilution, during the winter months. There were complaints at this time from Funkstown residents about odors in the stream. A midsummer sample shows a rather low D.O. here, but also low B.O.D., pointing to bad bottom conditions. These septic conditions during warm weather were undoubtedly due to the accumulation behind the dam during the winter months of the solids in the primary treated sewage effluent. Generally however, these records show a distinct improvement in the stream below the treatment plant and the plant superintendent states that he only received complaints from Funkstown once since 1933.

Judged solely by these meager data and from local testimony it may be said that the treatment plant improved the oxygen content and the physical conditions below the sewer outlet at the time it was put in; since the quantity of sewage has quadrupled in the last 19 years it has decidedly protected the streams against worse pollution and certain litigation.

The plant is operated by a conscientious superintendent who is interested in turning out the best possible effluent.

## Belair

Belair, the county seat of Harford County, has a population of 1,885 (1940 census). Prior to 1934, there was no sewerage, domestic sewage being disposed of in cesspools and septic tanks. In 1934 the town laid sewers and built a sewage treatment plant. The treatment consists of primary sedimentation in an Imhoff tank, a trickling filter of the fixed nozzle type, a secondary Imhoff tank, chlorination and a chlorination detention basin. The plant was completed and put in operation October 1934.

The final effluent is discharged into Bynum Run (Fig. 2), a small stream having a watershed of 12.71 square miles. The whole length of this stream from its source to its mouth is in Harford County. The stream empties into the upper end of Bush River, a tidal estuary of Chesapeake Bay. Bynum Run is a small country stream running through farm lands and woods and receiving only their drainage. Except for the usual rural contamination it was apparently an unpolluted stream.

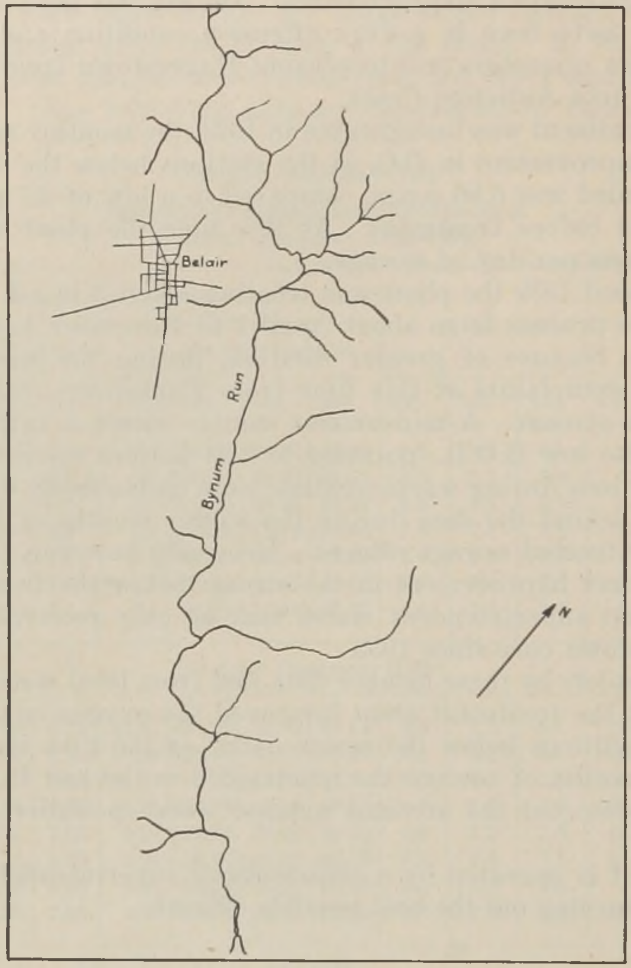


FIG. 2.—Belair and Bynum Run. 1″ = 2 mi.

The flow of Bynum Run at the sewage outfall can only be roughly estimated, since no gauging station exists along its course. Assuming a daily average runoff equal to that of nearby Deer Creek (0.8 m.g.d. per square mile of watershed) and a watershed at this point 8 square miles the daily flow would average about 6.4 m.g.d. With the ordinary quantity of sewage from a town of 2,000 people, this would give a dilution ratio of 1 : 32. The frequent, below average flows, of course, make this dilution even lower.

In the period 1934 to 1937 there was an average of four months a year in which the daily average runoff from the Deer Creek watershed was below 0.7 m.g.d. per square mile of watershed, the lowest daily average being 0.290 m.g.d. The daily minimum for these varied from 0.226 to 0.349 m.g.d. per square mile, and during the drought year 1931 as little as 0.089 was recorded one day (3). The designed degree of treatment was, therefore, required.

The records of the Maryland State Department of Health begin in 1935 after the completion of the plant. The samples have been taken at more or less irregular periods both below and above the point of discharge of the plant effluent. These samples were for bacteriological and chemical examination. The former were given usually the presumptive and confirmed tests for the coli-aerogenes group of organisms, and a number were given the completed test for *Escherichia coli.* The chemical examinations are for nitrogen as nitrates, biochemical oxygen demand color, turbidity and pH.

Although no records could be found before Bynum Run was used to carry away the sewage, the samples upstream should give a fair indication of what the conditions were in the remainder of its length since there are no waste discharges either up or downstream.

TABLE II.—*Summary of Analytical Results on Bynum Run Above and Below Belair Sewage Treatment Plant*

| | | B.O.D. (P.p.m.) | | | Coliform (M.P.N.) | |
|---|---|---|---|---|---|---|
| | | Max. | Min. | Ave. | Max. | Min. |
| 1936 | Above | 20 | 1.0 | 4.5 | 24,000 | 240 |
| | Below | 52 | 3.0 | 14.2 | 2,400 | 0 |
| 1937 | Above | 2.8 | 0 | 1.7 | 24,000 | 38 |
| | Below | 6.2 | 1.0 | 3.4 | 15 | 0 |
| 1938 | Above | 8.0 | 0.2 | 4.1 | 240,000 | 27 |
| | Below | 22 | 0.0 | 5.6 | 24,000 | 0 |
| 1939 | Above | 6.7 | 1.5 | 4.1 | 24,000 | 240 |
| | Below | 6.2 | 1.7 | 4.2 | 2,400 | 38 |
| 1940 | Above | | | 9.0 | 24,000 | 190 |
| | Below | | | 9.0 | 24,000 | 0 |
| 1941 | Above | 5.1 | 0.7 | 2.6 | 2,400 | — |
| | Below | 7.2 | 2.8 | 5.4 | | |
| 1942 | Above | 2.3 | 1.5 | 1.8 | | |
| | Below | 5.6 | 4.4 | 4.9 | | |

Table II summarizes the results of the B.O.D.; and of the confirmed test for the coliform organisms computed as most probable numbers per 100 ml. (M.P.N.). The upstream samples were with few exceptions taken 50 feet above the outfall while the downstream samples were usually 500 feet below.

The treatment plant was put in operation during October, 1934. The operation of the sewage works at Belair is only a part of the work of one of the city employees and it is often neglected for other duties. This neglect was especially apparent in the first years of operation. Health department memoranda indicate trouble with the chlorinator, clogged filter nozzles and bad physical conditions in the stream.

There were several complaints from some farmers and one threatened and eventually brought a lawsuit to court. The case was finally settled in 1937 when the court awarded the plaintiff $1,400. The threat of a lawsuit brought about better operation toward the end of 1936, and good operation was noted by health department engineers in the following years. However, in 1940 and 1941 the sanitary engineer several times reported bad conditions existing in the stream. Fallen trees and shrubs frequently dam the stream after heavy storms and sometimes sleek, scum and foam are found in the pooled water.

The records show that there are times when the plant improves the B.O.D. of the stream, four such occasions being noted downstream. The high coliform counts above the plant are probably due to cattle and barnyard washings brought down by rain. Below the plant the results show the effect of chlorination of the effluent, often with sufficient dosage to show a residual 500 feet downstream of 0.1 and 0.2 p.p.m. This dosage several times caused an absence of coli-aerogenes bacteria in the samples. When the plant is operating well, the stream is described as crystal clear above and below the outfall.

A sewage treatment plant of this type might be described as self-operating and one which requires a minimum of supervision. There are no moving mechanical parts that may easily fail except in the chlorinator. Yet even this type of treatment requires some attention. Foaming may sometimes occur in the Imhoff tanks and this is indicative of undesirable bacterial digestion. Solids passing through the settling tanks will clog the nozzles, throwing a greater burden on the unclogged nozzles, which then overwork their areas of filter material and defeat the purpose of the trickling filter. The chlorinators require the greatest attention but they do hold up remarkably well. All of these conditions can be corrected rather easily and none of them should take much time. The operator can and perhaps preferably should have other duties but he must realize the function and importance of sewage treatment; he must realize that the plant should always be kept in good operating condition otherwise the taxpayers' money is being wasted.

In Belair it appears that there have been times when the plant was neglected and the policing by the State Health Department was necessary to bring better operation. The value of the Department of Sanitary Engineering is obviously demonstrated in a case of this kind. The damages paid as the result of the lawsuit, whether completely justified or not, show the vigilance necessary to prevent such unnecessary waste of money.

## Annapolis

Annapolis, a city of about 13,000 inhabitants, is the capital of Maryland and seat of the U. S. Naval Academy. It is one of the oldest cities in the United States and at one time was the governmental and social center of the country. It lies on the south shore near the mouth of the Severn River. The Severn is a broad tidal estuary of the Chesapeake and is a favorite recreational area of Marylanders. Swimming, fishing, crabbing and boating are prevalent all along its reaches and its shores are spotted with public beaches and private summer homes.

Annapolis proper is situated between two tidal indentations: Spa Creek and College Creek. As the town developed sewers were laid on various streets independently and each one discharged into the body of water which terminated the street. In 1934, there were 49 sewer outlets running into Spa and College Creeks and the Severn River. These sewers also carried roof and street drainage. By this time (1934) most of the buildings in the city were connected to the sewers and the waters were so polluted that they were noticeably malodorous in warm weather, besides always containing floating matter of obvious sewage origin. For 20 years various groups agitated for corrective measures and finally, in 1933, plans and specifications were drawn up for an intercepting sewer and a sewage treatment plant. All of the old sewers were intercepted including those in the Naval Academy grounds and two outlets from the City of Eastport across Spa Creek from Annapolis. Storm water drains were separated from the domestic sewerage and this drainage still discharges into the harbor waters. The collected sewage is received by gravity at a pumping station in Eastport, whence, after chlorination, it is pumped through an underwater force main across Back Creek to the treatment plant, a distance of about one mile. The treatment works consists of two 150,000-gallon clarifiers with sludge removal and grease skimming mechanisms, two 180,000-gallon fixed cover digesters with gas collectors and heating coil systems, vacumm sludge filtering system and a fully equipped control laboratory. The capacity is 3 m.g.d. The effluent is discharged into the Severn about 3,000 feet offshore (4, 5).

The location of the sewage outlet was determined by float tests. The object was to locate it in such a way that the sewage was carried away from the south shore by the tidal currents.

The State Department of Health established 55 sampling stations in the creeks and the river in 1931 (Fig. 3), and since then eight sets of samples have been taken. Of this number, four were taken before the modernization of the system, *i.e.*, prior to 1934, and four after. Stations 56 to 62 were added in 1939 to determine the quality of the water in the vicinity of Annapolis Roads, a bathing club, and the effect in the river around the outlet. These samples were given the confirmed test for coliform organisms and a number of times analyzed for dissolved oxygen content.

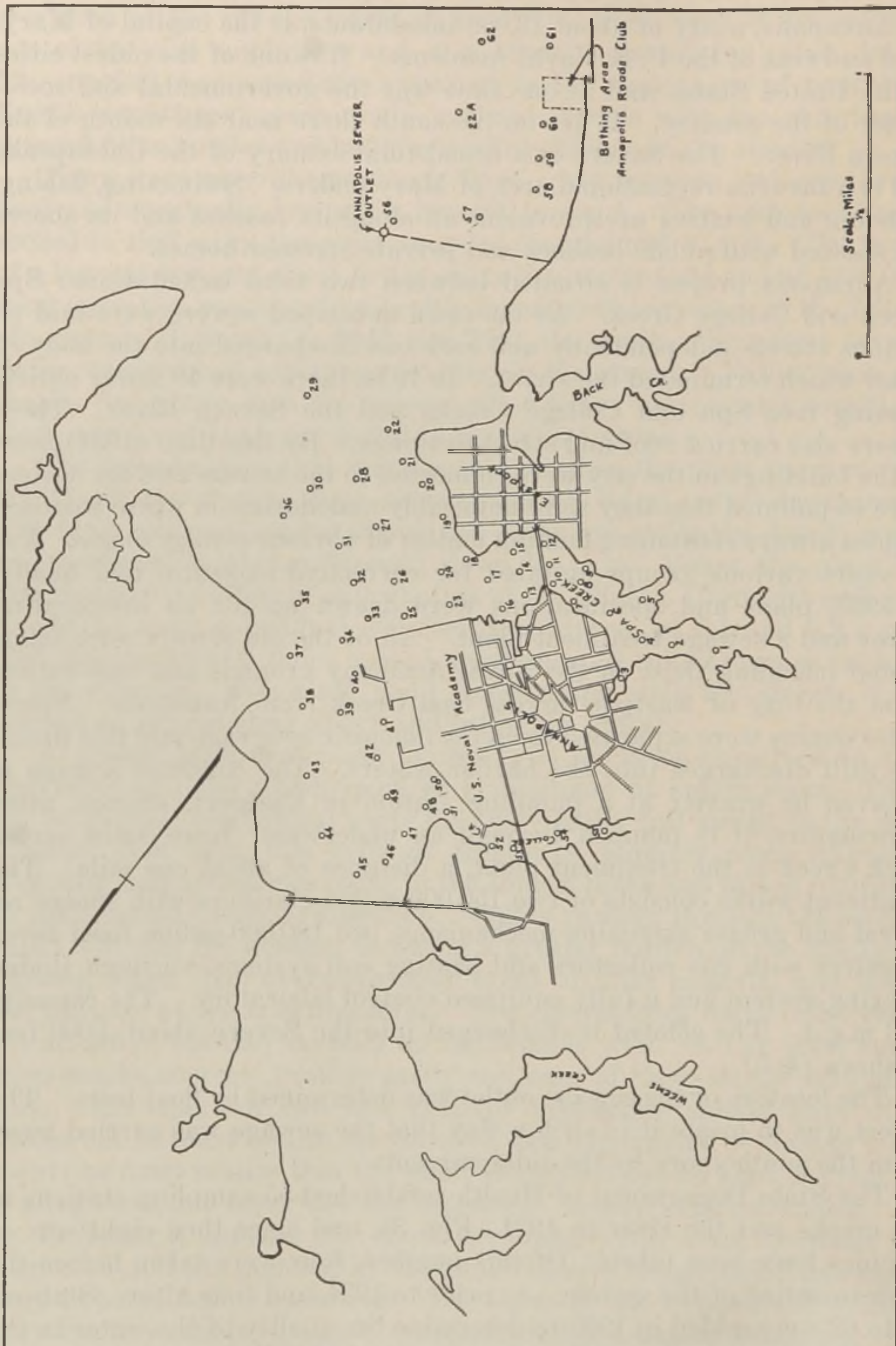


FIG. 3.—Annapolis Harbor and vicinity.

Usually ebb tide samples were taken on one day and flood tide samples the following day. A wide variation in bacteriological results will be noted for most of the stations for each tide both before and after treatment. This is particularly apparent on July 26, and 27, 1932, when flood tide samples were taken both days. The results would be expected to be fairly close together but in a good many cases they are not. This lack of consistency may be accounted for by the difference in the hours of collection at each station and by the lack of accuracy which is characteristic of grab samples. Generally speaking, however, the polluted sections are apparent even though they vary greatly from an average number.

The results (summarized in Table III) show that under the old sewerage system the two creeks were badly polluted bacterially, although

TABLE III.—*Maximum and Minimum Recorded M.P.N. of Coliform Bacteria in Severn River Before and After the Inauguration of Sewage Treatment at Annapolis*

| Station | Ebb Tide | | | | Flood Tide | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum | | Minimum | | Maximum | | Minimum | |
| | Before Treatment | After Treatment | Before Treatment | After Treatment | Before Treatment | After Treatment | Before Treatment | After Treatment |
| 1 | 2,400,000+ | 240 | 2,400 | 240 | 24,000 | 2,400 | 2,400 | 240 |
| 2 | 2,400,000+ | 38 | 9,400 | 38 | 24,000 | 240 | 24,000 | 240 |
| 3 | 2,400 | 240 | 2,400 | 240 | 240,000 | 24,000 | 24,000 | 240 |
| 4 | 2,400,000 | 2,400 | 2,400 | 38 | 24,000 | 2,400 | 24,000 | 240 |
| 5 | 240,000 | 240 | 2,400 | 240 | 240,000 | 240 | 24,000 | 38 |
| 6 | 2,400,000 | 38 | 2,400 | 38 | 190,000 | 240 | 24,000 | 240 |
| 7 | 2,400,000+ | 2,400 | 2,400,000 | 2,400 | 2,400,000 | 240 | 2,400 | 240 |
| 8 | 240,000 | 240 | 2,400 | 240 | 24,000 | 24,000+ | 24,000 | 240 |
| 9 | 240,000 | 24,000+ | 2,400 | 24,000+ | 24,000 | 2,400 | 2,400 | 240 |
| 10 | 240,000 | 240 | 2,400 | 240 | 24,000 | 2,400 | 2,400 | 38 |
| 11 | 24,000+ | 2,400 | 2,400 | 240 | 24,000 | 240 | 240 | 38 |
| 12 | 240,000 | 240 | 2,400 | 240 | 24,000 | 2,400+ | 2,400 | 240 |
| 13 | 190,000 | 38 | 2,400 | 38 | 24,000 | 2,400 | 2,400 | 38 |
| 14 | 2,400,000+ | 38 | 24,000 | 38 | 240,000 | 2,400 | 24,000 | 240 |
| 15 | 950,000 | 2,400 | 2,400 | 2,400 | 240,000 | 240 | 2,400 | 240 |
| 16 | 2,400,000+ | 2,400 | 24,000 | 2,400 | 240,000 | 2,400+ | 240,000 | 2,400 |
| 17 | 95,000 | 24,000+ | 24,000 | 240 | 240,000 | 2,400+ | 2,400 | 240 |
| 18 | 2,400,000+ | 2,400 | 24,000 | 2,400 | 24,000 | 240 | 24,000 | 240 |
| 19 | 95,000 | 24,000+ | 9 | 240 | 24,000 | 240 | 2,400 | 240 |
| 20 | 24,000 | 2,400 | 240 | 240 | 24,000 | 2,400 | 240 | 38 |
| 21 | 95,000 | 240 | 240 | 240 | 2,400 | 240 | 240 | 38 |
| 22 | 240,000 | 2,400 | 240 | 240 | 240 | 2,400 | 240 | 38 |
| 22A | — | 24,000+ | — | 240 | — | 2,400 | — | 5 |
| 23 | 240,000 | 240 | 2,400 | 240 | 2,400 | 2,400+ | 2,400 | 240 |
| 24 | 24,000 | 24,000+ | 23 | 240 | 2,400 | 950 | 2,400 | 38 |
| 25 | 24,000 | 24,000 | 2,400 | 240 | 2,400 | 240 | 2,400 | 38 |
| 26 | 24,000 | 240 | 23 | 38 | 2,400 | 240 | 2,400 | 38 |
| 27 | 2,400 | 24,000 | 240 | 38 | 240 | 240 | 38 | 38 |
| 28 | 2,400 | 38 | 0 | 9 | 2,400 | 240 | 240 | 240 |
| 29 | 2,400 | 2,400 | 240 | 38 | 240 | 24,000+ | 38 | 5 |
| 30 | 2,400 | 2,400 | 23 | 38 | 2,400 | 24,000+ | 240 | 0 |

TABLE III.—(*Continued*)

| Station | Ebb Tide | | | | Flood Tide | | | |
|---|---|---|---|---|---|---|---|---|
| | Maximum | | Minimum | | Maximum | | Minimum | |
| | Before Treatment | After Treatment | Before Treatment | After Treatment | Before Treatment | After Treatment | Before Treatment | After Treatment |
| 31 | 2,400 | 38 | 240 | 9 | 240 | 240 | 23 | 2 |
| 32 | 2,400 | 240 | 240 | 15 | 2,400 | 240 | 240 | 38 |
| 33 | 2,400 | 240 | 240 | 38 | 2,400 | 240 | 240 | 5 |
| 34 | 240 | 2,400+ | 230 | 5 | 240 | 240 | 240 | 12 |
| 35 | 2,400 | 240 | 230 | 8 | 2,400 | 240 | 23 | 0 |
| 36 | 2,400 | 38 | 230 | 2 | 240 | 38 | 23 | 2 |
| 37 | 2,400 | 240 | 23 | 15 | 240 | 240 | 0 | 5 |
| 38 | 2,400 | 2,400 | 23 | 38 | 240 | 2,400 | 240 | 2 |
| 39 | 230 | 38 | 23 | 9 | 2,400 | 2,400 | 240 | 240 |
| 40 | 2,400 | 240 | 230 | 5 | 2,400 | 240 | 38 | 38 |
| 41 | 2,400 | 38 | 240 | 9 | 24,000 | 38 | 950 | 38 |
| 42 | 24,000 | 240 | 240 | 38 | 2,400 | 240 | 240 | 9 |
| 43 | 2,400 | 38 | 230 | 38 | 240 | 38 | 240 | 2 |
| 44 | 230 | 240 | 23 | 15 | 240 | 2,400 | 23 | 5 |
| 45 | 2,400 | 38 | 230 | 9 | 2,400 | 38 | 38 | 5 |
| 46 | 2,400 | 38 | 23 | 38 | 38 | 2,400 | 23 | 38 |
| 47 | 24,000 | 240 | 240 | 38 | 240 | 240 | 23 | 12 |
| 48 | 24,000 | 240 | 240 | 9 | 240 | 240 | 23 | 5 |
| 49 | 2,400 | 38 | 230 | 15 | 2,400 | 38 | 240 | 15 |
| 50 | 240,000 | 240 | 24,000 | 240 | 240,000 | 2,400 | 2,400 | 38 |
| 51 | 24,000 | 2,400 | 240 | 240 | 2,400 | 240 | 2,400 | 38 |
| 52 | 9,000 | 38 | 240 | 38 | 2,400 | 240 | 2,400 | 38 |
| 53 | 2,400,000 | 2,400 | 2,400 | 38 | 2,400 | 240 | 2,400 | 21 |
| 54 | 2,400,000 | 2,400 | 24,000 | 240 | 2,400 | 240 | 2,400 | 38 |
| 55 | 240,000 | 240 | 24,000 | 240 | 950,000 | 240 | 950,000 | 38 |
| 56 | — | 24,000+ | — | 240 | — | 2,400 | — | 240 |
| 57 | — | 24,000 | — | 240 | — | 240 | — | 240 |
| 58 | — | 2,400 | — | 38 | — | 24,000+ | — | 240 |
| 59 | — | 2,400 | — | 240 | — | 240 | — | 240 |
| 60 | — | 240 | — | 38 | — | 240 | — | 38 |
| 61 | — | 240 | — | 38 | — | 24,000+ | — | 240 |
| 62 | — | 240 | — | 15 | — | 240 | — | 38 |

maintaining a high oxygen content. Physically, the creeks were almost disgraceful, especially at the headwaters and around the city docks where five sewers discharged. Fecal matter and other sewage material floated on the surface.

Stations 1 to 18 are in Spa Creek. Under the original system the lowest coliform index on the flood tide was 240 per 100 ml. at station 11 and this occurred in the spring. It is the only station in the creek having this low number. On the ebb tide, with the exception of station 3 where the indicated 0 is obviously erroneous, the lowest recorded number of coli-aerogenes bacteria is 2,400 per 100 ml. The highest M.P.N. on both tides was over 2,400,000. This figure occurs more frequently and at more stations in the creek on the ebb than the flood tide as would be expected since there is a negligible amount of fresh diluting water in this indentation. After the new system was put in operation the bacterial results show decided improvement at all points in Spa Creek, the highest coliform count being above 24,000 which was never recorded at more than two stations in a set of readings.

In College Creek the situation was not quite as bad physically as there were fewer sewer outlets. However, bacterially, the samples from stations 53, 54, and 55 in this creek show gross pollution under the original system and the greatest pollution again occurred on ebb tide. The improvement in conditions is shown by the figures for coliform bacteria and from the general physical appearance.

Out in the Severn River because of the large body of water, the greater effect of tides on dilution and the fact that most of the sewer outlets were in the creeks, the pollution was not as bad. The highest M.P.N. was 240,000 and this figure was only recorded at two stations (22 and 23) both taken the same day on ebb tide. The higher counts occur in the vicinity of the creek mouths and near the sewer outlets from the U. S. Naval Academy.

After the new system had been put into operation there was a notable bacteriological improvement at all stations, particularly in the upper reaches of the creeks. There are counts as high as 24,000 per 100 ml., which can probably be explained by the fact that storm water drains still empty into the waters untreated and these drains always carry a certain amount of pollution.

Station 56 was established just downstream from the new sewer outlet. The two coliform samples show no gross pollution although on one ebb tide there is fairly heavy contamination.

Stations 58, 59, 60 and 61 offshore from the Annapolis Roads Club have counts that vary greatly. Station 60 closest to the bathing areas has the lowest count for the two samples, the highest M.P.N. being 240 per 100 ml. It will be noted that this is above the 100 per 100 ml. recommended by many health departments, but well under the 1,000 per 100 ml. that other health officials will accept as safe.

Table III summarizes the maximum and minimum coliform counts at the various stations that were recorded under the old and the new sewerage systems. Figures 4, 5, 6 and 7 attempt to show graphically the improvements in the harbor waters. Figures 4 and 6 show conditions before treatment on the ebb and flood tides respectively, and Figs. 5 and 7 are the maximum counts recorded after treatment was inaugurated on the two tides.

Although only two sets were taken during the period, the dissolved oxygen samples show that even when the sewers discharged raw sewage, the D.O. was high. After interception and treatment the lowest D.O. recorded was 5.7 p.p.m. at station 40 which is in the Severn River and station 48 at the mouth of College Creek. The date was August 8th, when the temperature of the water was 27° C. With a chloride content of 5,000 p.p.m. this would be 74.3 per cent of saturation. The river is frequently supersaturated with oxygen and none of the samples show any danger to fish life nor sufficient depletion to cause a nuisance.

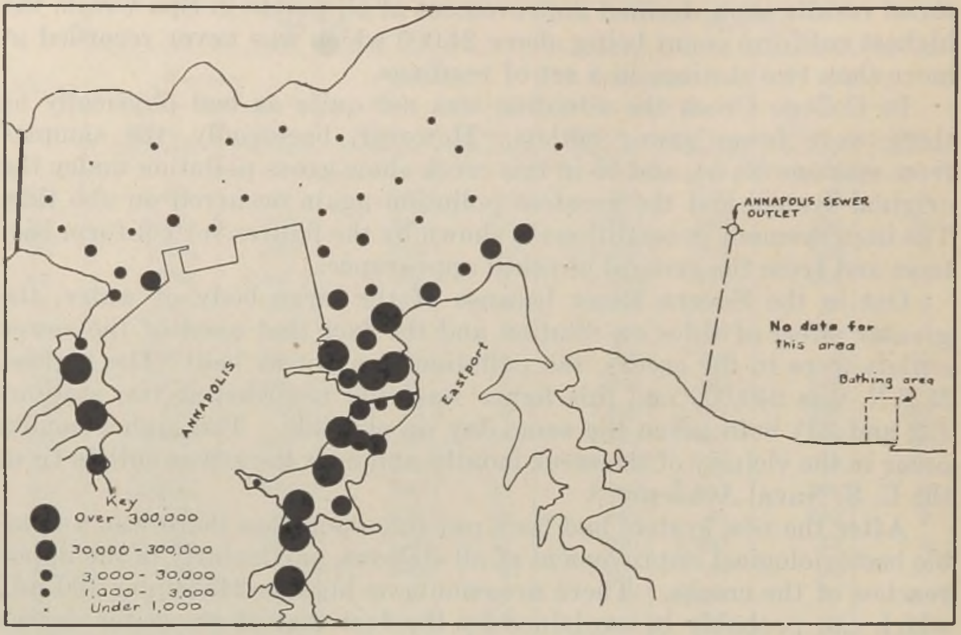


FIG. 4.—Annapolis maximum coliform indices before treatment, ebb tide.

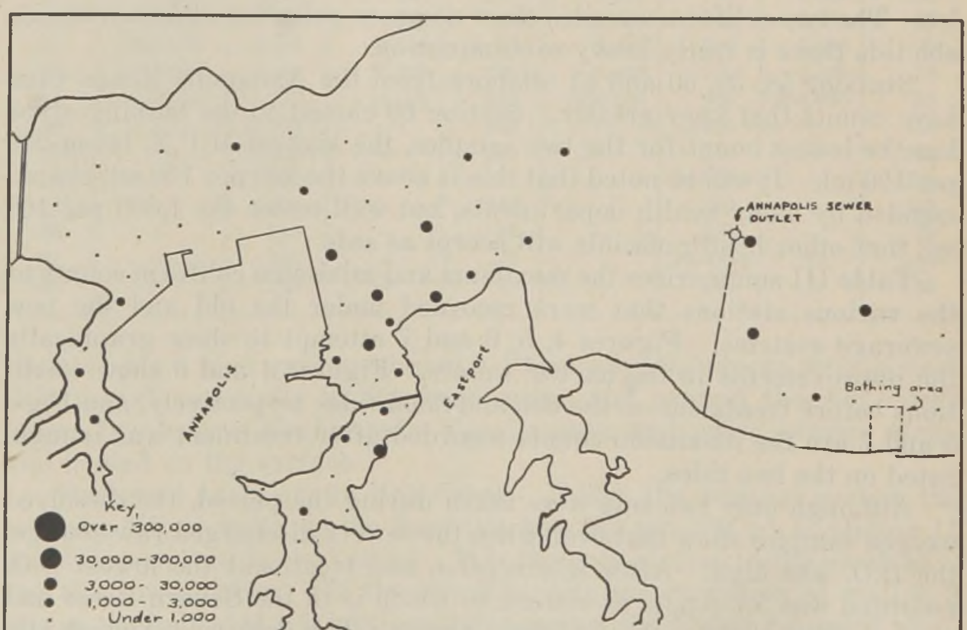


FIG. 5.—Annapoils maximum coliform indices after treatment, ebb tide.

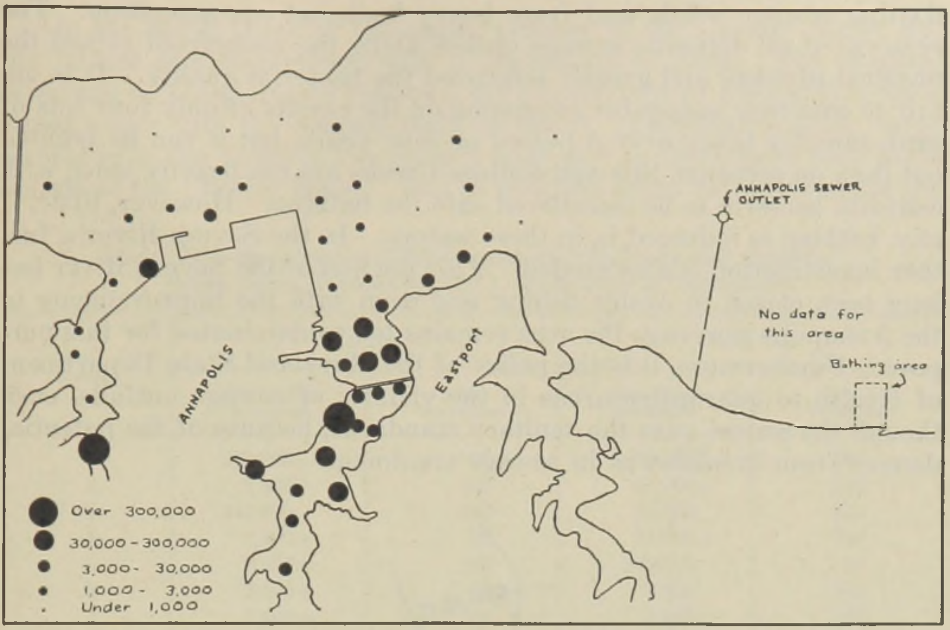


FIG. 6.—Annapolis maximum coliform indices before treatment, flood tide.

