SEWAGE WORKS JOURNAL

VOL. XVII MAY, 1945 NO. 3

Special Features

Industrial Waste Effects on Plant Operation—Symposium

Digester Loading and Supernatant Liquor—Rudolfs and Fontenelli

Trends in British Practice—Edmundson

Plankton Productivity in Lakes—Lackey and Sawyer

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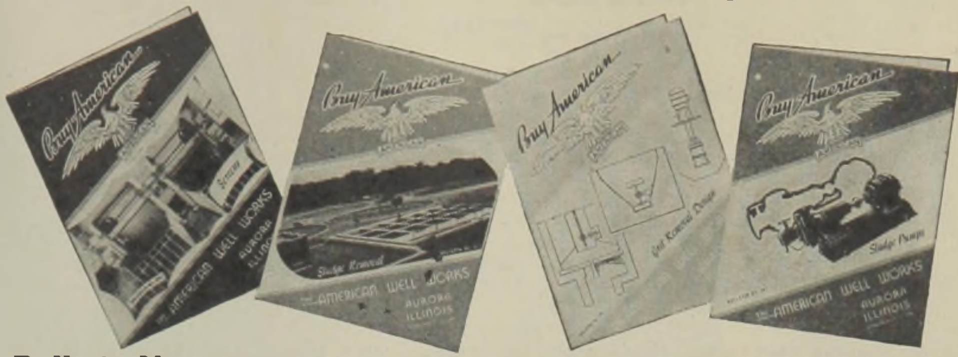
American Waste Treatment Equipment



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

Bulletin No. 260—
"Pre-Aeration-Grease Flotation"—The application of beneficial pre-treatment for new and existing plants.

Bulletin No. 257—
"Rotary Distributors" — Distributors to meet all field conditions. Recommendations for filters.

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

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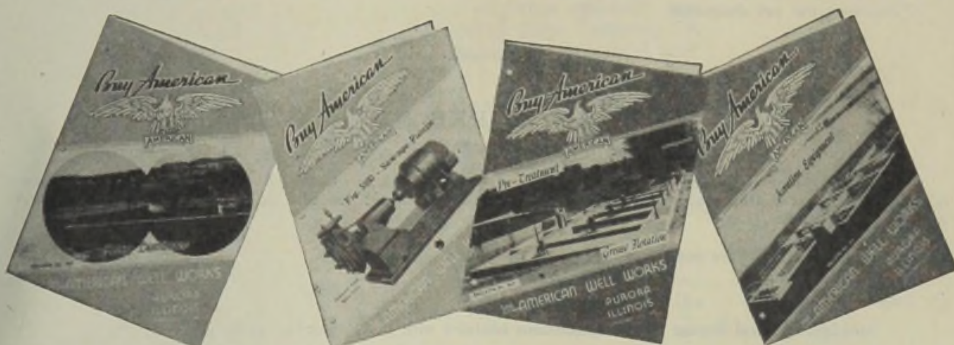

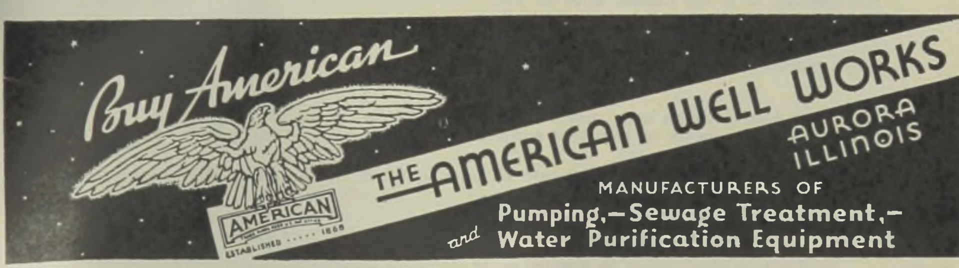

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

SEWAGE WORKS JOURNAL

REG. U. S. PAT. OFF.

A Bimonthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of sewage works.

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14	2200	3920	5150	....
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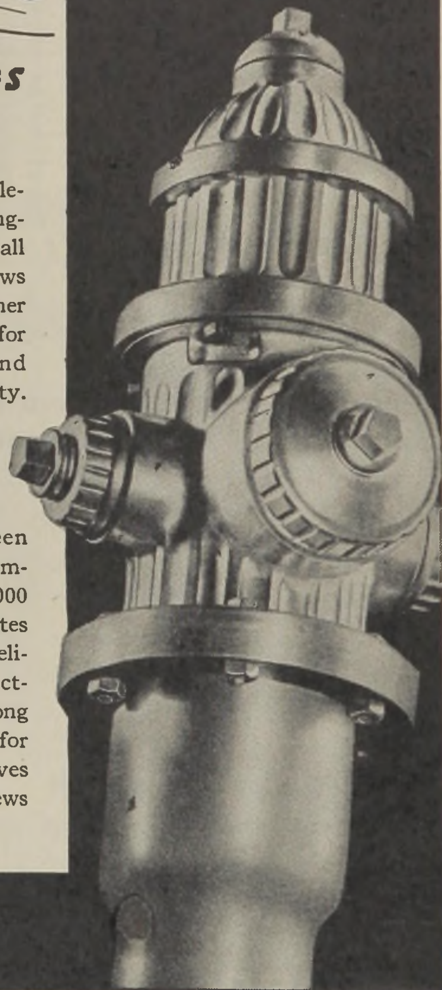

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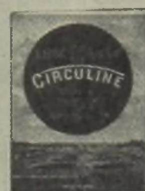

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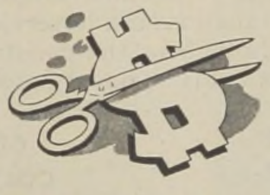

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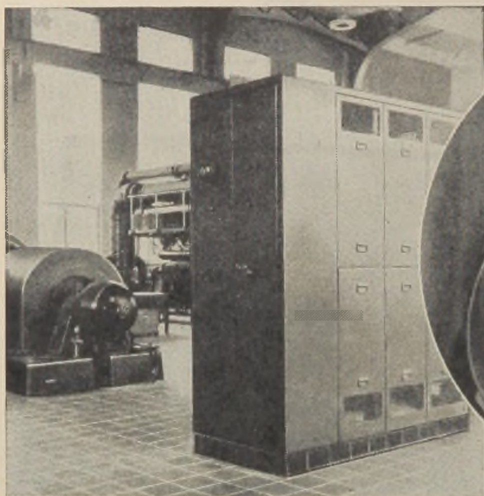
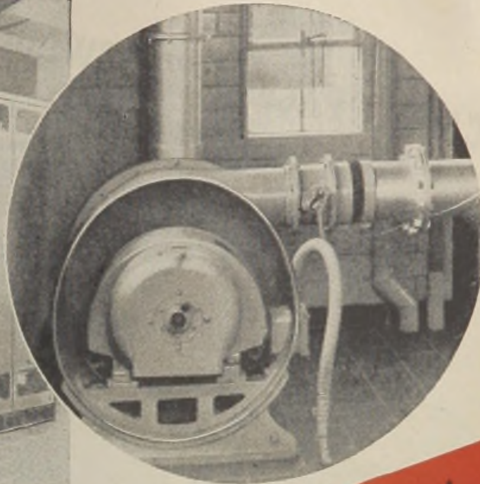


One of three secondary control cubicles for starting and regulating induction motors driving centrifugal blowers. Remote control from a gallery benchboard.



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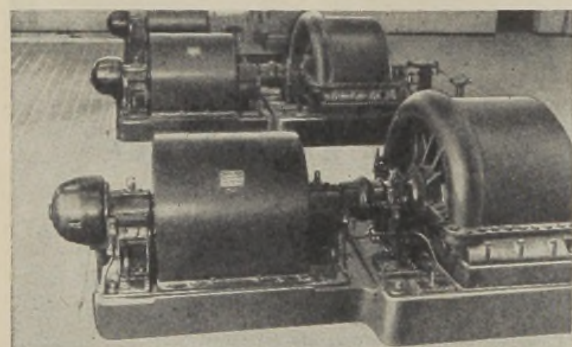

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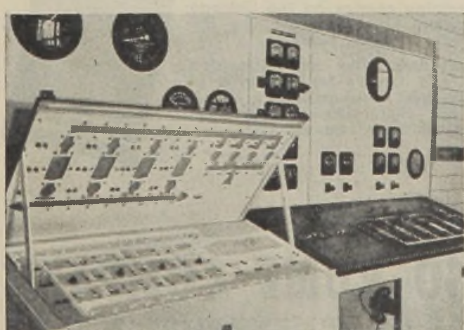
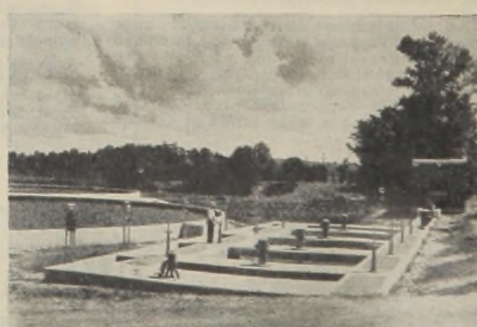


Main control desk with illuminated mimic piping layout to show flow of air and sewage. Provides complete control of all pumps, blowers, valves, etc.



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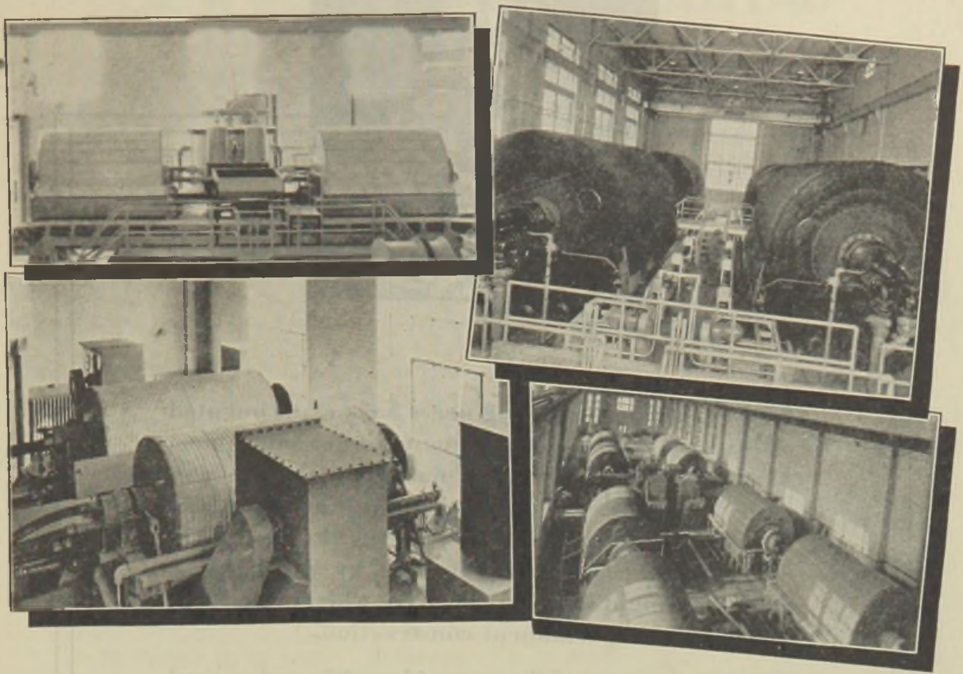

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Plant Operation

EFFECT OF INDUSTRIAL ACTIVITY UPON SEWAGE FLOWS *

By Don E. Bloodgood

Associate Professor of Sanitary Engineering, Purdue University, Lafayette, Ind.

All of us have been conscious of the increase in industrial activity in our country during the past several years. We have heard and read of water shortages in a number of instances and have known that many cities have been pressed to supply sufficient water to meet the demands. Knowing of the deficiency of rainfall in Indiana during 1944, the writer was of the opinion that the shortage of water had been the result of the combination of increased consumption and deficiency of supply, and had been under the impression that the drought had been the most important factor. When asked to discuss the effect of industrial activity upon sewage flows, it was thought advisable to obtain flow data from sewage treatment plants in industrial cities. Before proceeding very far it was very apparent that the increased usage of water must have been a much larger factor in the cases of water shortage than had been estimated.

No effort was made to select information from cities that would be outstanding examples of increased sewage flows. The cities from which data were selected—Indianapolis, Fort Wayne, Anderson, Muncie, and Marion—are all engaged in industrial activities of many types. The populations of these cities range from about 27,000 to 387,000 and so give a fair cross section of the cities in Indiana. Taken for comparison are the sewage flows for the months of May, June and July for the years 1942 and 1944. These are relatively short periods and, of course, might not be readily compared, especially if the precipitation were greater during the period of higher flows. The U. S. Weather reports for Indianapolis show, however, that the rainfall for the period in 1942 was 16.13 inches, and only 7.64 inches for the same period in 1944, or more than twice as much in 1942 as there was in 1944.

From the data obtained, the percentage increases of the 1944 sewage flows over the 1942 flows were found to be as follows:

Indianapolis	6.7%	Marion	30.1%
Anderson	19.4%	Munice	41.8%
Fort Wayne	23.8%		

One would expect that with such increases in flow there would be countless difficulties reported by the superintendents of the plants so

* Presented in Operator's Breakfast Forum, Seventeenth Annual Meeting, F.S.W.A., Pittsburgh, Pa., October 14, 1944.

affected. During the past year the writer has visited all of these plants one or more times. Some of the superintendents have been confronted with difficulties that could not be overcome but, in general, they have managed to accomplish the greatest degree of purification possible with the plants and equipment available. In most of these plants the sludge disposal problem has been magnified; this indicates that the strength of sewage has increased as well as the flow. On a recent visit to the Fort Wayne plant, Mr. Hoot and the writer reviewed the figures on suspended solids received at the plant and it was found that for May, June and July of 1944 they were 37 per cent higher than they were for the same period in 1942. The increase in sewage flow received at the Indianapolis plant is not as large as it would be if it were not for the fact that certain intercepting sewers are now taxed beyond their capacity and, as a result, it is impossible to get all of the city's sewage to the treatment plant.

It would seem from these data that the sewage flows in industrial cities in Indiana had probably increased an average of about 25 per cent. When it is realized that many sewage plants are designed to meet the need evident at the time of construction it is certain that with an overload of 25 per cent the superintendents can expect difficult situations.

The writer is indebted to Mr. R. Hoot of Fort Wayne, Mr. Frazier and Mr. D. O. Bender of Indianapolis, Mr. P. White of Muncie, Mr. D. Backmeyer of Marion, and Mr. R. R. Baxter of Anderson for their assistance in gathering the data used as the basis of these comments.

Open Discussion

M. M. Martens (Camp Breckenridge, Ky.)—We have experienced abrupt increases in flow at the Camp Breckenridge sewage treatment plant but I am unable to present accurate data offhand. As is the case in many plants serving military installations, our increased flows have been brought about by increased tributary populations.

W. Q. Kehr (Missouri State Board of Health)—As most of you know, the larger cities of Missouri are located along the Missouri and Mississippi Rivers, and dispose of their wastes, without treatment, into those rivers. Consequently our problems have been limited to those cities that have treatment facilities.