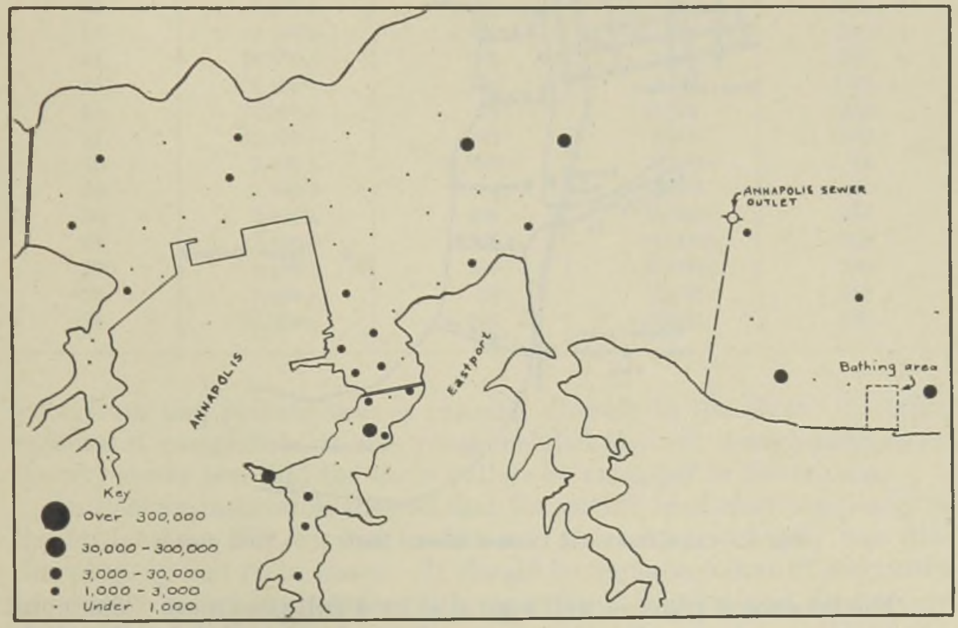


FIG. 7.—Annapolis maximum coliform indices after treatment, flood tide.

The greatest nuisances in the waters around Annapolis were from floating sewage solids and from heavy bacterial contamination. The removal of all domestic sewage outlets along the waterfront solved the physical problem and greatly improved the bacterial quality. It is unfair to condemn waters for swimming on the results of only four sets of grab samples taken over a period of four years, but it can be pointed out that, on occasion, Spa and College Creeks are too heavily laden with coliform bacteria to be considered safe for bathing. However, little, if any, bathing is indulged in in these waters. In the Severn River a further investigation is also needed. This portion of the Severn River has long been closed to oyster fishing and even with the improvements to the Annapolis sewerage the area remains too contaminated for this purpose. Furthermore, it is the policy of the Maryland State Department of Health to quarantine areas in the vicinity of sewage outfalls, even though the waters pass the sanitary standards, because of the potential danger from breakdowns in sewage treatment.

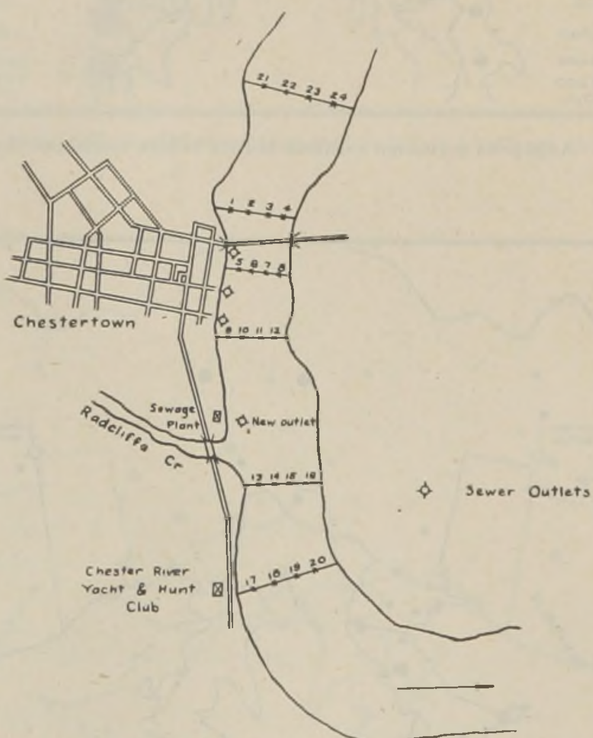


FIG. 8.—Chestertown and Chester River. Scale 1″ = 3300′ approx.

The treatment plant is well operated by a full time man. The point of discharge of the effluent can sometimes be detected by the slight disturbance of the water but there are no physical nuisances from it and the bacterial counts in the vicinity are remarkably low. D.O. content is likewise good.

## Chestertown

On the north shore of the upper reaches of the Chester River lies the village of Chestertown, with a population of 2,800. The original sewerage of Chestertown followed the old pattern of discharging each street sewer into the nearest body of water. Fortunately, only three streets here run down to the water's edge and so there were only three outlets in the Chester River. But in addition many residents along the

Table IV.—*Comparison of Coliform Index After Treatment with Maximum Counts Before Treatment (M.P.N.), Chester River at Chestertown*

| Station | Ebb Tide | | Flood Tide | |
|---|---|---|---|---|
| | Max. Before Treatment | After Treatment | Max. Before Treatment | After Treatment |
| 1 | 240,000 | 38 | 24,000+ | 240 |
| 2 | 2,400+ | 240 | 24,000+ | 240 |
| 3 | 240,000 | 240 | 24,000 | 240 |
| 4 | 2,400+ | 38 | 24,000+ | 240 |
| 5 | 2,400+ | 240 | 240,000 | 38 |
| 6 | 2,400+ | 96 | 2,400 | 240 |
| 7 | 2,400+ | 240 | 2,400 | 240 |
| 8 | 2,400+ | 240 | 2,400 | 240 |
| 9 | 240,000 | 2,400 | 24,000,000 | 240 |
| 10 | 240,000 | 38 | 2,400 | 240 |
| 11 | 2,400+ | 38 | 24,000+ | 240 |
| 12 | 2,400+ | 2,400 | 24,000 | 240 |
| 13 | 2,400+ | 2,400 | 24,000+ | 240 |
| 14 | 24,000+ | 240 | 2,400 | 240 |
| 15 | 2,400+ | 240 | 2,400 | 240 |
| 16 | 24,000+ | 38 | 24,000 | 240 |
| 17 | 2,400+ | 240 | 2,400 | 240 |
| 18 | 2,400+ | 24,000+ | 2,400+ | 12 |
| 19 | 2,400+ | 38 | 2,400 | 240 |
| 20 | 2,400+ | 240 | 24,000+ | 240 |
| 21 | 2,400+ | 240 | 24,000+ | 240 |
| 22 | 2,400+ | 240 | 24,000+ | 240 |
| 23 | 2,400+ | 38 | 2,400 | 240 |
| 24 | 24,000+ | 240 | 24,000 | 240 |

waterfront had private sewers running directly to the river. In 1925, because of complaints, it was recommended that all sewers connect to the city sewer and that the three outlets be extended to the channel.

In 1929 an inspection showed that the outfall in closest proximity to the bridge (see Fig. 8) was broken and the sewage actually was discharging six feet from shore. It should be explained that Chestertown becomes a resort in summer with swimming, boating and fishing are concentrated in this area.

The waterfront residents and other public spirited citizens, with the encouragement of the State Department of Health, attempted for years to convince the city of the need for relieving the obnoxious conditions on the city's front doorstep. But apathy on the part of local government and objections to spending money for such purposes by the uptown residents kept the river in a polluted condition in the vicinity of the three outlets until 1939.

In 1938 the State Department of Health finally convinced the populace that the situation should no longer be tolerated and in September, 1939, a treatment plant was completed and put in operation. Extensions to the sewerage system were made and an interceptor eliminated the old outlets and carried all of the sewage to the new plant about a half-mile downstream. Here the sewage receives plain sedimentation,

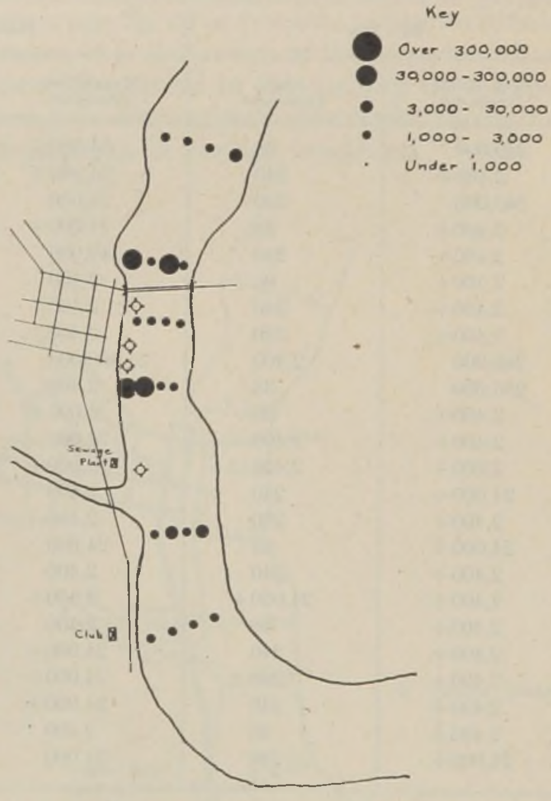


FIG. 9.—Chestertown maximum coliform indices before treatment, ebb tide.

separate digestion and chlorination. The digested sludge is discharged in the effluent pipe to the river.

The first systematic health department records on the river begin in 1931, when 20 stations were established. These sampling stations are in five cross sectional groups of four each (Fig. 8). Later in the year another cross sectional group was added upstream from the original set (stations 21 to 24).

After the establishment of the stations, three sets of samples on the ebb and the flood tides were taken in 1931. None are on record again until 1934 when two sets were taken; then in 1938 one more. All of these are prior to the installation of the new system. Since the modernization, only one set of samples has been examined.

The results of the analyses (Table IV) show a singular lack of consistency. Station 5, which one would expect to have the highest coliform count on either tide, frequently shows an unpolluted condition. Yet on days when the bacteria count was low, the physical description of the river was bad. On June 27, 1934, for instance, the ebb tide shows maximum M.P.N.'s of 2,400 at stations 1, 2, 9 and 14, all other stations have much lower counts; yet the memorandum for this day states that conditions on the surface were objectionable near the three

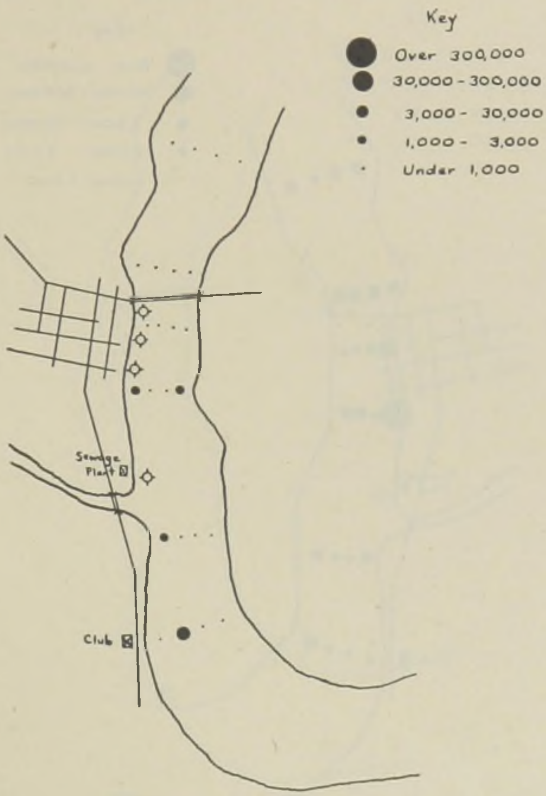


FIG. 10.—Chestertown maximum coliform indices after treatment, ebb tide.

outlets. The dissolved oxygen in the river on this day was sufficiently high; the lowest being 73.1 per cent of saturation. Nevertheless, the bacteriological data do show periods of heavy pollution and the greatest counts are usually on the Chestertown side of the river, in the vicinity of the older sewer outlets (Stations 1 and 2, 5 and 6 and 9 and 10). The downstream stations (13 to 20) would also get the effect of Radcliffe Creek, which until 1933 received skimmed milk, canning wastes and tar wastes from the municipal gas plant. These wastes would not affect the coliform counts, but would cause an oxygen depletion. Since the dissolved oxygen content is high at all times in the river, the waste nuisance would seem to have been confined to the creek. By 1933, due to complaints, tar was no longer wasted to Radcliffe Creek, skim milk rarely and the canning wastes were not considered objectionable.

After the new plant was completed the only set of samples taken shows a good bacteriological condition throughout the river. Table IV shows a comparison of this set with former maximum M.P.N.'s. And these results are shown graphically in Figs. 9, 10, 11 and 12. Figures 9 and 11 show the former maximum coliform counts recorded on the ebb and the flood tides respectively, and Figs. 10 and 12 show the results of the last set of samples taken on each tide. However, in the several

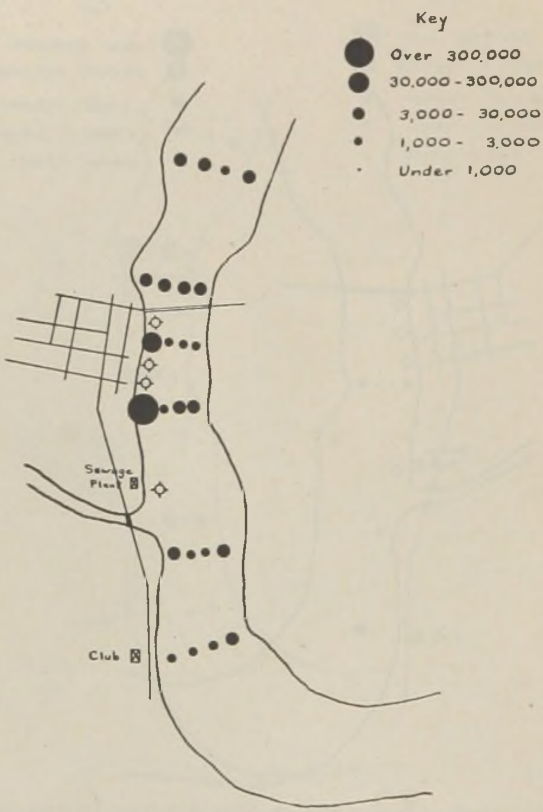


FIG. 11.—Chestertown maximum coliform indices before treatment, flood tide.

periodic inspections by the State sanitary engineers there is not infrequent evidence of poor operation of the treatment plant. For several months after the plant was put in operation, no chlorine was used, although chlorination of the effluent was considered essential. After chlorination was finally applied the chlorinator was usually operating faultily or shut down because it was not running satisfactorily. On two inspection trips the engineer found the operator absent and each time there were heavy accumulations of grease and scum at the discharge end of the clarifier. Once considerable solid matter was going over the outlet wier. On July 17, 1940, when the samples were taken for bacterial and D.O. tests the plant was in good working order. One of the State engineers noted that although the physical discharge of the effluent was noticeable in the river, it was entirely unobjectionable; neither grease nor floating solids were present.

The new sewerage layout eliminated the esthetic nuisance of floating solids along the shore front of Chestertown and relieved the public health menace. However, the new outlet, about a half mile downstream, can prove a nuisance in that area if the treatment works are not operating properly. If just one set of samples can be used as a criterion, it

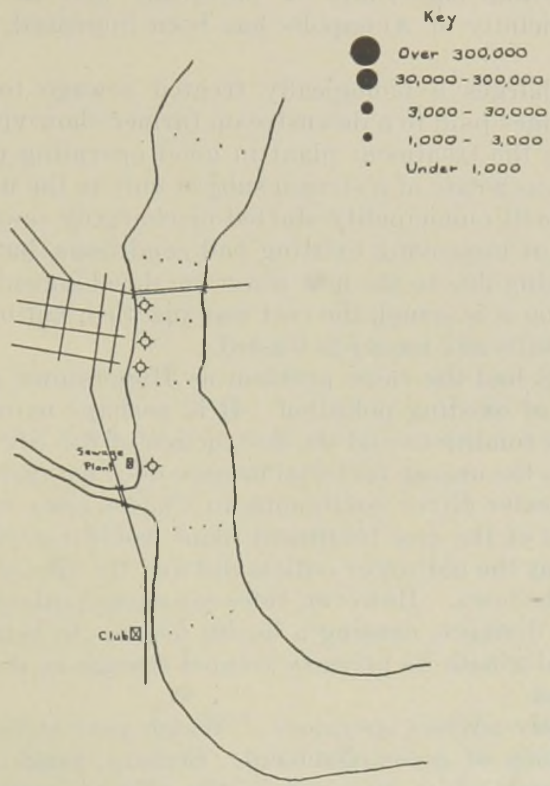


FIG. 12.—Chestertown maximum coliform indices after treatment, flood tide.

can be said that the river is generally safe for bathing as long as the plant operation is good. The only high coliform counts were at stations 9, 12, 13 and 18 on the ebb tide and, except at station 18, they are not excessive. The D.O. content was never a problem, since it was always high enough to support fish life.

## CONCLUSIONS

Summing up the data, it can be said that in the large towns of Annapolis and Hagerstown the treatment performs the function for which it was designed because of the employment of competent full time operators. In the smaller towns of Chestertown and Belair, there are not infrequent evidences of neglect. Small towns do not pay a good full time operator and they are faced with the problem of employing one on a small salary or using a part time man. It would be dogmatic to say that one is more desirable than the other. Either situation can be good or bad depending on the man.

Hagerstown uses a high degree of treatment and frequently turns out an effluent better than the stream into which it discharges. Annapolis, having only primary treatment, discharges into a body of water that furnishes ample dilution. Its effect on the receiving water is not particularly noticeable bacterially or physically and the whole Severn River in the vicinity of Annapolis has been improved, notably in the creeks.

Belair discharges a biologically treated sewage to a very small stream. Damages paid to a downstream farmer show vividly the necessity of keeping the treatment plant in good operating condition at all times. Here was a case of a stream subject only to the usual rural uses, into which a small municipality started discharging sewage. This was not a problem of improving existing bad conditions, but of preventing them from arising due to the new sewerage development. The method of accomplishing it is sound, the cost was justified, but neglect so easily nullifies the results and money is wasted.

Chestertown had the same problem as Hagerstown and Annapolis, the correction of existing pollution. It is perhaps natural that physically obnoxious conditions and the destruction of fish life will arouse the public, whereas the unseen bacterial menace does not cause so much concern. The Chester River contiguous to Chestertown was cleaned up. Poor operation of the new treatment plant would not visibly dirty the river as much as the old sewer outlets did and the site of the new outlet is away from the town. However, tides can carry pathogenic organisms a considerable distance, causing a health menace to bathers. Chestertown should chlorinate its primary treated sewage as designed, but too often it does not.

Streeter aptly advises operators: ''Watch your streams. They are the final criterion of accomplishment. Screens, tanks and filters are means to an end, which lies, not in the effluent conduit, but in the stream'' (6).

## Acknowledgments

The writer is indebted to Mr. George L. Hall, Chief Engineer of the Maryland State Department of Health, for all the data, and for the map of Annapolis and Chestertown.

Doctor Abel Wolman, Professor of Sanitary Engineering of The Johns Hopkins University, is responsible for the direction of this investigation.

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# THE OPERATOR'S CORNER

## SOMETHING NEW IS ADDED

In line with our constant endeavor to furnish the best available operation material in the JOURNAL, we take much pleasure in announcing that arrangements have been completed for three regular features of *The Operator's Corner* to be handled by a trio of outstanding men.

LeRoy W. Van Kleeck, Senior Sanitary Engineer of the Connecticut State Department of Health, will begin with an early issue to conduct the "Interesting Extracts from Operation Reports" section. Mr. Van Kleeck has an unusual experience background and has contributed in important measure to the plant operation literature. He has a thorough understanding of the problems of the operator and is ideally fitted to interpret operation data and to judge the items of greatest general value and interest. Space does not allow us to list all of Mr. Van Kleeck's excellent qualifications but reference must be made to the high respect and esteem in which he is held by the plant operators with whom he has contact in his work—a most significant fact.

Walter A. Sperry, Superintendent of the Aurora (Illinois) Sanitary District and one of the nation's most highly regarded plant supervisors, has consented to undertake the "Daily Log" column. The writer derived considerable pleasure in presenting this feature during his tenure as an operator and reader reaction has been so gratifying that it will be continued. If enthusiasm for his work, a probing mind, a penchant for detailed records and a sense of the human side of day-to-day occurrences are good qualifications for this assignment, Mr. Sperry has all of them in plus quantities. Operators may look forward to an interesting column, full of good suggestions and practical experiences.

The "Summary of Experience" series of articles, offering the detailed practice of competent operators in controlling various sewage collection and treatment works, has found more than enough favor to justify the labor and time required to compile and present them. These articles will be prepared henceforth * by Mr. Douglas E. Dreier, Senior Sanitary Engineer of the Illinois State Department of Public Health. Working entirely in the Sewerage and Stream Pollution Section of his office, Mr. Dreier is in constant touch with the wide variety in size and type of Illinois' many plants and has demonstrated a keen judgment in the evaluation of operation procedures. Like Mr. Van Kleeck, he enjoys the respect and esteem of his associates and can be depended upon to do a splendid job. It is hoped that at least two of these articles can be presented each year.

* "Experience in Mechanical Aeration Activated Sludge Plant Operation" is scheduled for the January, 1945, issue of *This Journal.*

The *Corner* will be benefitted by this new talent but we again remind every operator that this is your particular feature of the JOURNAL and that you have a definite responsibility too. Your annual operation reports, your contribution of articles, your co-operation in filling out and returning questionnaires, your letters describing unusual experiences—all of these are necessary. To those who have already been so willing to assist we are indeed grateful but there should be much wider participation than there is now.

It is also fitting that there be proper appreciation of the willingness of Messrs. Van Kleeck, Sperry and Dreier to be of service.

W. H. W.

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# SEWER MAINTENANCE AND CONTROL IN CONNECTION WITH PLANT OPERATION *

By CARL A. WAHLSTROM

*Superintendent, La Crosse, Wis.*

La Crosse has a population of about 43,000 and is located on the East bank of the Black and Mississippi Rivers. The city is divided into two sections by low marshy areas and the La Crosse River.

On the North Side there are 25.29 miles of sewers, consisting of storm, sanitary and combined sewers, 4.25 miles of which are storm sewers. On the South Side we have 76.52 miles of sewers, 13.32 miles of which are for storm water, the remainder being sanitary and combined sewers. There are three lift stations in the system, two on the North Side and one on the South Side sanitary sewer. All of the remaining sewers discharge by gravity to the plant. At the plant, pumps raise the sewage to a sufficient elevation to permit it to flow through the plant and to a point of outfall by gravity.

In summarizing the sewer system, there are 17.57 miles of storm sewer, 84.24 miles of sanitary and combined sewer, 1,318 manholes, 3,042 catch basins, three pumping stations, two syphons and three flood control gates. The control gates are located on the old sewer outfalls.

The storm sewers were all constructed during W.P.A. days. We have hopes that some day the storm sewer program will be completed, which will relieve our load at the plant, even though it may entail additional work in the sewer department, such as flushing, repair and inspection.

The sewage treatment plant construction was started in 1936 and the works were ready for operation in August, 1937. It is located on what is known as Isle La Plume. In later years, because of insanitary conditions along the river bank caused by dumping of refuse, it became the city dumping ground, approved by the City Board of Health. Dump

* Presented at Conference of Wisconsin Sewage Works Operators, Oshkosh, June 22, 1944.

men were employed and the dumping area is kept in as neat a condition as possible. The plant is located on the edge of this filled area, the fill around the plant being pumped from the river. Dump grounds are now maintained below the plant and a part of the old dump area has been converted into an attractive park.

After the plant had been in operation for approximately one year, it was decided by the Board that the maintenance of the sewage collection system should also come under the supervision of the treatment plant. Their theory was, that by combining the two departments, duplication of equipment and manpower could be avoided.

In 1939 new sewer equipment was purchased and a system of maintenance set up. At first it was rather difficult to change the old method of operation. It was the old story: "We have been getting along all these years, why change now?" Sewers were never repaired until a street cave-in occurred; the use of man powered equipment was slow and showed poor results. A short time after the power machines had been in operation, the men operating them took notice of the ease with which better and more work was accomplished, and fell in line with the new methods. Today they are well satisfied and very much pleased with the work they are accomplishing.

We have observed by our past experience that by having the sewer maintenance crew as an integral part of the treatment plant personnel, and having full control over all the sewers, complaints from the public and plumbers of sewer stoppages have been reduced to a minimum.

Manholes, intercepters, and sewer flow are checked by the foreman and notes taken of their condition. The catch basin crew reports any necessary repairs to catch basins, and the sewer cleaning crew reports condition of sewers. In this manner, repairs are made before large breaks occur. Cleaning of sewers begins as early in the spring as possible and continues until late fall. There are times, however, when this program is interrupted, and that is during a large repair job when all men available are required. Under present conditions, we are fortunate that our sewer crew personnel is made up of elderly men.

As soon as the basins are thawed out in the spring, the catch basin crew starts the routine of cleaning and inspection. We remove approximately one-half yard of dirt per basin in the first cleaning. By removing the sand and cinders washed off the streets, which material is used by the street department for slippery street conditions, we relieve the grit load on the plant, reducing equipment repair and maintenance.

The wet wells at the lift stations are cleaned and washed as often as it is necessary throughout the year by the sewer crew, the plant crew giving whatever assistance is necessary.

There is no duplication of equipment or supplies such as pumps, air-blowers, boots, waders, etc., both crews using the same equipment, some of which is stored at the plant and the remainder stored in the sewer department. We have been informed that some day we may have the sewer crew stationed at the plant.

In the past four years, the majority of the sewer breaks have been found at the time of cleaning the sewer. By inspecting the sewer at the time of cleaning, we have saved ourselves a great deal of additional

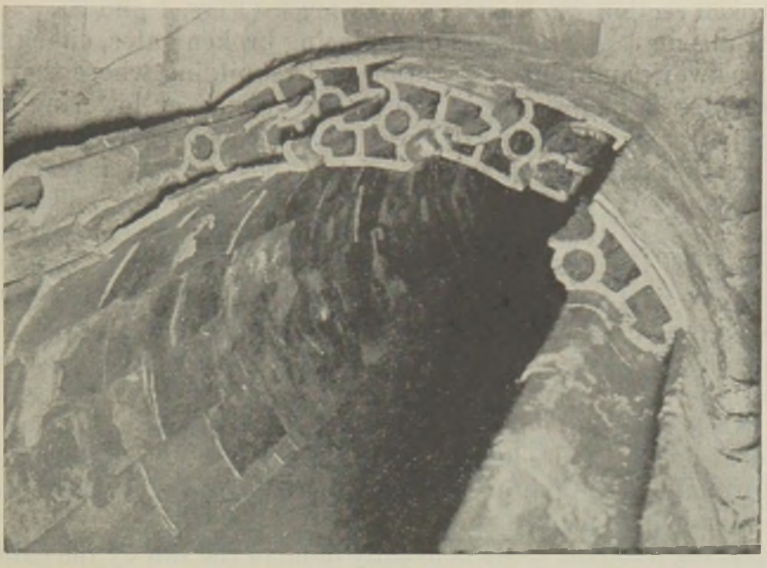

FIG. 1.—Sewer repair at La Crosse, Wisconsin. Broken arch in segmental tile sewer

FIG. 2.—Repair of sewer arch illustrated in Fig. 1.

work as well as convenience to the public. Broken sewers filled with sand cause flooded basements and other unpleasant complications.

A short time ago, after cleaning and inspecting a 36-inch segmental tile sewer, we found a section at which the top had settled and one tile was broken, with sand coming through the break. We measured the distance from the manhole to the center of the break, and sunk a 10-ft. by 16-ft. shaft which gave us ample room to make the necessary repair. It was necessary to remove 12 ft. of the top half section and rebuild it. The broken section was restored with brick (Figs. 1 and 2).

Catch basin repair consists of replacing broken gates, changing castings, brickwork and pipe restoration and rebuilding where they are beyond repair. Manhole repair consists of raising or lowering castings, brick repair and wedging rattling covers. Some years ago sand was used for silencing noisy manhole covers. The sand was placed on the seat of the frame and around the edge of the cover. This method proved satisfactory until the sand washed out. Then asphalt rings were used but the men complained about the difficulty in removing the covers. We now use wood wedges which have proven satisfactory, the covers being more easily removed and the wedges are cheap.

Flushing of sewers is supervised by the foreman and notes made of sections where the water will not run off properly. The location is given to the cleaning crew and, if conditions warrant, the sewers are cleaned at once. Work on the lift station wet wells and control gates is performed by the plant maintenance crew, assisted by the sewer crew when extra help is needed.

Replacing manhole steps is usually done in the fall by the catch basin crew. We use ¾-inch steel rod for repair and cast iron steps for all new work.

In late fall we also cover catch basins which are connected to shallow sewers. By covering them, frozen sewers are prevented and steaming is eliminated. In case of an early thaw, the covering is removed to relieve flooded corners, but replaced again until freezing weather is over.

Maintenance work is charged as follows: sewer breaks, sewer inspection, catch basin repair, manhole repair, replacing manhole steps, cleaning sewers, cleaning catch basins, flushing sewers, work on intercepters, cleaning wet wells, steaming catch basins, covering manholes and catch basins, and equipment repair. On the charge sheet we also have blank spaces for other work that may arise.

Now that we have educated our sewer crew to the importance of keeping the sewers clean and properly repaired, they are accomplishing more work in a more efficient manner. The Board is well satisfied with results and the minimum amount of complaints reported prove that by combining the two departments we can furnish additional service without additional cost.

# GAS COLLECTION AND UTILIZATION *

By Charles Gilman Hyde

*Professor of Sanitary Engineering, University of California, Berkeley*

## What is Sludge or Digester Gas?

Sludge or digester gas normally consists of a number of comparatively simple gaseous substances, as follows:

(*a*) Methane, a hydrocarbon, commonly known as marsh gas; also as fire damp in coal mines. Its chemical structure is indicated as made up of one atom of carbon linked to four atoms of hydrogen, $CH_4$. It is highly inflammable, a statement which signifies that it has strong affinity for oxygen; in other words that it is unstable in the presence of oxygen, if some igniting or heat source is present. In the process of oxidation it produces heat and forms carbon dioxide, $CO_2$, and water, $H_2O$;

(*b*) Carbon dioxide, a fully oxidized, stable, organic compound consisting of one atom of carbon attached to two atoms of oxygen, $CO_2$. It is a complete product of combustion and is inert as related to heat generation through further oxidation;

(*c*) Hydrogen sulfide, a so-called reduction compound, consisting of two atoms of hydrogen and one atom of sulfur, $H_2S$. It is inflammable and unites readily with oxygen. The hydrogen burns to form water, $H_2O$, and the sulfur burns to form sulfur dioxide, $SO_2$. In this process of oxidation heat is produced;

(*d*) Other gases, in relatively small amounts, such as nitrogen, an inert incombustible substance; and oxygen and hydrogen, both exceedingly inflammable and active in the sense that they combine readily with each other or with other elements, producing heat.

Sludge gas, under unsatisfactory conditions of digestion, particularly under conditions of high acidity, indicated by a low hydrogen ion concentration (pH value), may contain a number of volatilized putrefactive substances having exceedingly obnoxious odors. Among such substances are mercaptan, allyl sulfide and other organic compounds containing sulfur; also such organic and inorganic products as indol, skatol, phosphine, etc.

Digestion tanks or compartments should be properly seeded in advance with digested sludge, a difficult undertaking in most cases because of the unavailability of such material. Thereafter they should not be overloaded with excessive amounts of added fresh sludge. Unless such precautions are taken and acid decomposition thereby prevented, such objectionable odors as have just been referred to are bound to occur and will continue to be produced until alkaline digestion is fully established.

* Presented at Operators' Section, 17th Annual Meeting, California Sewage Works Assn., Fresno, June 24, 1944.

Acid decomposition of the organic solids in the sludge commonly represents the first stage, and alkaline digestion the second stage in the initial operation of any sludge digestion unit such as an Imhoff tank or a separate sludge digestion tank.

With well-established alkaline digestion the combustible gases, principally methane with some hydrogen sulfide, and possibly some oxygen and hydrogen, constitute from 65 to 80 per cent of the total volume and the inert gases, for the most part carbon dioxide with possibly some nitrogen, constitute the remainder, namely from 35 to 20 per cent of the volume. Obviously, the greater the proportion of the combustible gases the greater is the heat or energy capacity or potential of the combination.

The actual specific composition of the gas produced in any case depends upon several factors. Among these are the type of sewerage system, whether separate or combined; the food habits of the population; the kind and extent of industrial wastes; and the processes of sewage and sludge treatment.

## How Is Sludge Gas Produced?

Sludge gas is produced by the action of bacteria upon the organic material in sludge. All bacteria require oxygen just as does man and all other living things, both animal and vegetable, on this earth. Since free oxygen is practically absent in sewage sludge it is obvious that the oxygen demanded by the bacteria must be derived from some other source. That source is the oxygen combined with the various organic and other substances in the water supply and in the wastes discharged thereinto to create what we term sewage. The kind of bacteria capable of wresting this oxygen from relatively stable products is known as anaerobic, a term implying life without air; although life in the absence of free oxygen is actually meant.

The organic matter in sewage sludge furnishes an abundant food supply for these bacteria, as well as for other minute organisms. In the process of food consumption these organisms break down the complex and relatively unstable organic compounds into relatively simple and stable or fixed substances. This process is called sludge digestion. The final products are three in number and kind: (1) a more or less stable humus-like material; (2) a liquified or very finely divided—more or less colloidal—matter; (3) gases, as above described.

The measures of progress in sludge digestion are, therefore, three in number: (1) the rate or degree of destruction of the organic material; (2) the changes in weight or volume of the solids; (3) the volume and nature of the gases produced.

## How Much Gas May Be Expected?

The volume of gas produced will be determined by a number of factors or conditions. From the preceding discussion it is obvious that the principal one is the kind and amount of decomposable organic material in the sludge. This is related to the food habits of the contributing population, to the type and amount of industrial wastes in the sewage, and to the nature of the treatment process, for example, plain subsidence, chemical precipitation, trickling filtration, activated sludge process.

A customary unit of measurement is the volume of gas produced per day per person contributing to the treatment works. Imhoff and Fair * give usual values as follows:

| Treatment | Cu. Ft. per Capita per Day |
|---|---|
| Plain Sedimentation Alone | 0.83 |
| Chemical Precipitation Alone | 0.96 |
| Plain Sedimentation plus Low-Rate Trickling Filter Humus | 0.92 |
| Chemical Precipitation plus Low-Rate Trickling Filter Humus | 1.05 |
| Plain Sedimentation plus Activated Sludge | 1.06 |
| Chemical Precipitation plus Activated Sludge | 1.19 |

These average or usual values may be exceeded in certain cases and reduced in others. Moreover, in any given case, there may be large fluctuations, especially in unheated digestion tanks in which the biological activity will be depressed with low temperatures and greatly accelerated with higher temperatures approaching an optimum or most favorable one. Masses of undigested sludge accumulating during low temperature conditions may undergo rapid digestion when the temperature of the sludge mass becomes more favorable to biological activity.

## Is Sludge Gas Dangerous: Why and How?

Sludge gas is dangerous to human beings for two reasons. These are: (1) certain elements are toxic or poisonous; (2) when combined with certain volumes of air (oxygen) the gases are highly explosive.

Hydrogen sulfide is extremely poisonous. Exposure to concentrations of 1 part of hydrogen sulfide to 1,000 parts of air may cause death in a relatively brief period of time.

Sludge gas, mainly because of its methane content, becomes violently explosive when 1 volume of the gas is mixed with from 5 to 15 volumes of air. Every precaution must be taken to prevent contact with fire or flame when such combinations can exist.

## When May Sludge Gas Reasonably Be Collected?

This question must be considered under two sets of conditions: (*a*) established treatment plants in which no provision for gas collection and utilization has been made; (*b*) plants under design for which the reasonableness of gas collection and utilization is to be determined.

The fundamental criteria of such determinations may be indicated by the following queries: (1) to what economic use can the gas be put?; (2) are nuisances being or will they be caused, and do or will hazards exist if the gases are not collected?; (3) in an existing plant are the physical works adaptable to sludge gas collection?; (4) what kind and

* *Sewage Treatment*, Table 15, page 220.

degree of attention and attendance does the existing plant or will the proposed plant receive?; (5) will the volume of gas produced be sufficient to warrant the cost and effort of collection in terms of the dividend which will accrue through its utilization?

Unless a useful purpose is to be served through the collection of the sludge gas, it should not be undertaken because it will entail both out-of-pocket expense and attendance effort and cost.

With an existing plant the expediency and practicability of conversion to gas collection and utilization will depend in part upon whether sludge digestion is effected in an Imhoff tank or in a separate sludge digestion tank, an open, relatively shallow sludge digestion basin, or a sludge lagoon. Imhoff tanks of conventional design can readily be provided with gas collection devices and have been so equipped in many European installations; also in a few in the United States. It is feasible to collect the gas from comparatively shallow sludge digestion basins, as at Birmingham, England, by the use of floating pontoons, but such devices are costly to build and relatively difficult and expensive to maintain. Separate circular digestion tanks of considerable depth and correspondingly small area are naturally adapted to the provision of fixed or floating covers. To collect gas from shallow sludge lagoons is economically infeasible.

## How May Sludge Gas Be Collected?

This is a subject which might be discussed in great detail. Each case should be studied as an independent problem and those devices employed which best fit the controlling conditions. For present purposes we may consider only the Imhoff tank and typical separate sludge digestion tanks.

The problem is relatively simple in the case of Imhoff tanks because the water surface elevation therein normally fluctuates but slightly, even during sludge withdrawal. In these two-story tanks the walls of the flowing through chambers serve as gas-collecting covers deflecting the gas to the scum chambers or to special chambers operating both to collect the gas and to agitate or remove the scum. These constructions are well and thoroughly described in the textbooks and current technical publications.

Gas collection from a separate sludge digestion tank demands the construction of a tight roof or cover. This may be fixed in position or it may float like a section of a typical water-sealed gas holder. The design and/or operation must be such that air will not be drawn into the storage space beneath the cover when sludge is being withdrawn from the tank. Floating covers control this situation automatically. Fixed covers should preferably be almost completely submerged at all times; otherwise special precautions must be taken to maintain a positive gas pressure uninterruptedly. Gas holders (storage tanks) are useful for this purpose. Here, again, this general subject is covered at great length in the literature and requires no further elaboration in this avowedly brief discussion.

## What Are the Hazards, if Any, in Gas Collection?

As a practical matter, the hazards of gas collection are related to explosions which may destroy lives and property. Explosions can be prevented: (*a*) if no air is allowed to enter the gas storage compartment or elsewhere to combine with the gas to form an explosive mixture; (*b*) if lines leading to gas burners and gas engines are protected against back-flashing by suitable flame traps; (*c*) if other sources of flame, such as lighted matches, are never allowed to come into contact with appreciable volumes of sludge gas.

## How May Sludge Gas Be Utilized?

There are three general ways in which sludge gas can profitably be utilized. These are for light, heat and power. It may be burned to produce hot air, hot water and steam for the heating of buildings and of sludge in or in transit to separate sludge digestion tanks. It may be used as a fuel in gas engines to furnish power, either directly or through electric generators and motors, to pumps, blowers and other treatment plant mechanisms. It may be burned to produce light. It is effective in laboratory Bunsen burners. It may be employed to dry or incinerate sewage screenings, skimmings and sludge.

Imhoff and Fair, *Sewage Treatment,* pages 222–223, list other ways, of less immediate interest, in which sludge gas may be utilized.

## When Should Sludge Gas Be Utilized?

Sludge gas should be used to heat separate sludge digestion tanks in cold climates in order to reduce their size by shortening the required digestion period. It is well known that in the temperature range of mesophylic digestion, say from 40 to 110 degrees Fahrenheit, the required time for reasonably complete digestion, the rate of gas production, and the ultimate volume of sludge gas produced are all progressively more favorable as the temperature is increased up to a limit of approximately 95 degrees. Such a temperature cannot, other than by artificial means, be obtained in any climate. However, in generally warm climatic areas the need of digestion tank heating is not acute and such heating may not represent a logical undertaking.

Excess sludge gas, if available in sufficient quantity, may profitably be employed in gas engines to operate pumps, blowers and other machinery. It may also be profitably employed to heat buildings by steam, hot water, or hot air.

Open air burning of the sludge gas may be utilized to destroy odors therein and to destroy excess quantities which cannot be utilized.

## What Is the Heat Power or Calorific Value of Sludge Gas?

In general, sludge gas has a heat capacity or calorific value approximating one-half that of natural gas. Varying slightly with the type and extent of sewage treatment, sludge gas has a net fuel value, according to Imhoff and Fair, of from 636 to 646 B.t.u. per cubic foot. In terms of B.t.u. per capita per day the values are stated by them to be as follows:

| Treatment | B.T.U. per Capita per Day |
|---|---|
| Plain Sedimentation Alone | 530 |
| Chemical Precipitation Alone | 620 |
| Plain Sedimentation plus Low-Rate Trickling Filter Humus | 590 |
| Chemical Precipitation plus Low-Rate Trickling Filter Humus | 680 |
| Plain Sedimentation plus Activated Sludge | 675 |
| Chemical Precipitation plus Activated Sludge | 765 |

### What General Precautions Should Be Taken in Sludge Gas Utilization?

Aside from the danger of hydrogen sulfide concentrations, the principal precautions which must be taken with respect to the utilization of sludge gas relate to the prevention of explosions. Some of the precautions have already been stated.

Good and safe design calls for gas pipe lines of very ample capacity; therefore, relatively low velocities and attendant low friction losses. By-passes should be provided to give flexibility in operation but the flame trap must never be by-passed. Gas pipe lines must be tight, should slope to condensate traps, and must be protected against freezing. Pressure relief and regulating devices, as well as gas metering equipment, are valuable. It is important that all vents be carried to the open air.

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## THE DAILY LOG

By Walter A. Sperry

*Superintendent, Aurora Sanitary District*

With this issue there is a change in the source and authorship of "The Daily Log." Up to now it has been in a master's hands. I am both pleased and honored to have been asked to take it and I welcome this opportunity to be of some service to our group. On the other hand, I feel much like the apprentice in Dukas' symphonic poem, "The Sorcerer's Apprentice," i.e., lest I carry too much water and "get the boot" as he did. My approach to this, my first assignment, can only be accurately described by quoting from Roe Fulkerson, a brother Kiwanian, who in a similar predicament wrote as follows: *

Geezer with a pencil, looking mighty glum,
Gazing at the ceiling, gnawing on his thumb,
Twisting and turning, writhing in his chair—
Twiddles his fingers, rubs where once was hair.

* *Kiwanis Magazine*, August, 1944.

About a ream of paper lying on the floor—
Near him on the table five reams more.
    Also half a dozen weighty looking books—
    Encyclopedias and dictionaries, judging from their looks.
Tobacco, ashes, matches, scattered all about.
Twenty times an hour his pipe goes out.
    Deep and sweaty furrows corrugate his brow—
    Thus he's been working for two weeks now.
Batty in the belfry, yet sticking like a leech—
Here behold a Kiwanian preparing an "impromptu" speech.

This is my introduction and here begins "The Daily Log":

**May 1**—Two men on fifteen-inch interceptor stoppage at North Aurora. A sluggish flow and water standing in the manholes did not indicate the extent of the work to be done here though the fact that the sewer ran some 1,800 feet through wooded lots should have warned us of roots. Eventually 1,733 feet had to be cleaned with steel cable, winches and an expanding "pig" by a local plumber. It took ten days and the bill came in at 50 cents per foot, which amount seemed out of proportion for the men and hours involved. We "kicked" and the bill was promptly adjusted to 40 cents per foot, which was still plenty.

The several breaks in the tile which were necessary between manholes were repaired by using metal lath with a bar of iron across the center of the hole, slightly bent and then covered with a generous, thick patch of concrete—a quick and efficient repair of a hole in a running sewer.

Subsequent study revealed that by partially damming the lower end of the run among the trees and then applying several shovelfuls of copper sulfate at the manholes above, the roots would not only be killed but the roots themselves would slough off and come through without injury to the trees. Subsequently it was found that this method of treatment is beginning to be used to forestall trouble in a number of cities having many trees. (See **Water Works and Sewerage,** March, 1942.)

Found water in the oil pan on Engine No. 2. The source was finally located as a crack behind a valve insert on one of the head blocks. Could not be welded so a new block was installed.

**May 2**—Starting to apply a half-inch coat of "No-Drip" (an asphalt and cork mixture) to all pump piping in the pump room. This subsequently proved to be a long and expensive job but was effective. On certain days, however, there was still some slight condensation until we screened the side windows to give better circulation of air. No dripping since. Ventilation seems to be an important consideration for successful insulation.

**May 5**—East High School chemistry class out for inspection and talk on sewage treatment.

Took weekly digester sludge level inventory.

Found a local manufacturer who could sell us enough steel plate so that we could consider rebuilding the storage bin of the incinerator. This was good news. At present it is largely rust and holes, waiting for the war to end.

**May 6**—Cleaning plant for weekend—a regular Saturday job.

Completing the April data sheets for blueprinting and permanent record.

Placing new tie rods on scrapers at base of column in the pump suction pit of traction clarifier No. 1. Many rods had completely rusted through. Wished they might have been heavily "metallized" with zinc.

**May 7**—All normal at the plant. Out in A.M. for the regular Sunday work, record check and to weigh up the sludge samples for the daily sludge record.

**May 8**—Another East High School chemistry class out for lecture and plant inspection. Portable planks and horses make a quick lecture room out of the laboratory. Mr. Stutz, the instructor, estimates some 1,500 students have been instructed in the last 10 years. This is an important "must" job for a Superintendent. They are future citizens and taxpayers and have a right to know about the city's machinery.

Coached a West High School student into the whole (?) mystery of sanitary engineering and sewage treatment this evening. This helped her to make a talk the next day. Papa and Mama sincerely grateful. At that, it was time well spent, but why must they wait till the day before to get the information?

**May 9**—Repaired door frame of the garage. This time it was the bumper of a car—backing out.

Running nitrate tests on digester supernatant to prove an argument with a brother operator that, unlike effluent liquor from trickling filters, digester supernatant does not contain nitrates—there were none.

Program speaker at the Rotary Club of DeKalb, Illinois. Subject, "The Sanitary Engineering Field." This helped out Rotarian F. S. Simms, Manager of the DeKalb Sanitary District.

**May 10**—Regular Board Meeting. This has always been one of the most pleasant days of every month. The secret lies in a typed report of the month for each Trustee. This lists bills, pithy paragraphs of all important plant happenings—good or bad, complete cost data with comparisons and accumulated costs and a full resume of the more significant treatment results. This is a complete coverage of the month that the Trustees read gladly but would never have the patience to hear verbally or remember. It is also a valuable Superintendent's reference and review. The year's volume of monthly reports is a mine of reference as well as the nucleus for the Annual Report.

New contact points installed at the controls of the Holbrook Street Station.

Checked hydrogen sulfide content of some of the city's deep wells as an indication of the ferrous iron content—a favor to the City Water Works Superintendent. This is one of the neighborly gestures practiced between the District and the City, which makes for pleasant living and easy borrowing. We make our giving more liberal than our borrowing. Used methylene blue method for $H_2S$ determination (**This Journal, 8,** 576, 1936).

**May 12**—Holbrook Street Station back in service. Out 108 days since January 1, 1944, due to river level being higher than the station overflow.

Painted iron work in front of the Main Building.

**May 17**—Planted flower beds. One of the annual events is the distribution of many dozens of flower plants of several varieties to the families of the Trustees, officers and plant personnel. About two dollars worth of seed planted in flats in the small greenhouse, made possible through no cost for fuel, yields an amazing number of plants and no end of happiness for a lot of people.

Arranged with farmer neighbor to cut all alfalfa—about seven acres—on shares. Our share this year to be the mowing of the weeds about the grounds. This gave him generous pay and helped us out due to labor shortage.

**May 19**—A typical day:

Routine work in laboratory.
Pumps at downtown stations inspected.
Orsat gas tests run for the week.
Working on sludge beds.
Working on grounds, weeds and shrubs.
Greasing routine for the week.
Repaired shear pin on Carter sludge pump.

**May 22**—Completed annual overhaul of gas engine No. 3 and placed it on the line for another year.

Tractor stuck in a soft spot in the grit dump. Men sweated all day working with planks and timber to keep it from burying itself. Finally got it out next day.

**May 23**—Interest and bond payment checks signed by Trustees and to bank for June 1st payment. Final payment due in June, 1948, and "the baby will be ours"!

For three days the operation of the Carter sludge pump has been a headache. A constant round of opening the ball valve, back-flushing and running up and down a ladder in a pit to operate the proper valves. Finally we found it. A 12-inch, maple handled wire brush stuck in the elbow and just beyond reach from the ball valve. The wire bristles were pointed down and made an ideal trap for rags and debris to catch upon. To get it out, we looped the handle with a wire and broke it enough to turn the corner. By driving a screw in the end of the handle and rigging a wire at the lower end it finally came through and this trouble was over. The brush had accidentally fallen into a clarifier and is now hung up as a permanent trophy. One in 10 years is enough!

**May 24**—Long talk with power company man representing the Chamber of Commerce on permissible river pollution from a pickling plant which seeks to settle in our valley.

**May 28**—Sunday—out for routine work. A long day.

Day operator off to christen new baby—his first. On duty till noon, home for dinner and to wash the dishes—my "Sunday" job—and then back to plant from 3 to 6 to connect with the night man.

**May 31**—Signed up the 135th sewer connection in the Hercules Park District and collected forty dollars.

Comb plate of the Dorr automatic screen taken down to make hole pattern for new plates with longer and thicker teeth. Hope they wear longer!

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# ODOR CONTROL *

By C. R. Compton

*Assistant Chief Engineer, County Sanitation Districts of Los Angeles County*

There is probably no other industrial or manufacturing process known to mankind in which odor is used as quickly by the general public to measure success or failure as in sewage treatment. This applies also to the entire process of sewage collection and treatment, including sewers, pumping plants or any unit which handles sewage.

Many an operator or superintendent who thought everything was fine, that B.O.D. removal was just what it should be, suspended solids removal was great, pH was "on the beam" and the effluent looked good enough to drink, has been rudely awakened from a beautiful dream by some little odor atom that escaped from his plant and bounced across country into some citizen's nose. From then on he will get more complaints, both fancied and real, than he ever thought existed, and he and his plant will be marked. Every odor on the neighborhood will be blamed on him no matter from where it comes.

One of the most peculiar things about sewage odors and their control is that of all the effects which a sewage treatment system can have on the human senses, the effect of odor or the reaction of smell has received probably less study and thought than any of the others. We have had reams of literature on sundry and various subjects relating to various phases of sewage treatment, but very little on odor control.

One might say, of course, that the entire technique of sewage treatment is pointed towards the elimination of odors. This is probably true in the broad sense but it nevertheless remains a fact that for the

* Presented at 17th Annual Meeting, California Sewage Works Association, Fresno, June 22–25, 1944.

elimination of odors as odors themselves, a broad field of research and study still exists.

The sense of hearing is well taken care of by mufflers for engines, well designed pumps, and improved motors, and landscaping takes care of the appearance of things, but the control of odors seems to be something that is difficult to design for. It is one of those problems in which the situation has to develop and then the best remedy possible be applied. In most cases, two or three methods may have to be used before an answer can be determined.

One of the greatest difficulties in the control of sewage plant odors is the fact that, so far, no one has been able to establish a rational scale for the measurement of odors, either as to intensity or type. The ancients divided odors into two classes—good and bad. Since then efforts have been made by a considerable number of research men to designate and classify by grouping various kinds of odors ranging from the most pleasant to the worst. The biggest obstacle in obtaining a standard classification is the fact that no two persons have the same sense of smell and also that the olfactory nerves fatigue very quickly. This fatigue phenomenon is well known to sewage works operators and it is a common saying amongst sanitarians that one should never ask an operator whether his plant smells good or bad.

Considerable research has been carried on attempting to establish the measurement or intensities of odors. It has been proposed that a designation such as "threshold" odors be applied to the very faintest discernible odor and starting with this as a base, measurement of odor intensity would be carried through to the upper limits.

Fair and Moore did considerable work on this subject in an attempt to reduce the measurement of odor intensity to a mathematical formula. In their investigations, they evolved laboratory techniques and from these arrived at certain conclusions as to the rate at which intensities of odors increase. However, their experiments were based on the use of the human nose to determine the degree of intensity and, of course, were only that conclusive. It was, however, a broad step in an undeveloped field and it remains for further research to carry on that work in an attempt to obtain a usable method by which sewage plant operators can determine odor intensities, such as the colorimetric method used for pH determination. At present we are still forced to fall back on the "sniff system" and, as in the past, the answers are all different and in many cases they are incorrect.

While the problem sounds difficult, the answers are being given as time goes on. First, we are fairly well acquainted with the chief offenders. The list is headed by hydrogen sulfide along with the mercapatans, and a long list of organic acids, all of which are the products of putrefaction and decomposition of fats and the various other compounds and substances found in sewage.

The operator has long been the target of odor complaints. Practically all papers or articles that I have reviewed on odor control direct their remarks to the operator, advising as to how his plant should be run so as to get a minimum of odors. But what about the designer? He surely is also responsible for the elimination of odors to a great extent. The attack on odor control should start on the drafting board. That is where a treatment plant can be greatly improved as far as odor control is concerned. If the layout is faulty or capacities are inadequate, the results will be below standard and that means odors. Small details must get their share of attention for very often they will cause a great deal of trouble if not designed properly. For instance, is the wash water system laid out so that it can be operated as easily as possible, and has a good water pressure been provided? These are little things that mean a lot.

The designer must also see that the sewage collection system has the best velocities obtainable and that the shortest route from the point of sewage origin to the sewage treatment plant has been used so that the sewage may be delivered at the plant as fresh as possible. If pumping plants are necessary in a sewage collection system, extreme care should be given to their design to see that the sewage is not retained either in the wet wells or force mains any longer than is neceessary. The plant layout should be such that neatness and cleanliness can be easily accomplished.

Present emergency conditions make the control of odors hard to obtain in a great many cases, particularly where sewage from industrial areas is being received. There is hardly a sewage treatment plant in the state that has not been called upon to carry heavy industrial loads, either from new industries or increased production in old plants. In a great many cases the sewage treatment plants have been overloaded, and in places wastes have been sent to sewage works that were not originally contemplated in the plant design. This all adds up to more and new odors, each with its special control problem.

The war emergency has brought to our area dozens of new industrial processes—plants that we never thought would be established in the coastal area—such as plants where alcohol is obtained from molasses, new cracking processes for obtaining high octane gasoline, large acid manufacturing plants as well as numerous metal processing establishments which formerly were located in the Middle West or East. These have all contributed to the list of new odor problems. In one case where a new catalytic process for the production of high octane gasoline was installed, odor troubles started at once. Investigation revealed that, among other things, the manufacturer was unable to get the quality of sulfuric acid he needed, with the result that the process had to be readjusted. When this was done and other changes made, odors stopped except for an occasional incident. These are things that can only be worked out as they arise.

It is an old adage that things that look attractive are not so apt to smell bad. This is true in the case of sewage treatment plants. If the plant can be landscaped and presents a pleasing architectural appearance, it is more than likely that complaints will be made much less often than if no attempt had been made to improve the appearance. This, naturally, is not a cure-all for odor control but it is one of the things that can go a long way toward alleviating the fears and doubts of people living adjacent to sewage treatment plants.

The use of covered buildings to entrap odors and dissipate them into the air at some designated place also solves many problems. Care must be taken in instances of this kind that fouled air is injected into the atmosphere at a velocity sufficient to insure dilution. Burning of the odors in trapped air from buildings is also possible. One of the main difficulties in this process is that the very high temperatures, well above 1500 degrees F. in most cases, necessary to entirely burn out odors are sometimes costly and hard to obtain.

One of the most positive methods for the control of hydrogen sulfide is the application of chemicals. Their use is so well known to all of you that it is not necessary at this time to go into any of the details of application or expected results.

In summarizing the odor problem, it appears that, due to the many complexities, there is no definite formula that can be used for the elimination of odors from sewage treatment plants. However, there are a few very well defined rules which, if followed, will give the answer in most cases:

First, cleanliness. If ever the old saying: "Cleanliness is next to godliness" applies, it is in the maintenance of a sewage treatment plant, and it is the responsibility of the operator to keep his plant as clean as possible at all times—to see that walls are washed down, bar screens are kept clean, that well digested sludge is put on the drying beds, that screenings are properly and efficiently incinerated or buried, and that there is no place in the plant where septicity of sewage takes place.

Second, study the source and character of the sewage being treated so that you may be able to anticipate as nearly as possible potential odor nuisances.

Third, familiarize yourself with the territory which your plant serves as to the type of industrial plants and the nature of such wastes, particularly as to new plants that may come in. Attempt to eradicate troubles at the source as much as you can for once a potential odor condition gets into the system, it is doubly hard to eradicate.

Fourth, in some instances, one method will do and in others an entirely new type of attack must be used. Chemicals may offer the solution at times, where at others ventilation is all that is necessary. Incineration may also be used with success. Whatever the method used, it should be applied as soon as possible to obtain the necessary relief. There is no other one feature of a sewage treatment plant that will draw complaints more quickly and cause more difficulty than odors. It is the condition that the public is constantly alert to and, in most cases, seems to be only too happy to find.

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# INTERESTING EXTRACTS FROM OPERATION REPORTS

Conducted by LeRoy W. Van Kleeck

## REPORT ON SANITARY DISTRICT OF CHICAGO ENGINEERING WORK IN 1944

By William H. Trinkaus
*Chief Engineer*

### Section on "Maintenance and Operation of Pumping Stations, Sewers, Treatment Works and Waterways"

The following tabulation shows the type, treatment capacity, pumping capacity, and method of sludge disposal of the major works:

| Sewage Treatment Works | Type | Average Treatment Capacity, M.G.D. | Pumping Capacity, M.G.D. | Method of Sludge Disposal |
|---|---|---|---|---|
| Calumet | Activated Sludge | 136 | 270 | Drying, incineration, or sale. |
| North Side | Activated Sludge | 250 | 388 | Disposal at S. W. Works. |
| Southwest | Activated Sludge | 400 | 776 | Drying, incineration, or sale. |
| West Side | Imhoff Tank | 472 | 776 | Drying on open beds, disposal on dump. |

### Progress in Sewage Treatment

The sewage from approximately 99 per cent of the population is now treated at the four major sewage treatment works.

The population of the Sanitary District is approximately 4,000,000, and industrial wastes are estimated to be equivalent to the sewage from an additional population of approximately 3,000,000 including the Corn Products wastes. Hence, the total estimated population and industrial wastes equivalent amount to 7,000,000.

*General Operating Data*

General operating data for the four Sewage Treatment Works are shown in the two tables below:

TABLE I.—*Summary of Operating Data 1943*

| Item | 1943 Averages | | |
|---|---|---|---|
| | Calumet Works | North Side Works | Southwest Works |
| Sewage treated, m.g.d. | | | |
| Average | 93.6 | 195.8 | 352.0* |
| Maximum | 178.0 | 343.6 | 450.0 |
| Minimum | 65.5 | 0.0 | 160.0 |
| Air consumption, cu. ft. per gal. | 0.4 | 0.42 | 0.93 |
| Aeration period, hrs. | 4.6 | 5.3 | 7.0 |
| B.O.D., p.p.m. | | | |
| Raw sewage | 87.0 | 104.0 | 181.0 |
| Effluent | 11.0 | 6.8 | 15.0 |
| Per cent reduction | 87.4 | 93.5 | 91.7 |
| Suspended solids, p.p.m. | | | |
| Raw sewage | 115.0 | 135.0 | 187.0 |
| Effluent | 16.0 | 10.0 | 18.0 |
| Per cent reduction | 86.1 | 92.6 | 90.4 |
| Sludge disposal (dry basis) | | | |
| Total tons dry solids removed | 13,978.0 | — | 31,832.0 |
| Waste sludge, per cent moisture | 97.27 | — | 97.74 |
| Filter cake, per cent moisture | 81.8 | — | 83.7 |
| Dried sludge, per cent moisture | 6.6 | — | 4.7 |
| Dried sludge, per cent volatile | 56.1 | — | 67.6 |
| Dried sludge, per cent nitrogen | 4.28 | — | 5.35 |

* Preliminary settling only 209.

TABLE II.—*Summary of Operating Data 1943*
West Side Works

| Item | 1943 Average |
|---|---|
| Sewage treated, m.g.d. | |
| Average (including 4.5 m.g.d. preliminary sludge) | 413.4 |
| Maximum | 640.3 |
| Minimum | 255.6 |
| B.O.D., p.p.m. | |
| Raw sewage (1) | 126.0 |
| Effluent | 77.0 |
| Per cent reduction (1) (2) | 38.9 |
| Suspended solids, p.p.m. | |
| Raw sewage (1) | 181.0 |
| Effluent | 96.0 |
| Per cent reduction (1) (3) | 47.0 |
| Sludge removed from Imhoff tanks | |
| Total cu. yds. to drying beds | 529,626.0 |
| Total cu. yds. to lagoons | 10,626.0 |
| Total cu. yds. | 540,252.0 |
| Average per cent moisture | 92.4 |
| Dried sludge removed from drying beds | |
| Total cu. yds. | 145,623.0 |
| Average per cent moisture | 69.0 |
| Average per cent volatile | 49.4 |
| Average per cent nitrogen | 2.21 |

(1) Without allowance for Southwest preliminary sludge.
(2) Allowing for Southwest sludge, reduction 22.2 per cent.
(3) Allowing for Southwest sludge, reduction 31.9 per cent.

## Calumet Works

*Sludge Drying*

A balata impregnated canvas belt is on hand for replacement of the rubber conveyor belt carrying sludge. The rubber belt will require changing soon.

New wood decks have been installed on filters Nos. 1, 3, 4 and 5 and stainless steel scraper blades on all units. Plastic piping and fittings are on hand for the replacement of the interior piping of two filters. (Abst. note: Wood decks for vacuum filters have proven very acceptable at Chicago. Corrosion problem has been eliminated, and less clogging trouble has been experienced.)

## North Side Works

*Equipment Repairs*

Plant effluent has been used for seal water on the main sewage pumps during the past year. Growths in these lines were removed by steaming and blowing which restored the lines to their original capacity.

More cleaning of diffuser plates than in previous years has been required to maintain uniform distribution of air. In some instances several applications of chromic acid have been needed. Tests have also been made using wetting agents in conjunction with other treatments.

*New Work*

The waste sludge concentration tanks have been in operation since 1942 and have served to compensate for the gradual clogging of the waste sludge line, due to bacterial growths.

## Southwest Works

*Sewage Treatment*

All sewage reaching the Southwest Works during 1943 was treated by sedimentation and the solids removed in the preliminary settling tanks were diverted to the West Side Treatment Works. During the year a new plan for disposal of skimmings was put into operation. The skimmings were diverted to one of the preliminary settling tanks for concentration. A temporary screw conveyor was installed for loading the skimmings into trucks and a contract for purchase of this material was awarded to a refiner.

The portion of the sewage that was given complete treatment was limited by capacity of the drying equipment to dispose of waste sludge. One battery of aeration and final settling tanks was in operation only a part of the time. The new sludge lagoons and pipe line were completed and placed in operation in December. Use of these lagoons will make it possible to dispose of waste sludge and give complete treatment of sewage up to the aeration capacity of the works.

Experimental work conducted throughout the year has shown that fine dust in the low-pressure air is one of the major causes of the clogging of diffuser plates. Extensive maintenance work was done on the air filters to keep them in the best possible operating condition. However, consistent sampling showed that considerable dust still escaped through the cleaners and lodged in the diffusers. Cleaning the plates with acid was again found to be only a partial solution. Two diffusing media were found which seem to permit dust particles to pass without too rapid clogging. Of these the 80-permeability plates were found to be the more economical. One aeration tank was completely equipped with these plates and placed in service in December, 1942. It operated through 1943 with reasonable pressure losses while passing the desired amount of air per plate. Plates of lower permeability showed clogging in comparatively short periods of time.