The City of Springfield has experienced a considerable increase in sewage flow, occasioned largely by the increase in the capacity of plants producing milk products. The civilian population in Springfield has increased some and undoubtedly accounts for some of the increase in sewage flow, but it is believed that the industrial wastes account for a greater percentage of the increase, both in the strength and volume.

We did have two problems in small municipalities adjacent to a large cantonment. One of those cities, Neosho, Mo., is a very short distance from Camp Crowder. Fortunately, the Government provided for the necessary increase in sewage treatment plant facilities, and that situation is fairly well solved.

The other situation is at Lebanon, Mo., some sixty miles from Fort Leonard Wood. The population in this city before the construction of Fort Leonard Wood was about 5,000. The sewage flow has about trebled, and the plant is considerably overloaded. For some time we have been trying to interest the various federal agencies in constructing additions to the plant. So far, we have had little success. That is a very definite case of overloading, due to an increase in population. Incidentally, the present population is estimated at about 8,500.

William Storrie (Toronto, Ont., Can.)—May I inquire of Prof. Bloodgood if all five of the cities he reported upon have combined or separate sewers?

Prof. Bloodgood—They are all combined. I do not at the moment recall any Indiana city which is not served by combined sewers.

Charles A. Emerson (New York City)—In regard to the Fort Wayne data, does the increase in the total amount of dry solids reaching the plant roughly agree with the increase in volume of flow? That is, is there any change in the strength of the sewage?

Prof. Bloodgood—The sewage flow increase at Fort Wayne was 23.8 per cent and the increase in suspended solids on a dry basis was 37 per cent. This would indicate a stronger sewage as well as an increased volume.

DIFFICULTIES OCCASIONED BY DISCHARGE OF GREASE AND OILS INTO SEWERAGE SYSTEMS *

By Reuben F. Brown

Superintendent of Sewer Maintenance, Los Angeles, Calif.

Industrial waste problems should be considered from the viewpoint of the manufacturer and from that of the public. Decisions on and methods of treatment are complexly interwoven with the economic structure of society. The presence of grease and oil at treatment plants has been viewed with alarm in the past, but improvements in equipment and processing have neutralized many of the difficulties.

Fig. 1.—Eight-inch steel pipe, showing heavy encrustation of grease deposited by wastes from soap and cleaning rag manufacturing plants.

High grease content in Army camp sewage has focused the attention of operators on the grease and oil disposal problem, and it has been found that grease digests effectively and rapidly if well interspersed among the other solids. In some of the larger cities, grease recovered in sewage treatment plants is sold to local concerns specializing in the rendering of fats. Some of those sales have amounted to as much as $8,900 per annum for otherwise waste material.

* Presented in Operator's Breakfast Forum, Seventeenth Annual Meeting, F.S.W.A., Pittsburgh, Pa., October 14, 1944.

The character and composition of municipal sewage is apparently remaining static, except in areas congested by war work, where sewage treatment difficulties due to grease and oil have been intensified. The development of many new industries in different parts of the country has resulted in a sectionalizing of such problems. Among the sewage treatment plant difficulties experienced because of high grease content are: overloading of skimming facilities at sedimentation tanks, heavy accumulation of floating scum, often reaching several feet in thickness, in sludge digester tanks; clogging of sludge and sewage piping (Figure 1); clogging and reduction in the life of vacuum filter cloths; increased air consumption in activated sludge units and interference with oxidation by trickling filters.

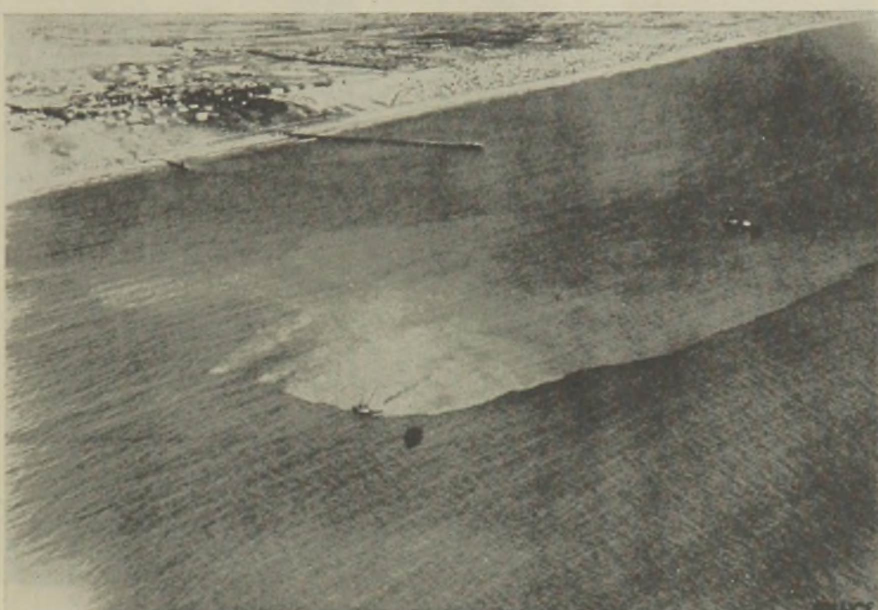

FIG. 2.—View of ocean at Los Angeles showing grease and oil scum a mile offshore. This film drifts with the wind and tide along a series of bathing beaches.

Oil wastes from garages, filling stations, wash racks, oil-cargo ships, ship yards, oil terminals and refineries, gas plants, and oil fields, have caused many problems in sewage treatment plants and it is recommended that regulations be adopted and enforced so as to eliminate such wastes from the sewerage system. Pretreatment at the source with suitable separating traps at all establishments producing oily wastes appears to be the trend in most communities. It is imperative that oil separators and traps be given proper inspection to assure their continuous effectiveness. The effects of oil wastes on sewage treatment plant operation are similar to those listed above for grease. When the oil is not completely removed, bathing beaches and waterfront property are damaged by the unsightly scum accumulation (Figure 2).

Cutting oils used in machine shops and industrial plants, if neutralized or diluted at their source, may be handled without too much difficulty in modern sewage treatment works. Such oils are seldom very troublesome if the sewage volume is relatively large in proportion to the quantity of oil.

In some cases, industrial wastes have had beneficial effects, as where precipitating or neutralizing chemicals may be present. This is never true, however, in regard to wastes containing grease or oil. Aside from the tendency to cause clogging of sewers, there is the always present hazard of explosion or fire resulting from the presence of fuel oils or cleaning fluids. Disintegration of sewer lines and manholes has also

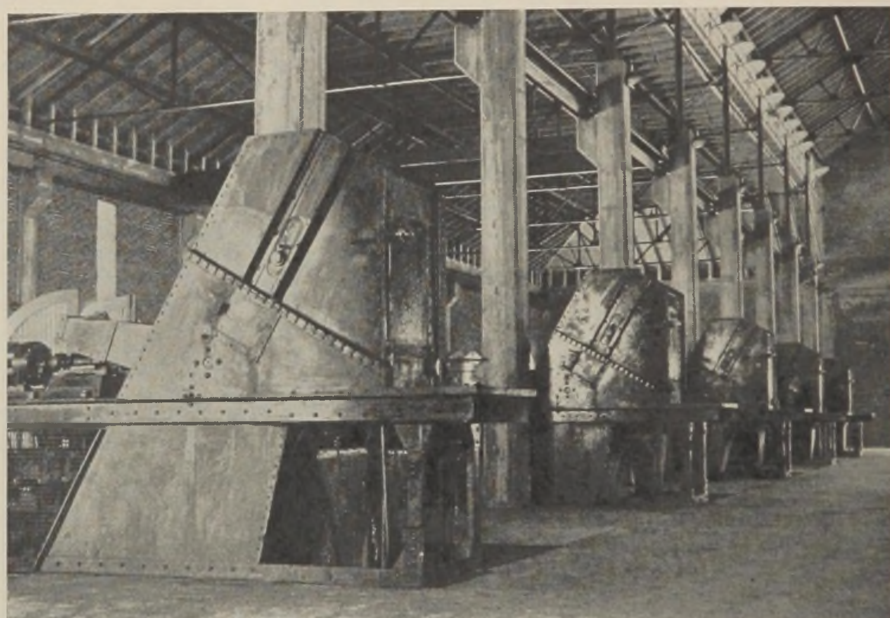

FIG. 3.—Hyperion screening plant at Los Angeles, showing elevators which carry screenings from the pit to the ejectors for discharge to the roll press and dryer. Heavy grease accumulations in the screen pit have occasionally put these elevators out of operation.

been a problem in Los Angeles because of acid wastes discharged from industries using large quantities of petroleum products.

A planned preventive maintenance program will correct many of these troublesome sewer system and treatment works conditions and eliminate the hazards involved. Industrial waste control based on proper field investigations and laboratory data affords the information necessary to determine the character and extent of damage which might result from such wastes. This type of program has been found absolutely essential in Los Angeles where "win the war" effort of industry has resulted in rapid expansion of manufacturing facilities, heavy concentration of population, and a marked increase in sewage flow. Extraordinary attention to repair and maintenance work has been required to furnish adequate service by the overtaxed sewer lines, pumping plants, and treatment facilities.

Los Angeles is unique in that it has one of the longest outfall sewers in the world. It requires 18 hours for sewage to flow the entire length, which results in the delivery of a strong, stale sewage, containing substantial quantities of hydrogen sulfide, at the Hyperion screening plant (Figure 3). Beach pollution was a problem in 1941 when the plant was already overloaded, but with the increased average flow from 147 m.g.d. to 163 m.g.d., the situation became alarming and ten miles of beach has been placed under state quarantine. Grease and oils have been received at this plant in such quantities at irregular times that the screens were rendered completely ineffective, making it neces-

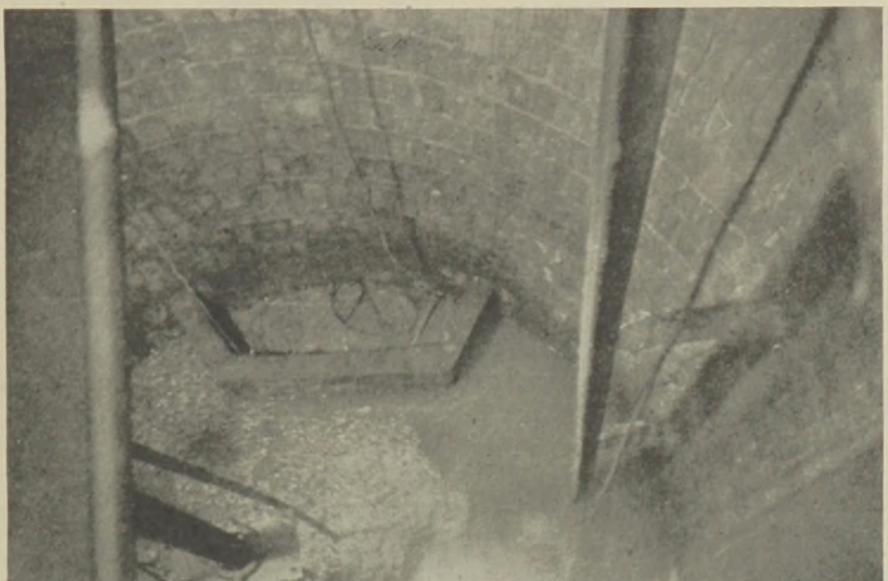

FIG. 4.—Electrode stillwell in wet well of a sewage pumping station, showing heavy grease scum which interfered with operation.

sary to bypass them entirely. At the plant outlet, an oil film can be seen on the surface of the ocean drifting with the tide and winds (Figure 1). The bathing beaches on both sides of the plant have become contaminated with a floating scum which will adhere to any object with which it comes in contact.

The firm of Metcalf and Eddy has made a survey of the sewage disposal problem under the direction of the Board of Public Works; their technical report includes recommendation of a new twenty-one million dollar activated sludge treatment plant. This report has been approved by Mayor Bowron and has been adopted by the city councils of Los Angeles and of the other contributing communities. It is expected that the present pollution of beaches will be eliminated upon the completion of this project.

The increased sewage flow at present, coupled with the heavy grease and oil content of the sewage, has created a need for additional maintenance attention at sewage pumping stations in Los Angeles. Thick hard mats of grease are found to accumulate in pumping plant wet wells and in the float or electrode stillwells (Figure 4). Increased cleaning and hosing of these wells has become necessary in order to avoid serious shutdowns and the production of odors and gases. Pumping stations especially affected were in the area serving large military centers, new housing projects, and airplane industries.

TABLE 1.—*Industrial Waste Field Investigation of Industrial Discharge, Los Angeles, Calif.*

Type of Waste	Average Gals. per Unit per Day	Average Grease (p.p.m.)	Average Susp. Solids (p.p.m.)	Average Settleable Solids (%)	Average pH	Average Temp. F°	Processed Unit	Average Daily Flow (gal.)
Packinghouse	1,050	587	1,220	0.7	7.5	90	Bullock	501,750
Dairy Industry	122	178	400	0.2	5.5–9.0	90	100 No. Milk	95,821
Overall Cleaning	5,292	250	855	0.3–1.5	6.0–9.0	65–150	Tub	29,365
Waste Rag Laundry	6,701	4,080	4,460	1.0–10.0	6.0–9.0	100–150	Tub	31,000
Bottling	11.2	23	107	1.5–0.15	9.0	79	Case	62,560
Bottle Washing	15,115	39	265	2.5	9.0	80–110	Washer	26,033
Cooperage	42	4,266	2,093	0.5	too cloudy	130	Barrel	13,000
Yarn Dyers	5,160	95	95	none	3.0–9.0	90–175	Tub	33,557
Film Processing	2.2	13	43	none	7.5	62	Foot of Film	157,800
Cleaning and Dyeing	70,000	166	118	none	5.0–8.0	80–140	Water Consump.	70,000
Paper Industry	—	60	487	1.2	7.0	7	S.D.M.H. Check	240,000
Laundry Industry	6,700	320	220	1.0	8.0	65–180	Tub	269,570

Table I illustrates the character of the information which is being gathered in the course of the field industrial wastes investigation at Los Angeles. The increased volume and changes in composition brought about by the war in the sewage received at the Hyperion screening plant are illustrated in Table II.

TABLE 2.—*Composition of Sewage at Hyperion Screening Plant, Los Angeles, Calif.**

	Parts per Million				Pounds per Capita (Daily)		
	May 1935	Aug. 1942	Nov. 1943	June 1944	May 1935	Aug. 1942	Nov. 1944
Suspended Solids	388	310	270	—	0.235	0.208	0.183
5-Day B.O.D.	—	200	174	—	—	0.134	0.115
Grease	—	160	139	—	—	0.107	0.094
Flow—m.g.d.	112.7	149.2	156.5	163	—	—	—
Population—Millions	1.55	1.85	1.93	—	—	—	—
Flow—Daily Gallons per Capita	74	81	81	—	—	—	—

* All samples 24-hr. composites.

The field investigation has been extended to the Los Angeles River, which receives wastes from breweries, soap manufacturing plants, bottling plants, packing houses, and butadiene plants. At some river stages, the *Coli* index ranged from 100,000 to 500,000, the B.O.D. varied from 65 p.p.m. to 332 p.p.m. and suspended solids from 61 p.p.m. to 106 p.p.m. The discharge from the butadiene plant showed heavy corrosive action at sewers, manholes and spillway structures, this waste being highly variable in character as shown by a pH range from 1.5 to 10.8 at varying intervals of three to five hours. The industries involved have given splendid co-operation by installing preliminary treatment devices and river conditions have measurably improved.