The second workable diffuser tested was slotted pipe. Sections of one-half inch pipe with transverse slots of different widths were tried. Brass pipe with slots 0.035 to 0.40 inches wide gave the best results. However, the slotted pipe used more air than the 80-permeability plates to accomplish the same oxygenation of sewage. It was therefore decided that all of the remaining tanks and the channels should be equipped with 80-permeability plates. Upon completion of this work it should be possible to give complete treatment to all sewage reaching the plant.

Construction of the new final settling tanks, now held in suspense by war conditions, should be completed as promptly as possible to aid in the settling of the added quantities of sewage that will receive activated sludge treatment.

*Power and Sludge Disposal*

Little progress was made in 1943 on major contract work. The sludge loading building was put into operation on a temporary basis in October and all loading gradually transferred from the old temporary building. The change to the new building eliminated one principal source of the atmospheric dust that has caused so much trouble by clogging diffuser plates. Screening and cooling of the sludge before loading is still being done in a temporary structure that is rapidly wearing out and is inadequate to do the work during warm weather. Nearly all of the equipment for the permanent screening and cooling system is now on hand and a contract for its installation should be awarded soon.

Sludge filters have given satisfactory service since the interior piping was replaced, scrapers were redesigned and reconditioned, and all units were converted to a panel type of deck support that permits holding the filter cloth on with wedge strips instead of a wrapping wire. (Abst. note: Other filter operators take particular note!) Life of the filter cloths has been remarkably good because of the method of holding the cloths on the drum, the weave of the cloth, installation of scraper stops, and the development of a counterweighted scraper that adjusts itself to the shape of the revolving drum. An arrangement has been made for by-passing sludge, in order to maintain the desired submergence of the filter drums, before the ferric chloride is added. A saving in ferric chloride should result when automatic equipment is installed to control the sludge level in the filters.

One of the more serious problems in connection with the drying system has been the maintenance of the hot gas ducts between the furnaces and the vapor heaters. Additional expansion joints and new spring hangers have been installed to relieve pressures and give proper support. From the very beginning of plant operation the refractory brick lining of these ducts has required considerable maintenance. Experiments are now being made with a material cast in place to determine whether a method can be developed that does not require so much maintenance. The inherent nature of the materials handled in the sludge drying system makes a considerable amount of repair and maintenance work necessary. Improvements in materials and design are being made continually and in time this work will be greatly reduced.

## West Side Works

The Imhoff tanks were kept in satisfactory operation by maintaining higher sludge levels to allow adequate seeding of the increased quantity of solids. Sludge handling with pneumatic ejectors was satisfactory except for the increased electrical maintenance required on solenoid switches and springs. Complete overhaul of these switches will be undertaken. The accumulation of scum in the gas vents continues to be serious and requires continual removal during all times when sludge is not being drawn. Partial cleaning of all three batteries was completed in 1943 but was not adequate to keep pace with the increased accumulation.

The amount of dried sludge taken from the spoil dump by gardeners increases each year.

## Experimental Work, Tests and Investigations

### *Main Laboratory*

Special studies were made in 1943 of the coagulation of sludge prior to filtration, including the effect of electricity on the moisture content of the filter cake. Although application of a direct current resulted in reduction of the moisture content by several per cent, computations indicated that the procedure would not be economically justifiable.

## Miscellaneous

### *Sale of Dried Activated Sludge*

Heat-dried activated sludge is sold to H. J. Baker & Bro. under a contract giving them the exclusive right to purchase at ten per cent under the current market price based on the content of ammonia and available phosphoric acid. Net receipts under that contract in 1943 were $463,-072.22. Average ammonia content was 5.89 per cent for the year and the available phosphoric acid was 2.03 per cent, both of which were slightly lower than in the previous year. The sludge sold contained a total of 2,229 tons of ammonia and 169 tons of available phosphoric acid. The sludge is shipped in bulk by rail to manufacturers of commercial fertilizers principally in the southeastern states.

Changes made in the drying equipment have made it possible for us to produce the material in a more desired form containing less fine dust. The manufacturers are anxious to secure dried sludge to mix with the chemical concentrates and reduce the tendency of the finished fertilizer to cake because of absorption of moisture from the air.

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## ANNUAL REPORT: BUFFALO SEWER AUTHORITY
### 1942–1943

(For previous extracts in this JOURNAL see: *This Journal*, 11, No. 6, pp. 1083; 13, No. 3, pp. 592; 14, No. 2, pp. 455)

### PART II
### SEWAGE TREATMENT WORKS

BY JOHN W. JOHNSON

*Works Superintendent*

AND GEORGE F. FYNN

*Chief Chemist*

*Pumping*

The volume of sewage pumped at the Treatment Works increased over the previous year by 1,163,800,000 gallons, resulting in an annual grand total of 54,608,000,000 gallons for the current year. The sewage flow averaged 150 m.g.d. with a daily pumpage of 284 m.g.d. as the maximum recorded for the period. The greatly increased total flow was accounted for in part by the abnormal precipitation, which was 7.31 inches above the total for last year, by the increase in lake level and also by the increased industrial and population loads brought about by the growth of defense industries.

About mid-year an inspection was made of the inlet wells at the Main Pumping Station. It was found that the floor under the suction of each of the vertical centrifugal pumps was badly worn, and in one area the worn spot was so deep that the reinforcing steel of the floor was exposed. This wear was caused by the vortex action at the bell of the pumps with the subsequent swirling causing the abrasive solids in the sewage to cut into the concrete. A proposed design for the elimination of this condition was submitted to the pump manufacturer to check the structural and hydraulic characteristic. Upon approval of same the construction of concrete conical deflectors was undertaken. At the same time it was noted that large deposits of grit had occurred in the quiet locations of these wet wells. As an experiment to eliminate the fault, a temporary wood baffle was placed halfway across the entrance to one of the wells. It is expected that the consequent diversion of flow will prevent further settling. Should this experiment prove satisfactory, a more permanent structure will be installed.

For some time operating difficulty was experienced with the main pumps after a shutdown because of heavy scale washing back into the pump before the check valve was closed, allowing an accumulation to lodge in the rings. This action would result in a frictional loss on the next start and often caused the pump to stall. Examination of the interior of the steel discharge piping from one of the pumps indicated the source of the scale formation. This interior was subjected to heat descaling, and corrosion resistant paint was applied. After one year of operating life it was found to have given the desired results of preventing further corrosion.

### *Disinfection*

Upon completion of studies to determine the effects of discontinuance of aeration on the settling of solids in the plant sewage conduits, the air-blowing equipment was shut down. The porous carborundum plates were protected for future use, if necessary, by cleansing with chlorine gas and sealing them with removable concrete covers. Frequent inspections have indicated no harmful effects due to settling or to improper ventilation. The cessation of this aeration has provided several benefits such as (1) elimination of noise and destructive vibration in the Main Building; (2) removal of the source of obnoxious, corrosive fumes, which often spread to outside areas by greatly overtaxing the ventilating system; and (3) the power saving realized from the shutdown of the continuous operation of the 60 h.p. equipment.

Predicated on the success of the chlorine potential cell apparatus, operating on water treatment chlorine dosage control, experiments were under way by the manufacturer of this equipment to adapt it to sewage treatment. The advent of the war, however, prevented immediate further factory development and we were requested to take over the project. About mid-year the apparatus was installed at the plant and studies were begun with the purpose of establishing a relationship between the coliform bacteria content of the sewage and readings in millivolts registered on a potential recorder. Upon completion of this work the unit is to function as a controller for providing automatic dosage of chlorine to the sewage, dependent on its concentration. Thus, instantaneous demands will be met, eliminating the over or under chlorination, which exists under present methods. For several months the equipment was subjected to numerous revisions and at the end of the year reconstruction of the potential cell was proposed to eliminate plugging of sampling lines and trays, and to prevent the poisoning of the cell by grease and sand in the sewage.

### *Solids Disposal*

Physical features of the piping in the Sludge Control Station had for some time prevented an equal distribution of sludge loading to the digestion tanks. All attempts to clear incrusted lines failed because of the lengths involved and the inaccessibility of two distributing lines within the digestors. It therefore became necessary to consider the revision of the raw sludge feed lines. In order to perform this work the tanks would have to be partially emptied of sludge and scum to a depth to provide access and working space. One tank was selected and the removal of material was begun. After a short time all the sludge was removed, leaving a large amount of stiff scum within the tank. The dry solids content of this material exceeded 20 per cent, making it necessary to soften it by flushing or heating. Supernatant and filtrate liquors were used in an attempt to soften this material, but best results were obtained by the addition of live steam. While this operation was proceeding, the heating coils began to leak. (Abs. note: This leakage shows the hazard which exists when potable make-up water piping is directly connected with heating coils in digesters. Either the open tank system or closed tank system fed by a segregated pumped supply (in either case with the water inlet above the overflow rim of the feed tank) should be used to prevent pollution reaching potable water supplies.)

After a purging period, working platforms and a ventilating system were installed within the tank. It was possible to support these platforms on the surface of the scum mass remaining in the tank.

The existing 8 in. C. I. raw sludge line, consisting of two circular branches each 60 ft. in length, which had carried sludge to diagonally opposite sides of the digester, was removed. One of these lines was completely plugged and the other was only partially open. A new 8 in. cast iron line, eliminating the former "T," was constructed straight out from the tank wall to a distance of about 15 ft. towards the center. The original 4 in. gas line, which had proved to be inadequate for removal of gas during times of maximum production, was replaced with a 6 in. line. The circulating hot water coils for heating the sludge, which had pulled apart or were split open, were repaired by means of couplings and nipples, or by electric welding. The use of the latter required a great deal of precautionary work to prevent the chance of explosion should a gas pocket have formed within the tank. This required frequent procurement of samples to determine the condition of the air within the working area. The recording thermometer line, which had broken down in the scum, was repaired and installed upon the structural steel framework in place of the old cable support. The improved operation of this tank since its restoration to service has been beyond expectations. Breaking a further precedent, the scum within the tanks failed to soften with the advent of warmer weather as had been the experience in the past. This made it necessary to continue throughout the year the recirculation of lighter material into the top of the digesters to break up the heavy scum solids.

The experiments with acid washing of filter cloths after varying operating periods were continued. One cloth treated with acid after each 100 hours of operation ran a total of 390 hours, which is about twice the life formerly obtained.

After a prolonged study of materials to be used for linings in the sludge and ash cyclones in place of critical steel, a ceramic known as "Packinghouse Floor Tile" was selected. Two of the cyclones were lined with this material and after a year's service were found to be in excellent condition; it is believed this change will double the life formerly obtained from steel plate. The installation of this tile has made maintenance more flexible because it is now possible at points of uneven wear to replace a few tile with little effort, whereas formerly it was necessary to renew an entire steel section. The remaining four cyclones are to be lined with this material. Further improvement was made in the ventilation of this department by the construction of two additional large roof ventilators. Now all of the dust and fumes are sucked up out of the building with consequent lower working temperatures and less working hazards.

*Miscellaneous*

The need for fertilizers for farms and victory gardens again gave emphasis to the use of sludge for this purpose. A report on the use and availability of plant sludge for this purpose indicated that little benefit could be expected from the use of the material produced at the Treatment Works.

*Laboratory Activities*

During the previous year an electric fly trap was obtained and a study of its efficacy made by the department in order to eliminate this nuisance. On the basis of studies completed, additional traps were purchased and placed throughout the plant. This action aided in eliminating an employee grievance in several departments.

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## PART III
## SEWERS DEPARTMENT

By Carl L. Howell

*Supt. of Sewers*

Water depth gauges have been installed at critical points in the sewerage system and records of flow depth are being kept to determine the effectiveness of the system in the handling of storm water.

From information obtained from 234 concerns in 18 different industrial classifications in the City regarding the character of their wastes, the Authority has determined during this past year to adopt and put into effect special charges for the treatment of industrial wastes of unduly high concentrations which cause increased treatment expense to the Authority. These special charges are only for the purpose of reimbursing the Authority for the cost of chlorine consumption and of chemicals and power used for the disposal of solids in excess of normal sewage requirements. The special charges are determined from a rate formula, as follows:

$$R = F\ Pc\ (C - Nc) + F\ Ps\ (S - Ns).$$

where $R$ = rate of special charge per 1,000 cu. ft. of waste,
F = conversion factor to convert from parts per million to lbs. per 1,000 cu. ft.,
$Pc$ = cost of chlorine,
$C$ = measured chlorine demand of waste,
$Nc$ = normal chlorine demand of Buffalo sewage,
$Ps$ = cost of chemicals and power as determined from plant operations,
$S$ = measured quantity of suspended solids in waste,
$Ns$ = normal quantity of suspended solids in Buffalo sewage.

*Buffalo, New York. Summary of Operating Data, July, 1942–June, 1943*

| Item | This Year Average | 5-Year Average |
|---|---|---|
| Temperature sewage, F.° | 62.1* | 59.0 |
| Sewage flow, m.g.d. | 150.0† | 140.0 |
| Kw. hrs. per m.g. | 115.0 | 122.0 |
| Suspended solids | | |
| Raw, p.p.m. | 205.0 | 187.0 |
| Raw, lbs. per capita | 0.43 | 0.36 |
| Effluent, p.p.m. | 134.0 | 120.0 |
| Per cent removal | 34.5 | 35.7 |
| B.O.D. | | |
| Raw, p.p.m. | 127.0 | 137.0 |
| Effluent, p.p.m. | 101.0 | 109.0 |
| Per cent removal | 19.8 | 20.7 |
| Chlorine demand | | |
| Raw, p.p.m. | 4.76 | 4.92 |
| Supernatant liquor, p.p.m. | 338.0 | 225.0 |
| Total, p.p.m. | 5.16 | 5.33 |
| Chlorine dose, lbs. per day | 4,900.0 | 5,400.0 |
| Presumptive coliform bacteria | | |
| Raw, 1,000 per ml. | 68.4 | 63.1 |
| Effluent, 1,000 per ml. | 1.42 | 1.32 |
| Per cent kill | 97.9 | 97.9 |
| Grit | | |
| Cu. ft. per m.g. | 2.27 | 3.16 |
| Per cent dry solids | 57.6 | 52.5 |
| Per cent volatile matter | 38.9 | 39.8 |
| Raw sludge | | |
| 1,000 gals. daily | 178.0 | 278.0 |
| Per cent dry solids | 7.8 | 6.1 |
| Per cent volatile matter | 60.5 | 59.1 |
| pH | 6.3 | 6.5 |
| Digested sludge | | |
| 1,000 gals. daily | 81.0 | 72.0 |
| Per cent dry solids | 9.2 | 9.61 |
| Per cent volatile matter | 54.1 | 48.1 |

* Max. 82.0, min. 43.0.
† Max. 284.0, min. 97.0.

| Item | This Year Average | 5-Year Average |
|---|---|---|
| Supernatant liquor | | |
| 1,000 gals. daily | 179.0 | 256.0 |
| Per cent dry solids | 3.3 | 3.6 |
| pH | 6.7 | 7.0 |
| Digestion tank temperature, F.° | 89.8 | 86.7 |
| Gas production, 1,000 cu. ft. daily | 439.0 | 462.7 |
| Gas analyses | | |
| Carbon dioxide, per cent | — | 33.8 |
| Methane, per cent | — | 63.3 |
| B.T.U. per cu. ft. | — | 635.0 |
| Cu. ft. gas per capita | — | 0.77 |
| Incineration | | |
| Tons of wet sludge cake, daily | 73.0 | 74.0 |
| Per cent dry solids in sludge cake | 37.6 | 37.4 |
| 1,000 lbs. dry solids in sludge cake, daily | 55.0 | 55.0 |
| Per cent volatile matter in sludge cake | 49.4 | 43.1 |
| Per cent CaO | 7.86 | 10.01 |
| Per cent $FeCl_3$ | 1.94 | 2.51 |
| 1,000 lbs. dry ash | 23.7 | 25.0 |
| Per cent volatile matter in ash | 3.73 | 3.57 |

# WARTIME OPERATION PROBLEMS AT SEATTLE *

By William McNamara

*City Engineering Department, Seattle, Washington*

The major problem in maintenance in this war period applies similarly to practically all lines of endeavor and may be summarized in a simple statement—the lack of available manpower. This may appear to be an excuse rather than a fact, but when we encounter any emergency we seem to come back again to the manpower question before it can be met and relieved. I have no doubt that everyone here engaged in municipal work must, like the City of Seattle, get along with 30 per cent of the labor he desires and is entitled to under his budget.

The making of necessary repairs is further complicated by some delay in securing material and repair parts, which situation has probably been partly due to the lack of manpower in the manufacturing plants. We have all had our priority problems in the past but at last we in the sewage works field can point proudly to our AA–1 rating, which is the best rating given in relation to other municipal purchases. Although the manufacturers have been placed in a difficult situation in meeting our needs, they have given us their best co-operation and have helped us avoid critical circumstances.

Another serious problem in wartime operation is the sudden increase in population which results in greater loads on the sewers and treatment plants. One example of this is in connection with a large disposal plant operated by the Seattle Engineering Department. This plant was origi-

* Presented at Pacific Northwest Sewage Works Association Conference, Olympia, Washington, May 11, 1944.

nally designed to handle the sewage from a certain district estimated to have an ultimate population of 32,000 people with a flow of 8 million gallons per day, but on this line was erected the Boeing Plant employing some 28,000 persons, the Isaaccson plant with possibly 2,000 persons and numerous smaller industrial plants that have come into existence since the start of the war. It can be seen that the industrial population now served by the plant is greater than the original design population. The sewage entering the plant is very fresh, due to its short distance of travel and the amount of trade wastes is greatly increased. To illustrate one phase of the problem, just yesterday we obtained 33,000 cu. ft. of gas from our digesters, which flow being over the capacity of our meters, is causing us considerable trouble. The normal consumption of gas for the plant and digester heating is about 10,000 cu. ft. per day and the excess burner is constantly flaming.

Recently we had an acid condition develop at the digesters and the pH dropped into the foaming range. Upon investigation we found the wastes responsible were coming from the Boeing factory, where the aluminum is dipped in a bath of chromic acid to give the metal a surface that would take paint pigments in camouflage. This was brought to the attention of the Boeing engineers and correction was made which cleared up our problem. Another problem resulted from the depositing of sponge rubber strips in the toilets at the factory which practice caused much trouble at our pumps.

We have had to make several changes at our pumping and treatment plants in the past year. One such change was the installation of electrical controls at the pumps so as to obtain more continuous pumping and thus relieve the stage starting devices. At the treatment plant we have been able to reduce greatly the amount of sand reaching the digesters by reducing the velocity through the detritor, resulting in the removal of about 4 times as much grit as had been produced previously. Further, we have installed automatic timing devices at our sludge pumps so that pumping of sludge from the clarifier to the digester takes place during a definite interval of every hour, whether an attendant is present or not. The latter change has improved digester operation materially.

From a study of pump operation times at our 16 sewage pumping stations, we find that our pump capacities are such that the pumping time is very short in comparison to the rest period during filling of the wet well. Installation and power costs would have been reduced if smaller pumps had been used so that they would operate more continuously. Our study of the pumping periods and the resulting adjustment of floats and controls has accomplished a reduction in our power bill of approximately 25 per cent.

Lack of manpower is causing a real problem in connection with the maintenance of sewer systems. The proper cleaning of catch basins and inlets, the flushing and dragging of sewers and the removal of tree roots has had to be considerably curtailed. Our department now maintains about 1,100 miles of trunk and main sewers, of which some 200 miles require annual attention in the form of removal of roots. At present, we are able to give this attention only once in three years. This situation, of course, has increased the liability of the City for damages due to blocked sewers and flooded basements.

How is this manpower problem to be met? I can only say that in our department, every man is being used where he can do the most good and that all available personnel has been apportioned to the various divisions of the department in as equitable a manner as possible. Whenever any emergency occurs in any of the divisions we all hold ourselves in readiness to furnish all of the men and assistance that we can. I can only recommend that you accomplish the very best results possible with what you have or can obtain without interfering with the major war effort.

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## SEWAGE EFFLUENT CHLORINATION *

By Lt. E. A. Bell

*Sanitary Engineer, Office of Supervising Engineer, 13th Naval District, Seattle, Wash.*

In order to approach the subject of disinfection of sewage effluents, we must look back to those days when the treatment of sewage was non-existent. The use of surface supplies for potable water was, and still is, common for cities and smaller municipalities. Disease was rampant throughout the world and once an epidemic of cholera, typhoid or other waterborne diseases was started, many lives were lost before the dreaded plague had run its course—and that is the way epidemics usually ended. As human habitation began to spread out over larger areas, springs and wells also gathered pollution by seepage of wastes into the ground.

The development of water treatment units such as filters, coagulation tanks and disinfection devices arrested such disease and retarded it to a point that now a waterborne epidemic is very rare. At the turn of the century, it became apparent that the most practical approach to the problem of pollution was removal of the source rather than an attempt to treat all water supplies as extensively as the necessity demanded. The use of sewers for the removal of wastes dates back to the Roman Empire, but the collection of sewage and its subsequent treatment has occurred within the last century and has only reached its peak in the past twenty-five years. The disinfection of the effluent is usually the final step in rendering harmless the discharge of treated sewage into various streams, river, lakes and other bodies of water used not only for potable purposes, but also for bathing and the habitat of edible shellfish.

Experimentation over a period of years has demonstrated many methods of destroying bacteria in water. However, the use of chlorine gas, in properly controlled doses, has proven not only the most effective, but also the most economical. The development of hypochlorite com-

* Presented at Pacific Northwest Sewage Works Association Conference, Olympia, Washington, May 11, 1944.

pounds of high chlorine content (approximately 70 per cent) has also played an important part, but the relatively high cost of such chemicals when used in large quantities, and the difficulty in handling has made their use impractical in large installations. Chlorine is an ideal agent for sewage disinfection because of the remarkable ability of a small amount of chlorine to kill a large percentage of bacteria—practically 100 per cent of the pathogenic group which causes so much illness. Another feature is that the control of chlorine dosage is very simple and any layman properly instructed can compute and adjust the rate of feed so that the treatment will be complete but not wasteful.

In applying chlorine to sewage effluents, two components must be considered, the demand and the residual. The former is important because it is the amount normally required for complete sterilization and the latter is important because of the facility with which it can be determined. The term ''residual chlorine'' is the one most commonly used in sewage treatment and is usually expressed in parts per million. It is the quantitative amount of free chlorine remaining after a known period of contact of chlorine with the sewage. There are several methods of determining the residual, but the two most used are (*a*) starch iodide, and (*b*) orthotolidine. The latter method is preferred over the others because it is rapidly performed and, by the use of color standards, will give quantitative results that are sufficiently accurate for all practical purposes.

The chlorine demand of sewage effluents varies with the degree of treatment; it may run as high as 40 p.p.m. in the case of septic primary effluent to as low as 1 p.p.m. in highly treated effluents. The demand also varies with the strength and age of the sewage. Economy of operation dictates the amount of chlorine to be used and, for that reason alone, it is not desirable to carry a high residual after the contact period. There are many opinions both as to contact period and the amount of residual desired; in all instances, it is best to follow the requirements laid down by your state department of health. The various states have slightly different requirements but, in general, the regulations are not so divergent as to warrant any discussion. Some authors report that a residual of 0.2 p.p.m. after 5 minutes contact will guarantee destruction of pathogenic organisms while others go high as 1 p.p.m. after 30 minutes contact. After a careful study of many reports on this subject, the writer prefers to use 0.5 p.p.m. residual after 15 minutes contact as a general practice.

In designing a new sewage treatment plant, one of the problems of the designer is—do we need disinfection? Again it is wise to follow the suggestion of the state health authorities; you will rarely find them arbitrary or unreasonable. If the solution is left to the designer, a good rule is ''If in doubt—chlorinate.'' All phases of the problem should be studied carefully—the course of the effluent after it leaves the plant; the amount of dilution; whether or not the receiving stream is used for potable supply, bathing or shellfish; and, last but by no means least, will untreated sewage cause a nuisance or health hazard further downstream? The cost of chlorination equipment is normally so small compared to the entire cost, that the designer can never be wrong by providing for disinfection. Obviously, there may be instances where the use of any means of sterilization is unnecessary and foolish and should not ever be considered, however, there again you will find the state health engineers ready and willing to advise.

The continued advance in the art of feeding chlorine gas has made the problem of effective sterilization a simple one. The development of automatic equipment permits the positive and accurate control of correct amounts of chlorine to meet the ever fluctuating rate of flow. The chlorine-potential machine is probably the most highly refined unit available in that it not only meets variation in flow, but also meets variations in demand. Chlorine gas, uncontrolled, does not provide suitable treatment, and the present day devices are responsible for the highly efficient methods of disinfection.

There are many other uses for chlorine in the treatment of sewage, but in order to keep this paper within the bounds of discussion they have been purposely omitted.

## Discussion

By E. A. Heiss

*Division Manager, Wallace and Tiernan Corp., Seattle, Wash.*

The basic and preliminary phases discussed by Lt. Bell lead to further discussion of the specific uses of chlorination in sewage disposal. For the purpose at hand, the many miscellaneous uses will be mentioned first and discussed briefly, leading up to the main topic of effluent chlorination—its general use in the past, its purpose and what the sewage plant operator and engineer may expect in the future.

Digressing then from the main topic we will first mention prechlorination of sewages. Generally, prechlorination of sewage is used for odor control and this has often been considered the outstanding application of chlorination in sewage treatment. The value of prechlorination lies in the ability of chlorine to halt the bacterial decomposition of sewage and resultant odors by destroying bacterial life. Incipient septicity can often be postponed several hours by minor chlorine doses added to sewage, which later, due to slight aging, would present severe odor problems. This postponement often also permits the handling of aging sewage without excessive masonry, plant and structure deterioration or ineffective treatment plant operation. The oft-mentioned classic example of masonry deterioration and its correction is the Orange County outfall sewer at Los Angeles where, before chlorination, the $H_2S$ ranged from 10–60 p.p.m. at the upper end of the sewer and 5–10 p.p.m. at the lower end. The total operating cost of several chlorination stations on feeder lines was about $3.25 per m.g., which resulted in reducing the $H_2S$ to less than one p.p.m. and extended the life of the sewer indefinitely. The original cost of the sewer was $1,000,000 and the structure had been expected to deteriorate 100 per cent in 10 years. This treatment returned over 800 per cent on the investment of some $6,000 per year for chlorine. Last but not least, a very bad odor nuisance was corrected at the same time and disinfection was accomplished.

Prechlorination for odor control ahead of sewage disposal plants has, in many instances, improved sedimentation and increased the amount of settleable solids removed. It is often used at Imhoff tanks to decrease foaming and in clarifiers to reduce scum formation. Several authorities report no harmful effect of prechlorination in sludge digestion. In fact, the reverse has been reported on several occasions.

Intermediate chlorination within the sewage treatment plant is common for various reasons. Among these, chlorination has been used to control sludge bulking in activated sludge plants. It has been widely used to correct filter ponding in trickling filter plants, and to control *sphaerotilus* growths in sedimentation and flocculating tanks. It is used to condition supernatant return liquors and in sludge thickeners as well as grease removal units. In addition to all these uses, however, the basic advantage of chlorination lies in its value as a sterilizing agent for final disinfection of sewage effluents before discharging them into receiving channels or waterways. This use is now regarded as a necessity in nearly all instances and, when the many advantages of chlorination in plant processes are considered, the modern sewage plant without chlorination facilities is rare.

Although chlorination of raw sewage is rarely recommended, a development in one Puget Sound area can be used as an example. Many small sewers serving relatively uncongested areas discharge into the Sound adjacent to Seattle. Pending construction of adequate disposal plants, present treatment consists of comminution followed by chlorination during summer months and discharge to the Sound at a 40-ft. depth. Apparently, passable results are obtained and no defiling of bathing beaches or pollution is noticeable from such disposal.

When effluent chlorination was first used, Tiedeman at Huntington, L. I., in 1927 described a classic bacteriological work done on bacterial reductions as related to chlorine applications and contact times. This was the first published data on the results of chlorination for this purpose. Shortly thereafter it was recognized by various operators that chlorination of sewage and plant effluents resulted in B.O.D. reduction and further extensive work was done in this regard by many independent workers. The A.P.H.A. reviewed all available data and concluded:

1. Chlorination to give residuals of 0.2 to 0.5 p.p.m. after 10 minutes reduces the 5 day B.O.D. from 15 to 35 per cent; the reduction of B.O.D. being approximately proportional to quantity of chlorine absorbed.
2. For each p.p.m. of chlorine assimilated, a reduction of 2 p.p.m. of B.O.D. is obtained.
3. Chlorination sufficient to produce free chlorine residual in the chlorinated sewage or effluent will retard normal decomposition

processes, thereby tending to prevent anaerobic conditions during the normally critical period of rapid oxygen depletion, thus permitting opportunity for reaeration and additional dilution from tributary streams to maintain aerobic conditions.

Rudolfs and Lacey studied partial chlorination and B.O.D. reduction, finding that chlorination to 50 per cent of the chlorine demand caused a 10–20 per cent reduction in five and ten-day B.O.D., while further chlorination to 100 per cent caused a 25 to 27 per cent reduction. Further work indicated that most of the five-day reduction was caused by chlorine doses from 20 to 40 per cent of the chlorine demand.

Connecting these data to that of Tiedeman's work on bacterial reductions indicates that the field of subresidual chlorination for the large plant is worthy of considerable further investigation. Were it not for the war we would today probably be able to cite other data on this subject. Possibly this will be available soon. In this field lies the value of chlorination to the large plant and it is in this field that the major development in sewage chlorination will probably come in the postwar period.

It is an established fact that regrowths of organisms will occur in receiving bodies but to what extent is debatable. The Columbia River pollution investigation indicates that prolific slimes result from the addition of an ample food supply to water carrying dormant bacterial life. This tendency has been noted where sterile sewages containing plenty of bacterial food were discharged into small receiving streams carrying little bacterial life, with the result that bacterial activity immediately flourishes to a disastrous extent.

Another type of regrowth occurs where suspended solids are not completely removed. In such a case, chlorine does not get to bacteria encased in particles of suspended matter. When such particles reach receiving bodies some of the bacteria escape and grow prolifically. Normally, the inherent bacteria in the receiving water get a decided impulse with the addition of a large food supply and a subsequent increase in bacterial life will follow.

It is obvious to anyone studying the reports and literature that further experimental laboratory work is necessary in the sewage field and that postwar sewage disposal will show marked advances in the art and manner of sewage chlorination.

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## REVISED ORDER P–141

### (AS AMENDED JULY 15, 1944)

PART 3287—GOVERNMENT SERVICES

[Preference Rating Order P–141, as Amended July 15, 1944]

*Public Sanitary Sewerage Facilities; Maintenance, Repair and Operating Supplies*

§ 3287.26. *Preference Rating Order P–141*—(*a*) *Definitions.* For the purpose of this order:

(1) "Operator" means any individual, partnership, association, corporation, governmental corporation or agency, or any organized group of persons, whether incorporated or not, located in the United

States, its territories, or possessions, engaged in or constructing facilities for the purpose of engaging in, the operation of a public sanitary sewerage system or a public sanitary sewerage system combined with a storm sewerage system, whether or not such operator has applied the preference ratings herein assigned.

(2) "Controlled material" means steel—both carbon (including wrought iron) and alloy—copper (including copper base alloys) and aluminum, in each case only in the forms and shapes indicated in Schedule I of C.M.P. Regulation No. 1.

(3) "Material" means any commodity, equipment, accessory, part, assembly, or product of any kind.

(4) "Maintenance" means the minimum upkeep necessary to continue an operator's property and equipment in sound working condition.

(5) "Repair" means the restoration of an operator's property and equipment to sound working condition after wear and tear, damage, destruction of parts or the like, have made such property or equipment unfit or unsafe for service.

(6) "Operating supplies" means:

(i) Material which is essential to the operation of the system specified in paragraph (*a*) (1) and which is generally charged to operating expense account.