The planned program of industrial waste control in Los Angeles has included the passage of ordinances which make it illegal to discharge an industrial waste having a temperature exceeding 100° F., containing more than 1,000 p.p.m. suspended solids or more than 600 p.p.m. oil. Inflammable or explosive wastes and quantities of chemicals, grease, oil, or tar in sufficient amounts to affect the operation of a sewer system are prohibited. The wastes discharged must be within the range of pH 5.5 to 9.0. Wastes which are odorless and stable for five days at 20° C. are not permitted to be discharged to sanitary sewers. Industries are required to obtain a permit before discharging wastes to the sewer system and manholes must be provided for sampling and measurement of the industrial waste flow. Oil and grease traps are required at all garages, filling stations, and wash racks.

An industrial waste program including the following procedures will reduce pollution and insanitary and dangerous conditions brought about by the discharge of all types of industrial wastes, including those containing grease and oils.

(1) Analytical study and investigation of industrial wastes discharge where sewer line trouble occurs or plant operation may be affected or where volume of wastes can be reduced.

(2) Adequate ordinances establishing standard requirements for industrial waste control.

(3) Field investigations by means of a trailer laboratory especially equipped for sewage and industrial waste analysis.

(4) Creation of an industrial waste fund so that governmental agencies may be able to co-operate and participate in the cost of such changes as may be required to accomplish controlled industrial waste discharge. Such changes may include: construction of new sewer lines due to overloading of existing ones; provision of facilities for discharging non-putrescible and otherwise unharmful wastes to storm drains; emergency construction of facilities to relieve unusual condition; etc.

(5) Establishment of service charges to industries based upon the extra cost of maintenance, treatment and disposal of industrial wastes.

(6) Elimination of many problems at the source by requirement of suitable pretreatment facilities.

(7) Investigation and research on the reclamation of salable byproducts recovered at sewage treatment plants.

(8) Annual or more frequent inspection of industrial wastes pretreatment facilities, including even small grease and oil trap installations such as those at garages and filling stations.

(9) The requirement of permits covering the discharge of industrial wastes to public sewers, with careful preliminary investigation and subsequent inspection of facilities.

A co-operative relationship between industry and government is essential to the welfare of the community. Every individual and agency should have the right to use the public sewerage system as long as the public welfare is not affected and it is the duty of the municipality to see that proper control is exercised. This thought has been aptly expressed by Morris M. Cohn in his statement, "A municipality has a certain inalienable responsibility to its constituents and that is to remove through a public sewerage system all waste materials which can be removed without endangering the ability of that sewer to serve all other persons in the community."

The Engineer-Director of the Los Angeles Bureau of Maintenance and Sanitation is H. P. Cortelyou. John H. Ashley is Industrial Waste Engineer of the Sewer Maintenance Division, and A. A. Appel is Assistant Superintendent of Sewer Maintenance.

Discussion

By John R. Szymanski

Superintendent of Sewage Treatment, New Britain, Conn.

Similar to the military practice of furnishing a full course meal packed into a small container of concentrated foods, Mr. Brown has packed a volume of information into his digest of difficulties occasioned by the discharge of greases and oils into sewerage systems.

There being no need of repeating theoretical introductions, I shall present a few illustrations and examples of actual experiences at New Britain.

The city of New Britain, Connecticut, is what one may call an average New England industrial center. With pride, during peace times, we boast of being the hardware center of the world because of the builders' hardware, tools, etc. which are manufactured and shipped to all parts of the world. Being a manufacturing center it is natural that the sewage load is composed of a high percentage of industrial wastes. The greater portion of these wastes consists of pickling waste liquors and industrial cutting oils. Normally the quantity of oils arriving at the sewage plant was small, comparatively speaking, averaging about 22 cubic feet per day or an average of 2.4 cubic feet per million gallons. A daily routine of skimming, floating and removing this waste was incorporated into the operational routine without causing any undue problems. Furthermore, it must be remembered that the city of New Britain has an ordinance which prohibits the discharge of oil wastes from garages, filling stations, wash racks and industrial plants, thus protecting the sewerage system and sewage plant from any extremely heavy loads of oils and greases.

Following the national trend, New Britain industries went 100 per cent into war work as soon as possible in 1940. This boom in industrial activities immediately resulted in an increased load on the sewer system as well as the sewage plant. Confining ourselves to the problem of grease and oil, we find the following increases:

Year	Cu. Ft. Oil Removed per M.G. Sewage
1937	2.4
1938	2.4
1939	2.9
1940	3.0
1941	3.4
1942	4.8
1943	3.6

It was with tolerance that the gradual increase was noted up to 1942. The extra work involved up to this point did not bring about any grave situation. Then, in the early part of 1942, when manufacturers had to produce materials to meet the demand of our armed forces, came the climax. For weeks at a time the daily removal of these heavy oils averaged as high as 434 cubic feet.

Not only was this load becoming expensive to remove and dispose of, but the effects on the sludge were disastrous. Vacuum filtering of sludge became a serious problem. Combined with the above difficulties was the gradual accumulation of layers of grease and oils in pipe lines conveying this material.

The state departments of water and health were consulted and conferences were held with the manufacturers in order to determine means and methods of disposing of these wastes without affecting any party involved. The manufacturers were extremely co-operative, and soon these wastes were removed from the sewer system at the point of discharge by the contributing parties. In order to co-operate with the manufacturers, the city agreed to permit the dumping of these wastes at the sewage treatment plant dump and to cover them up with the available incinerator ash.

This practice proved successful, and one after the other the manufacturers followed suit, so that at the present time a definite reduction of the oil and grease load has been noticed at the plant.

Without doubt the above method of handling this problem may not apply to all communities, but for cases similar to New Britain it would seem to be the most practical.

EFFECTS OF INCREASED INDUSTRIAL WASTE LOADS ON SEWAGE TREATMENT PROCESSES AT WORCESTER, MASS.*

By Roy S. Lanphear

Supervising Chemist, Sewage Treatment Works

The city of Worcester treated its sewage by the chemical precipitation method from 1890 to 1925, a period of thirty-five years. This method was in use in England prior to 1890 and was favorably considered for adoption by the city of Worcester because its sewage contained ferrous sulphate or spent acid iron waste liquors from wire mills. Lime was added to the sewage in the form of milk of lime and was the only chemical which had to be purchased.

Intermittent sand filtration of sewage was first placed in operation in 1898 and construction of filters continued until 72.5 acres were in use in 1910. During the period, 1910 to 1925, the quantity of sewage treated by this method averaged about 4.0 m.g.d. The remaining 14.0 m.g.d. were treated by the older method.

In 1919 by Act of Legislature, the city of Worcester was required to construct a new sewage treatment plant, approved by the State Department of Health.

Operation of experimental sewage treatment plants since 1904 had demonstrated:

1. The Imhoff tank-trickling filter method successfully treated the sewage.
2. The activated sludge method required the use of four cubic feet of air per gallon of sewage and six hours aeration for treatment of the organic matter and the iron content of the sewage.
3. The problem of disposal of the large quantity of sludge from the latter method had not been solved in 1919, either by the city of Worcester or any other municipality. Vacuum filtration of activated sludge was first practiced in 1925 at Milwaukee.

The present Imhoff tank-trickling filter plant was constructed in 1919–1925, and placed in operation on June 25, 1925. The plant has produced a better effluent than did chemical precipitation and the average annual cost of operation has varied from $5.50 to $6.50 per million gallons of sewage treated. Chemical precipitation, with much lower wage rates, averaged from $8 to $10 per million gallons of sewage treated.

The effect of acid iron waste liquors upon trickling filter operation has been particularly noticeable in three respects:

1. The filter and final effluents were perfectly stable throughout the depression years, whereas the stability had generally dropped to ten days for a few weeks in midwinter.

* Presented in Operators' Breakfast Forum, Seventeenth Annual Meeting, F.S.W.A., Pittsburgh, Pa., October 14, 1944.

2. The filter fly was not a nuisance until the summers of the depression years.
3. During the past two summers, the flies have not been as numerous as in the pre-depression years.

No serious operating difficulties were experienced during nearly eighteen years of operation of the present plant. Sewage containing acid iron wastes was successfully treated for a total period of 53 years, 1890 to 1943.

The first indication that the character of the sewage had changed was noticed in Imhoff tank sludge drawn early in April, 1943. The pH was 5.6, as compared with the usual 6.8 or 6.9. The March average was 6.9 and the April average 6.0.

Determination of the pH of the daily composite plant samples had been discontinued when two laboratory assistants entered military service. This work was again resumed and, since the hourly samples were composited in the laboratory, it was possible to make pH tests of the hourly samples of sewage. The results of these tests showed acid sewage throughout the 24 hours, with extreme acidity during the latter half of the night.

Samples of sewage were collected throughout 24 hours on a number of occasions from the three main sewers discharging into the outfall sewer. The sources of the large quantities of acid iron waste liquors were located on two sewers, both of which entered the same main sewer.

During the next few months the following conditions developed pertaining to trickling filter operation.

1. There was considerable difficulty in drying an abnormally heavy growth upon the surface of the filters.
2. The pH of the sewage and Imhoff tank effluent or trickling filter influent averaged about 6.5.
3. The iron content of the sewage and filter influent was greater than for some years. At times, it was greater than in pre-depression years. Calculations of quantities show, however, that iron was not being retained in the filters.
4. There was no spring unloading of suspended solids from the filters.
5. The dissolved oxygen and nitrate nitrogen contents of the trickling filter effluents were much less than usual.
6. The stability of the filter and final effluents had been perfect the previous fall; it dropped to about 50 per cent during the winter because of the pooling produced by the growth; during the spring of 1943, it improved only slightly to from 60 to 65 per cent.

Conferences were held with the officials of the four industrial plants concerned and suggestions were made that the quantity of free acid discharged in the waste liquors be reduced. The increased acidity of the sewage was attributed to the dumping of partly used acid in order to increase compensation of piece-work employees as well as war time production.

Correction of conditions called for agreement by all four plants to cooperate and treat the whole or a part of the acid iron wastes. This agreement was not reached nor were serious efforts made to reduce the acidity of the waste liquors. The attitude of industry can be attributed to the temporary nature of increased war production, together with 53 years of precedent covering discharge of industrial waste liquors into the sewerage system. The Superintendent of Sewers has been obliged to recognize these conditions in fairness to industry. The results of sewage treatment had deteriorated but the physical structure of the sewage treatment works appeared to be without damage.

The results of plant operation during the past twelve months are summarized as follows:

1. The pH of the sewage, sludge and trickling filter influent continues to average about 6.5.
2. Imhoff tank sludge production has been considerably greater in 1944 than in 1943.
3. Digestion of the Imhoff tank sludge does not appear to be unfavorably affected.
4. There appears to be no breaking down of the filter media.
5. The growth upon the filters was heavier this past winter than during the previous winter. Favorable weather permitted earlier drying but a considerable part of it remains on the filters in the form of small hard kernels when dry.
6. During 1944, the iron content of the sewage is exceeding that of 1943. Slightly less iron has been contained in the filter influent and an increased quantity in the filter effluent. This is an encouraging result as concerns filter clogging.
7. The dissolved oxygen and nitrate nitrogen contents of the filter and final effluents have been practically nil.
8. The stability of these effluents has averaged about two days, or 37 per cent.

This experience has been presented for a number of reasons:

1. The presence of an excessive quantity of acid seriously affected the results of biological treatment of sewage.
2. Change to a more modern and efficient method of sewage treatment developed into a troublesome situation in spite of operation of an experimental sewage treatment plant which showed successful operating results under normal loads.
3. The operation of at least three sewage treatment plants in the United States has been adversely affected by the discharge of unlimited quantities of acid iron waste liquors into the sewer system.
4. Where a sufficiently large proportion of industrial waste liquors is discharged into the sewerage system, there is need of control of the situation by the municipality.
5. This paper is limited in subject and no attempt will be made to discuss the matter of control, which must take into consideration the industrial growth responsible for the growth of the municipality itself, as well as the purpose of the sewerage system and the sewage treatment plant.

Discussion

By W. M. Wallace and C. A. Habermehl

Superintendent and Chemist, Respectively, Dept. of Filtration and Sewage Treatment, Detroit, Mich.

We agree with Mr. Lanphear that a short paper of this nature is too limited in scope to do justice to a subject having as many ramifications as this one. Mr. Lanphear is entirely too conservative in the statement he makes that only three sewage treatment plants in the United States are adversely affected by the discharge of quantities of acid iron waste into the sewer systems. From recollection of the literature of published accounts of plant operation over the country during the past several years, an estimate of closer to 50 per cent of total plants operating might appear more in order.

Mr. Lanphear's description of the change in character of the wastes between depression years and later times appears to be in line with steel mill practice. When times are slack it is customary to use the acid, with longer pickling periods, reducing the acid concentration to less than 1 per cent. In this condition the waste will carry approximately 20 per cent anhydrous ferrous sulphate. In present times, vats may be dumped with acid in the range of 5 to 8 per cent and, consequently, a much lower iron content. Little imagination is necessary to picture the effect of a batch of this material reaching an activated sludge or trickling filter type treatment plant, as likely as not with little mixing.

The effect of ferrous iron waste discharge on chlorination operation has not been mentioned but actually this effect can be as severe as that on a biological process. As stated above, the usual practice in industry is to dump a pickling vat in one batch so the material is likely to reach the treatment plant as a slug. Under such conditions the chlorine demand of the mixture may, in the normal chlorine application equipment installation, exceed the capacity of feed by as much as ten times. Chlorine, if applied at such times, serves only to cause precipitation of the iron in settling tanks if applied as prechlorination, or causes a dirty looking effluent and sedimentation in the receiving stream if post chlorination is practiced. Costs involved can also be considerable when little or nothing is accomplished in bacterial reduction. As an illustration, consider the case of a small mill discharging a 2,500-gallon vat at 20 per cent anhydrous iron concentration. There would then be contained about 5,000 pounds of ferrous sulphate that would require 1,150 pounds of chlorine for reaction. At three cents a pound for chlorine the additional cost would amount to $34.50.

Open Discussion

Mr. Lanphear.—I shall anticipate one question, that is, did we consider using lime to neutralize some of the acidity of these wastes? We did make an extensive study of this possibility and it would take too long to report on it in detail. We decided, however, that lime treatment was not feasible at this time.

Wm. A. Allen (Pasadena, California).—Did I understand Mr. Lanphear to say that vacuum filtration of sludge was first accomplished by Milwaukee in 1925?

Mr. Lanphear.—That is as I understand it. I believe that considerable experimental work was done previously.

Mr. Allen.—For the record, I would like to state that vacuum filtration of sludge was being carried on at Pasadena before the Milwaukee plant was placed in operation.

Mr. Lanphear.—Another question which might be asked is in regard to the clogging of the trickling filters. We expect that we will continue to get poor efficiency and, as long as the clogging does not get too bad, that the filters will restore themselves.

Chairman Siebert.—I am reminded of a small sewage treatment works in western Pennsylvania which was installed by an industrial concern to serve its own housing development. Pickling liquors from the industrial plant were also discharged to this treatment works. It was only a few years until concrete, piping and valves were so disintegrated that it was necessary to resort to complete reconstruction.

EFFECTS OF RUBBER WASTES ON SEWAGE TREATMENT PROCESSES *

By T. C. Schaetzle

Engineer-Chemist, Akron, Ohio

The use of rubber products is as much a part of our daily lives as the use of food, clothing, and fuel. The production of rubber commodities, especially tires, was of little concern to the general public until the introduction of gasoline rationing and the inception of large scale manufacturing of synthetic rubber. When one realizes that before the war eight million acres of plantations produced 1,600,000 long tons of crude rubber annually, and that this supply was almost completely cut off, we can visualize to a limited extent the magnitude of the problem of supplementing the very small quantities of crude rubber still obtained by reclaiming all available used rubber and producing over one million long tons of synthetic rubber per year.

As in all manufacturing processes, some wastes are produced. Since Akron is considered the "Rubber Capitol," it is fair to assume that the wastes produced here are typical. These may be divided into four general classes:

(1) Steel products
(2) Rubber commodities
(3) Reclaim
(4) Synthetic

The first three of these have been with us in Akron since our treatment plant began operating in December, 1928. The fourth, synthetic waste, was present to a very limited extent until 1942. For approximately ten years prior thereto some synthetic materials were produced, such as chemigum, butaprene, and hycar, but in such small quantities that the wastes from their manufacturing processes were not noticeable at the treatment plant.

Steel Products Wastes

Some companies manufacture steel rims for all types of demountable tire wheels, metal parts for mechanical rubber goods and stainless steel lined beverage containers. Zinc and brass plating is done. Hot caustic, rinsing water and acid are used. To date the only disadvantage as far as treatment is concerned has been an occasional discharge of acid waste which has resulted in a pH as low as 1.8 near its source. This is counteracted by other alkaline wastes so that normally the sewage at the plant is alkaline.

* Presented in Operators' Breakfast Forum, Seventeenth Annual Meeting, F.S.W.A., Pittsburgh, Pa., October 14, 1944.

Manufacture of Rubber Commodities

This is essentially a washing, compounding, calendering and curing process followed by the actual manufacturing of all sorts of rubber products. Large volumes of cooling water are used but the main source of wastes to the sewers is that of washing the impurities from the crude rubber. The need for washing was diminishing prior to the war because of better control at the plantations and, consequently, is not significant at our plant. Washing of synthetic rubber is not necessary except for stock recovered from spillages. When considerable crude rubber was washed the liquid wastes therefrom were low in solids and oxygen consumption.

Reclaim Wastes

The recovery of used rubber is accomplished essentially as follows. The old rubber is shredded, discharged onto a traveling belt where it passes under a magnet for the removal of metal parts then, in some plants, a portion of the cotton fabric is recovered. Generally, however, the ground rubber and fabric, free of metallic substances, are subjected to a caustic treatment under high temperatures for several hours to destroy the fabric. The recovered rubber is then washed, dried, milled, strained, and refined for re-use. The wastes from this process are treated in some form of settling device. Some plants use continuous flow tanks and others the fill and draw type. The recovered sludge is vacuum filtered, dried and used. A brief summary of maximum and minimum values obtained on reclaim plant wastes, as discharged to the city sewers from the recovery devices, will give some idea of their nature.

Total Solids	16,800 to 63,400 p.p.m.
Suspended Solids	1,000 to 24,600 p.p.m.
Oxygen Consumed	3,600 to 13,900 p.p.m.
B.O.D.	3,500 to 12,500 p.p.m.
Chlorides	130 to 2,000 p.p.m.
Hydroxide Alkalinity	0 to 2,700 p.p.m.
pH	10.9 to 12.2

Synthetic Wastes

This is essentially a process of mixing butadiene with some other monomer such as styrene or acrylonitrile, together with a catalyst, in a soap solution to produce latex. The latex is then coagulated in an acid brine solution or with alum, washed, dried, and baled. The coagulated rubber is more or less crumbly and has a specific gravity very close to unity. That which escapes, together with the acid and salty liquid, plus occasional batches of materials which will not polymerize properly, are discharged to some kind of a settling device and then go to the city's sewerage system. Typical maximum and minimum values for the material reaching the sewer follow:

Total Solids	1,900 to 9,600 p.p.m.
Suspended Solids	60 to 2,700 p.p.m.
Oxygen Consumed	75 to 4,500 p.p.m.
B.O.D.	25 to 1,600 p.p.m.
Chlorides	90 to 3,300 p.p.m.
pH	3.2 to 7.9

Alum coagulants generally produce lower results than brine, but the wastes are usually much more acid.

Effects on Sewage Treatment Plant

The Akron plant was designed for an average of 185 p.p.m. suspended solids or 25.4 tons of dry solids daily and 33 m.g.d. flow. No B.O.D. design figure was given by the consulting engineers, but from 1930 thru 1933 the average was 20.1 tons per day. Reference to Figures 1 and 2 will show that the plant was immediately overloaded, primarily with reclaimed rubber wastes. After some collaboration with the three rubber companies, recovery equipment was installed at each plant and their combined discharge of suspended solids was reduced from 24.7 to 2.75 tons per day. A portion of this reduction may have resulted from the depression.

In spite of the fact that our solids load always was greater than the design value, reasonably good plant efficiencies were maintained until the onset of the war. Solids and flows continued to climb until in 1943 we reached an annual daily average flow of 52.2 million gallons containing 80.4 tons of dry solids and 51.8 tons of B.O.D. By this time the reclaim plant wastes had increased to 9.3 tons of dry solids daily with 1.2 tons of additional solids from the synthetic plants. The dissolved solids in the reclaim wastes can be changed to suspended if the pH of the combined sewage reaches something less than 5.0. On the other hand our sewage flocculates at 8.5. Whereas the average daily composites have a pH value of about 7.4, on individual samples taken at 1½ hour intervals this has varied from 3.5 to 10.3.

The Akron plant has passed through a very critical overload period during the last three years. Annual average over all suspended solids and B.O.D. removals have dropped from 85.5 and 89.7 per cent to 64.6 and 75.6 per cent, respectively. Combined nitrites and nitrates in the plant effluent have dropped from an annual average of about 6.0 to 1.1 p.p.m., dissolved oxygen saturation from as high as 59 to as low as 18 per cent, and stabilities from 89 to 47 per cent. As long as our filter loading remained near 200 pounds of B.O.D. per acre foot these units produced good results but during 1939 and since then it has exceeded 250 pounds per acre foot. At this loading a definite break toward unsatisfactory results has occurred.

Sludge production has increased enormously. For example, in 1930 we disposed of 121,700 cubic yards of sludge as against more than three times this amount or 377,330 cubic yards in 1943.

The hydraulic, solids and B.O.D. overload do not tell the complete story. At times we receive slugs of a very heavy viscous black oil which appears to originate in some part of a rubber plant. From 10 to 30 cubic yards of this will reach the sewage plant in 24 hours. It

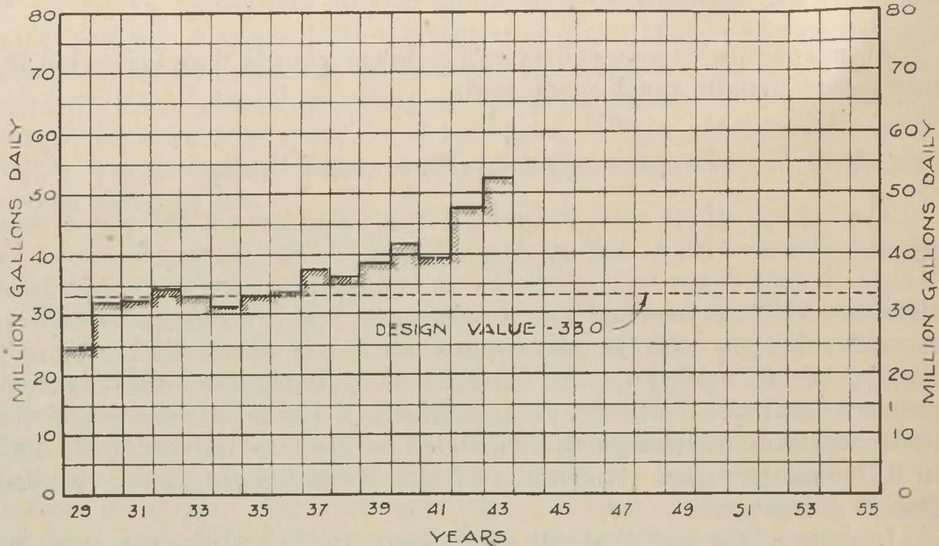

FIG. 1.—Trend in sewage flow received for treatment at Akron, Ohio.

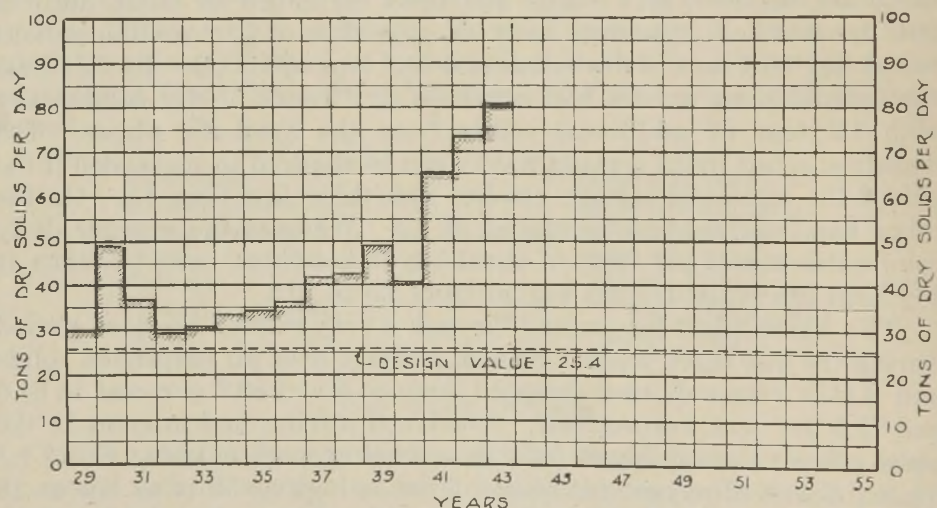

FIG. 2.—Trend in solids loading at Akron, Ohio sewage treatment works.

cannot be handled on the grease beds so must be removed from the detritus tanks by hand. Furthermore, the raw sewage will change without warning from a green to a black with an intermediate grayish clay color. At intervals, for as much as three hours at a time, the raw sewage contains a floc sufficiently golden brown to be taken for the best possible activated sludge obtainable.

Synthetic rubber crumbles have decreased in quantity but synthetic fines, pin head size or slightly larger, still reach the plant in varying quantities. After passing through three sets of tanks, a 20-mesh screen and a 10-foot depth filter, a small percentage of these fines are found intermittently in the plant effluent. For approximately six weeks we received a synthetic waste, apparently an unfinished product, which acted like rubber cement or chewing gum. It reached the filters and would stick to the nozzles and to the hands of the filter bed attendant. It created a very serious situation because of the possibility of plugging the 14 acres of filter beds. Fortunately, the companies recognized the product and removed it.

The introduction of carbon black in connection with a new process for coloring synthetic rubber causes the raw sewage to appear exceedingly septic at times, yet, except for the psychological effect on the public, we cannot show how the material affects our treatment process.

The odor of synthetic hydrocarbons is observed intermittently at the sewer outlet some 6 to 8 miles from the manufacturing plants but, except for complaints from the operators, has caused no damage.

The city of Cuyahoga Falls treats a portion of Akron's sewage by the Guggenheim process. It is easily upset by the slugs previously mentioned. It cannot produce the effluent for which it was designed because of overload and abrupt changes in the sewage characteristics. During a 5-day strike period at the rubber plants a satisfactory effluent was produced. This showed quite conclusively that both trickling filter and activated sludge installations are affected similarly by the present discharges of reclaim and synthetic wastes.

In conclusion, it should be stated that we realize the essentiality of rubber and must accept the overload pending gradual developments and improvements in the factory recovery systems. Eventually, however, more efficient local recovery systems must be installed or sizeable additions to both the Akron and Cuyahoga Falls sewage treatment plants must be made to handle these overloads.

Discussion

By Ben H. Barton

Operator, Sewage Treatment Works, Findlay, Ohio

This short paper is a supplement rather than a discussion of the paper presented by Mr. Schaetzle. The data presented were procured in anticipation of treating rubber reclaiming wastes in accordance with an order of the State Department of Health to the rubber companies. This order has not been complied with due to the demand of local municipal officials that the wastes be modified at the manufacturing plants before admittance to the city sewer system. The only alternative of the rubber companies was to discharge their wastes to a drainage ditch and the Blanchard River until suitable pretreatment devices could be installed following removal of war restrictions.

Because the same waste outlet is used by the local oil refinery and beet sugar refinery, as well as the rubber manufacturing, processing and reclaiming factories, a comprehensive study was made by the sewage plant personnel to ascertain the individual loadings and to proportion the pollutional values among the respective industries. Thus, the responsibility for the pollution of Blanchard River was shown to rest with the industries and the city sewage treatment plant was relieved of liability.

The diversion of rubber wastes was begun in 1939 and completed in December, 1943. Evaluation of the wastes began in 1939 and continued into the current year. The preliminary studies were presented before the Northwestern Ohio Conference on Sewage Treatment at Carey, Ohio, on August 16, 1940, and are reported in the transcript of that meeting.

Rubber Reclaiming Wastes

Samples of the rubber reclaiming wastes were taken three times each day; at daylight, at noon and at sundown in order to get samples as nearly representative as possible without working in the dark. The period ran from June to September, 1940, and the following data were determined from weighted, composite samples:

	Average	Maximum
Total solids, p.p.m.	49,280	173,820
Suspended solids, p.p.m.	15,550	77,340
5-Day B.O.D., p.p.m.	1,490	7,800

The discharge from the reclaiming plant carried all wastes including processing, sanitary sewage and wash water, which subjected the rubber waste to more or less dilution at various times. There were few times that any dissolved oxygen was present in the individual samples and no dissolved oxygen was found in any composite sample at any time. Determination of pH value was not possible because of the lack of proper comparator discs. It is assumed that the Akron valves for pH are in the order of those attained at the Findlay reclaim plants. The wastes are predominantly caustic.

It is our experience at the Findlay activated sludge plant that the treatment process can become inured to a given pH value within a limited range. This range cannot vary from alkaline to acid without upsetting the process. The upset is greater as the pH becomes lower, while an increasing pH is reflected in high turbidity. As long as the pH remains more or less constant, no difficulty occurs, particularly if milk wastes are responsible and are discovered early enough to make plant adjustments. These adjustments include the increase of quicklime application to green garbage prior to grinding it into the sewage flow and recirculation of secondary sludge to the wet wells for dilution and neutralization of acidity.

Conversely, when sewage flows are too highly alkaline, the amount of quicklime added to the green garbage before grinding it into the sewage is reduced or omitted. It is obvious that the alkalinity of sewage containing the various rubber manufacturing and reclaiming wastes would be beyond any expectation of successful treatment by the Findlay activated sludge plant, regardless of the amount of garbage that might be available for neutralization.