(ii) Material for an addition to or an expansion of sewerage system or works, other than buildings, provided that such an addition or expansion shall not include any work order, job, or project, in which the cost of material shall exceed $1,500 and provided that no single construction project shall be subdivided into parts in order to come below these limits.

(7) Material for "maintenance," "repair" and "operating supplies" includes any material which is essential to minimum service standards, and does not include material for the improvement of an operator's property or equipment through the replacement of material which is still usable.

(8) "Supplier" means any person with whom a purchase order or contract has been placed for delivery of material to an operator, or to another supplier.

(9) "Calendar quarterly period" means the several three months of the year commencing January 1, April 1, July 1, and October 1, or the operator's customary accounting period closest to such period.

(10) "Inventory" means all new or salvaged material in the operator's possession, unless physically incorporated in plant, without regard to its accounting classification, excluding, however, material which is segregated for use in additions and expansions specifically authorized under paragraph (*g*) (2) of this order or by an operative preference rating order or certificate issued by the War Production Board.

(*b*) *Preference ratings.* A preference rating of AA-1 is hereby assigned to orders to be placed by an operator for material to be used for maintenance or repair, and for operating supplies.

(*c*) *Controlled materials; steel, copper and aluminum.* Subject to the quantity restrictions contained in paragraph (*f*) of this order, any operator requiring delivery of any controlled material for maintenance, repair or operating supplies may obtain the same by placing on his delivery order the certification required in paragraph (*e*) (1) hereof. An order bearing such certification shall constitute an authorized controlled material order.

(*d*) *Restrictions on use of symbol and ratings.* (1) The allotment symbol and preference ratings hereby assigned shall not be used by an operator or supplier to obtain deliveries of scarce material, the use of which could be eliminated without serious loss of efficiency by substitution of less scarce material or by change of design.

(2) The preference ratings assigned by paragraph (*b*) shall not be used to obtain any item included in Lists A or B of Priorities Regulation No. 3.

(*e*) *Application and extension of ratings; application of C.M.P. allotment symbol*—(1) *Certification.* The AA-1 rating assigned by paragraph (*b*) of this order and the C.M.P. allotment symbol MRO-P-141 may be applied by an operator to deliveries of material for use in maintenance, or repair, or as operating supplies only by use of a certification in substantially the following form:

> Preference Rating AA-1, C.M.P. Allotment Symbol MRO-P-141. The undersigned purchaser certifies, subject to the penalties of Section 35 (A) of the United States Criminal Code, to the seller and to the War Production Board, that to the best of his knowledge and belief the undersigned is authorized under applicable War Production Board regulations or orders to place this delivery order, to receive the item(s) ordered for the purpose for which ordered, and to use any preference rating or allotment number or symbol which the undersigned has placed on this order.
>
> ........................................................................
> Name of operator
>
> ........................................................................
> Signature of designated official

Such certification shall be signed manually or as provided in Priorities Regulation No. 7.

(2) The ratings assigned by this order may be extended by a supplier in the manner provided in Priorities Regulation No. 3, and C.M.P. Regulation No. 3.

(*f*) *Restrictions on deliveries, inventory and withdrawals*—(1) *Deliveries and withdrawals.* No operator shall, during any calendar quarterly period, accept delivery of any material or withdraw from inventory any material, to be used for maintenance or repair or as operating supplies or for any other purpose (except material to be segregated for use in extensions specifically authorized under paragraph (*g*) (2) of this order or by an operative preference rating order or certificate issued by the War Production Board), the aggregate dollar value of which shall exceed the aggregate dollar value of materials used for maintenance or repair or as operating supplies, during the corresponding calendar quarterly period of the year 1942, or at the operator's option, twenty-five per cent of the aggregate dollar value of materials used for said purpose during the operator's fiscal year ending closest to December 31, 1942.

(2) *Inventory.* No operator shall at any time, accept delivery of any material if the operator's inventory will, by virtue of such acceptance, be in excess of a practical working minimum.

(3) *Exceptions.* The provisions of paragraph (*f*) (1) of this order are subject to the following exceptions.

(i) An operator who, during the calendar year 1942 (or fiscal year ending closest to December 31, 1942), used for maintenance, repair, and as operating supplies, materials of the aggregate value of not exceeding $5,000, and whose estimated requirements for materials to be used for maintenance, repair and as operating supplies during any calendar year (or corresponding fiscal year) do not exceed $5,000 may, during such year, exceed the quantity restrictions prescribed by paragraph (*f*) (1) of this order. If the actual requirements of material for maintenance, repair and operating supplies for each year should prove to be in excess of $5,000, such operator shall not accept any deliveries of material or withdraw from inventory any material to be used for maintenance, repair or as operating supplies if such deliveries or withdrawals, when taken together with other deliveries or withdrawals within such year, would, in the aggregate, exceed $5,000. In such case the operator may apply for specific authorization to exceed such quantity restrictions pursuant to the provisions of paragraph (*f*) (4) hereof.

(ii) An operator may, in any calendar quarterly period, increase scheduled deliveries, and withdrawals of material required for maintenance or repair or as operating supplies over the limits prescribed in paragraph (*f*) (1) of this order, in proportion to the increase in the load on the system during the preceding calendar quarterly period of the year 1942 corresponding to the calendar quarterly period in question, determined by a measurement of the average daily flow for the two comparative periods: *Provided,* That in determining the average daily flow of sewage, any flow of surface storm water which enters the system shall not be taken into account.

(iii) An operator may, in any calendar quarterly period, accept deliveries of material or make withdrawals from inventory of material, necessary for the maintenance or repair of the operator's property or equipment which is damaged by acts of the public enemy, sabotage, explosion, or fire or by flood, storm or other similar climatic conditions: *Provided,* That if the restrictions of paragraph (*f*) (1) are exceeded because of such deliveries or use, a full report thereof shall be made within thirty days after such delivery or withdrawal, to the War Production Board.

(iv) An operator may, in any calendar quarterly period, accept delivery of material, having in the aggregate, a dollar value of not more than the dollar value of material of the same class taken from the operator's inventory for delivery to other persons authorized to accept delivery under applicable regulations of the War Production Board but only if, and to the extent that such taking has reduced the operator's inventory of material below a practical working minimum.

(v) An operator may, during any calendar year (or his fiscal year), withdraw from inventory, material, having in the aggregate, a dollar value of not more than the dollar value of usable material of the same class salvaged from plant during such year.

(vi) The provisions of paragraph (*f*) (1) and (*f*) (2) shall not apply to fuel or to chemicals for sewage treatment.

(4) The War Production Board, on its own initiative, or on application of any operator by letter, in triplicate, addressed to the Government Division, War Production Board, Washington 25, D. C., Ref: P–141, may modify the limitations on practical working minimum inventory, and on scheduling or accepting deliveries, or on use or withdrawals, set forth in this paragraph (*f*).

(*g*) *Restrictions on construction of sewerage facilities.* No operator shall construct any sewerage facilities, including but not limited to sewer pipelines, manhole structures, pumping stations, sewage disposal or treatment plants and connections, and no operator shall, in case of contract construction, accept deliveries of material for such purposes except as follows:

(1) An operator may construct an addition to or an expansion of, sewerage system or works, other than buildings: *Provided,* That such addition or expansion shall not include any work order, job or project in which the cost of material shall exceed $1,500: *And provided,* That no single construction project shall be subdivided into parts in order to come below these limits: *And further provided,* That in making house connections or extension of line to serve premises, no iron or steel pipe shall be used except the minimum quantities required in making necessary connections.

(2) An operator may construct an extension of sewerage facilities, other than buildings, to serve premises which are being built or remodeled under authority of any Preference Rating order of the P–55 series, a specific authorization issued pursuant to Conservation Order L–41 or pursuant to any Petroleum Administrative Order issued by the Petroleum Administrator for War if all of the following conditions are satisfied:

(i) The cost of material for such extension does not exceed $5,000 but exceeds $1,500.

(ii) The extension does not duplicate an adequate service already installed.

(iii) No other operator can render the same service with lesser amounts of critical material.

(iv) The extension will not cause an overload on system including sewage disposal plants.

(v) The operator has completed Form WPB–3445 and delivered it to the builder of the premises to be served for attachment to the builder's application for L–41 approval. Preference ratings and allotment number to acquire material required for such extensions are assigned by paragraph (*h*) of this order.

(3) In addition to the authorization contained in paragraphs (*g*) (1) and (*g*) (2) an operator may construct sewage facilities of any kind if such construction is specifically authorized by the War Production Board. Application should be made on Form WPB–617 (formerly PD–200) or on such other form as may be prescribed. The following preference rating orders or certificates include permission for construction under this order although they do not say so: P–19–h, CMPL–127, CMPL–224. In all other cases a preference rating is not enough unless the instrument which assigns the rating also states that construction is permitted. However, any operator who prior to January 15, 1944, has been specifically authorized in writing by the War Production Board to use the lowest rating assigned to a rated project to obtain material to construct sewerage facilities to serve such project may use such rating to obtain material required for that purpose within the limits of said authorization.

(*h*) *Assignment of preference rating and C.M.P. allotment symbol for extensions authorized under paragraph* (*g*) (2). (1) The preference rating AA–3 is hereby assigned to orders for material other than controlled material, and the abbreviated allotment number S2 is hereby assigned to orders for controlled material to be placed by an operator for use in the construction of extensions of facilities authorized by paragraph (*g*) (2) of this order or to replace in inventory material so used.

(2) The preference ratings and allotment number assigned by paragraph (*h*) (1) may be applied by an operator by using the certification provided in C.M.P. Regulation No. 7. An order for controlled material bearing such certification and allotment number shall constitute a controlled material order.

(*i*) *Sales of material from inventory.* Any operator may sell to another operator, material from seller's inventory in excess of a practical minimum working inventory: *Provided,* That (1) a preference rating of AA–5 or higher assigned by this order or by any preference rating certificate, or (2) a specific direction issued by the War Production Board, is applied or extended to the operator selling such material.

(*j*) *Audits and reports.* (1) Each operator and each supplier who applies the preference ratings or allotment symbol hereby assigned, and each person who accepts a purchase order or contract for material to which a preference rating or symbol is applied, shall submit from time to time to an audit and inspection by duly authorized representatives of the War Production Board.

(2) Each operator and each such supplier shall execute and file with the War Production Board, such reports and questionnaires as said Board shall from time to time request, subject to approval by the Bureau of the Budget as required under the Federal Reports Act.

(3) Each operator shall maintain a continuing record of inventory and of segregated material in his possession and all material used by him for maintenance, repair or as operating supplies.

(*k*) *Communications to the War Production Board.* All reports required to be filed hereunder and all communications concerning this order shall, unless otherwise directed by the War Production Board, be addressed to the War Production Board, Government Division, Washington 25, D. C., Ref: P–141.

(*l*) *Violations.* Any person who wilfully violates any provisions of this order or who, in connection with this order, wilfully conceals a material fact or furnishes false information to any department or agency of the United States, is guilty of a crime and, upon conviction, may be punished by fine or imprisonment. In addition, any such person may be prohibited from making or obtaining further deliveries of, or from processing or using material under priority control, and may be deprived of priorities assistance.

(*m*) *Revocation or amendment.* This order may be revoked or amended at any time as to any operator or any supplier. In the event or revocation, deliveries already rated pursuant to this order shall be completed in accordance with said rating, unless the rating has been specifically revoked with respect thereto. No additional applications of the ratings to any other deliveries shall thereafter be made by the operator or supplier affected by such revocation.

(*n*) *Applicability of regulations.* (1) Preference Rating Order P–141 is issued in lieu of Preference Rating Order P–46 in so far as it affects public sanitary sewerage systems as defined in paragraph (*a*) (1) hereof and any reference in any order or regulation of the War Production Board to said Preference Rating Order P–46 shall constitute a reference to orders in the P–141 series.

(2) This order and all transactions affected hereby, except as herein otherwise provided, are subject to all applicable regulations of the War Production Board as amended from time to time, *Provided,* That none of the provisions of C.M.P. Regulations No. 5 or No. 5A shall apply to operators as defined in paragraph (*a*) (1) hereof, and no such operator shall obtain any material under the provisions of either of said regulations.

Issued this 15th day of July 1944.

War Production Board,
By J. Joseph Whelan,
*Recording Secretary.*

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# TIPS AND QUIPS

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Issuing from Oshkosh, Wisconsin, where the Central States Sewage Works Association gathered for its Seventeenth Annual Meeting on June 22–24 . . . the opening day devoted to the program of the Wisconsin Conference of Sewage Works Operators . . . a meeting room offering wall decorations a la Petty (or Varga) to compete with the speakers for audience interest . . . also, a juke box to furnish music to attract corridor loiterers into the sessions . . . a total of 178 registrations—not the record but good, nevertheless . . . permanent award of the Federation Convention Attendance Cup, earned by aggregating 93,890 man miles in attending the New York, Cleveland and Chicago meetings of the Federation . . . a splendid Gadget Contest with eight fine entries . . . the Radebaugh Award to Samuel A. Greeley for his paper "High Rate Biological Sewage Treatment" presented at the Chicago meeting in 1943 . . . a well deserved rising vote of thanks to "Standard Methods" Hatfield, in recognition of his fine leadership of the Federation committee of the same designation . . . a scintillating spur-of-the-moment open forum on activated sludge, filling a program spot vacated when a scheduled speaker was unable to get to the meeting . . . the early but non-putrescible toastmastering at the banquet, which could have been put over by no one but C. C. (Swede) Larson of Springfield, Illinois, who did it . . . the spotless, efficient sewage treatment plant at Oshkosh, supervised by R. W. Frazier and inspected by the group . . . a well arranged conference from A to Z, reflecting credit to Host Frazier, Secretary Mackin, President Bloodgood and others.

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Two good quips heard in the program of the Central States meeting at Oshkosh:

President Ray E. Dempsey of the Oshkosh Sewerage Commission, in the course of his remarks on public relations, told of the call he received from an impatient housewife after a deluge of rain had almost inundated the city. In response to her query, "When are you going to take care of my basement?" he replied, "We will be right over as soon as I get my own pumped out and cleaned up!"

"One cannot be complacent or impetuous when operating a packing plant waste treatment works," observed D. H. Nelson, Chief Chemist of the Oscar Mayer Packing Company at Madison, Wisconsin, as a side comment incidental to his discussion of packinghouse waste treatment. Which is good advice to any operator in this field!

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More good advice comes from Eric A. Johnston, President of the U. S. Chamber of Commerce, writing on postwar planning in the annual directory issue of *The Constructor,* official publication of The Associated General Contractors of America.

"States and municipalities should assume every responsibility they can assume," he says, "but they will be helped in putting their shoulders to the reconversion wheel . . . if Congress will declare a reasonably clear line of demarcation between public works which will receive federal aid, such as highways, and public works which will not, such as waterworks and schools.

"The states and municipalities," he continues, "are in better position than in many years to resume the practice of financing their own public works, rather than depending upon the federal government . . . their debts have been reduced, their current tax collections are at peak levels, and their relief responsibilities at a minimum.

"In addition, the federal government can set an example for the states and municipalities by general adoption of the contract method of public construction," he asserts and points out, that "experience has demonstrated that to secure better performance in shorter time and at lower costs, public construction should be carried out through competitive contracts with private construction enterprise and not through hiring day labor or resorting to work relief methods.

"All construction work should be planned as far in advance as practicable. This is particularly urgent in getting ready for a rapid and orderly shift from a wartime to a peacetime economy."

*Blueprint Now!*

• • •

"Even the Russians are doing it!" points out E. L. Filby of "Blueprint Now" fame, in referring to the story "The Terrible Woman of Ilsk" appearing in *Colliers* of July 24, 1944. The lovely Serafina, ultra-efficient leader of the City Soviet, struck a most responsive Filby chord in her impassioned plea to the council of Ilsk:

> Comrades, we have done our utmost, but this is not enough. There remains the vital subject of sewage disposal. Moscow has solved this problem. Will Ilsk remain behind?
>
> A comprehensive plan for sewage disposal has been proposed to the City Soviet—of which I have the honor to be Chairman—by Comrade Leopold Meyerovsky. Citizens, support this plan!

• • •

If you please, just one more reference to the postwar planning situation. Data recently made available by the A. S. C. E. Committee on Postwar Construction indicate that more than $377,000,000 of sewerage construction was in or through the blueprint stage on August 9. This was 10.7 per cent of all planned construction, including industrial and commercial classes.

An Honor Roll by states would find Ohio at the top with $64,273,000 of planned sewerage construction; New York second with $50,784,000; Illinois third with $35,855,000 and California fourth with $23,155,000.

But what about the 15 states from which no sewerage construction plans have as yet been reported?

• • •

Getting back to plant operation, the following, written by Edward S. Rankin and included in the June 15, 1944, report of the Elizabeth (N. J.) Joint Meeting, may aid in establishing the proper atmosphere:

*The Road to Arthur Kill*

From the Oranges and Millburn,
  And from Summit's lofty hill,
Runs the old Joint Outlet Sewer
  Flowing down to Arthur Kill;
Gathering sewage too from Union,
  Roselle Park and Maplewood,
Hillside, Irvington and Newark,
  Joining in one mighty flood.
    Rushing eastward in a flood,
    Carrying sludge and sand and mud,
    'Till the treatment plant receives it,
    Purifies that turbid flood.

On the road to Arthur Kill,
Tunneling through Headly's hill,
Just across from Staten Island
Lies the outlet on the Kill.

Eddie,* standing in the screen house,
Scans the flow with eagle eye,
Filters out the grit and screenings
As the sewage rushes by.
To the settling tanks it travels,
From this coarser stuff set free,
Where the solids slowly settle
Thus reducing B.O.D.
Cutting down the B.O.D.
While the effluent flows to sea
As the Health Board nods approval
And the watchful I. S. C. †
On the road to Arthur Kill
Here our engineering skill
Stops pollution by the sewage
Of the waters of the Kill.

When the frost is on the sludge tanks
And the mercury drops low,
When the sludge grows thick and viscous
And the pumps refuse to go—
Listen to our Eddie swearin'
With his eye upon the clock,
For the overtime mounts swiftly
When the barge is at the dock.
Waitin' calmly at the dock
While the motors grind and knock,
Can't you hear the captain chucklin'
Sittin' lazy at the dock.
At the dock at Arthur Kill
Waitin' for the barge to fill—
Wish I'd gone and joined the navy,
Got away from Arthur Kill.

Take me somewhere east of Jersey
To the Arabs or the Turks
Where there ain't no sanitation
Nor no need for treatment works;
Where the gutters run with sewage
And where microbes are unknown,
And your sleep is never broken
By the janglin' of the phone.
Hear that bloomin' telephone—
"Hey! the screens are plugged with stone
And the whole plant's under water,
Grab your boots and come on down."
Curse that road to Arthur Kill!
Lead me to some peaceful hill,
Far from screens and pumps and barges,
Far away from Arthur Kill!

* Edward P. Decher, Acting Chief Engineer.
† Interstate Sanitation Commission.

That Mr. Rankin writes truth into his poetry is demonstrated by his service as Secretary of the Joint Meeting for 30 years and as Division Engineer of Sewers for the City of Newark for the past 56 years.

• • •

Figure 1, showing the exterior of the Albert Lea, Minn., sewage treatment plant after an explosion on February 12, 1944, is a sharp reminder that danger may lurk in the gases and fumes emanating from sewage. The damaged building houses an Imhoff tank. Although

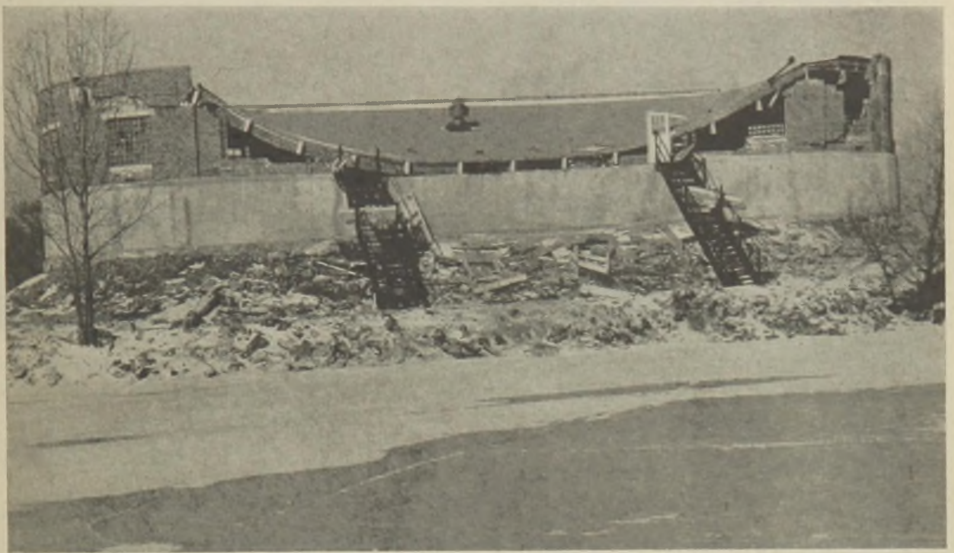

FIG. 1.—Damage to Albert Lea, Minn., sewage treatment works by explosion in February, 1944.

the ventilating exhaust fan had been operating for an hour, sufficient explosive gas remained entrapped beneath the roof to produce the illustrated result when ignited by a stray spark.

The accident sent two men to the hospital, seriously burned, and caused $10,000 damage to the treatment works.

• • •

'Twas a grand day that the Indiana Sewage Works Operators Association picked for their annual gathering last July 19. About 80 operators assembled beneath the "big top" tent on the attractive grounds of the Anderson treatment works for a very practical and interesting program. The criterion of success of an operators' meeting is the quantity and quality of the discussion from the floor and this meeting made the grade in fine fashion.

Host R. R. Baxter, Superintendent of the Anderson sewage works, maintains a simple exhibit (Fig. 2) to demonstrate to visitors the plant nourishing properties of sewage sludge. The stair-step plants illus-

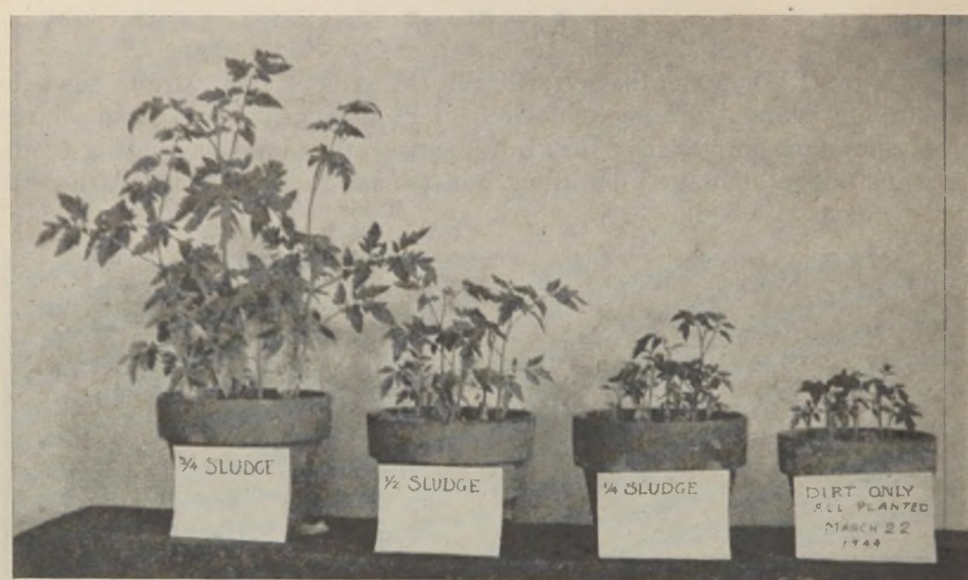


FIG. 2.—Demonstration of tomato plant growth in sewage sludge, Anderson, Indiana.

trated are tomato vines, all planted at the same time in varying mixtures of sludge and soil.

• • •

The severe winter temperatures encountered in northern U. S. bring about sewage works operation problems that require careful and detailed attention. Superintendent Charles Price at Rapid City, South Dakota, reports marked improvement in digester efficiency following improved insulation at the tank. Dried sludge with a waterproof surfacing was used as the insulating material.

South Dakota operators will learn the details at the September meeting of the South Dakota Water and Sewage Works Conference.

• • •

# Editorial

## FEDERATION AWARDS

In our opinion, the recognition of outstanding achievement by the granting of appropriate awards has been a much more notable undertaking than the Federation has been given credit for up to this time. Perhaps this activity has been overshadowed by more spectacular developments and has not been with us long enough to be more thoroughly appreciated. It is our purpose here to review the basis for the various Federation awards and to present a brief biographical sketch of each of the men after whom the awards are named.

The establishment of a schedule of awards to reward and encourage meritorious endeavor in the sewage works field was recommended in 1941 by the General Policy Committee and was promptly approved by the Board of Control. An Awards Committee comprising E. Sherman Chase, Gail P. Edwards, Carl C. Larson, Howard E. Moses and headed by Prof. Charles Gilman Hyde as chairman, was immediately appointed. At the 1942 Board of Control sessions, the following awards were recommended by the Committee and authorized by the Board:

HARRISON PRESCOTT EDDY MEDAL (For Research)

For outstanding research contributing in important degree to the existing knowledge of the fundamental principles or processes of sewage treatment and as comprehensively described and published during any stated year in SEWAGE WORKS JOURNAL; such description and discussion to outline the problem, the method of attack, the conclusions reached, and the application to the science and art of sewage treatment.

GEORGE BRADLEY GASCOIGNE MEDAL (For Operation)

For outstanding contribution to the art of sewage treatment works operation through the successful solution of important and complicated operational problems; and as comprehensively described and published during any stated year in SEWAGE WORKS JOURNAL.

CHARLES ALVIN EMERSON MEDAL (For Services to the Federation as a Whole)

For outstanding service in the sewerage and sewage treatment works field as related particularly to the problems and activities of the Federation of Sewage Works Associations in such terms as the stimulation of membership, improving standards of operational accomplishments, fostering fundamental research, etc., and to be given yearly, if feasible, to some member of the Federation.

KENNETH ALLEN AWARDS (For Service in Local Member Associations)

For outstanding service in the sewerage and sewage treatment works field, as related particularly to the problems and activities of any Member Association; to be in the form of a certificate issued from the headquarters of the Federation of Sewage Works Associations and bearing proper and adequate signatures; and to be granted to any one Member Association once in three years, according to schedule, in rotation with other Member Associations.

Harrison Prescott Eddy (1870–1937), whose name is perpetuated by the research award, was a native of Massachusetts and a true pioneer in the art of sewage treatment. He was educated in Worcester, Mass., where he graduated from Worcester Polytechnic Institute in 1891 with the degree of B.S. in Chemistry. His notable professional service led to his being conferred with the honorary degree of Doctor of Engineering by W. P. I. in 1930 and with the same degree by

Northeastern University of Boston in 1931. Upon graduation from college, Mr. Eddy assumed the duties of chemist in charge of the Worcester sewage treatment plant and, after only one year, was advanced to the position of Superintendent of the Department of Sewers, which post he held for fifteen years. During this time he fostered and conducted fundamental research in sewage treatment methods which are in current usage. Mr. Eddy's first engagement as a consultant, in connection with the design of a sewer system at Louisville, Ky., in 1906, led to his joining with the late Leonard Metcalf to create the well known consulting engineering firm of Metcalf and Eddy in 1907. This partnership served more than 125 cities in water and sewage works improvements and the firm continues to function under the original name. Messrs. Metcalf and Eddy also co-authored the books "American Sewage Practice" and "Sewerage and Sewage Disposal," which volumes are standard references today. Reference to Mr. Eddy as the "Dean of American Sanitary Engineers" in his memoirs as published in A. S. C. E. *Transactions,* October, 1939, is a fitting summation of the place he held in his profession.

George Bradley Gascoigne (1844–1940), whose name designates the award for meritorious contribution in sewage works operation, was a resident of Ohio during his entire life. He was a graduate of Ohio State University in 1910, receiving the degree of Civil Engineer. Mr. Gascoigne began his professional career as an engineering assistant in the Engineering Department of the City of Sandusky, Ohio, where he remained until 1912. He then entered the employ of the City of Cleveland where he was placed in charge of the newly created Subdivision of Sewage Disposal. This engagement yielded valuable experience including basic sewage treatment research in screening methods, sludge dewatering and disposal and secondary treatment methods, which work prefaced the design and construction of Cleveland's excellent treatment works. In 1922, Mr. Gascoigne embarked into the practice of consulting engineering, organizing the firm of Gascoigne and Associates. The firm specialized in sewerage and sewage treatment work and, since the death of Mr. Gascoigne, has continued to function under the name of Havens and Emerson. Early in his professional life, Mr. Gascoigne recognized the extreme importance of plant operation experience in the analysis of design problems and, as a consultant, he maintained an unusual contact with the operation of all of the works which were engineered by his firm. Thus, it is most appropriate that the plant operation award bear his name.

The award for service to the Federation could not be better exemplified than by the unselfish devotion of Charles Alvin Emerson, President of the Federation during its first thirteen years of existence. Although he no longer carries the responsibility of leadership, the advice and guidance of Charlie Emerson is still sought and valued by the officers of the Federation. Born at Beloit, Wisconsin, on July 10, 1882, Mr. Emerson attended Beloit College where he received the degree of B.S. in 1903. He then attended the Massachusetts Institute of Technology, receiving the degree of B.S. in Sanitary Engineering in 1905. He was conferred with the Honorary Degree of C.E. in 1917 by Pennsylvania State College. After a year at Columbus, Ohio, and five years with the Baltimore Sewerage Commission on design and construction of water and sewage works, Mr. Emerson joined the staff of the Pennsylvania State Health Department as Principal Assistant Engineer and, three years later, became Chief Engineer, which position he held for ten years. In 1923, he associated with Fuller and McClintock, Consulting Engineers, with which firm he carried heavy responsibilities in the performance of many important municipal sanitary engineering projects. Since 1936 Mr. Emerson has been an associate and partner in the firm now operating as Havens and Emerson, Consulting Engineers and he now manages the New York office. Charlie is a member of many technical organizations but of them all, the Federation has received the greater share of his effort and interest. Reference has been made in these pages many times to the part he played in establishing the Federation, to his leadership through the lean and doubtful early years and to his participation in the 1941 reorganization. Charlie Emerson is truly the "Father of the Federation" and holds the distinction of being its first Honorary Member.

Kenneth Allen (1857–1939), for whom the award for service to Member Associations of the Federation was named, was born at New Bedford, Mass., and was a graduate of Rensselaer Polytechnic Institute in 1879. Mr. Allen had broad experience in the water and sewage works fields. He was in charge of the preliminary studies connected with the Baltimore sewerage problem and served for some years as Engineer for the Metropolitan Sewerage Commission of New York City. From 1913 to the time of his death he was Sanitary Engineer on the staff of the Board of Estimate and Apportionment of New York City. In 1913 Mr. Allen visited Europe to inspect and study sanitary engineering works. He was the author of a book entitled "Sewage Sludge" and of many published articles contributing to the science of sewage treatment. That the name of Kenneth Allen is appropriately selected to designate the award for Member Association service is proven by his own participation in the activities of the New York State Sewage Works Association. He is credited by that organization as being the individual most responsible for its creation and, as its first President, for the impetus which has made the N.Y.S.S.W.A. one of the Federation's largest and strongest units today.

At the Fifth Annual Meeting of the Federation held in October, Dr. John Raymond Snell became the second winner of the Eddy Award for his contribution "Nitrogen Changes and Losses During Anaerobic Digestion" (*This Journal,* **15**, 56; January, 1943). Harry W. Gehm received the first Eddy Award in 1943.

The paper, "Rotary Vacuum Filtration of Sludge and the Effect of War on Operation" (*This Journal,* **15**, 807; September, 1943) brought the 1944 Gascoigne Award to James T. Lynch and Uhl T. Mann of Auburn and Cortland, N. Y., respectively. This award was won by Kerwin L. Mick in 1943.

In recognition of his valuable researches into the underlying principles of sewage and industrial waste treatment; of his many contributions to SEWAGE WORKS JOURNAL; and of his unwavering loyalty to the welfare of the Federation," Dr. Willem Rudolfs received the 1944 Emerson Award. Dr. Floyd W. Mohlman was the recipient of this honor in 1943.