Laboratories studies proved that rubber reclaiming wastes can be readily treated to a point where they can be safely accepted for the activated sludge process. The settleable solids frequently ran as high as 450 ml. per liter and, without exception, settled quite rapidly. The supernatant liquid was neutralized by passing exhaust gases from the plant gas engine through the liquid for about 30 minutes. However, it was found impossible to neutralize the unsettled sample containing the settleable solids regardless of the length of the period of treatment with exhaust gas.

Effect of Wastes on Blanchard River

Following the period of discharge of rubber reclaiming wastes in the summer of 1940, determinations were made upon samples from the Blanchard River at stations above and below the confluence of the drainage ditch. The ditch carried the wastes from beet sugar manufacture, oil refining, and rubber reclaiming during the period from October to December, 1940, inclusive. Daily grab samples were taken throughout the three months and the following results were obtained.

	River Above	River Below
Dissolved Oxygen, p.p.m.	7.5	6.1
D.O. Saturation, %	58.0	53.6
5-Day B.O.D., p.p.m.	9.0	106.0
pH	7.64	7.68

To eliminate the effect of the sugar refining wastes, samples were taken from the ditch during October, 1941, and from the river above and below its confluence with the ditch.

Drainage Ditch Data

	Range	Average
Total Solids, p.p.m.	1,428–2,266	1,915
Suspended Solids, p.p.m.	210–1,066	612
5-Day B.O.D., p.p.m.	275–2,000	724
pH	7.5– 7.9	7.8

Average River Data (Concurrent With Above)

	River Above	River Below
Temp., °C.	13.6	14.8
Dissolved Oxygen, p.p.m.	5.4	2.7
B.O. Saturation, %	50.9	24.8
5-Day B.O.D., p.p.m.	21	97
Total Solids, p.p.m.	584	854
pH	7.6	7.7

The routine summer survey of the sanitary character of the Blanchard River as protection against possible claims against the municipal sewage treatment plant was made during July, 1944. During this time the river had received the treatment plant effluent, rubber wastes, oil refining wastes and the wastes from the overflow ponds at the sugar refining plant. These ponds had received potato dehydration wastes in the spring and summer of 1944 and produced unholy and widespread odors to the point of nausea when wind directions were right (or wrong). Results of 5-day B.O.D. determinations on Blanchard River samples during July, 1944, follow:

	P.p.m.
Above Treatment Plant	18
Below Treatment Plant	19
Below Ditch Confluence	26
4 Miles Below Ditch	19
8 Miles Below Ditch	18
12 Miles Below Ditch	3
Below Ottawa Village	49

For purposes of evaluation it might be said that the Blanchard River has a drainage basin of about 250 square miles above the city, about 100 square miles additional above the drainage ditch and that the sewage effluent from the city of Findlay averages 2.25 m.g.d. The dry weather flow in the ditch, determined by a sharp-crested weir, was 0.5 m.g.d., most of which originated in the oil refinery. The rubber reclaiming plant waste flow is less than 0.1 m.g.d. and the sugar refining plant during its campaign season adds from 2.0 to 3.0 m.g.d. Readings in excess of 5.0 m.g.d. were made in the drainage ditch during rainy seasons.

Synthetic Rubber Waste

There was only one experience with the processing of synthetic rubber. That was the receipt at the sewage treatment plant of wash waters following the application of a solvent to synthetic rubber that had been shipped into the local tire factories for use in manufacturing. This extremely volatile waste resulted in a minor explosion caused by a light switch arc and which blew an operator some 30 feet through the air. It was quickly and completely detoured to the much abused drainage ditch.

Open Discussion

Mr. Schaetzle.—Since the preparation of my paper, I have received information that the Rubber Reserve Company is working on additional processes for the recovery of more of the synthetic wastes. In the early period of large scale synthetic rubber manufacturing we received a considerable quantity of large solids with these wastes. Some of these particles were as much as an inch in diameter. By the exercise of greater care in their manufacturing operations the synthetic plants have reduced the loss of these large solids but we still receive a large quantity of synthetic fines of pinhead size or smaller.

I have been questioned as to the effect of these wastes upon the digestion of sludge. There apparently is no interference from either reclaimed rubber wastes or from the synthetic wastes with the actual digestion of sludge. Rubber impregnated sludge will digest about as rapidly as sewage solids alone, but the rubber itself does not digest and our centrifuged sludge samples contain a considerable quantity of rubber particles.

On one occasion the Guggenheim process used at the Cuyahoga Falls plant was discontinued and straight activation was used. We found both processes to be materially affected by the slugs of rubber waste received. In the operation of the fill and draw settling tanks used in some reclaim factories there are times when a loss of heavy material occurs because the operator does not stop siphoning when all clear supernatant has been removed. We had an admirable opportunity during a 5-day strike at the rubber factories to note how the Guggenheim process could operate without the rubber wastes. It operated well and gave good results during that period.

In my opinion, the solids increase is of greatest concern in handling the synthetic wastes. The low pH of these wastes are important also but we are rather fortunate in that the alkaline wastes from the reclaim plants bring about neutralization to an average pH of 7.4.

EFFECTS OF OXIDIZING OILS AND OTHER WAR INDUSTRY WASTES ON SEWAGE TREATMENT WORKS *

By Robert M. Bolenius

Chemist, Sewage Treatment Works, Lancaster, Pa.

Prior to our entrance into the war, rigid industrial waste control programs were strictly adhered to by industrial plants in Lancaster. Since 1941, however, due to the exigencies of war production and the very large increase of relatively inexperienced industrial personnel, they have been unable to maintain the efficiency of these waste control programs. As a result, considerably greater operating difficulties are encountered at the sewage treatment works.

Since 1941, the sewage flow at the North sewage treatment works at Lancaster has increased 33⅓ per cent, and peak flows considerably above designed capacity are encountered almost daily. The frequency and volume of industrial waste discharges has likewise increased, the greatest increase being in the past year. Generally speaking, these industrial waste discharges appear in extremely high concentrations of relatively short duration, since most of them represent vat or tank dumpings. The frequency of these discharges varies greatly.

The problem in Lancaster consists of treating sewage containing periodic large discharges of oxidizing or drying oils, mineral oils, and casein paints. The oxidizing or drying oils represent those oils, mainly boiled linseed oil, used in the manufacture of linoleum and linoleum products. The mineral oils consist of cutting oils and crank-case drainings. The casein paints are those used for "backing-in" the felt base for linoleum and contain large quantities of very finely divided "slate flour," or clay, high in iron filler.

The sewage treatment works receiving these wastes employs conventionally designed activated sludge of the diffused air type, and includes separate sludge digestion, storage tanks, and open air drying beds.

The influx of frequent large quantities of oxidizing or drying oils has definitely been deleterious to sludge digestion and secondary treatment. Catch samples of raw sewage on this waste have shown as high as 1,768 p.p.m. of total grease; all grease determinations in this paper representing petroleum ether extractions from acidified samples. The greater portion of these drying oils are rather easily disposed of by flotation and subsequent incineration. Appreciable quantities, however, also appear both in the primary effluent and in the primary settled sludge. Primary effluent containing as high as 60 p.p.m. total grease and raw sludge containing as high as 17.02 per cent on a dry basis have

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resulted. Floating oil in the primary tanks results in gummy, semi-solid masses on the side walls of the tanks and on the scum and sludge removing mechanisms. These masses are unsightly and difficult of removal.

Activated sludge treatment has been adversely affected by the frequent presence of these large quantities of oil. The efficiency of aeration is reduced as witnessed by the drop in dissolved oxygen content and in nitrification, the quantity of applied air remaining reasonably constant at 0.6 cubic feet per gallon of sewage. The average D.O. in the aerators has dropped from 3.6 p.p.m. in July, 1943, to 1.1 p.p.m. in July, 1944, with a lower suspended solid content in 1944. As a result, the nitrate content of the secondary effluent has dropped from 10 p.p.m. in July, 1943, to 2.0 p.p.m. in 1944. The activated sludge appears to take up considerable quantities of the oil—the mixed liquor in the aerators showing 7.59 per cent total grease content on the dry solid basis. This oil is apparently unloaded slowly to the secondary effluent, since, even during periods when no appreciable quantities of oil are entering in the raw sewage, an oily film persists on the secondary effluent, the total grease being 4 p.p.m.

The oil appears to retard sludge digestion as shown by the volatile solids reduction of the digested sludge. In 1943 the average volatile reduction was 56.6 per cent and it dropped to 47.9 per cent in August, 1944. Large quantities of scum appeared in the digesters and on the storage tanks. The drying time of the sludge was also effected adversely, with the average drying time for July, 1943, being 32 days as opposed to 48 days in July, 1944; the total rainfall during these two periods being practically the same.

Mineral oils have an effect similar to that stated for the oxidizing or drying oils on digestion and secondary treatment. In primary treatment, however, greater difficulty is encountered in removing the floating oil and greater quantities appear in the primary effluent, particularly during peak flow periods. The application of fine wood shavings and even dried grass has greatly facilitated its removal.

The treatment of periodic large quantities of the casein paint with activated sludge has produced some interesting results. The casein, as would be expected, very considerably increases the B.O.D. load. The very finely divided "slate flour" filler does not settle out to any considerable extent in primary treatment, thus imposing high solid loads on the activated sludge. The activated sludge removes this material without difficulty; the slate flour adding considerably to the density of the sludge. As a result, the sludge index, representing the volume in ml. to be occupied by 1 gm. of sludge solids after settling for one-half hour, drops very considerably—frequently being in the low thirties. Within definite limits, small quantities of this waste actually helps the activated sludge portion of the plant, since the casein present has been insufficient in quantity to show any decided ill effects on the Lancaster plant to date.

Discussion

By L. D. Matter

Engineer, Pennsylvania Department of Health, Harrisburg, Pa.

The experiences reported by Mr. Bolenius have concerned the *effects* of the discharge of certain industrial wastes on sewage treatment works. In most instances, the effects of such discharges have not been exactly beneficial. It is generally agreed that if these wastes had been excluded from the sewer system, or given proper preliminary treatment prior to their discharge into the sewer, the troubles reported would not have developed. It might be well, therefore, to consider *how* and *why* these objectionable wastes are present in the Lancaster sewage to harass the treatment plant operators.

In Pennsylvania, control over the discharge of sewage into state streams began in 1905, although it was not until 1937 that the Legislature made possible control over industrial wastes. As a result, our sewerage situation is much further advanced than the industrial waste treatment program, although considerable progress has been made since 1937. It is true that prior to 1937 many industries have installed and operated waste treatment works but the vast majority of industrial plants continue to discharge their raw wastes into nearby streams or public sewers, usually by way of common drainage systems which carry sanitary sewage, industrial wastes, collecting and condensing waters and even roof water. No serious attempt was made to separate industrial wastes from the other wastes simply because at that time there was no need for separation.

When public sewers, which in Lancaster are of the combined type, were made available to these industrial plants, the common drainage systems were usually connected thereto without apparently causing much trouble except in the receiving stream. But after the two sewage treatment plants were constructed by the city, it was found that certain wastes interfered with the successful operation of the plants. This resulted in the exclusion of some plant wastes from the public sewers and the installation of waste treatment works at several industrial plants.

However, one large industrial plant, which was served by a single drainage system, found it was impracticable to separate strictly industrial wastes from other wastes for treatment on the premises, so there was installed, throughout the plant, small collecting pits or separators near the sources of industrial wastes. The successful operation of this arrangement depended upon the frequency of the removal of the collected contents for disposal elsewhere. Unfortunately, most of these small separators or holding tanks had a connection to the plant sewer, usually in the form of an overflow pipe, and in spite of the sincere efforts on the part of the management to prevent it, spills occurred and comparatively large quantities of wastes entered the city sewer system.

The difficulties at the North sewage treatment plant at Lancaster, as described by Mr. Bolenius, were caused by circumstances similar to those just outlined.

The establishment of new war industries and the conversion of existing plants into war industries in the Lancaster area has resulted in an increase in the quantity of industrial wastes reaching the sewage treatment plants. During the early days of the war, the development and expansion of war industries was carried out so quickly and with so much secrecy that many connections were made to the public sewers which, in ordinary times, would not have been permitted. There were few municipal officials in any city who had the courage to protest against the establishment of a war industry on the grounds that trade wastes from that industry might prejudicially affect the city's sewage treatment plant. It just wasn't done, and the forgotten man at the sewage treatment plant had to "take the rap."

Prior to the war, in Lancaster, spent crank case oil was collected at regular intervals from garages and service stations. Since Pearl Harbor, this collection service has ceased to operate and the effect is very noticeable at the sewage treatment plants.

What is the outlook for the future? With the cessation of hostilities, many so-called war industries will cease to exist and their waste problems will be automatically eliminated. Converted plants will return to the manufacture of peacetime products, thus eliminating the wastes produced in war work. New materials will be manufactured, which means that new types of wastes can be expected. Municipal officials must be ever watchful to exclude from sewer systems or require suitable preliminary treatment of those wastes harmful to sewage treatment processes before such wastes are discharged into public sewers. Municipal sewage treatment plants have a definite function to perform but if they are handicapped by the introduction of material which prevent their successful operation, great harm can result.

EFFECTS OF PAPER MILL WASTES ON SEWAGE TREATMENT PLANT OPERATION *

By Harry W. Gehm

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There are few sewage treatment plants in this country which are required to treat wastes discharged from plants manufacturing pulp, paper and paperboard products. The type of wastes which are received by these plants consists of white water and bleach liquors, as the high strength of pulping liquors have excluded them from sewerage systems. However, as the mills follow the present trend toward partial treatment of the weaker wastes, more sewage works will probably be called upon to handle these wastes than is at present the case. This is particularly true of the discharge from small paperboard mills using waste paper as raw material. This is because most such establishments are able to treat the white water to a degree by recovery processes that its strength is comparable to domestic sewage, its volume can be reduced by re-use of a considerable (often to 75 per cent of the original) quantity of the treated water, the fact that the treated effluent will respond to the usual treatment processes, and the suitabiliy of condenser and wash waters for direct discharge to streams. High degrees of treatment cannot be achieved economically by the small board mill, hence the municipality already operating a treatment plant is the logical recipient for such wastes if they respond to the sewage treatment process employed and if capacity is available.

The character of partially treated board mill wastes is shown by the following analysis:

	No. 1	No. 2	No. 3
pH	6.8	6.2	6.0
Suspended solids, p.p.m.	200	50	120
B.O.D., p.p.m.	150	35	100

The suspended solids consist generally of short fibers, clay, ink, and debris and the dissolved solids of adhesives such as sodium silicate and glue together with wood residues, water impurities, and extraneous organic matter.

In regard to response to treatment, such wastes behave as follows:

1. *Sedimentation.*—On admixture with domestic sewage and passage through sewers and settling tanks the short fibers tend to coagulate in the form of light floc which will settle in adequately designed tanks. Removals in the range of 30 to 50 per cent can be expected. If flocculation precedes settling, greater removals than those obtained by settling alone can be expected. A considerable volume of mill waste in relation

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to the total flow can be handled without perceptible loss in settling efficiency.

2. *Chemical Treatment.*—The suspended matter contained in partially treated board mill waste responds well to coagulants employed in sewage treatment. A dense floc is formed which settles more rapidly than sewage flocculated with chemicals. Alum appears to be very adaptable for this purpose. The chemical dosage required for such wastes has been found to range from 200 to 1,000 pounds per million gallons. This is in the same dosage range as that of domestic sewage of average strength. Hence chemical treatment of mixtures of sewage and such waste should prove at least as satisfactory as treatment of the sewage alone. It will be recalled that the Laughlin process for sewage treatment once employed milled paper to aid floc formation and settling. While no conclusive benefit was demonstrated by the use of fiber in this process, its application was decidedly not detrimental and some engineers feel that its use would allow shorter detention time in settling devices.