Kenneth Allen Awards are now held by the following, the respective Member Associations being indicated:

Alfred E. Berry (Can. Inst.)
Harry T. Calvert (I.S.P.-Eng.)
Edward F. Eldridge (Mich.)
Van P. Enloe (Georgia)
Alfred L. Genter (Md.-Del.)
F. Wellington Gilcreas (New Eng.)
Charles A. Holmquist (New York)
John K. Hoskins (Federal)
Dana E. Kepner (Rocky Mt.)
Fred Merryfield (Pac. Northwest)
Edward P. Molitor (New Jersey)
Robert S. Phillips (No. Car.)
Leon B. Reynolds (Calif.)
W. Waldo Towne (Dakota)
Alfred H. Weiters (Iowa)
William H. Wisely (Cent. St.)

# Proceedings of Member Associations

## CALIFORNIA SEWAGE WORKS ASSOCIATION

**Seventeenth Annual Meeting**

**Fresno, California, June 22–25, 1944**

Registered attendance at this, the Second Wartime Conference, was 156, an increase of 9 over the First Wartime Conference held last year. One feature of the program was the full day sessions devoted to Industrial Waste Disposal problems which have been intensified greatly by wartime manufacturing activity in this State. There were in addition to the Association members, many technical men from the industrial field also present who took a very active part in the program.

### Thursday, June 22

*Smoker and Get-together*

Sixty-three members and guests assembled in the Patio Room of the Hotel Californian at 8:00 P.M. for a buffet dinner and refreshments, furnished by the manufacturers whose representatives are members of the Association. After a very enjoyable dinner, President Richard D. Pomeroy called the meeting to order. With a few opening remarks he turned the meeting over to Mr. E. A. Reinke, Master of Ceremonies.

Mr. M. F. Tiernan, President of Wallace & Tiernan Company, Inc., was introduced and called on for a few remarks. Mr. Tiernan replied with a humorous, yet serious and enlightening talk in which he traced the development and progress in the art of chlorination by a review of the history and activities of his company. This was followed by other introductions, some story-telling, after which the meeting was adjourned at 10:30 P.M.

### Friday, June 23

The Technical Meeting started promptly at 9:00 A.M. with 93 members present. President Pomeroy, after a few opening remarks, turned the meeting over to Mr. Keeno Fraschina, Chairman for the day. There were 102 members present at the afternoon meeting.

### Dinner Meeting—Election of Officers

In the evening, 112 members and guests met for dinner, followed by entertainment and election of officers. Reuben F. Brown, accompanied by Mrs. Carl M. Hoskinson at the piano, sang a solo, the lyrics of which were written by Mr. Brown, with musical accompaniment composed by Mr. Berle Phelps—all of which was composed during the evening meal immediately preceding the presentation. The members, I am certain, agree that these men should give up engineering work for this far more enjoyable profession of songwriting. Later in the evening the same team, with Brown as the blindfolded mind reader and with Phelps as his assistant designating articles and individuals in the audience for identification, these men demonstrated that they possess many varying and divergent talents and it became apparent that maybe their success in the sewage disposal field can be explained and attributed to the finesse with which they have been able to apply such mystic acts of vaudeville origin during these many years.

The speaker of the evening, Ralph Stevenson, presented a talk—"Experience in Field Sanitation in North Africa," in his usual entertaining manner with "lighting" effects.

Following this, President Pomeroy reported that the Nominating Committee made the following recommendations for officers to be elected:

| | |
|---|---|
| *President* | Frank S. Currie |
| *First Vice-President* | Keeno Fraschina |
| *Second Vice-President* | G. A. Parkes |
| *Secretary-Treasurer* | Harold H. Jeffrey |
| *Director, Federation* | Clyde C. Kennedy |
| *Director, C. S. W. A., 1949* | Paul A. Shaw |

These were the unanimous nominations of the Nominating Committee, composed of Harold Farnsworth Gray, Chairman, Carl M. Hoskinson and Harold K. Palmer.

The nominee for each office was placed in nomination individually by motion, duly seconded and voted unanimously.

## Saturday, June 24

### *Operators' Breakfast*

Toastmaster James H. Van Norman called the Breakfast Meeting to order after some delay occasioned by the fact that it apparently was unusual at this hotel, for guests to expect breakfast to be served at the early hour of 7:00 A.M. There was lively discussion of problems of operation as well as discussion regarding certification of operators. The Breakfast Meeting was adjourned at 9:00 A.M. to permit participation in the remainder of the day's program.

## Operators' Section and Industrial Wastes Section

The program for the day was divided into parallel sections with the usual Operators' Section, as well as an Industrial Wastes Section.

*Operators' Section*

With F. W. Jones, Chairman of the Operators' Section, presiding, 82 members convened for the morning session and 62 members for the afternoon session.

*Industrial Waste Section*

With W. T. Knowlton, Chairman of the Industrial Waste Section, presiding, 67 members met at the morning session and 81 members at the afternoon session.

### Chemists' Luncheon

Mr. Harold H. Jeffrey presided at the Chemists' Luncheon. There were 35 in attendance including industrial chemists, in addition to members of the Association.

### Annual Banquet

Ninety-seven members and guests attended the Annual Banquet in the Ballroom of the Hotel Californian. Deputy Mayor Warner of the City of Fresno was introduced and he extended a welcome to members and guests visiting Fresno. He called attention to many interesting sights and places which should be visited while in Fresno, one of which was a large winery. Mr. John B. Gill, accompanied at the piano by Mrs. Carl M. Hoskinson, favored members by singing several solos.

Mr. A. M. Rawn, President of the Sewage Works Federation, as well as a charter member of the California Sewage Works Association, was presented by President Pomeroy. Mr. Rawn, in his usual inspiring straight-forward manner, reviewed the history and cited the aims of the Association. He told of some of his experiences as Engineering Consultant heading the Sanitation Branch of the Government Division of the War Production Board. He urged that those in the sanitation field adopt Blueprint Now and prepare plans for construction when material and manpower become available. He pointed out the treatment and disposal of industrial waste is one of the most pressing problems in this connection.

### Sunday, June 25

The Sunday session was devoted to the subject "Emergency Measures and New Ideas." President Pomeroy closed the section in time for the members to attend the luncheon and business meeting.

During the afternoon, members and guests inspected the Fresno Sewage Disposal Plant and the Hammer Field Treatment Plant.

### Business Meeting

President Richard D. Pomeroy called the Business Meeting to order, at the close of the luncheon, with 46 members in attendance. He explained that in order to save time and permit discussion of the reports on which there has been a lively interest shown, the committee reports were considered by the Governing Board and only those committee reports on which there is this interest would be presented at this Business Meeting.

### Honorary Membership—Gunnar Kjellburg

President Pomeroy reported the Governing Board had, by letter earlier in the year, voted to extend to Mr. Gunnar Kjellburg, retiring Maintenance Superintendant of Riverside, a complimentary membership for 1944 in the Sewage Works Association. The Board decided to request an expression from the membership regarding their desire to make this a life membership. On motion of Mr. W. T. Knowlton, seconded by Mr. Carl M. Hoskinson, that honorary life membership be extended to Mr. Kjellburg and the Treasurer instructed to annually pay such dues in to the Federation, the members voted unanimously, approving by standing vote, to bestow this life membership upon Mr. Kjellburg.

### Kenneth Allen Award—Professor Leon B. Reynolds

Mr. William J. O'Connell, Jr., placed Professor Leon B. Reynolds' name in nomination for the Kenneth Allen Award. On motion of Carl M. Hoskinson, seconded by E. A. Reinke, nominations were closed and by unanimous vote the Secretary was instructed to cast unanimous vote for Professor Reynolds and to so notify Mr. W. H. Wisely, Executive Secretary of the Federation.

### Committee Reports

The following committee reports were presented:

| | |
|---|---|
| Membership | Wm. J. O'Connell, Jr., Chairman |
| Report of Secretary-Treasurer | Judson A. Harmon, Secretary-Treasurer |
| Conference Attendance | Judson A. Harmon, Secretary-Treasurer |
| Journal | Judson A. Harmon, Manager |
| Auditing | Harold H. Jeffrey, Chairman |
| Certification of Operators | G. A. Parkes, Acting Chairman |

By unanimous vote the members instructed the incoming secretary to write Messrs. Bowlus, Updegraff and Harmon, expressing the appreciation of the Association for their successful efforts in publishing the Journal during these difficult times.

President Pomeroy called attention to the fact that advertising material was already in for the 1944 Journal and a considerable portion of the material was in the hands of the printer. He reported the Governing Board had requested, in order to facilitate the issuing of this

JOURNAL, that J. A. Harmon continue as Manager of the JOURNAL until issue is completed.

Harold H. Jeffrey reported the Auditing Committee consisting of himself as Chairman, E. C. Hardenburg and Wm. A. Allen, had audited the books of the Secretary-Treasurer and found them in proper order. On motion duly seconded, report of the Auditing Committee was unanimously approved.

G. A. Parkes, Chairman of the Acting Committee on Certification, reported that the Committee had been in session a total of over eight hours during this conference in an effort to formulate a plan of certification which could be reported to the Federation as requested at the time of the fall meeting. He explained that the Committee had recommendations to make at this time, among which is the recommendation that additional consideration be given this subject before the fall conference of the Federation, to the end that Mr. Allen will have a definite proposal from the Association for presentation to the Federation at that time. On motion duly seconded, and passed unanimously, the committee report was accepted.

The meeting was turned over to Incoming President Currie, who announced the Membership of the Committee on Certification, Wm. A. Allen, Chairman, R. F. Goudey, Advisory Member, H. W. Davey, Carl M. Hoskinson, E. A. Reinke, Wm. J. O'Connell, Jr., F. Wayland Jones, J. A. Harmon and E. A. Fiscus. There being no further business, President Currie adjourned the meeting.

JUDSON A. HARMON,
*Past Secretary-Treasurer*

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## KANSAS WATER AND SEWAGE WORKS ASSOCIATION

**Fifteenth Annual Meeting**

**Topeka, May 25–26, 1944**

The fifteenth annual meeting of the Kansas Water and Sewage Works Association was held in the Municipal Auditorium in Topeka on May 25 and 26. The total registration, including members and guests, was 103. Thirty-one Kansas cities were represented. The meeting was called to order at 10:00 A.M. on May 25 by President W. O. Myers of Ottawa. Mayor Frank J. Warren of Topeka gave the address of welcome.

Various water supply problems, including plumbing, meter maintenance, distribution, and an outbreak of water borne dysentery, were discussed during the first day. Highlights of the program on the second day were papers and discussions on postwar planning, pump and chlorinator maintenance, cathodic protection of steel tanks, well water supplies, water and sewerage systems at army posts, and sludge digesters.

At the business meeting following the progress, the following new officers were elected: R. H. Hess, Wichita, President; Herman Weigand, Leavenworth; F. D. Elliott, Goodland; H. H. Huffman, Topeka; Rex Reynolds, Dodge City, Vice-Presidents. Paul D. Haney continues as Secretary-Treasurer.

PAUL D. HANEY, *Secretary-Treasurer*

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## NEW YORK STATE SEWAGE WORKS ASSOCIATION

**Annual Spring Meeting**

**Syracuse, N. Y., June 16–17, 1944**

The annual spring meeting of the New York State Sewage Works Association was held in Syracuse, N. Y., on June 16 and 17, 1944, with headquarters at the Hotel Syracuse. Approximately one hundred members and guests were registered.

General arrangements for the meeting as well as arrangements for the entertainment were made by a committee from the Central New York Section of the N.Y. S. S. W. A. composed of Uhl T. Mann, H. H. Wagenhals and J. M. MacCrea as chairman. The Central New York Section acted as hosts for the meeting.

On the evening of June 15 the Executive Committee of the N. Y. S. S. W. A. held its usual dinner meeting. Present at this meeting were William H. Larkin, president, William D. Denise, H. O. Johnson, Uhl T. Mann, George W. Moore, Henry H. Rath, Edward J. Smith and Charles L. Walker, members of the Executive Committee; C. George Andersen, representative of the N. Y. S. S. W. A. to the Federation; A. S. Bedell, Secretary-Treasurer; J. C. Brigham, Assistant Treasurer, and A. W. Eustance, Assistant Secretary.

Following a brief business meeting on Friday morning, June 16, the technical session was opened with a paper by Channel Samson, Superintendent at Tonawanda, N. Y., on the subject of "Sewage Treatment Practices in the Town of Tonawanda." Mr. Samson pointed out that the design of their sewage treatment plant serving a population of 52,000 was based to a large extent on laboratory results obtained when the old Imhoff plant was being used. The new plant was therefore provided with a complete and well equipped laboratory and the plant is being run with laboratory control. Mr. Samson also discussed various phases of plant operation and maintenance in his interesting paper. The several operators at this plant work on a rotating schedule so all can become familiar with all phases of operation.

Considerable discussion from the floor followed this paper.

The next paper on the program was an exceedingly interesting one by Fred J. Biele, Consulting Engineer, Huntington, N. Y., on "Overcoming Ground Water Difficulties in Sanitary Construction." One point in particular brought out by Mr. Biele was the necessity of always taking test borings before starting the design. Mr. Biele also pointed out methods and examples of pipe laying to overcome the problem of ground water.

In the discussion of this paper, Mr. Glenn O. Holmes of Syracuse sketched on the blackboard an instrument developed to take test borings. This was merely a piece of pipe about 1″ to 1½″ in diameter provided with a point and a slotted opening near the bottom. This opening was made by cutting the pipe lengthwise for a distance of from 6″ to 12″ and bending out the pipe wall. The instrument was operated by driving to the desired depth and then rotating so that an earth core could be picked up by the cut edge of the pipe which had been bent out. This would give a sample of the soil at the depth of the opening in the pipe, the sample not being disturbed when the pipe was pulled out.

The last paper of the morning session was entitled "Operation of a Mechanical Aeration Activated Sludge Plant" and was given by William D. Denise, Superintendent of Water and Sewer Departments, Greece, N. Y. In this paper Mr. Denise stated that aeration of the primary tank effluent before the addition of return sludge relieved bulking conditions at his plant.

The meeting was then adjourned for the inspection of gadets and for luncheon.

The afternoon session was opened with a paper entitled "Safeguards Against Hazards at Sewage Treatment Plants," by L. L. Langford, Eastern Sales Manager of the Pacific Flush-Tank Co. At the beginning of his paper, Mr. Langford compared the accident rates at sewage treatment plants with accident rates at industrial plants, pointing out that rates at sewage treatment plants were higher than at industrial plants when figured on the same basis. In his most interesting paper Mr. Langford listed the places of hazards at a sewage treatment plant with particular reference to explosion and asphyxiation hazards. This paper was illustrated with many slides, some showing the results of explosions at several sewage treatment plants.

There was considerable discussion from the floor following this paper. Mr. Langford also referred to the work of the Committee of the Federation studying the problem of hazards at sewage treatment plants under the chairmanship of Morris Cohn of Schenectady, which is preparing a manual on this subject.

The next paper was entitled "Postwar Plans for Sewage and Sewage Disposal Projects in New York State" and was given by Earl Devendorf, Assistant Director, Division of Sanitation, New York State Department of Health. In this paper Mr. Devendorf explained in detail the Postwar Planning Legislation, policy and procedure in New York State, and indicated he felt new sewage treatment plants are among the most important of postwar projects.

A brief intermission was then held for the inspection and balloting on the gadets submitted.

The last paper of the afternoon was entitled "The Operation of a Wartime Industrial Sewage Plant" and was presented by Harold Fanning, Superintendent of Sanitation, Bendix Aviation Corp., Elmira,

N. Y. In this paper Mr. Fanning pointed out the need for designing for peak loads at a sewage treatment plant to serve this type of industrial plant.

An informal banquet was held in the East Room of the Hotel Syracuse on Friday evening. Informal entertainment was provided by E. C. LaValley at the piano and Bill Farrell playing a harmonica.

Following the banquet the presentation of the Rating Award to the operator submitting the best report on the operation of his plant for the preceding year was made by A. W. Eustance, Chairman of the Rating Committee, to Uhl T. Mann for his report on the operation of the city of Cortland sewage treatment plant. Mr. Mann, who was formerly the Superintendent of the Cortland sewage treatment plant, is now the Superintendent of the Ley Creek sewage treatment plant at Syracuse.

The guest speaker of the evening was Dean M. Lyle Spencer, School of Journalism, Syracuse University, who spoke on "Behind the News in Asia." Dr. Spencer gave an exceedingly interesting talk on the subject and pointed out the differences between the customs and thinking of the people of the East from ours. He stated that if we could understand the people of Asia, we then could not understand our own people. Dr. Spencer believed that we had a long flight ahead of us in our war against Japan when we consider the distances involved and the fact that Japan controls so much vital war material, including rubber, tin and quinine. When asked concerning the aid to be expected from China, he stated that this depended on how soon we could get into the Pacific theatre with adequate men and material. Unless this were accomplished at an early date, very little aid could be expected from China who has already been fighting Japan for some eight years. Dr. Spencer gave a most interesting talk and answered a number of questions from the audience.

The Saturday morning session opened with an announcement by George Moore on the winners of the gadget contest. A total of five gadgets was submitted but it is believed that if traveling conditions had been better a larger number would have been submitted because there is always considerable interest shown in this contest. A certificate is awarded to the members whose gadgets receive first, second and third place in this contest. The winning gadgets submitted and their order in the contest are as follows:

The lime slacking machine submitted by Harold R. Fanning of 510 West Second Street, Elmira, N. Y., who is Superintendent of Sanitation at Bendix Aviation Corporation, received first place.

The sludge sampler submitted by Mr. Alexander S. Zele of the Long Island State Park Commission, Belmont Lake State Park, Baylon, New York, received second place.

The diagram of the sludge sampler submitted by Byron Evans of Pine Camp was third choice of the membership.

Following the announcement regarding the gadget contest winners, Morris Cohn of Schenectady pointed out the need of this nation for more money to conduct this war and appealed to everybody to buy an extra War Bond in the Fifth War Bond Drive. In a show of hands as to who was planning on buying that extra bond, the group was unanimous in promising to buy an extra War Bond.

The technical session for Saturday morning consisted of a controlled discussion period on "Sludge Disposal" under the leadership of F. W. Gilcreas, New York State Department of Health, Albany, N. Y. Prepared discussions were given by William D. Denise of Greece on "Disposal of Raw Sludge," Glen Searls of Rochester on "Digestion in Imhoff Tanks," Charles Velzy of New York City on "Digestion in Separate Tanks," Uhl T. Mann of Syracuse on "Vacuum Filtration," Prof. C. L. Walker of Ithaca on "Drying on Sand Beds," and by A. W. Eustance of Geneva on "Disposal of Dewatered Sludge." Following each paper there was considerable discussion of the subject from the floor so that time did not allow the prepared discussion by Mr. Gilcreas on "Use of Sludge as Fertilizer."

Following the paper by Mr. Eustance on "Disposal of Dewatered Sludge" in which he pointed out that sludge disposal at about 50 per cent of our plants is an expense and that with a little salesmanship this could be a paying proposition. Mr. Cohn of Schenectady explained how they handled sludge at his plant. At Schenectady the sludge is ground and sold under the name of "Gro-Hume" and its use is increasing with advertisement.

The next meeting of the New York State Sewage Works Association will be held in New York City January 19, 1945.

A. W. Eustance, *Assistant Secretary*

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## OHIO CONFERENCE ON SEWAGE TREATMENT

**Eighteenth Annual Meeting**

**Marion, June 21–22, 1944**

Hotel Harding at Marion, Ohio, was the headquarters for the Eighteenth Annual Ohio Conference on Sewage Treatment held on June 21 and 22. Registration for the event totaled 80. Sixteen new members were received during the Conference, boosting the total membership to 105.

The Conference opened at noon Wednesday and the entire afternoon was given over to round table discussions which evoked considerable interest, allowing all to present their problems and interchange ideas and information by means of general discussion. Round table discussions and their leaders were as follows:

| | |
|---|---|
| Laboratory Practice | B. H. Barton, Findlay |
| Sprinkling Filters | T. C. Schaetzle, Akron |
| Sludge Drying | G. E. Flower, Cleveland |
| Maintenance | H. Bloem, Elyria |
| Activated Sludge | J. R. Turner, Mansfield |

Headlining the two day session was the Annual Conference Banquet in the hotel ballroom Wednesday evening, attended by members and their wives. Among those who spoke briefly was F. H. Waring, Chief Engineer of the State Department of Health. Honoring their wedding anniversary, Chairman R. F. Snyder in behalf of the Conference presented Mrs. Waring with an orchid.

The guest speaker of the evening was Morris M. Cohn, Sanitary Engineer of the City of Schenectady, N. Y., and Editor of *Sewage Works Engineering*. Mr. Cohn's subject was "Where is Sanitation Going." In a thoroughly amusing and interesting manner, Mr. Cohn covered the various divisions of the field of sanitation, and pointed out the present trends and what could be expected in the future.

Chairman Snyder opened the Thursday morning session by reading a message on the state of the Federation by W. H. Wisely, Executive Secretary, who was unable to be present. Following this E. L. Filby, Field Director; Committee on Water and Sewage Works Development, spoke on "Blueprint Now," urging members to go back home, check their needs, and then lay the groundwork for the needed improvements.

"Oils and Greases as They Affect Sewage Plants" was a very interesting paper effectively presented by Fred G. Nelson, The Dorr Co. The final paper was on "Sludge Digestion" by W. A. Sperry, Superintendent, Aurora Sanitary District, and J. D. Walker, Sanitary Engineer, The American Well Works, and presented by the latter. This paper attacked some of the conventional theories of digestion and evoked more discussion than any other presented at the Conference.

Officers elected to serve during the coming year are as follows:

*Chairman* ........... J. R. Turner, Mansfield
*Vice Chairman* ....... Don Heffelfinger, Alliance
*Secretary-Treasurer* .. L. B. Barnes, Bowling Green

D. D. HEFFELFINGER, *Retiring Secretary*

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## MEMBER ASSOCIATION MEETINGS

| *Association* | *Place* | *Date* |
|---|---|---|
| South Dakota Water and Sewage Works Conference | Watertown, S. D. | Nov. 14–15 |
| Oklahoma Water and Sewage Conference | Municipal Water Treatment Plant, Oklahoma City | Nov. 20–22 |
| New York State Sewage Works Association | Hotel Pennsylvania, New York City | Jan. 19 |
| Texas Short School | College Station | Feb. 5–7 |

# Federation Affairs

## THE SIXTEENTH ANNUAL MEETING*
## PITTSBURGH, PENNSYLVANIA
## OCTOBER 12–14, 1944

Designated by the Board of Control as the Sixteenth Annual Meeting* instead of the Fifth Annual Meeting, as had been announced, the 1944 convention of the Federation at Pittsburgh on October 12–14 ranks among the most successful conferences held to date. The registration of 524, which included 35 ladies, was deemed highly satisfactory under present conditions, comparing favorably with the average registration of 534 recorded at the five meetings held since 1940.

About 150 early comers were on hand for the Pre-Convention Get-Together held on the evening of October 11, which event featured fellowship and refreshments. Earlier in the evening, officers of the Pennsylvania Sewage Works Association entertained Federation officers, Directors, and Committee representatives at a most enjoyable informal dinner. This pleasant innovation presaged the hospitality which was accorded throughout the succeeding days of the meeting by the Federation's host Member Association.

The meeting proper was called to order by President Rawn at 10:30 A.M. on October 12. In the absence of Mayor Cornelius D. Scully, who could not attend because of a conflicting engagement, the Federation was greeted by the Hon. Frank M. Roessing, Director of Public Works of Pittsburgh. In his well-chosen remarks of welcome, Mr. Roessing referred to his experiences as an observer of emergency sanitation procedures during the London "blitz" and to his personal interest in the aims of the Federation. The remainder of the morning was devoted to the presentation of business items of general interest, including the annual report of the Executive Secretary and a progress report on the work of the Joint Committee on Water and Sewage Works Development, in which the Federation is a participant. The latter report was read by C. A. Emerson, a member of the Committee, and discussed by E. L. Filby, formerly Field Director of the program.

More than 250 members and guests were in attendance at the Federation Luncheon which followed the opening session. Dr. Alexander H. Stewart, Secretary of the Pennsylvania Department of Health and Chairman of the State Sanitary Water Board, addressed those in attendance on "Stream Pollution Control in Pennsylvania," relating the progress which has been made and outlining the plans underway for future pollution control activity. A special table was provided at the luncheon for members of the Quarter Century Operator's Club. Frank Woodbury Jones, organizer of the club, introduced those members present, including seven new affiliates.

The afternoon technical session comprised a symposium on the operation of sewer systems. The following papers were included:

Locating Lost Sewers and Manholes. By Eugene T. Cranch (read by C. A. Emerson)
Control of Infiltration and Storm Water Flow. By Ralph W. Horne
Ventilation of Sewers. By Richard D. Pomeroy (read by R. F. Brown)

The Thursday program was brought to a close by the Stag Smoker in the Pittsburgh Room. More than 400 were present to enjoy the refreshments and entertainment which were provided.

The morning program on the second day opened with a demonstration of the use of safety equipment in the operation of sewerage systems (a most appropriate beginning

* While technical programs have been included only in the programs of the annual meetings held since the 1940 gathering in Chicago, business meetings of the Federation had been held annually since its organization in 1928. Consequently, the Board of Control in session on October 14, 1944, decreed by resolution that the 1944 meeting is to be designated as the sixteenth and that future ones be numbered thereform.

for Friday, October 13). Chairman LeRoy W. VanKleeck of the Sub-Committee on Safety Hazards, assisted by S. H. Ash, R. F. Brown and L. L. Langford, other members of the Sub-Committee, staged the demonstration in excellent fashion. A discussion of Manual of Practice No. 1 on "Occupational Hazards in the Operation of Sewerage Systems," as completed recently by the Sub-Committee, was presented by Morris M. Cohn, Chairman of the Sewage Works Practice Committee of the Federation. Other papers presented at this session were:

Design of Final Settling Tanks for Activated Sludge. By Norval E. Anderson
A Comparison of the Quantity and Biochemical Characteristics of the Film in a Biofilter and Standard Filter. By H. Heukelekian

The Luncheon and Business Meeting of the Pennsylvania Sewage Works Association was held at 12:15 P.M. with 125 in attendance. Messrs. Charles A. Emerson and H. E. Moses, both members of the Pennsylvania Association and leaders of the Federation during its early years, were signally honored at this function.

Dr. F. W. Mohlman presided at the symposium on industrial wastes which comprised the Friday afternoon technical program. Papers included were the following:

Treatment of Packinghouse Wastes. By K. V. Hill
Treatment of Oil Industry Wastes. By W. B. Hart
Florida's Citrus Canning Waste Problem. By Robert S. Ingols
Treatment of Some Chemical Industry Wastes. By Thos. J. Powers
Industrial Wastes in Connecticut and Their Treatment. By Wm. S. Wise

A most delightful event was the dinner dance held on Friday evening with 350 in attendance. Following the dinner, President Rawn introduced the new officers of the Federation and presented the various 1944 awards as authorized by the Board of Control on October 11. The awards presented were:

*Honorary Membership*

Floyd William Mohlman

*Harrison Prescott Eddy Award (For Research)*

John Raymond Snell

*George Bradley Gascoigne Award (For Operation)*

James T. Lynch and Uhl T. Mann

*Charles Alvin Emerson Award (For Federation Service)*

Willem Rudolfs

*Kenneth Allen Award (For Service to Member Associations)*

Albert Edward Berry (Canadian Institute)
Van Porter Enloe (Georgia)
Albert Legrand Genter (Maryland-Delaware)
F. Wellington Gilcreas (New England)
Charles A. Holmquist (New York)
Dana Ewart Kepner (Rocky Mountain)
Leon Benedict Reynolds (California)
Wilson Waldo Towne (Dakota)

An accomplished orchestra, a skillful organist, a duo of unusually fine singers in Mary Martha Briney and Bob Carter and an extraordinary novelty presentation by the "Television Kids" completed the evening entertainment in a most satisfactory manner.

The Operator's Breakfast Forum on Saturday morning, October 14, featured a symposium on the effects of increased industrial waste loads on sewage treatment processes, under the leadership of Christian L. Siebert, Executive Engineer of the Pennsylvania Sanitary Water Board. The following papers were included:

Effects of Greatly Increased Flows of Sewage. By DON E. BLOODGOOD
Difficulties Occasioned by Discharge of Grease and Oils. By REUBEN F. BROWN
Effects of Increased Volumes of Acid-Iron Wastes on Sewage Treatment Works Operation. By ROY S. LANPHEAR
Effects of Rubber Wastes on Sewage Treatment Processes. By T. C. SCHAETZLE
Effects of Oxidizing Oils and Some Other War Industry Wastes on Sewage Treatment Works. By ROBERT M. BOLENIUS
Effects of Paper Mill Wastes on Sewage Treatment Plant Operation. By HARRY W. GEHM
Effects of Industrial Wastes from Fish Canneries on a Sewage Treatment Plant. By W. T. KNOWLTON

The technical program was concluded by an open discussion of the 1943 report of the Committee on Operator's Qualifications (*This Journal,* 15, 1235). President-elect A. E. Berry awarded the 1944 Convention Attendance Trophy to the Central States Sewage Works Association, which Federation affiliate has won the contest four consecutive years. This year, 57 Central States members travelled an aggregate of 29,580 man-miles to Pittsburgh. Contenders were the New York, Pennsylvania, New Jersey, Canadian, and New England Associations.

The Arrangements Committee provided a very enjoyable program for the 35 ladies who registered for the meeting. Events included were a luncheon and bridge party on Thursday afternoon, a theater party on Thursday evening and a tour of the Cathedral of Learning at the University of Pittsburgh on Friday afternoon, in addition to the dinner dance on Friday evening.

Business sessions of the Federation Board of Control were held as luncheon and afternoon meetings on Wednesday, October 11 and Saturday, October 14. Officers elected for the year 1944–45 are:

| | |
|---|---|
| *President* | Dr. A. E. Berry, Toronto, Canada |
| *Vice-President* | J. K. Hoskins, Washington, D. C. |
| *Treasurer* | W. W. DeBerard, Chicago, Ill. |
| *Director-at-Large* | F. W. Mohlman, Chicago, Ill. |

Toronto, Canada, was selected as the site of the Seventeenth Annual Meeting in 1945. The detailed minutes of these sessions will appear in the January, 1945, issue of the JOURNAL.

The usual interesting and educational exhibit was sponsored by the Water and Sewage Works Manufacturer's Association under the management and supervision of Secretary-Manager Arthur T. Clark. A total of 31 manufacturers participated in the display.

Following are the Convention Committees to whom all credit and thanks are due for the staging of the Sixteenth Annual Meeting:

CONVENTION MANAGEMENT

C. A. Emerson *Honorary Chairmen* H. E. Moses
L. S. Morgan, *Chairman*
C. H. Young, *Vice-Chairman*

W. S. Andrews
A. T. Clark
D. E. Davis
F. S. Friel
E. P. Johnson
Mrs. M. G. Mansfield
M. G. Mansfield
W. J. Murdoch
L. M. Oaks

PENNSYLVANIA SEWAGE WORKS ASSOCIATION

W. J. Murdoch, *Chairman*

T. S. Bogardus
R. M. Douglass
T. R. Haseltine
H. E. Moses
J. M. Rice

### Registration

M. G. Mansfield, *Chairman*

R. H. Beck
R. D. Hoak
H. M. Olson
E. A. Walker

### Finance

E. P. Johnson, *Chairman*

N. B. Jacobs
R. L. Phillips
W. P. Snelsire
W. H. Wisely

### Hotel Arrangements

D. E. Davis, *Chairman*

C. H. Barrett
E. A. Holbrook
C. M. Holt
L. W. Monroe
H. M. Olson

### Publicity and Attendance

E. J. Cleary, *Chairman*

M. M. Cohn
L. H. Enslow
A. P. Folwell
W. S. Foster

### Program

F. W. Gilcreas, *Chairman*

Rolf Eliassen
F. S. Friel
C. E. Green
C. C. Larson
F. W. Mohlman
R. S. Phillips
E. W. Steel
F. M. Veatch
W. H. Wisely

### Manufacturers' Exhibits

A. T. Clark, *Chairman*

J. L. Austin
Pierce Benner
W. W. Hendrix

### Entertainment

W. S. Andrews, *Chairman*
L. M. Oaks, *Vice-Chairman*
Clinton Inglee, *Advisory Chairman*

J. T. Campbell
F. J. Durner
J. E. Egolf
G. F. Linn

### Ladies' Entertainment

Mrs. M. G. Mansfield, *Chairman*

Mrs. W. S. Andrews
Mrs. D. E. Davis
Mrs. F. S. Friel
Mrs. E. P. Johnson
Mrs. L. S. Morgan
Mrs. W. J. Murdoch
Mrs. L. W. Oaks
Mrs. C. H. Young

# Reviews and Abstracts

GLADYS SWOPE

Mellon Institute of Industrial Research,
Pittsburgh 13, Pennsylvania

## A STUDY OF PAPER MILL WASTE DISPOSAL AT KALAMAZOO VALLEY PAPER MILLS

BY E. F. ELDRIDGE

*Bulletin No. 99, Michigan Engineering Experiment Station.* 71 pages. (July, 1944)

Much of the paper industry in which old-paper stock is used as a basic raw material is located within a distance of 20 miles along the Kalamazoo River. There are 17 mills operated by 11 companies, 13 of the mills being located in the city of Kalamazoo. Four of the mills manufacture paper board from old-paper stock and sulphite or kraft pulp. They make about 600 tons of board daily. The other mills produce about 870 tons of high grade book or writing paper daily from different types of the same general stock. All wood pulp comes from other areas.