3. *Oxidation Treatment Processes.*—Laboratory experiments have demonstrated that the B.O.D. of such wastes could be reduced to the same degree as domestic sewage by the activated sludge process. B.O.D. curves on the waste alone demonstrated that its oxidation proceeds at a rate similar to that of domestic sewage. There is, therefore, no reason to believe that mixtures of this waste and sewage cannot be treated satisfactorily by the activated sludge process and by trickling filters.

4. *Chlorination.*—Where waste paper is used for board making, effluents generally contain bacteria in quantities similar to those found in sewage. Both laboratory and plant data are available which show that by the application of chlorine to a residual of 0.2 p.p.m., the *B. Coli* count is reduced to less than 1 per cc. This is the usual state department of health requirement for sewage effluents. The chlorine demand of such wastes generally is in the range of strong domestic sewage (10 to 20 p.p.m.). Admixture of a considerable volume with domestic sewage will raise the chlorine demand of the untreated mixture. The rise in demand after sewage treatment processes is likely to be less apparent, as much of the chlorine absorbed by this waste is taken up by the fiber which most processes remove. We can conclude, therefore, that efficient disinfection of sewage-waste mixtures can be obtained with normal chlorine dosages.

5. *Difficulties.*—One difficulty which may be experienced by the sewage plant to which a board mill is connected is that during mill cleanup periods a considerable quantity of pulp may be discharged over a short period of time as accumulations forming on the machines are washed off. This condition can be minimized to a great degree by co-operation on the part of the mill personnel in seeing that a minimum of pulp is washed into drains during cleaning up periods. The writer has seen demonstrations of such co-operation in which the sewage plant experienced no particular trouble during cleanup periods.

6. *Flows.*—Discharge of white water from board mills returning 75 per cent of the treated waste for re-use runs between 2,000 and 5,000 gal. per ton of product per day. Acceptance of such effluents by sewage treatment plants should be predicated upon a degree of treatment at the mill which will yield a waste of substantially the same strength as domestic sewage and the adequacy of the treatment plant to handle the flow, maintaining proper unit loadings.

Conclusions

Partially treated board mill wastes and other white waters can be handled successfully by sewage treatment plants particularly where the volume of such waste is reduced substantially by re-use of process water. Municipalities should give careful consideration to such possibilities as both the industry and the municipality in many cases stand to gain by such co-operation.

Discussion

By Sol Seid

Supervising Engineer, Sewage Treatment Plant, New Brunswick, N. J.

The paper presented by Dr. Gehm on the "Effect of Paper Mill Wastes on Sewage Treatment Plant Operation," is of great interest in that he gives a fairly complete picture of the character and response to treatment of the type of paper mill waste that sewage plants are likely to be called upon to handle more and more in the future.

It is interesting that in our city, which has a large number of industries, one of the main industrial wastes is the paper manufacturing waste from a converting mill which consists of white water. At no time have we experienced any trouble handling this waste by chemical treatment. However, I must admit that twice in the past seven and a half years we have had plugging of our bar screens due to the cleaning out of stock chests at the mill. Upon investigation and conferences with the industry involved, this difficulty has been eliminated. This was brought about mainly by the exercise of care on the part of the industry.

Where the capacity of the sewage treatment plant is such that it can handle additional loads of industrial wastes in addition to its normal flow of domestic sewage, the method of mutual treatment works to the advantage of both the industry and the municipality. This is particularly the case where high degrees of treatment are involved. Many industries have shown willingness to provide partial treatment but find very high degrees of treatment an excessive burden.

For example, in the city of New Brunswick, we have some 90 industries, small and large, and of these some 28 have wastes requiring treatment. If each and every one of these wastes were treated individually they would require a tremendous capital and operating outlay and most substantial duplication or repetition of supervision and operation. When these wastes are combined they can be handled at the municipal treatment plant. In order to overcome the additional costs of treatment brought about by the industrial waste, our municipality, after much investigation, passed an industrial waste or factory effluent ordinance. This ordinance is set up in such a manner that the amount of money collected by the city offsets the money spent for industrial waste treatment.

In *Sewage Works Journal*, Volume 16, No. 4, for July, 1944, can be found the complete text of this industrial waste ordinance of the city of New Brunswick. This ordinance appears along with an article by Mayor Chester W. Paulus on a resume of the over all picture in our city. The basis of charge, which I feel is worthwhile repeating, is as follows:

Flow—$22.00 per m.g.
Chlorine Demand—$5.00 per 100 lb.
Solids—$5.00 per ton.

The paper mill waste received at our plant amounts to 356,000 gallons per day, which is 3.3 per cent of our flow. The solids loading amounts to 1 ton of dry solids a day. It is interesting to note that this paper mill waste does not appreciably affect digestion and appears to handle very well on the vacuum filters. I might state that the solids from this waste, in conjunction with sewage, react in regard to sludge treatment and handling in very much the same manner as sewage solids.

It is very important that there be complete co-operation between industry and municipality and the desire on the part of both to share their burden equally. The industries should be more than willing to share their part of all costs. Both municipality and industry should be willing to spend time, money and research in solving of the problem of industrial waste disposal. With this sort of co-operation we can expect rapid advances in stream pollution abatement. These rapid advances can not be made by any single agency; co-operation of all the agencies is required.

Open Discussion

Chairman Siebert.—A short time ago I visited a paper mill in Pennsylvania from which absolutely no wastes were discharged. It is a small tissue mill which produces about 6 tons per day of ten-pound paper from bleached and unbleached sulfite, used newsprint, ledger, fly-leaf, and some scrap stock. The mill has a small storage basin about 30 feet in diameter and 3 feet deep and all water is treated and recirculated in a short connected system.

The mill officials state that their felts last longer than two competing mills which discharge large amounts of wastes. No disinfectants are used in the recirculated wastes. Possibly high temperatures have something to do with the success of the method. The paper produced is said to pass federal specifications.

EFFECTS OF INDUSTRIAL WASTES FROM FISH CANNERIES ON SEWAGE TREATMENT PLANTS *

By W. T. Knowlton

Consulting Engineer, Los Angeles, Calif.

Industrial wastes from fish canneries are a problem to that industry and the adjacent communities. In Los Angeles, California, these wastes were for many years discharged into the ocean waters near the canneries. As this disposal eventually proved very unsatisfactory, the canneries were obliged to divert such wastes for disposal into the ocean at a more remote point.

The fish cannery wastes may be divided into three parts, according to Herbert C. Davis (1). First is the ocean water used for unloading, fluming, and carrying the fish from the boats to the canneries. In Los Angeles, this ocean water has an average volume of 2,000 gallons per ton of sardines received by the canneries, and contains 5,000 p.p.m. by weight of organic solids in suspension and in solution. The second division is the bilge water from the fishing boats, added to the cargo in the hold when unloading. This bilge water amounts to about 400 gallons per ton of fish unloaded, and may contain 10,000 p.p.m. of organic solids.

The third division is the ''stick water,'' or press liquors, remaining after the oil has been removed. Each ton of sardines produces 1,000 lbs. of press liquor, or 133 gallons. As the average reduction plant in the Los Angeles fish canneries may handle 10 tons of fish per hour, the press liquors from these canneries would be 300,000 gallons per day, and they contain 60,000 p.p.m. of solids. The total wastes from these canneries have a B.O.D. content equivalent to the sewage load of a community of several hundred thousand people.

The effect of fish cannery wastes on the sewage treatment plant of the city of Los Angeles on Terminal Island is caused by fish canneries in the Wilmington district. The domestic sewage of Wilmington and the fish wastes from these canneries are pumped to this sewage treatment plant, which includes a clarification tank, pumping plant, digester, decanting tanks, gas holder, sludge beds, incinerator, and administration buildings. This plant was placed in operation in September, 1936.

The Wilmington canneries have received 150 tons of fish daily during the sardine season, which is about one-sixth of the tonnage from the entire Harbor district.

The sewage entering the treatment plant for the first four or five years averaged 3.5 m.g.d. in which the content of suspended solids was

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425 p.p.m., and that of grease was 340 p.p.m. As the content of suspended solids in sewage in many Eastern plants in this country varies from 150 to 300 p.p.m. (2), the influent to the Terminal Island plant shows the content of suspended solids to average at least 80 per cent above the average of the Eastern plants and 30 per cent above the highest content of suspended solids in the list of Eastern plants.

During the sardine season from November to March, inclusive, the volume of fish waste has exceeded the yearly average by 65 per cent. Accordingly, it is estimated that the content of suspended solids in the influent to the plant during the sardine season may be 25 per cent over the normal content of suspended solids in sewage, and 50 per cent over such normal content during peak conditions at the Wilmington canneries. To permit other fish canneries to dispose of their wastes into this treatment plant would soon cause the influent to the plant to have two or more times the normal content of suspended solids in sewage. This condition may be handled by the city, but at an increased cost of maintenance and operation.

The normal content of grease in sewage varies from 50 to 200 p.p.m. (3) but, in fish waste, the grease content may vary from 1,000 to 30,000 p.p.m. or more. Such content will depend on the manner of securing the sample of waste to be analyzed, and on the laboratory method of determination of the content of the grease or ether soluble matter in the sample.

In a similar manner as that used to show how the suspended solids content in the influent to the Terminal Island plant can be doubled or more, the grease content in this influent may be doubled in the sardine season over that of the yearly average. To prevent such increase in the influent will without question increase the cost of handling the situation and may require the bypassing of the influent for some days while the plant is being renovated.

Assuming that the recovery of grease is desirable, it is believed that this may be obtained more economically by a plant to treat the fish waste, rather than by a sewage treatment plant. The disposal of fish waste from fish canneries into a sewage treatment plant should be permitted only after the content in such waste of suspended solids and grease has been reduced to the amount in normal sewage.

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2. "Report on Sewage Treatment and Disposal from Los Angeles, California," by S. A. Greeley, Charles G. Hyde, and Franklin Thomas—November, 1939.
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Sewage Research

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

III. Nitrification and Nitrifying Capacity of the Film *

By H. Heukelekian

Associate, Dept. Water and Sewage Research

The subject of nitrification and nitrifying capacity of standard and biofilters may be considered as a part of the biochemical characteristics of the film found in these filters. It is generally accepted that the production of nitrates in aerobic sewage purification systems is not so much a yardstick of purification as a criterion of the biochemical condition of the active biological material. The presence of nitrates in an effluent constitutes proof that: (1) the nitrifying organisms are established, (2) the system is aerobic, (3) contact time is adequate, (4) ammonia nitrogen is present in adequate quantities. Ammonia nitrogen is usually present in sufficiently large quantities in relation to carbonaceous materials, in normal domestic sewage, and seldom becomes a limiting factor in nitrification. The successful establishment of nitrifying organisms is dependent on adequate contact time (rate of application of sewage) and on the presence of oxygen supply. In the effluent from the biofilter and other high rate filters, no appreciable quantities of nitrates are produced, usually because of the inadequacy of contact time. It is not known, however, whether nitrifying organisms are present in such filters.

By determining the nitrates in the effluents from the filters the actual production of nitrates *in situ* can be shown. In contrast with this, the nitrifying capacity can be defined as the potential capacity of the biological material to produce nitrates under certain empirical and standard conditions in the laboratory. The nitrifying capacity is indicative of the presence of nitrifying organisms in the original biological material.

Method

The nitrifying capactiy of the film from the different levels of the beds was determined by taking a volume of sludge containing one gram of total solids and adding sufficient sewage to make up one liter of

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mixture. The mixture was aerated for a period of twenty-four hours and settled for one hour. Nitrites and nitrates were determined in the clear liquor. The sewage supplied the ammonia for nitrification and the necessary minerals for the nitrifying organisms. The production of nitrites and nitrates is taken as an indication of the activity of the nitrifying organisms present originally in the film. Undoubtedly multiplication of these organisms took place during the twenty-four hour areation period, but, if the number of nitrifying organisms in the film was only of the order of that present in the sewage, twenty-four hours' aeration would not have been sufficient to produce appreciable amounts of nitrites and nitrates. Therefore, if significant amounts of nitrites and nitrates are produced within this length of time, it would be indicative of the presence and establishment of a nitrifying flora in the film. Furthermore, the higher the quantities of nitrites and nitrates produced, the greater generally are the numbers of nitrifying organisms if conditions of aeration time and aeration intensity, as well as the quantity of sludge, are kept at a constant value.

TABLE I.—*P.p.m. Nitrites and Nitrates in the Effluent from the Secondary Clarifiers in the Biofilter and Standard Filter Plants*

	Biofilter		Standard Filter	
	NO_2–N	NO_3–N	NO_2–N	NO_3–N
Jan. 6	0.15	0	0.15	10.0
Jan. 19	0.25	0	0.30	8.0
Feb. 3	—	0	—	8.0
Feb. 24	—	0	—	6.0
Mar. 18	0.20	0.8	0.15	5.0
April 7	0.50	0.6	0.20	6.0
April 28	0	0	0.30	8.0
May 19	0.3	0.3	0.20	10.0
June 10	0.4	0	0.08	12.0
June 23	0	0	0.003	8.0
July 21	2.0	1.6	0.3	10.0
Aug. 4	—	4.0	—	9.0
Aug. 18	0	0	0	6.4
Sept. 9	0.5	2.4	0.1	12.0
Sept. 29	0.2	0.4	—	—
Oct. 13	0.3	0.0	0.2	3.0
Nov. 3	0.08	0.8	0.18	12.0
Nov. 12	0.1	0	—	—
Dec. 1	0.04	0	0.14	8.0
Jan. 5	0.1	0.8	—	—

The nitrifying capacity was determined as outlined above on the regular film samples taken from the different levels of both filters and on the sludge from the secondary clarifiers throughout the period of study. Simultaneously, nitrites and nitrates in the filter effluents were also determined.

Nitrites were determined by the alpha-napthalamine and sulfanilic acid method and nitrates by the phenoldisulfonic acid method.

Results

The nitrites and nitrates produced by the biofilter and the standard filter are given in Table I. The quantities of nitrates and nitrites in the effluent from the biofilter were on the whole insignificant and variable. On one or two occasions appreciable quantities of either nitrites or nitrates were obtained. These occurred during the summer months. In the previous papers of this series (1), (2), it was shown that the film accumulation was low and biochemical activity was high during the summer months. During the first and second winters of operation, the nitrites and nitrates were low. It appears that the temperature affected nitrification in the same way as the other biochemical activities of the film.

In the standard filter effluent, the nitrites were low, but the nitrates were consistently high varying from 3 to 12 p.p.m. during the year. The average nitrate content was somewhat higher in the summer period (9.1 p.p.m.) than in the winter (7.3 p.p.m.).

The average results obtained for the entire year from the two filters and the ratio of nitrates to nitrites were as follows:

	NO_2–N (p.p.m.)	NO_3–N (p.p.m.)	Ratio NO_3/NO_2
Biofilter	0.31	0.73	2.3 : 1
Standard Filter	0.15	8.4	56.0 : 1

In the biofilter relatively larger quantities of nitrites were found in comparison with nitrates, giving a ratio of nitrates to nitrites of 2.3 to 1. In the standard filter the nitrites were low in comparison with nitrates, giving a ratio of 56.0 to 1.