In the manufacture of paper board no attempt is made to remove ink, coating or filler from the old stock. The greater part of the liquid waste is the white water from the paper machine. In book or writing paper manufacture, however, the ink, coating and filler is removed by the use of alkalies and washing. The converted pulp thus obtained is mixed with pulp from other sources along with filler, color, clay, etc. The waste from these mills consists of wash water from the conversion mills and white water from the paper machines.

In 1940 the "Paper Mill Waste Research Committee" was organized for the purpose of studying the waste disposal problem. The committee was composed of one technical man from each of the companies. An agreement was made with the Michigan Engineering Experiment Station, Michigan State College, East Lansing, whereby the Station was to supervise such investigations as were deemed necessary and to act as a consulting agency.

The primary object of the investigation was to improve methods of waste disposal in order that the various mills might effectively and economically reduce the pollution of the Kalamazoo River. In addition, as a secondary objective, it was desired to find uses for material recovered from the wastes.

During the first part of the studies careful surveys were made at the mills to determine the quantity and concentrations of the wastes. The following table shows the total wastes discharged to the river.

| | |
|---|---|
| Volume, gallons per day | 45,194,930 |
| Suspended Solids, pounds per day | 220,957 |
| Fiber, pounds per day | 96,874 |
| 5-day B.O.D., pounds per day | 27,428 |

The table below shows the wastes discharged from the mills of five firms manufacturing book paper, showing separately the quantities discharged in the conversion wastes and the white paper.

| | Ink Washer Wastes | | White Wastes | | Total |
|---|---|---|---|---|---|
| | Amount | % | Amount | % | |
| Volume, gal. per day | 7,182,400 | 33.0 | 14,476,400 | 67.0 | 21,658,800 |
| Susp. Solids, lb. per day | 112,786 | 72.2 | 43,224 | 27.8 | 156,010 |
| Fiber, lb. per day | 31,329 | 58.7 | 21,853 | 41.3 | 53,182 |
| B.O.D., lb. per day | 14,153 | 74.5 | 4,893 | 25.5 | 19,046 |

A pollution survey of the Kalamazoo River was made as part of the studies. Sixteen sampling points were established, eight of which were on the main stream and the rest on tributaries. Three series of samples were collected at each station, morning, afternoon, and night. Analyses were made for suspended solids, dissolved oxygen, and 5-day B.O.D. Studies of the results indicated that about 57 per cent of the suspended matter settled on the stream bed.

Thought had been given at times to the advisability of a plant for the treatment of combined municipal and paper mill wastes. Fourteen of the 18 mills are so located that this would be possible. However, owing to the large volume of the wastes from the mills, about 37 m.g.d., many of the existing sewers and interceptors would have to be increased in capacity.

The municipal sewage from the area amounts to about 7 m.g.d. Thus, with a combined plant of 44 m.g.d. capacity only 16 per cent of that capacity would be for the treatment of domestic sewage. Since the paper mill wastes require chemical treatment for effective solids removal the combined plant would necessarily be of that type. Such a plant if built would be the largest chemical precipitation plant in the country.

The use of a combined plant was deemed inadvisable because (1) such a plant would be limited to chemical treatment, (2) the high cost, (3) secondary treatment would have to be provided for 44 m.g.d. in order to reduce the B.O.D. of 7 m.g.d. of domestic sewage, and (4) recovery of paper mill wastes would be impossible.

Many of the mills use some process of recovery whereby the quantity of suspended solids in the wastes is reduced. These are: (1) the recirculation of white water in partially or completely closed systems, (2) the use of clarified white water on washer systems, (3) the use of efficient save-alls in the white water systems, (4) the use of counter-current washings, and (5) the use of coagulation and sedimentation tanks as treatment units. Most of the mills utilize white water recirculation in some form. There has been some objection to the use of recirculation resulting from improperly installed equipment. Properly designed and installed equipment operates without difficulty and is economical.

Most of the save-alls used by these mills fall short of fulfilling that term since they pass most of the particles which pass through the machine screen. The term save-all is applied to equipment which will remove usable material from the wastes and return it to the process; thus it may serve a treatment unit as a secondary function. The various types of save-alls in use include the wire or screen type, the vacuum type, the settling type, and the flotation type.

Early in the studies it became apparent that the removal of solids from the wastes could best be done by a coagulation-sedimentation process. The recommended procedure first involves reducing the volume to a minimum by recirculation of the white water. There then remain the washer wastes, excess white water wash-up during color and grade changes, and general wash-up water. Coagulation-sedimentation is best adapted for these wastes owing to the considerable variation in volume and concentration.

A pilot plant was built for studying the process at representative mills manufacturing various products. A portable unit was adapted with the coagulation tank built within the settling tank. Wastes were pumped to a mixing box mounted on the outside of the settling tank. Chemicals were added here and mixing accomplished by means of a rapid mixer, with a period of 40 to 60 seconds. The coagulation compartment was 2 ft. 9 in. diameter and 3 ft. 6 in. deep overall. Paddles mounted on a vertical shaft were provided for agitation. The coagulated liquor passed into the settling compartment through a number of large holes in the bottom.

The settling tank was 6 ft. 4 in. diameter and 6 ft. 6 in. deep at the center. A hopper was provided in the bottom with slopes about 2 vertical to 3 horizontal. The designed periods were 20 minutes for coagulation and 2 hours for settling.

The unit was operated at two mills representative of the book mills, and at two others manufacturing board. It was also used in connection with studies on the treatment of rag mill wastes and on the treatment of conversion wastes. The following table shows results obtained at the book mills and the board mills. The figures represent averages of runs for three to six days, except as noted.

| Plant | Chemical | Dosage, p.p.m. | Suspended Solids | | | 5-day B.O.D. | | |
|---|---|---|---|---|---|---|---|---|
| | | | Influent, p.p.m. | Effluent, p.p.m. | % Red. | Influent, p.p.m. | Effluent, p.p.m. | % Red. |
| *Book Mills* | | | | | | | | |
| 1 | None | — | 1060 | 248 | 75.2 | 232 | 121 | 44.3 |
| 1 | Alum | 347 | 1885 | 171 | 89.0 | 288 | 165 | 43.7 |
| 1 | Bentonite | 107 | 612 | 67 | 88.1 | 123 | 45 | 62.3 |
| 2 | None | — | 500 | 84 | 81.7 | 94 | 45 | 53.5 |
| 2 | Alum | 71 | 563 | 55 | 90.0 | 140 | 51 | 62.4 |
| 2 | Bentonite | 252 | 660 | 64 | 89.5 | 112 | 45 | 59.9 |
| *Board Mills* | | | | | | | | |
| 1 | None | — | 244 | 111 | 53.4 | 80 | 56 | 29.5 |
| 1 | Bentonite | 79 | 255 | 65 | 76.4 | 63 | 32 | 58.0 |
| 1[a] | Alum | 110 | 366 | 188 | 48.5 | 66 | 58 | 12.0 |
| 1[a] | Lime | 502 | 324 | 110 | 66.0 | 51 | 23 | 54.8 |
| 2 | None | — | 356 | 43 | 89.1 | 60 | 28 | 48.3 |
| 2 | Alum | 42 | 369 | 21 | 94.1 | 57 | 32 | 43.4 |

Considerable laboratory work was done on the study of the treatment of conversion wastes to serve as a guide for pilot plant operation. Coagulants used included alum, ferric chloride, lime, ferric sulfate, ferrous sulfate, sulfuric acid, rosin, gelatine, and chlorine. The first three mentioned gave the best results, and lime appeared to afford the best removal of the three. Operation of the pilot plant gave rather wide variations in the removal of suspended solids. The daily variations ranged from 20.7 to 62.2 per cent, 45.4 to 84.6 per cent, and 36.7 to 81.1 per cent with plain settling, alum coagulation, and lime coagulation, respectively. Chemical dosage varied from 455 to 745 p.p.m. and from 515 to 900 p.p.m. for alum and lime, respectively.

During the course of the studies it was found that at times coagulation was extremely difficult to obtain. Studies indicated that wastes in which the casein concentration was higher than 4 lb. per 1,000 gal. could not be coagulated. Since this particular mill used batch washing the casein concentration was high at the start of each washing. Dilution with white water was found to be very effective, and the most difficult waste could be coagulated readily when diluted in a ratio of 1 to 1. Tap water was not as effective as white water as a diluting agent. Further studies indicated that alum in the white water caused the good results obtained, and that alum added ahead of lime might give equally good results. General conclusions were that lime was the better coagulant for ink washer wastes, and the quantity of lime required varies from 5 to 10 lb. per 1,000 gallons.

The recommended plant for the treatment of wastes from the mills in the Kalamazoo area was the coagulation-sedimentation type. The following units were suggested, flow meter, flash mixer, chemical feed equipment, coagulation tank, settling tank, and sludge disposal facilities, either sludge storage ponds or lagoons, or vacuum filters. The coagulation tank should be mechanically agitated, with a period of about 20 minutes. The settling tank should provide a detention period of about 2 hours, and should be equipped with a suitable sludge removal mechanism.

Sludge storage ponds should have a capacity of about 1,000 cu. ft. per m.g.d. of waste, based on 6 months storage. Owing to the rather large areas required and difficulty and cost of cleaning, vacuum dewatering is desirable. Tests indicate that cake moistures of 70 to 75 per cent can be obtained and that with total mill wastes an area of 250 sq. ft. per m.g.d. would be required. This area is based on a filter operating period of 20 hours daily.

Proposals made to individual plants included two alternate plans. The first involved treatment by coagulation and sedimentation of the total mill waste in present concentration and volume. This plan was not recommended but might be preferred at certain mills. Chemicals would be used only during periods of low river stage, about 5 months per year.

The second and recommended plan called for a reduction in the volume of the waste by recirculation of the white water, the installation of efficient save-alls, and the treatment by coagulation and sedimentation of the remaining wastes. Recommendations as to the chemical, lime, alum, or bentonite varied at the different plants, depending on the waste.

Combination plants for two groups of mills were recommended where such plants were possible.

T. L. Herrick

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## THE TREATMENT OF SPENT PICKLE LIQUOR

By N. Swindin

*Industrial Chemist* (Great Britain), 20, 291–300 (June, 1944)

This is an abstract of a paper read at a joint meeting of the Institute of Chemical Engineers and the Chemical Engineering group in London on April 25, 1944.

Swindin indicates that the principal use of acid is in pickling sheet steel. Except where preliminary to galvanizing and enamelling, sulfuric acid is used. In the wire industry, hydrochloric acid is used. Tube, bar, and plate pickling (as distinct from sheet pickling) used about one-fourth the sulfuric acid used for pickling in Great Britain. This liquor is discharged with a low iron content and much free acid. Half the hydrochloric acid used is for pickling galvanized, enamelled, and tin fabricated vessels.

Experiments indicated the benefit of using a mixture of hydrochloric and sulfuric acids at a temperature not exceeding 60° C. There was some loss of hydrogen chloride by fuming.

The chemistry of pickling baths has heretofore been studied from the point of view of speed of pickling and quality of surface exposed; treatment and regeneration of the acid being secondary. Modern baths of mixed sulfuric and hydrochloric acid promote easy regeneration of the acid. The low solubility of ferrous sulfate at high temperatures is utilized in several processes, *e.g.*, the Gin process, which depend on separating ferrous salts from other salts. Swindin discusses the solubilities of ferrous sulfate and ferrous chloride in water and of ferrous sulfate in sulfuric acid solutions.

Most of the existing processes of regeneration are for liquor from the use of sulfuric acid alone. However, hydrochloric acid works vigorously on the scale and owing to the higher solubility of ferrous chloride as compared with ferrous sulfate, the bath need not be changed so often. Hydrochloric acid is volatile and more expensive than sulfuric acid. However, by dosing a spent hydrochloric acid bath with sulfuric acid, it is possible to regenerate the hydrochloric acid bath. Of this type is the de Lattre process.

With the mixed hydrochloric and sulfuric acid baths, it is generally believed that the hydrochloric acid attacks the iron or iron oxides, forming ferrous chloride, which is then converted into ferrous sulfate by the sulfuric acid, with simultaneous regeneration of the hydrochloric acid. The pickling bath usually starts with 20 per cent acid for pickling wire, etc., and is worked down to 10 per cent acid. If sulfuric acid be added, equivalent to the ferrous chloride formed, the hydrochloric acid is recovered. Such a mixed bath can be made from sulfuric acid and common salt. From forty years' experience, Swindin believes more attention should be paid to inhibitors. In 1904 Davis used the sulfuric-hydrochloric bath, but lacked a control. Later Davis and Fearon described a process using a similar bath, worked to saturation of metallic sulfate and its crystallizing, with reuse of the mother liquor.

Later Jones took spent sulfuric acid pickling liquor and cooled it, crystallizing out the copperas, for drying and roasting. The mother liquor was reused. In the Davis-

Bueb process appeared the recovery of ferro-prussiate from coal gas, using hydrochloric acid spent pickle liquor.

At the beginning of the war a de Lattre plant was built for Baldwins, Ltd., which works satisfactorily.

Swindin describes three plants for the regeneration of spent pickle: (1) in which sulfuric acid pickle is cooled; Steele-Peech and Tozer, Ltd. (Heastie); Kestner-Fakler; (2) in which pickle liquor from a mixture of hydrochloric and sulfuric acid is cooled; de Lattre, Tinsley; (3) in which pickle liquor from mixed hydrochloric and sulfuric acid is evaporated; Swindin. The procedures are described in detail, with diagrams of lay-out and flow.

A modified de Lattre process is operating at Baldwins, Ltd. (Stourport) using about 14 g. of sulfuric acid and 1 g. of hydrochloric acid per 100 ml. The concrete tanks are rubber lined, protected with acid-resisting brick set in siliceous cement.

Swindin advocates the regeneration of the free acid and conversion of ferrous sulfate to sulfuric acid and metallic iron, using mixed acids and evaporation to recover a monohydrate sulfate. He favors for the evaporator a submerged flame burner where gas is economic. Before evaporation the proper amount of sulfuric acid is added to the spent pickle, reducing the solubility and helping throw out the monohydrate sulfate, which is recovered in form of snow by a centrifugal machine and washed with a salt solution to remove any strong acid.

A Kestner-Fakler acid recovery plant has operated at the Whitehead Iron and Steel Co., Ltd., since 1939. The spent acid is pumped into a 2,000 gal. (Imp.) tank, held at 70° C., to settle. The liquid is pumped to one of two 1,000 gal. (Imp.) crystallizers, fitted with a cooling coil and motor-driven paddle. The cooled liquor is removed to a tank, then reheated to 70° C. in a storage tank and is ready for reuse. The advantages are (1) operating at 75° C., (2) improved pickling quality, (3) removal of good quality iron sulfate, (4) saving of acid, and (5) avoiding neutralization of waste acid before discharge to sewer.

The submerged flame burner differs from the American type (where air and gas are compressed separately and mixed in the burner, combustion taking place in a long pipe laid along the bottom of the bath) in that air and gas are premixed and compressed together, and supplied to a small burner for immediate combustion (instead of a slow combustion and lazy flame).

Swindin indicates for the immediate future copperas would be a drug on the market. Ultimately he recommends it be converted to iron and acid, through a central roasting plant and sulfuric contact plant. The iron oxide can be reduced to iron in a blast furnace.

LANGDON PEARSE

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## TRADE EFFLUENT POLICY

By John Hurley

*The Surveyor*, 103, 343–345, 355–356, 370–371 (1944)

The author discusses the Public Health (Drainage of Trade Premises) Act, 1937 (Great Britain), which obliged municipalities to receive trade wastes into their sewers. In most cases such wastes can be economically handled at the public works. In some cases preliminary treatment at the factory is required, *e.g.*, to neutralize acidity, to remove heavy solids, separate oil, and reduce toxic constituents. However, little was done to implement the Act prior to the war.

Very few authorities have drafted trade-effluent by-laws. One difficulty has been to assess the prescriptive rights vested in the premises. New connections are subject to the Act, including fair payment for the facilities used.

Local authorities may be grouped: (1) those which have for years received trade wastes without payments; such may now have trouble in obtaining payment; (2) those which have accepted effluents subject to safeguards and payments; (3) those who had not admitted trade wastes to their sewers. These latter are most favorably situated to apply the full provisions of the Act. The author questions whether such distinctions are fair and concludes that the only equitable solution is to amend the Act and abolish prescriptive rights of discharge.

To prepare to apply the Act (where little data are available) a careful survey is required to determine if any effluent was discharged to the sewers for the twelve months ending March 3, 1937, and whether any is discharged currently. Two sets of particulars should be obtained following the form of the trade effluent notice proposed by Porthouse (cf. *J. Inst. Sew, Purifn.*, 1939, Part I). The main points to fix for all effluents are the maximum daily flow, the maximum rate of discharge (gal. per hr.), and the nature or composition of the discharge. Some actual gagings and analyses may be required. To check back to 1936–1937 may prove difficult. A legal question may arise as to whether an effluent was "lawfully discharged." If unlawful, no prescriptive right exists. If the flow exceeds the prescriptive rights, the excess may be subject to control.

With the survey and facts in hand, the basis of charges may be considered, and particularly what portion of cost should be a general obligation of the municipality. If the charge is to be on an economic basis, the charge may be determined by individual arrangement or based on a schedule at so many cents per 1,000 gallons; or on groups, each with a flat-rate charge. Probably the fairest way is based on treating each case individually.

To determine the charges, the cost of various operations of the treatment works must be known. A formula suggested by Townend takes account of the three main stages, namely, preliminary treatment, biological purification, and sludge disposal. The formula is:

$$1 + M/75 + S/60 = P.$$

In this, $M =$ McGowan strength figure of the settled trade waste;
$S =$ Suspended solids in effluent in parts per 100,000;
$P =$ Price in pence (approximately 2 cents) per 1,000 gal. (Imp.).

For a normal sewage Townend suggests 2½ pence per 1,000 gal. (Imp.) or 3.5 cents per U. S. gal.

In some localities pumping cost may need consideration.

Other technical questions arise in implementing the trade waste policy, to cover not only existing but future developments. Each case may be dealt with individually under the form of consent. The technical considerations are, first, the measures needed to protect the sewers and sewage treatment works, and, second, the calculation and collection of a fair payment. Whatever is done must be equitable.

In negotiating, accurate knowledge of the situation is desirable, plus personal contact. Many authorities are inclined to postpone action until after the war. On the other hand, the Act is in force. The exemption of laundry wastes has caused some comment and may be unjustifiable, where laundries serve areas outside the district in which located. Lack of regulation under war conditions may have permitted discharge of industrial wastes which interfered with or damaged sewage works. For post-war planning, knowledge of volume and nature of industrial wastes is helpful.

In conclusion, it is pointed out that abolishing prescriptive rights will simplify enforcement and be more equitable. He further recommends immediate action to utilize the Act.

LANGDON PEARSE

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## NOTES ON OXYGEN ABSORBED TESTS

BY WILLIAM M. CAMERON

Presented at the March 29, 1944 meeting of the Institute of Sewage Purification, 7 pages

The use of potassium permanganate as a measure of the organic content of drinking water was suggested as long ago as 1850 but it is felt that the limitations of the test have never been fully demonstrated. The equation given for the potassium permanganate test is:

(1) $2KMnO_4 + 3H_2SO_4 + \text{oxidizable matter} \rightarrow K_2SO_4 + 2MnSO_4 + 3H_2O + 2\tfrac{1}{2}O_2$

The oxygen combines with the oxidizable matter. However, no allowance is made for the deposition of higher oxides of manganese. The deposition of oxides of manganese may be represented as:

(2) $4HMnO_4 + 2H_2O \rightarrow 4\ MnO\ (OH)_2 + 3O_2$

The effect of the deposition of oxides of manganese together with the effect of other variables was studied as follows:

(1) Routine estimation carried out in the normal manner, adding more permanganate if need be.

(2) As in (1) but performed in a closed graduated cylinder. The volume of deposit was measured at the end of four hours. The deposit was then filtered off, washed with water, dissolved in dilute sulfuric acid and potassium iodide and titrated with sodium thiosulfate. Before dissolving the contents of the filter, the filtrate was removed and titrated separately. The two titrations were then added to determine the oxygen absorbed.

(3) Estimation with insufficient permanganate performed in a graduated cylinder, but merely measuring volume of deposit and titrating the whole as one.

(4) Estimation with sufficient permanganate but using 10 cc. concentrated sulfuric acid.

(5) Estimation with insufficient permanganate using 10 cc. concentrated sulfuric acid.

The results of these tests are shown in tabular form and indicate that the oxides of manganese have a marked influence on the result. It appears that there are two reactions in the test, one leading to the deposition of manganese oxides and the other following equation (1) for inorganic and easily oxidized organic matter.

A consideration of the relationship between quantity of sample and quantity of potassium permanganate leads to the following practical inferences: (1) 50 per cent absorption gives the most reliable results; (2) too little permanganate leads to low results; (3) too much permanganate leads to high results.

Reasonably comparable results should be obtained if the absorption limits are set from 30 to 70 per cent.

The test was further studied by using both N/8 and N/80 permanganate. The conclusion drawn from these studies is that the oxygen absorbed value does not necessarily vary according to the strength of the potassium permanganate. Actually the following conditions define the test:

(1) final volume of sample and reagents,
(2) a particular weight of $KMnO_4$ (the aim should be to obtain 50 per cent absorption),
(3) a particular time at a particular temperature.

It can be concluded that the test does measure organic pollution since the amount of sample used has to vary. It is a good relative test but lacking in the absolute sense chemically and it does not bear any essential relationship to biochemical needs.

During the course of this investigation a three minute oxygen absorbed test was studied. The use of dichromate and hypochlorite as oxygen absorbed test reagents were also studied. Study was also given to the problem of controlling the temperature and time for oxygen absorbed tests.

Data are presented in nine tables. There are eight references.

PAUL D. HANEY

## THE DETERMINATION OF INORGANIC SULFATES IN SEWAGE

By L. A. Allen

*Journal of the Society of Chemical Industry*, 63, 89–94 (1944)

The gravimetric method of determining sulfate as barium sulfate is laborious. The precipitation of sulfate as benzidine salt with subsequent titration was therefore investigated and the accuracy of this method compared with the gravimetric method.

In the gravimetric method silica and iron were eliminated in the usual way.

In the benzidine method it was necessary to clarify the sewage first by filtration through Seitz pads which was found to have no effect on the sulfate content.

The sulfates are precipitated as benzidine sulfate which is very slightly soluble by the addition of benzidine hydrochloride according to the formula:

$$(C_6H_4 \cdot NH_2)_2\ 2HCl + R_2SO_4 = 2RCl + (C_6H_4 \cdot NH_2)_2 \cdot H_2SO_4$$

The benzidine sulfate formed can be determined by titration with standard alkali using phenophthalein as the indicator.

The method in detail is as follows: Weigh 4 grams of pure benzidine and make a thin paste in a mortar with distilled water. Transfer to a 2 liter graduated flask with 500 ml. of water. Add 5.3 ml. of concentrated hydrochloric acid and shake until benzidine has dissolved. A .05N sodium hydroxide solution is used with a 5 ml. microburette. A benzidine sulfate solution is prepared by adding a little sodium sulfate solution to 200 ml. of benzene hydrochloride reagent. Filter through an asbestos pad in a Gooch crucible and wash thoroughly with cold water and suspend the precipitate in about 2 liters of hot water. Next day filter through a Gooch crucible until quite clear.

Centrifuge the sewage at about 2,000 r.p.m. for 5 minutes to free it from coarse particles. Pass supernatant through Seitz filter. To 200 ml. of filtered sewage add a few drops of bromphenol blue and measure the amount of N hydrochloric acid required to turn the indicator yellow. To another 200 ml. portion of clarified sewage add the required amount of N acid but no indicator. Add, with constant stirring, 200 ml. of benzidine hydrochloride reagent and let it stand for about an hour. Filter by decantation under moderate suction through a thin pad of asbestos in a Gooch, taking care not to allow the precipitate to become dry. Transfer the precipitate into the filter and wash with four successive quantities of 10 ml. of saturated benzidine sulfate solution. Wash down the sides of the crucible with the same solution. Transfer the filter pad to a flask and wash the residue in the crucible into the flask with boiling water. Stopper the flask and shake vigorously until the precipitate is emulsified. Wash down the inside of the flask with hot water. Add phenophthalein and titrate while hot with .05 N sodium hydroxide. When titration is complete, boil the liquid for 5 minutes avoiding bumping. Continue the titration until a faint permanent pink color is produced.

$$1 \text{ ml. of } .05N \text{ NaOH} = 2 \text{ mg. } SO_3$$

Duplicate and triplicate determinations by this method gave good agreement with the benzidine method with smaller deviations.

Accurate results were obtained only when the liquor containing the precipitate filtered with ease.

H. Heukelekian

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## RECOVERY OF GREASE FROM SEWAGE SLUDGE

By T. W. Brandon

*Journal Society of Chemical Industry*, 63, 185–186 (1944)

This paper deals with quantity and value of grease which could be extracted from sludge produced from domestic sewage.

The sample was acidified to pH 3.5, dried and extracted with light petroleum with a boiling range of 100–120°.

The grease content of skimmings from primary sedimentation tanks varied from 52.4–77.8 per cent (3 samples) and of fresh sewage sludge from 13.3–18.4 per cent (5 samples). The grease content of fresh sewage sludge on drying beds decreased from an initial of 23.3 per cent to 9.7 per cent after five weeks on dry matter basis.

The grease extracted from skimmings and fresh solids had the following characteristics:

| | Ash % | Saponif. Value as mg. KOH/gm. | Unsaponif. Matter | Acid as mg. KOH/gm. | Iodine Value gm./I per 100 gms. |
|---|---|---|---|---|---|
| Skimmings | 0.6– 2.0 | 121–167 | 8.3–31.2 | 50–104 | 26– 49 |
| Fresh sewage | 0.3–14.1 | 134–171 | 5.6–37.8 | 36–126 | 26–101 |

Because of the high percentage of unsaponifiable matter, the value of the grease is not great. It has the possible use in soap manufacture. The value of grease was set at £10 per ton.

H. Heukelekian

## THE CHLORINATION OF SEWAGE AND SEWAGE EFFLUENTS

By L. A. Allen

*Proc., Soc. Agricultural Bacteriologists,* pp. 5–8 (1943)

Laboratory experiments were conducted on the effect of addition of various quantities of chlorine to sewage on the bacterial numbers. The chlorine dosage in one experiment varied from 0 to 100 per cent of the chlorine demand of the sewage. After 15 minutes contact the reduction of total number of bacteria was 18, 29, 93, and 99 per cent with 10, 25, 50, and 100 per cent, respectively, of the chlorine demand being satisfied. After 2 days contact bacterial numbers increased beyond the numbers in the original unchlorinated sewage in all except where 100 per cent of the chlorine demand was satisfied.

In another experiment the chlorine was added equivalent to 100, 140, and 180 per cent of the chlorine demand of the sewage. The original number of bacteria in the sewage was 3.48 million per cc. After 15 minutes contact the numbers were 25,500; 12,100; and 9,600 per cc. with 100, 140, and 180 per cent chlorine demand satisfaction, respectively.

After 3 days contact the numbers with the 100 and 140 per cent demand satisfactions had increased beyond the level in the original sewage while with 180 per cent demand satisfaction had increased above the original level.

Chlorination experiments with an effluent of the secondary type treatment plant were also made. When 50 per cent of the demand was satisfied 99 per cent reduction in the total number of organisms was obtained after 1-hour contact.

H. Heukelekian

## REPORT TO AKRON, OHIO, ON SEWAGE TREATMENT. A PROGRAM OF IMPROVEMENTS AND ADDITIONS TO EXISTING FACILITIES

By Havens and Emerson

*Mimeographed.* 125 pp.: 10 plates. May 29, 1944

This report to the Director of Public Service outlines the history of sewage treatment at Akron; the condition and performance of the present plant, and proposed improvements and additions.

Following suits in 1910, a sewage testing station was operated in 1912 by H. B. Hommon, which resulted in an Imhoff tank-trickling filter plant (15 m.g.d. capacity; 120,000 population; cost $460,000), put in operation in 1917. In 1920 the population rose to 208,000, grossly overloading the works. In 1923 Metcalf and Eddy made a report providing for handling 300,000 population and 38.1 m.g.d., advising that industrial wastes be treated at the source. The old plant was rehabilitated for 40,000 population and 5.1 m.g.d. This remained in service until February, 1941. A new plant (Imhoff tank-trickling filter type) was built at Botsum for 260,000 population and 33 m.g.d., at a cost of $3,644,000. A suspended solids load of 25.4 tons per day was expected. This went into service in December, 1928. Additions costing $632,200 have been added.

At present the plant is overloaded. Thirty-five damage suits have been brought, even though the plant is located inside an area of 834 acres. Ten have been tried, with damages assessed against the city, totaling $16,650. Nuisances claimed were from odors, flies, and gnats. The existing works and site are available for continued use.

Owing to the failure of industry to pretreat its wastes, the Botzum plant started at capacity. In 1943 the flow increased to 52.2 m.g.d., and daily dry solids to 80.4 tons. The plant was well designed, soundly built, properly maintained, and run to its limit.

The report assumes that rubber plant wastes will be given proper pretreatment. The study provides for the period ending 1960, with a population between 310,000 and 330,000; and a flow between 56 and 67.5 m.g.d. The city area is 55 sq. miles. The expected population density may be from 8.8 to 9.4 per acre.

Between 1929 and 1943 the sewage analyses have varied as follows:

| Determination | Results in P.p.m. | | |
|---|---|---|---|
| | Average | Maximum | Minimum |
| Solids: | | | |
| Total | 1,893 | 2,476 | 1,603 |
| Suspended | 297 | 392 | 202 |
| Free $NH_3$ | 10.5 | 14.1 | 8.0 |
| Chlorides | 707 | 995 | 544 |
| 5-Day B.O.D. | 171 | 242 | 131 |
| Dissolved Oxygen | 0.8 | 1.6 | 0.3 |
| pH | 7.3 | 7.5 | 7.2 |
| Alkalinity | 218 | 301 | 128 |

Occasional data show ether soluble (chloroform) for 1941 average weekly composites 123 p.p.m., and volatile solids 73.7 per cent for three days in 1943.

Industrial wastes from the rubber plants are high in suspended solids, chlorides; brown in color and contain petroleum. Fine rubber particles also occur.

The suspended sewage solids per capita have increased from 0.23 lb. per day in 1933 to 0.58 in 1942 and 1943.

For this report the assumed analyses for the raw sewage are: total solids 1,900 p.p.m.; suspended solids 335 p.p.m., and B.O.D. 200 p.p.m. The tonnage of suspended solids is 94 per day (including an industrial surload of 44.5 tons per day).

The plant should serve 330,000 population and handle an average flow of 67.5 m.g.d.

The Cuyahoga River at Portage has a drainage area of 405 sq. mi. and a flow between 1921 and 1935 averaging 434 sec. ft., with a minimum monthly flow of 51 sec. ft., and a minimum daily of 25 sec. ft. Monthly flows under 70 sec. ft. have occurred in nine of the 178 months of the record.

The river below the Botzum outfall is unattractive. Above Botzum the river flow contains in the summer 5.1 p.p.m. dissolved oxygen. The oxygen balance shows the river can absorb treated sewage amounting to 67.5 m.g.d., if the plant effluent contains over 30 p.p.m. suspended solids and averages 15 p.p.m. 5-day B.O.D.; 3 p.p.m. dissolved oxygen, and 4 p.p.m. nitrates and nitrites. Improvement of the existing works should include facilities for chlorination; provision for filter flooding; and a method of sludge disposal to minimize odors.

*Existing Works*

The existing works include coarse screens (one automatically cleaned bar grate; clear openings 7/8 in.); grit and grease removal in two circular detritus tanks (designed for 15 min. detention) from the bottom of which about 20 per cent of the total flow was to be diverted to duplicate grit channels (vel. 1 ft. p. s.) with inclined conveyors for washing and elevating the grit. Periodical skimming of grease from the detritus tanks is practiced by movable arms.

Primary treatment is furnished by Imhoff tanks (24 units; 2 hr. detention at avg. flow; settling compartments totaling 426,000 cu. ft.; digestion compartments totaling 672,000 cu. ft.). Secondary treatment is by trickling filters (14 acres; 10 ft. deep; divided into seven units). The original design provided for 1,850 persons per acre foot, with a liquid flow of 2.36 m.g.a.d. The influent passes through a 20-mesh screen.

Humus tanks include 12 units, 10 ft. total depth, with 1½ hr. detention.

Since 1943 the Imhoff tanks have served chiefly as settling tanks. Separate sludge digestion tanks have been provided (2 units, total volume 145,500 cu. ft.), one with floating cover, the other with stirring mechanisms.

The digested sludge was intended to be dried on sludge drying beds, of total area 163,200 cu. ft. (0.63 sq. ft. per cap.) divided into 68 units. These have been supplemented by 19 acres of auxiliary drained drying beds, and a large volume of lagoons. At present all sludge is lagooned.

End products (grit, grease, screenings, and dried sludge) are dumped at remote points.

Siphon overflows protect the plant from receiving more than 93 m.g.d.

At infrequent intervals flood heights in the river submerge the humus tanks, and water locks the drainage of the filters.

TABLE I.—*Performances of Sewage Treatment Botzum Plant, Akron, Ohio*

| Year | Average Sewage Flow, M.G.D. | Removed in Cu. Ft. per M.G. | | | Removed in Per Cent | | Final Effluent | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | p.p.m. | | Per Cent Saturation D.O. |
| | | Coarse Screenings | Grit | Grease | Suspended Solids | B.O.D. | Suspended Solids | 5-Day B.O.D. | |
| 1930 | 27.4 | 0.44 | 5.41 | 0.14 | 80.4 | 87.7 | 94 | 43.2 | 43.8 |
| 1931 | 28.1 | 0.42 | 5.65 | 0.16 | 85.5 | 89.7 | 37 | 15.8 | 56.7 |
| 1932 | 31.2 | 0.46 | 6.52 | 0.21 | 74.7 | 87.4 | 50 | 16.8 | 66.4 |
| 1933 | 31.4 | 0.51 | 8.01 | 0.19 | 81.5 | 88.9 | 41 | 17.2 | 60.3 |
| 1934 | 27.7 | 0.69 | 8.85 | 0.23 | 84.1 | 90.8 | 41 | 17.7 | 59.1 |
| 1935 | 29.6 | 0.68 | 7.32 | 0.11 | 78.2 | 89.2 | 54 | 18.4 | 62.5 |
| 1936 | 30.2 | 0.77 | 8.68 | 0.10 | 79.6 | 87.9 | 54 | 19.4 | 60.1 |
| 1937 | 32.9 | 2.03 | 7.09 | 0.10 | 80.2 | 88.8 | 55 | 17.6 | 61.1 |
| 1938 | 32.7 | 1.52 | 10.63 | 0.09 | 83.0 | 88.3 | 50 | 18.1 | 67.3 |
| 1939 | 38.4 | 0.73 | 8.31 | 0.11 | 83.9 | 87.7 | 49 | 17.9 | 57.3 |
| 1940 | 41.0 | 0.80 | 9.53 | 0.14 | 79.1 | 83.9 | 61 | 27.2 | 52.7 |
| 1941 | 39.8 | 0.75 | 12.19 | 0.12 | 81.4 | 86.6 | 73 | 29.3 | 50.7 |
| 1942 | 46.9 | 0.53 | 8.34 | 0.28 | 75.7 | 85.7 | 91 | 34.7 | 40.2 |
| 1943 | 52.2 | 0.42 | 7.44 | 0.12 | 64.6 | 75.6 | 131 | 58.0 | 24.0 |

Data compiled from 1943 Annual Report.

The performance of the plant is indicated by the annual averages from 1930–1943 (Table I).

Under screenings, the fine screenings (20-mesh) are excluded. The original bar grates with 2⅞ clear spacing, were replaced in 1936 by ⅞-inch automatically cleaned bar grate. A screenings grinder then installed was removed after three years' use. Small particles of synthetic rubber pass through the 20-mesh screen.

Only a part of the grit is removed by the detritus tanks. During low flows deposits occur in a flat 4-mile section of the intercepting sewer. Those are flushed out in excessive amounts at time of storm. This condition necessitated cleaning of the digestion tanks in 1938, 1940, 1941, 1943. The grit recovered ranged from 17 to 54 per cent volatile. Better facilities are required.

The skimmings removal (0.15 cu. ft. per m.g.d.) is inadequate, considering the grease in the raw sewage (petroleum ether 45 p.p.m.; chloroform 123 p.p.m.; special ether 132 p.p.m.).

With the overloaded plant, the primary settling has been lower than expected (50 per cent). The general results from 1930–1943 are:

*Removal of Suspended Solids and B.O.D. Imhoff Tanks at Akron*

| Per Cent Removal | Influent Susp. Solids and B.O.D. (p.p.m.) | | | | |
|---|---|---|---|---|---|
| | 100 | 150 | 200 | 250 | 300 |
| Suspended Solids with Detention: | | | | | |
| 1½ hr. | | 42 | 44 | 47 | 50 |
| 2 hr. | | 44 | 46 | 49 | 52 |
| 2½ hr. | | 46 | 48 | 51 | 54 |
| 3 hr. | | 48 | 50 | 53 | 56 |
| B.O.D. with Detention: | | | | | |
| 1½ hr. | 24 | 26 | 28 | — | — |
| 2 hr. | 26 | 28 | 30 | — | — |
| 2½ hr. | 29 | 31 | 33 | — | — |
| 3 hr. | 31 | 33 | 35 | — | — |

Settling efficiency has varied from year to year (41 to 54 per cent) and month by month (43 to 63 per cent). Any deficiency of sedimentation is due to the comminution of solids, low sp. gr. of some solids, and a substantial portion of solids resulting from presettling at industrial plants.

Data on the trickling filter performance is shown in Table II.

The tables do not reflect pooling troubles of recent years, due to rubber particles accumulating on the stones, or the fly nuisances or interference of flooding by high river stages.

From 1930 to 1943 the sludge recovered increased from 88,000 to 318,800 cu. yd. Even under the overload, from 1931 to 1938 the Imhoff tank sludge showed a volatile content from 45 to 49 per cent volatile and moisture content from 89.1 to 93.4 per cent. During the period 1932–1938 the sludge withdrawn ranged from 84,900 to 133,300 cu. yd. annually. In 1939 the sludge jumped to 184,400 cu. yd. and rose to the maximum in 1943. The detention periods for digestion have varied widely.

Separate sludge digestion in heated tanks treated about 14 per cent of the solids recovered in the Imhoff tanks. A temperature of 93° F. was maintained in the primary tank, whereas in the secondary it falls to 76°. Tests indicate that a reasonable digestion can be had in 30 days (Table III).

TABLE II.—*Trickling Filter Loadings and Performances, Akron, Ohio*

| Year | Filter Influent | | | Filter Effluent | | | | |
|---|---|---|---|---|---|---|---|---|
| | Average Flow, M.G.D. | B.O.D. | | Nitrites, P.p.m. | Nitrates, P.p.m. | Relative Stability, Per Cent | B.O.D. | |
| | | P.p.m. | Lbs. per Acre Foot | | | | p.p.m. | Lbs. per Acre Foot |
| 1930 | 27.4 | 105 | 171 | 0.35 | 3.11 | 68 | 22.0 | 36 |
| 1931 | 28.1 | 109 | 182 | 0.73 | 2.92 | 76 | 20.8 | 35 |
| 1932 | 31.2 | 91 | 169 | 0.54 | 3.38 | 87 | 23.8 | 44 |
| 1933 | 31.4 | 105 | 196 | 0.49 | 5.27 | 88 | 24.0 | 45 |
| 1934 | 27.7 | 127 | 209 | 0.29 | 6.99 | 86 | 26.7 | 44 |
| 1935 | 29.6 | 120 | 211 | 0.49 | 8.18 | 84 | 26.5 | 47 |
| 1936 | 30.2 | 107 | 192 | 0.35 | 6.17 | 83 | 23.2 | 42 |
| 1937 | 32.9 | 106 | 207 | 0.47 | 5.46 | 79 | 24.1 | 47 |
| 1938 | 32.7 | 102 | 198 | 0.51 | 5.59 | 81 | 23.3 | 45 |
| 1939 | 38.4 | 106 | 242 | 0.49 | 4.78 | 74 | 23.2 | 53 |
| 1940 | 41.0 | 128 | 312 | 0.69 | 3.12 | 68 | 36.1 | 88 |
| 1941 | 39.8 | 159 | 376 | 0.47 | 2.71 | 68 | 35.7 | 84 |
| 1942 | 46.9 | 181 | 505 | 0.42 | 2.00 | 59 | 40.9 | 114 |
| 1943 | 52.2 | 191 | 592 | 0.25 | 0.97 | 45 | 64.5 | 199 |

Data taken from Annual Reports.

TABLE III.—*Separate Sludge Digestion for Shortened Periods Akron, Ohio*

| | 53 Days | 50 Days | 35 Days |
|---|---|---|---|
| Volatile Matter Added, tons | 915.76 | 499.85 | 537.09 |
| Volatile Matter Withdrawn, tons | 385.86 | 118.44 | 298.46 |
| Volatile Matter Destroyed, tons | 529.90 | 257.90 | 238.63 |
| Total Gas, cu. ft. | 11,671,844 | 6,847,400 | 6,941,100 |
| Cubic Feet of Gas per Pound of Volatile Matter Destroyed | 11.0 | 13.5 | 14.5 |
| Cubic Feet of Gas per Pound of Solids Added | 3.86 | 3.61 | 4.40 |
| Pounds of Solids per Month per Cubic Foot of Digester Capacity | 4.15 | 4.33 | 3.87 |
| Per Cent Reduction in Volatile Matter | 57.8 | 51.7 | 44.3 |

For future designs for sludge digestion, factors suggested are:

| | | |
|---|---|---|
| Digestion load, as total solids per month per cubic foot of digestion capacity | 4 | pounds |
| Solids Reduction | | |
| In total solids | 35 | per cent |
| In volatile solids | 46 | per cent |
| Gas production, per pound of dry solids added | $3\frac{1}{2}$ | cu. ft. |
| Gas production, per pound of volatile matter destroyed or digested | 12 | cu. ft |

The existing works (improved somewhat) are adequate for treating a flow of 30 m.g.d. carrying raw sewage suspended solids of 335 p.p.m. and a B.O.D. of 200 p.p.m. The plant was capable of treating about 50 per cent of the 1943 solids and 40 per cent of the B.O.D.

Various repairs, additions, and betterments are suggested; in particular, provisions for flooding the trickling filters. Additional administration, service, and laboratory quarters are required. Lagoons are needed as a temporary expedient.

New works are needed to carry the 37.5 m.g.d. excess over the 30 m.g.d. to be handled at Botzum. Various processes and types of plants are discussed pro and con. The conclusion is that only trickling filter or activated sludge plants are suited to the needs established at Akron, or a combination such as short period aeration followed by high-rate filtration or two stages of high-rate filtration.

For the disposal of sludge, air drying of digested sludge is eliminated. Digestion and mechanical dewatering, alone, or followed by incineration were considered. Incineration was estimated at $5.02 per ton of dry solids, as compared with direct disposal by dumping at $4.40 per ton. Incineration was recommended.

The recovery of gas from digestion is approved for the new works to develop about 600 H.P. The recovery of material for fertilizer after digestion is dismissed as of doubtful value in the long term. The marketing of air-dried Akron sludge (Akra-Soilite) has been abandoned after four years' trial.

Various alternative projects are discussed along the lines mentioned. These show a construction cost ranging from $5,100,000 to $6,512,000; with annual operation from $290,100 to $322,000 and annual fixed charges between $618,800 and $693,000. The best project for Akron is Project I, briefly rehabilitating and continuing the existing plant at 30 m.g.d.; providing a new complete activated sludge plant with separate sludge digestion tanks for 37.5 m.g.d. and mechanical dewatering and incineration for all sludge. This has a construction cost of $5,100,000 and annual operation $322,000, with fixed charges of $618,000. The new plant is estimated at $3,402,000; rehabilitation of the existing plant at $633,00, and sludge disposal for both at $1,065,000.

The report describes the proposed program in detail.

The maximum capacities are set at:

| | | |
|---|---|---|
| Imhoff Tank-Trickling Filter | | |
| Complete treatment to | 93 | m.g.d. |
| Activated Sludge Plant | | |
| Complete treatment to | 75 | m.g.d. |
| Primary treatment only to additional | 39 | m.g.d. |
| Total | 207 | m.g.d. |

*Design Data*

| | | |
|---|---|---|
| Year | 1960 | |
| Population | 330,000 | |
| Sewage Flow | | |
| Average | 67.5 | m.g.d. |
| Maximum | 207 | m.g.d. |
| Sewage | | |
| Suspended Solids | 335 | p.p.m. |
| B.O.D. | 200 | p.p.m. |
| Complete treatment | 168 | m.g.d. |
| Primary treatment for excess | 39 | m.g.d. |
| Screenings for maximum day | 270 | cu. ft. |
| Grit for maximum day | 200 | cu. yd. |

*New Works*

| | | |
|---|---|---|
| Chlorine—Provide 12 p.p.m. for 67.5 m.g.d. | | |
| Grit Detritors | 2 | |
| Screening Macerators | 4 | |
| Aeration Channel | 3 | min. detention |
| Air | 0.02 | cu. ft. per gal. |
| Primary Sedimentation | 6 | units |
| Period | 1 | hr. |
| Rate overflow | 1,700 | gal. sq. ft. per hr. |
| Removal assumed (suspended solids) | 54 | per cent |
| Aeration Tanks | 8 | units |
| 2-pass spiral flow period | 6 | hr. |
| Sludge return | 25 | per cent |
| Final Settling | 8 | units |
| Two groups— | | |
| Period at 125% average flow | 2 | hr. |
| Overflow rate | 850 | gal. per sq. ft. per hr. |
| Suspended solids removal assumed at | 40 | per cent |
| Blower installation: | Gas and electric driven | |
| Total | 45,000 | c.f.m. |
| Sludge Digestion— | | |
| 4 units floating covers | | |
| 2 existing tanks | | |
| All heated | | |
| Total Volume | 815,000 | cu. ft., or 4.45 c.f. per cap. (on nominal 183,000 pop.) |
| Gas Storage | 80,000 | cu. ft. |
| Sludge Filters | 4 | units (includes 1 spiral) |
| Operate 3 shifts daily for 6-day week at rate 5 lb. of dry solids per sq. ft. per hr. | | |
| Elutriation Tanks for 4 to 1 wash of digested sludge. | | |
| Sludge Incinerators | 4 | units (includes 1 spiral) |
| Operate 3 shifts daily for 6-day week. Computed at a drying-burning rate of 40 lb. dry solids per sq. ft. of hearth area per day, but alternative types admissible. One stack. | | |

Detailed estimates are given. Special foundations are required for certain structures. A railroad siding is essential.

A force of 89 employees is estimated at an average of $2,080 per year.

The program for construction estimates two working seasons.

LANGDON PEARSE

# URBANA AND CHAMPAIGN SANITARY DISTRICT

## Operation Report for Fiscal Year, May 1, 1943–April 30, 1944

By W. M. Kunsch

The Urbana and Champaign Sanitary District serves a connected population of 45,000. The flow record for the past three years shows:

| Year | Sewage Flow | | Water Consumption |
|---|---|---|---|
| | Total M.G. | Per Capita Gal./Day | Per Capita Gal./Day |
| 1943–44 | 1394 | 89 | 99 |
| 1942–43 | 1424 | 87 | 93 |
| 1941–42 | 1609 | 99 | 94 |

In 1943–44, 90.6 per cent of sewage received complete treatment. All sewage received primary treatment.

The amount of dilution afforded by the Saline Ditch was sufficient to maintain the desired dissolved oxygen. The duration of various rates of flow are:

| Stream Flow M.G.D. | Per Cent of Time | | |
|---|---|---|---|
| | 1943–44 | 1942–43 | 1941–42 |
| Less than 2 | 0.3 | 0.5 | 0.5 |
| Less than 3 | 12 | 6 | 10 |
| Less than 5 | 42 | 19 | 15 |
| Less than 50 | 76 | 83 | 60 |
| Less than 100 | 87 | 93 | 86 |
| Over 100 | 13 | 7 | 14 |

The average removal of wet screenings was about 3 cu. ft. per day. These are ground and returned to the raw sewage. The grit chamber was cleaned twice, the removal of grit being 0.41 and 0.49 cu. ft. per million gallons.

The Imhoff tanks removed an average per cent of 67.4 of suspended solids; 48.2 of B.O.D.; and 95.9 of the settleable solids. There was no difficulty with foaming. The loading on the tanks was excessive.

| Data | Avg. | Max. | Min. |
|---|---|---|---|
| Flow, m.g.d. | 4.63 | 6.69 | 2.81 |
| Detention Period, hr. | 1.58 | 2.14 | 0.87 |
| Digestion Temp., deg. C. | 16 | 22 | 13 |
| Susp. Solids, lb. per cu. ft. per mo. | 1.44 | 1.83 | 1.07 |
| Vol. Susp. Solids, lb. per cu. ft. per mo. | 1.18 | 1.47 | 0.95 |

The flow is reversed twice a year.

An average of 3.37 m.g.d. was pumped to the trickling filter, with an average of 140 K.w.h. per million gallons. Current costs per K.w.h., $0.0155.

A total of 65 beds of sludge and 19 of scum were drawn. 80 beds were cleaned. All of the dried sludge (2,200 cu. yd.) went to the stock pile, whence farmers and gardeners load a considerable amount. The average drying time was 49 days, ranging from 21 to 95 days. The moisture content as removed is about 60 per cent. The beds are loaded at the rate of 16.6 lb. per sq. ft. per year. Nine beds were resanded, at a rate of 0.4 cu. yd. of sand per 1,000 sq. ft. of bed per year.

On the trickling filters, once a month the dosing tank piping is flushed, all filter nozzles removed and cleaned, and distribution system riser pipes brushed clean. Pooling on the filters was very slight, in a few isolated spots at the end of the winter.

Forty per cent of the final effluent is passed through the lagoon.

The population equivalent dropped from 52,900 to 47,900 for 1943–44, probably due in part to the drop in enrollment at the University of Illinois.

The plant performance averaged in overall removals in per cent:

| Removal | Effluent Secondary Tank | Effluent Lagoon |
|---|---|---|
| 5-Day B.O.D. | 90.1 | 91.9 |
| Suspended Solids | 88.8 | 91.4 |

The performance of the Imhoff tanks was as follows:

| Removal | Per Cent |
|---|---|
| 5-Day B.O.D. | 48.2 |
| Suspended Solids | 63.1 |

The trickling filter data show:

| Data | |
|---|---|
| Removal B.O.D. per cent | 67 |
| Application of sewage, m.g.a.d. | 2.11 |
| B.O.D. lb. per acre foot p.d. | 249 |

The final sedimentation tanks removed 39.5 per cent of the suspended solids with 1.07 hr. detention.

Treating 40 per cent of the final tank effluent, the lagoon reduced the suspended solids from 26 to 20 p.p.m. and the B.O.D. from 27 to 22 p.p.m. The lagoon effluent contained 6.3 p.p.m. of dissolved oxygen, slightly less than the 6.6 p.p.m. in the final tank effluent.

The total cost of operation was $23,681.38, or $0.527 per capita. All bonds have been retired. Excluding trustees' salaries and legal expense, the operating costs were:

| Cost | 1943–44 | 1942–43 | 1941–42 |
|---|---|---|---|
| Total | $21,731 | $19,126 | $19,345 |
| Per Capita per Year | 0.482 | 0.407 | 0.412 |
| Per M.G. treated | 15.58 | 13.43 | 12.03 |
| Per 1000 lb. 5-day B.O.D. removed | 7.91 | 6.58 | 6.72 |
| Population Connected | 45,000 | 47,000 | 47,000 |

ANALYTICAL DATA

Monthly Averages 1943–44

| Suspended Solids | Parts per Million | | |
|---|---|---|---|
| | Average | Maximum | Minimum |
| Raw Sewage | | | |
| Total | 233 | 332 | 143 |
| Volatile | 190 | 274 | 114 |
| Imhoff Effluent | | | |
| Total | 86 | 108 | 64 |
| Volatile | 67 | 88 | 52 |
| Filter Effluent | | | |
| Total | 43 | 61 | 30 |
| Volatile | 33 | 25 | 48 |
| Final Tank Effluent | | | |
| Total | 26 | 39 | 16 |
| Volatile | 20 | 30 | 13 |
| Lagoon Effluent | | | |
| Total | 20 | 30 | 11 |
| Volatile | 15 | 21 | 9 |

| 5-day B.O.D. | Parts per Million | | |
|---|---|---|---|
| | Average | Maximum | Minimum |
| Raw Sewage | 272 | 332 | 168 |
| Imhoff Effluent | 141 | 181 | 68 |
| Filter Effluent | 46 | 69 | 28 |
| Final Tank Effluent | 27 | 44 | 17 |
| Lagoon Effluent | 22 | 33 | 12 |

LANGDON PEARSE

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## ANNUAL REPORT OF COMMISSIONER OF PUBLIC WORKS, FITCHBURG, MASS.

BY J. M. PEIRCE (1943)

This Annual Report contains the report of H. B. Allen, chemist-in-charge, on the operation of the sewage works.

In 1943, the annual rainfall was 40.82 inches, compared with a normal of 40.43. The extreme temperatures were 97° and −21° F., with an average of 47.7°, compared with a normal of 47.5° F. The average flow of sewage and surface water treated was 3.17 m.g.d. (81.9 gal. per cap. per day), or 8.8 per cent less than in 1942. The monthly flow was 2.20 m.g.d. as a minimum, and 4.23 m.g.d. as a maximum, the peak daily flow being 8.9 m.g.d. The maximum capacity of the trickling filter is 6.36 m.g.d.

The design and operating bases for the respective units are as follows:

| Units | Mil. Gal. Daily Design Basis | Average 1943 |
|---|---|---|
| Flow, Gal. per cap. per day | 125 | 81.9 |
| Population | 55,000 | 40,000 |
| Imhoff Tanks | | |
| Capacity, m.g.d. | 6.875 | |
| Average, m.g.d. | | 3.11 |
| Maximum, m.g.d. | | 4.23 |
| Detention, hr. | 3 | 7.23 |
| Sludge removed, gal. | | 740,000 |
| Trickling Filters | | |
| Area, Acres | 2.12 | 1.86 |
| Load, m.g.a.d. | 2.0 | 1.70 |

On November 1, 82 per cent of the sludge storage was available. The sludge was drawn during May to October, inclusive. During the year the skimmings averaged 4.4 cu. ft. per day, with a maximum monthly average of 11.2 cu. ft. per day. The tanks were skimmed once a day in the winter and twice daily during the summer. All sludge from the tanks was air dried, 661 cu. yd. being removed from the drying beds. The beds were resanded during the summer. At the end of the drying season, ten units are empty.

The average number of nozzles on the trickling filters cleaned daily was 14.8, with a maximum month of 18.4.

The analytical results are as follows:

| Determination | Crude Sewage | Effluent | | | Per Cent Removal |
|---|---|---|---|---|---|
| | | Imhoff Tank | Trickling Filter | Final | |
| Free Ammonia | 30.5 | 23.8 | 7.1 | 6.6 | 78.5 |
| Alb. Ammonia | 5.6 | 3.1 | 1.0 | 0.8 | 85.2 |
| Organic Nitrogen | 14.8 | 7.1 | 2.4 | 2.1 | 85.8 |
| Oxygen Consumed | 67.5 | 23 | 12.2 | 9.3 | 86.3 |
| Suspended Solids | | | | | |
| Total | 231 | 41 | 29.3 | 22.0 | 90.5 |
| Volatile | 185 | 26.5 | 18.8 | 17.0 | 90.8 |
| Fixed | 46.5 | 14.5 | 10.5 | 5.0 | 89.3 |
| Nitrates (N) | — | — | 11.2 | 10.6 | — |
| Alkalinity | 168 | 138 | 50 | 45.5 | 73.4 |
| 5-day B.O.D. | 215 | 81 | 7.7 | 9.1 | 95.8 |

The operating cost in 1943 was $13,133.99, as compared with $11,529.23 in 1942. This was distributed as follows:

| Distribution | Personal Service | Expense |
|---|---|---|
| Administration | $1,375.05 | $1.50 |
| Laboratory | 1,375.08 | 8.32 |
| Grit and Siphon Chamber | 683.80 | 311.97 |
| Imhoff Tanks | 2,548.27 | 40.90 |
| Sprinkling Filters | 698.82 | 149.50 |
| Secondary Tanks | 383.57 | 65.24 |
| Sludge Beds | 560.75 | 91.32 |
| Care of Grounds | 451.98 | 29.32 |
| Watchmen | 3,508.71 | |
| Miscellaneous and Vacations | 271.37 | 628.52 |
| Total | $11,857.40 | $1,326.59 |

Langdon Pearse

## SEWAGE DISPOSAL FOR LOS ANGELES AND ASSOCIATED COMMUNITIES

By Metcalf and Eddy

April 25, 1944

This is a report submitted to the Board of Public Works of Los Angeles recommending the construction of a high-rate activated sludge plant at Hyperion, with a new multiple outlet ocean outfall one mile offshore in about 60 feet of water, with capacity to treat an average dry weather flow of 380 c.f.s, equivalent to the sewage of 3,000,000 people. The estimated cost of the project is $21,000,000, of which the treatment plant and outfall cost $19,500,000. The total cost is $7.00 per capita on a design basis. The operating cost annually is estimated at $525,000, or $5.88 per m.g., or $0.175 per capita.

The 1940 tributary population of 1,700,000 is estimated to increase to 2,500,000 by 1950 and approach 2,900,000 by 1955. The present total sewage flow from two outfalls averages 378 c.f.s., with a peak around 540 c.f.s. The water consumption of Los Angeles is 115 g.c.d., but the sewage flow is 81 g.c.d. in 1943. The sewage at Hyperion is stale and strong. For the purpose of the report, it is estimated to contain in p.p.m.—suspended solids, 300; 5-day B.O.D., 250; grease, 100; with a flow of 82 g.p.c.

The quarantine on the use of the beaches on Santa Monica Bay cut the visitors from 40,000,000 in 1942 to 14,500,000 in 1943.

Six alternate programs were considered, including preliminary treatment by settling and grease removal, alone; preliminary treatment in part, with part of the load given activated sludge treatment; or all activated sludge. The situation requires far more treatment than fine screens provide.

Metcalf and Eddy recommend a plant consisting of rack screening; pre-chlorination equipment; grit chambers; primary settling; short period aeration; and final settling tanks. The sludge will be pumped to heated separate digestion tanks (2-stage digestion), dewatered on vacuum filters, and dried for fertilizer or incineration. Gas will be utilized in gas engines, the waste heat from the cooling water of the engines to be utilized in heating the digestion tanks. Disinfection of the plant effluent by chlorine will be provided. About 200 acres is needed for a site.

The report further recommends that when the sewage flow near Hyperion reaches 90 per cent of the design capacity, a new trunk sewer be constructed to divert from the north outfall sewer the flow in this sewer east of the divide between the Los Angeles River and Ballona Creek to a new treatment plant of the activated sludge type, or equivalent, to be located in the industrial area along the river.

Langdon Pearse

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## HOW TO MEET THE DEMAND FOR BETTER WASTE DISPOSAL

By Earl S. Fenelon

*Food Industries*, **15**, 84–86 (1943)

The article discusses the need for studying the wastes from food process industries due to increased pressure on the part of State and Federal Government to reduce the load on streams.

Thirty-two states have passed acts permitting sewer rental charges and one of the bases for the charge includes the volume of water consumed and the B.O.D. of the sewage discharged.

In the food industries this should lead to an analysis of production methods so as to reduce volume of waste to a minimum and to separation of pollutional portion from the unpollutional.

The branches of the food industry having high B.O.D.'s are meat packing, slaughtering, vegetable canning and allied operations (including dehydration) candy manufacturing and brewing.

A table is given showing analyses of wastes from canning processes taken from an article by W. A. Ryan which was published in SEWAGE WORKS JOURNAL, 11, 100 (1940).

GLADYS SWOPE

## BROMINE AND CHLORINE DIOXIDE AS WATER DISINFECTANTS

BY J. A. MCCARTHY

*Journal, New England Water Works Assn.*, 58, 55–68 (1944)

The efficiency of bromine and chlorine dioxide in the distribution of bacteria was compared with that of chlorine. Neither agent is as effective as chlorine but either could be used as bactericide. Both agents are more affected by organic matter in water than is chlorine and neither agent has nearly as much residual effect as chlorine.

The bactericidal action of bromine and chlorine dioxide is largely a function of the chlorine demand or the amount of organic matter present. With pure cultures suspended in sterile tap water where the chlorine demand is negligible, bromine and chlorine dioxide are nearly as effective as chlorine in equal concentractions. Bromine has a flash effect on bacteria. In any reasonable concentration the kill in 15 minutes is as great as in one or twenty-four hours. Chlorine dioxide produces less chlorphenol tastes than chlorine.

H. HEUKELEKIAN

## SAFETY OF MECHANICAL RESUSCITATION APPARATUS

(A Reply by the Council on Physical Therapy of the American Medical Association to Professor Yandell Henderson's Article in *Science*, December 24, 1943, on "The Return of the Pulmotor as a 'Resuscitator'—A Back-step Toward the Death of Thousands." The abstract of the original article appeared in the SEWAGE WORKS JOURNAL, 16, 854 (1944)).

Professor Henderson claimed that mechanical devices for artificial respiration known as resuscitators are essentially identical with a device formerly known as the pulmotor. The modern devices are, however, essentially different from the pulmotor, since they incorporate mechanisms for the control of pressure. In the resuscitators accepted by the council, dangerous pressures are not produced. The maximum positive pressure of 13 mm. of mercury created in them is less than that which a human being can voluntarily produce in his own lungs without discomfort. The Council agrees with Professor Henderson that in order to avoid delay which may be fatal, manual artificial respiration should be administered at the earliest possible moment, whether or not an inhalator or a resuscitator is expected. The Council has advocated Red Cross training of persons for giving first aid by manual methods. The Council has failed to find a single instance in which loss of life or injury has been caused by accepted resuscitators.

H. HEUKELEKIAN


EMCO Sewage Gas Meters and PITTSBURGH-EMPIRE Hot Water Met
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# *In Sewage Treatment Plants*

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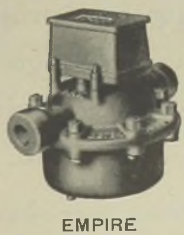
When making decisions, facts are often more important than judgment. The figures resulting from accurate measurement are essential facts to the proper management of every sewage disposal plant.

Meters answer such ever-occurring questions as:

*"How much hot water was used to heat the digestion tanks during that sub-zero period?"*

*"What was the volume of gas produced in digestor No. 3 during the past 24 hours?"*

*"How many cubic feet of sludge gas did we generate last month and what did it save over the cost of purchased power?"*



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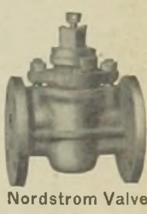

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