Table II.—*Nitrifying Capacity of the Biofilter Film*

	$NO_2 + NO_3$ (p.p.m.)			
	Top	1-ft.	2-ft.	Effl. Sludge
Jan. 6	0.2	0.2	—	0.3
Jan. 19	0.3	0.1	—	0
Feb. 3	1.5	1.0	—	0.3
Feb. 24	0.6	0.6	0.6	—
Mar. 18	7.7	1.5	0.5	0.2
April 7	2.9	1.0	0.8	0.4
April 28	5.6	4.6	3.0	—
May 19	5.0	1.9	1.2	2.7
June 10	12.0	2.8	6.2	4.6
July 21	4.7	8.0	6.0	3.8
Aug. 4	11.9	10.0	12.0	6.2
Aug. 18	25.0	21.5	20.5	5.8
Sept. 9	7.0	5.5	6.5	3.6
Oct. 13	32.5	18.7	17.5	10.0
Nov. 3	9.0	5.0	5.5	3.5
Dec. 1	14.0	11.0	3.8	6.6
Jan. 5	4.3	3.9	3.5	0.5

The nitrifying capacity of the film from the different levels of the biofilter is given in Table II. The results are expressed as p.p.m. of nitrites plus nitrates produced in twenty-four hours by one gram of dry solids in the film. The nitrifying capacity of the biofilter was low during the first winter. This corresponds to low nitrites and nitrates recovered from the plant effluent. Thereafter, large but fluctuating quantities of nitrites and nitrates were obtained from the material taken from the bed. During the winter of 1944, the nitrifying capacity

TABLE III.—*Nitrifying Capacity of the Standard Filter Film*

	$NO_2 + NO_3$ (p.p.m.)				
	Top	1-ft.	2-ft.	6-ft.	Effl. Sludge
Jan. 6	3.6	16.1	—	—	—
Jan. 19	0.6	1.4	—	—	0.1
Feb. 3	2.9	5.0	—	—	0.5
Feb. 24	6.2	4.3	4.4	1.8	1.6
Mar. 18	6.1	13.5	10.5	1.4	0.3
April 7	2.5	2.2	3.8	0.4	0.3
April 28	2.6	4.1	16.0	0.7	0.5
May 19	12.5	11.0	16.0	5.5	5.5
June 10	10.0	1.0	2.5	2.6	1.9
July 21	4.4	6.5	6.5	1.0	2.0
Aug. 4	9.0	9.2	8.0	4.0	1.8
Aug. 18	4.2	3.6	6.3	0.7	1.6
Sept. 9	16.5	5.5	9.5	1.3	1.5
Oct. 13	5.1	15.0	15.5	1.0	2.0
Nov. 3	7.5	11.5	12.5	3.8	3.3
Dec. 1	4.2	8.7	9.7	2.3	1.0

did not revert to the level of the first winter. Yet the effluent from the bed did not contain more nitrites and nitrates than during the first winter. The highest quantities in all levels were obtained from the August 18 and October 13 samples, when the bed under operating conditions was producing an effluent with practically no nitrates.

The average and relative quantities of nitrites and nitrates for the entire period were as follows:

	NO_2–N (p.p.m.)	NO_3–N (p.p.m.)	Ratio NO_3/NO_2
Top	5.6	3.4	0.6 : 1
1-foot	3.6	2.1	0.6 : 1
2-foot	4.0	2.3	0.6 : 1
Effluent sludge	2.5	0.7	0.3 : 1

More nitrites and nitrates were produced from the material collected from the top level than the lower levels and the least from the effluent sludge. The one- and two-foot levels were nearly alike. There are only two exceptions to this, in the individual values where the material from either one- or two-foot levels produced somewhat higher nitrates than the material from the top.

Relatively more nitrites than nitrates were produced when the film was aerated. The ratio of nitrates to nitrites was 0.6 : 1 for the materials from the top, one- and two-foot levels and 0.3 : 1 for the effluent sludge. The average ratio obtained from the plant effluent was 2.3 : 1. Although the absolute quantities of either nitrites or nitrates produced were higher when the film was aerated under laboratory conditions than in the plant effluent, the ratio of nitrate to nitrite was lower.

The nitrifying capacity of the materials collected from the standard filter is shown in Table III. Generally the highest quantities of nitrates and nitrites were produced from film collected from the two-foot level and not from the top, as in the biofilter. The least quantities were produced from the materials collected from the six-foot level and the secondary clarifier sludge. The average and relative quantities of nitrites and nitrates produced from the materials collected from the standard filter were as follows:

	NO_2–N (p.p.m.)	NO_3–N (p.p.m.)	Ratio NO_3–N/NO_2–N
Top	2.8	3.3	1.2 : 1
1-foot	1.6	5.9	3.7 : 1
2-foot	1.2	8.1	6.7 : 1
6-foot	0.7	1.3	1.8 : 1
Effluent sludge	0.8	0.7	0.9 : 1

The material collected from the top level produced relatively higher quantities of nitrites than nitrates, giving a narrower ratio. At the one- and two-foot levels the nitrites produced decreased and the nitrates increased, giving wider ratios. The materials from the six-foot level and the effluent sludge produced decreasing quantities of both nitrites and nitrates but the nitrate decreased relatively more than the nitrites, again giving narrower ratios.

Discussion

The nitrifying capacities of the two filters are compared in Figure 1. Nitrite producing capacity of the biofilter was higher than that of the standard filter, whereas the reverse was true for nitrate producing capacity. The nitrite and nitrate producing capacities in the biofilter were higher at the top level than at the lower two levels. Nitrite producing capacity in the standard filter also decreased with depth but nitrate producing capacity increased with depth down to the two-foot level and then decreased at the six-foot level. The total nitrifying capacity (nitrite plus nitrate) in the two filters was practically alike. It was somewhat higher at the top of the biofilter than at the same level in the standard filter. In the two lower levels it was higher in the standard filter than in the biofilter. The nitrate-nitrite ratio was low at the different levels of the biofilter in comparison with the standard filter. The nitrate-nitrite ratio was 0.6 as compared with 2.3 in the biofilter plant effluent. The ratio in the standard filter increased with depth to a value of 6.7 at the two-foot depth and decreased again at the six-foot level. The ratio in the plant effluent was 56.

Several questions arise in the proper evaluation and interpretation of the above observations. The first question that must be answered is: What is the significance of the values obtained to represent what is called the "nitrifying capacity"? It is a measure of the presence and the activity of nitrifying organisms. If the nitrifying organisms were not present in large numbers, it does not seem possible that the appreciable amounts of nitrates and nitrites could have been obtained with 24 hours of aeration. It is known that sewage requires 10 to 12 days

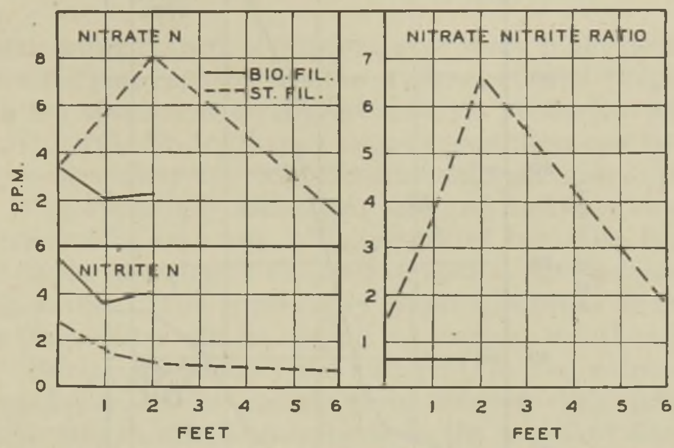

FIG. 1.—Comparison of nitrite and nitrate producing capacities of the film from the different levels of the biofilter and standard filter.

of aeration before nitrification becomes established. The results, therefore, show that with the exception of the working-in period, nitrifying organisms were firmly established in the biofilter. The logical explanation for the absence of nitrates in the plant effluent seems to be the limited contact period due to the high volumetric loading in the shallow bed or, to express it differently, due to the high rate of application per unit volume of stone.

The existence and multiplication of these organisms is assured as long as they can oxidize a certain amount of ammonia to nitrite and nitrate. It has been shown that limited amounts of the products of oxidization of these compounds, namely, nitrites and nitrates, were present in the effluent from the biofilter plant.

The maximum nitrification capacity occurred in the top two-foot levels of both filters. In the biofilters no samples were taken below this level and in the standard filter a sample was taken from the six-foot level. It is difficult, therefore, to set the zone of maximum nitrifying capacity on the basis of these results. It is evident that somewhere between the two- and six-foot levels of the standard filter the efficiency of nitrification decreased. Since this filter is underloaded, it is not surprising to find the maximum zone in the upper rather than in the lower part of the bed. The biofilter, which in comparison with the standard filter was heavily overloaded, gave nearly as high a nitrifying capacity in the top two-foot levels as the standard filter. In other words the heavy pollution in this zone resulting from the straining action and the high B.O.D. values of the film was not inimical to the establishment of the nitrifying flora, which on longer contact could produce large

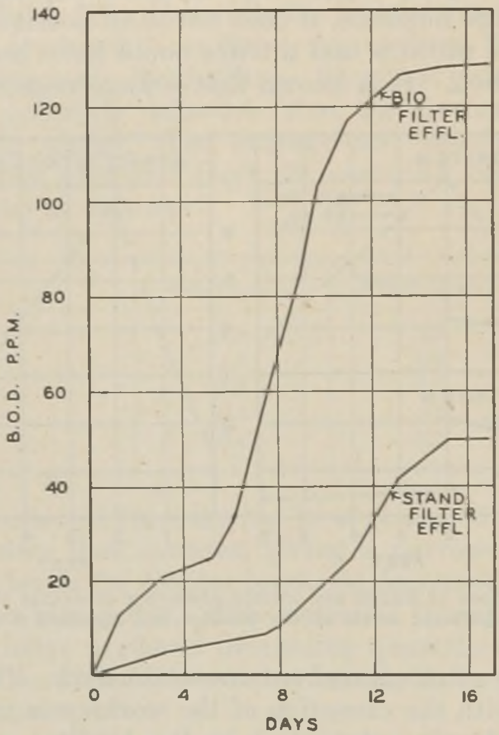

FIG. 2.—Deoxygenation characteristics of the effluent from the biofilter and standard filter plants.

quantities of nitrites and nitrates. It has been shown (3) that in the presence of adequate numbers of nitrifying organisms, nitrification is not retarded by the oxidation of carbonaceous materials. It does not seem, therefore, that the failure of the nitrifying organisms to produce nitrites or nitrates in the biofilter is due to the effect of high rate biochemical oxidation of carbonaceous materials, but rather to the short contact time.

The deoxygenation characteristics of the effluents from the biofilter and standard filter plants presented in Figure 2 do not show an essential difference in the type of the curve except for the magnitude of the values. The break in the curve occurred on the fifth day in the biofilter effluent and on the eighth day in the standard filter effluent. The break in the curve is indicative of the second stage or nitrification and is dependent on the numbers of nitrifying organisms in the sample. The early occurrence of the break confirms the conclusion that in the biofilter the nitrifying organisms are well established.

The production of relatively higher amounts of nitrites in proportion to nitrates in the biofilter effluent and in the aeration of the film with sewage points to the conclusion that organisms responsible for the first stage of nitrification, nitrite producers, are more firmly established in the biofilter than the second stage, the nitrate producers. When nitrification is more firmly established, as in the standard filter, the nitrate to nitrite ratio widens and the absolute quantities of nitrites become lower than in the biofilter. During 24 hours of aeration larger quantities of nitrates could have been produced if the nitrate producing organisms were present in as great numbers as the nitrite producing organisms.

The outstanding feature of this phase of study is the demonstration of the high nitrifying capacity and the existence of nitrifying flora in the biofilter, in the absence of significant amounts of nitrites and nitrates in the effluent. It indicates that as soon as conditions become favorable the organisms are ready to produce substantial quantities of nitrites and nitrates. Meanwhile, they abide their time and maintain themselves by a limited amount of oxidation. The return of favorable conditions is predicated on the lowering of the load applied to the filter and increase in the temperature. The appreciably larger quantities of nitrites and nitrates in the biofilter effluent during the summer months substantiate this view. During the summer the load (B.O.D. and suspended solids applied) was lower, as has been shown in the previous papers (1), (2).

The difference in nitrification between the standard filter and the biofilter is therefore one of degree, as was found to be the case with the other biochemical characteristics of the film.

Summary and Conclusions

The nitrite and nitrate content of the effluent from the biofilter and the standard filter plant were determined for a period of a year. Simultaneously the nitrifying capacity was determined by aerating the mixture of the film and sewage containing 1,000 p.p.m. of solids for a 24-hour period. The test indicates the presence of the nitrifying organisms. The results show that:

1. In general, nitrite and nitrate production in the biofilter was small and variable. During the summer when the load applied to the filter was low and the temperature was high, on occasions, appreciable quantities of nitrites and nitrates were produced.

2. In the standard filter, nitrification was consistently high during the entire period of study.

3. The nitrifying organisms were well established in the biofilter as measured by the ability of the film to produce nitrites and nitrates upon

aeration. The early onset of the second stage in the deoxygenation curve supports this view.

4. The highest nitrifying capacity was found in the top two-foot level of both filters. It supports the view that the nitrifying organisms are not adversely affected by carbonaceous oxidation and that they can at least exist in the straining zone where the B.O.D. of the film is highest.

5. The ratio of nitrates to nitrites both in the effluent and in the determination of nitrifying capacity of the film is narrower in the biofilter than in the standard filter. The first stage of nitrification, namely nitrite production, appears to be more firmly established than the second stage, nitrate production, in the biofilter.

6. The evidence presented in connection with nitrification and nitrifying capacity in the biofilter supports the view that the difference from the standard filter is merely quantitative. The organisms are well established in the biofilter, but with the high rates of application the time of contact is not long enough for them to produce appreciable quantities of nitrites and nitrates.

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THE APPLICATION OF MICRO-ANALYTICAL METHODS TO THE EXAMINATION OF SEWAGE

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The volume of sample usually taken in the analysis of sewages and industrial effluents by standard methods varies according to the nature of the sample, but it is generally between 5 and 100 ml. In an investigation the authors are undertaking, only 1 or 2 ml. of sample will be available for individual determinations. It therefore became necessary to adapt existing methods of analysis so as to apply them to the examination of small volumes without loss of accuracy. The determinations involved were mainly those concerned with the biological oxidation of sewage and included ammonia, nitrite, nitrate, dissolved oxygen and biochemical oxygen demand, phosphate and grease. The results of the analytical investigation showed that suitably modified micro-methods can be used satisfactorily for the examination of sewage. These methods are described in this paper in the hope that they may be of use to other investigators, and possibly to those engaged in field work.

Ammonia Determination

For macro work the authors ordinarily use titration methods, distilling off the ammonia into an excess of N/140 H_2SO_4 and back-titrating the boiled distillate hot with N/140 NaOH in the presence of mixed indicator (industrial alcohol containing 0.8 g. methyl red and 0.2 g. methylene blue per litre), to a green end point. When speed of working is all-important, the volume of sample taken is reduced so that when it is distilled into water and 50 ml. of distillate collected, the ammonia concentration lies between 0.2 and 5.5 parts of N per million. The distillate is nesslerized and the ammonia read off directly by finding the light absorption in a Spekker Absorptiometer—an absorption photometer made by Adam Hilger, London.

Distillation methods were first used in working out a micro method, the ammonia in the distillate being determined by titration or nesslerization. The methods were tried out with known amounts of ammonium compounds and then with sewage.

Ammonia by Distillation without the Use of Steam

The apparatus used, shown in Figure 1, was made of pyrex glass since the alkali released from ordinary glass caused inaccuracies in titration. The type of condenser used is important. The air condenser evolved gives little trouble in sucking back or splashing over and has

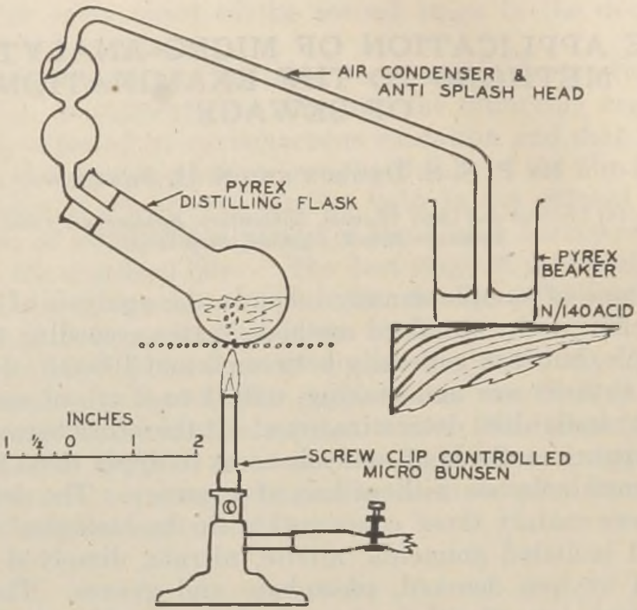

Fig. 1.—Apparatus for distillation without the use of steam.

little cooling surface. Rubber connections must be kept at a minimum due to the tendency of new bungs to liberate ammonia from the decomposition of proteins and nitrogenous compounds used as vulcanizers and anti-oxidants. All bungs were well boiled before use and the apparatus steamed out before a determination.

Titration

Two ml. of NH_4Cl solution containing 10 p.p.m. N, 1 or 2 drops borate buffer pH 9.2 and 10 ml. water are distilled from the flask over a small flame into 1 ml. N/140 H_2SO_4 and 2 drops mixed indicator contained in a 30 ml. steamed out pyrex beaker. Distillation is carried out at a

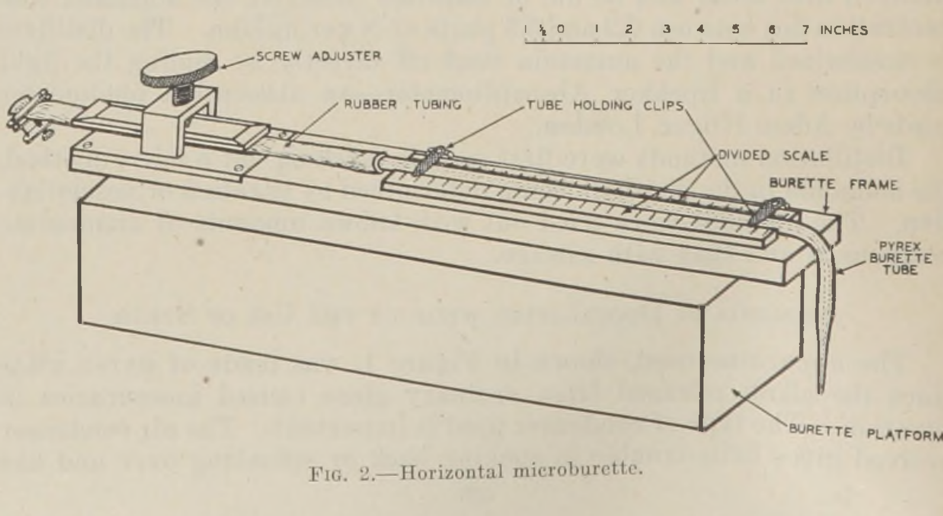

Fig. 2.—Horizontal microburette.

steady rate for 8 minutes with the tip of the delivery tube just submerged and for a further 2 minutes with the tip above the liquid. A micro burner with a fine adjustment on the gas supply is essential to avoid sucking back. The hot distillate is immediately titrated with N/140 NaOH to a green end point using a 1 ml. microburette. This burette was made from a length of thick walled capillary tubing which was found by mercury thread calibration to be of uniform bore. The burette was calibrated by weighing water and by standard acid-alkali titration. A length of 27.5 cm. corresponded to 1 ml. and gave an accuracy in titrations to within 0.75 per cent. Constructional details are given in Figure 2.

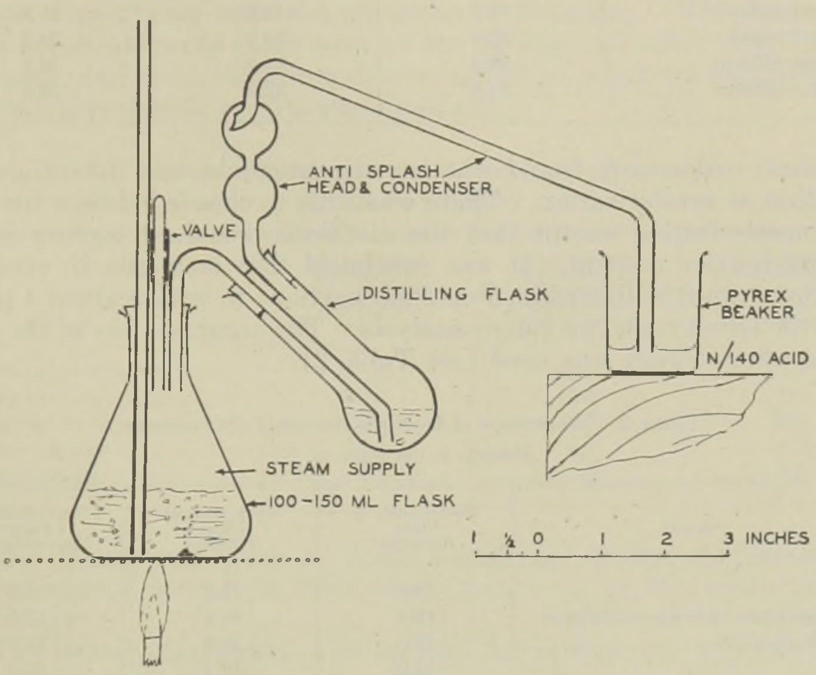

FIG. 3.—Steam distillation apparatus.

Nesslerization

The ammonia was distilled as described above into 1 ml. N/140 H_2SO_4 and a total volume of 10 ml. collected. To the cooled solution, 0.4 ml. nessler reagent was added and the ammonia concentration determined in the Spekker Absorptiometer. A Hellige comparator has also been used, in addition to the ordinary method of making comparisons in nessler cylinders with standard ammonia solutions. The first method is the best on account of the elimination of personal error.

Ammonia by Distillation with Steam

The procedure followed was the same as before except that steam alone was used to distil off the ammonia. From the point of view of steadiness in distillation this method was the better one.

With known ammonia solutions the results obtained by distillation with and without steam differed slightly (see Table 1). Differences of

TABLE 1.—*Determination of Ammonia by a Micro Method With and Without Steam Distillation, Compared with Results Obtained by Macro Analysis*

(Results in p.p.m. N)

Sample	Ammonia Found by Macro Analysis	Ammonia Found by Micro Analysis, Using	
		Distillation Without Steam	Steam Distillation
1. River water	20.3	20.1	19.9
2. River water	17.7	16.6	16.6
3. River water	26.8	24.8	24.5
4. Filter effluent	33.6	34.2	36.7
5. Filter effluent	34.6	32.5	28.8

the same order were found whether the ammonia was determined by titration or nesslerization. There was little to choose between titration and nesslerization except that the distillates required cooling before adding nessler reagent. It was concluded that ammonia in standard solutions could be determined on 2 ml. portions to within about 1 p.p.m. N of the result found by macro analysis. The accuracy was of the same order when sewage was used (see Table 2).

TABLE 2.—*Comparison of Results of Ammonia Determinations*

(Results in parts p.p.m. N)

Sample	Macro Analysis Using Titration	Micro Analysis Using Titration	Micro Analysis Using Nessler Reagent
1. Ammonium chloride containing 16.6 p.p.m. N	16.6 16.6 16.6 16.6	16.2 16.4 16.3 16.2	16.2 16.2 16.7 16.5
2. Polluted river water	22.5	21.6	24.0
3. Polluted river water	24.8	25.0	22.5
4. Filter effluent	34.6	32.9	33.9
5. Filter effluent	33.6	34.8	35.0
6. Activated sludge effluent	36.4	37.2	35.0
7. Activated sludge effluent	36.1	36.7	35.5

NITRATE

The macro method used by the authors is to reduce the nitrate to ammonia in boiling solution after addition of powdered Devarda alloy and magnesia, and to distil the ammonia into N/140 H_2SO_4 as previously described. This determination is carried out on the residue left after boiling off ammonia.

The above method was tried in the micro-distillation apparatus (Figure 3), using borate buffer instead of magnesia, for the reason that the nesslerized solutions always gave high results when magnesia was employed. It is possible that traces of magnesia were carried over into the distillate, causing a slight turbidity with nessler reagent which would increase the absorption of light by the solution and thus give an apparently greater ammonia concentration.

The reduction of nitrate and distillation of the ammonia formed was carried out on standard nitrate solutions in the micro apparatus. The values obtained were too low to make the method a useful one for precise work. Different reducing agents were tried at different pH values. The best combination was Devarda alloy in the presence of sodium hydroxide, but this caused excessive frothing on distillation; borate or magnesia were not altogether satisfactory. The determinations of nitrate were made both on the residue left after distilling off ammonia, and by the separate determination of ammonia and ammonia *plus* nitrate; similar results were obtained.

TABLE 3.—*Determination of Nitrate Nitrogen by Titration*

(Results in p.p.m. N)

Sample	Macro Method Consisting of Reduction With Devarda Alloy	Micro Method Consisting of Reduction and Distillation Without Steam	Micro Method Consisting of Reduction and Steam Distillation
1. Polluted river water	11.9	12.0	11.6
2. Polluted river water	10.9	10.9	7.1
3. Polluted river water	10.3	9.7	9.0
4. Filter effluent	10.0	8.1	4.3
5. Filter effluent	9.7	7.3	6.0

The results are given in Table 3 and lead to the conclusion that nitrate cannot always be determined accurately by the micro method described.

The phenol disulphonic acid method for nitrate (1) was tried on 2 ml. of standard nitrate solution containing 10 p.p.m. N and on filter effluents. The results found agreed with those obtained by macro determinations and were accurate to within 1 p.p.m. N. Visual comparison of the color was replaced by measurement of the light absorption of the colored solution. The disadvantage of the phenol disulphonic acid method is its sensitivity to chlorides above concentrations of 30 p.p.m. chloride and nitrite in excess of 1 p.p.m. N.

Ammonia and Nitrate Determination by the Conway Micro-Diffusion Technique

The micro-diffusion technique for the determination of ammonia and other volatile substances has been fully described by Conway (2). The apparatus used is a pyrex glass cell known as a Conway Unit, which consists of a dish, rather like a petri-dish, with a smaller inner low-walled dish fused to the bottom, making a separate inner compartment.

A ground glass plate fits on the ground edge of the outer dish. The outer compartment contains the sample under test, the inner dish contains an agent such as standard acid, which fixes the volatile substance, *e.g.*, ammonia, diffusing out of the sample when the unit is incubated (see Figure 4).

Ammonia Method.—Two ml. of sample and 2 drops of 20 per cent NaOH are placed in the outer compartments (borate buffer is unsuitable). One ml. of N/140 H_2SO_4 and 2 drops of mixed indicator are added to the inner chamber. The glass cover is smeared with vaseline, the cover is placed on the outer dish and the unit incubated overnight at 20°–27° C. The excess of N/140 H_2SO_4 is titrated cold in the inner cell with N/140 NaOH, keeping the tip of the microburette submerged and gently rotating the unit by hand.

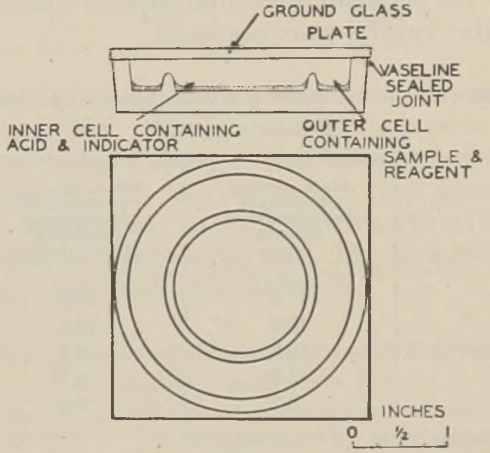

Fig. 4.—Conway Unit.

Nitrate Method.—The method adopted was to place 2 ml. of sample, 0.1 g. Devarda alloy in aqueous suspension and 2 drops NaOH solution in the outer cell, and N/140 H_2SO_4 in the inner cell. The covered unit is then incubated overnight at 20° C. and the ammonia liberated from ammonium salts and by reduction of nitrate and nitrite is determined by back-titration of the N/140 H_2SO_4 in the inner compartment with N/140 NaOH.

As the results in Table 4 show, the agreement between the Conway method and a reliable macro-method was good and generally accurate to within 1 p.p.m. N.

The method described above, *i.e.*, to determine the ammonia in one cell, and the ammonia plus oxidized nitrogen in another, was found to be more expedient than using the same sample for the two determinations. Prolonged incubation beyond 24 hours caused high nitrate results, owing to hydrolysis of organic nitrogenous compounds to ammonia.

The Conway method as described above was the one selected for the micro determination of ammonia, and nitrite plus nitrate.

Nitrite.—The Spekker Absorptiometer was found to be suitable for the determination of nitrite by the Griess-Illosvay method (3) and the napthol-naphthionate method (4), provided the concentration of nitrite was not less than 1 p.p.m. N. Below this concentration it is necessary to use the visual method of comparison.

Phosphorus.—Inorganic phosphorus in sewage is estimated satisfactorily by the molybdenum blue method as described by Truog and Meyer (5). The stannous chloride solution required was made up freshly each day.

There are several methods available for the determination of total phosphorus, including organic phosphorus. The authors have found the following original procedure to be the most convenient for sewage

TABLE 4.—*Results of Comparisons Between a Macro Method and a Micro Method, Using Conway Units, for the Determination of Ammonia and Oxidized Nitrogen*

Results in p.p.m. N

Sample	Ammonia		Oxidized Nitrogen	
	Macro [1]	Micro [2]	Macro [1]	Micro [2]
1. NH_4Cl containing 25 p.p.m. N	25.0	25.1		
2. $NaNO_3$ containing 20 p.p.m. N			20.0	20.3
3. NH Cl + $NaNO_3$ containing 16.6 p.p.m. N as ammonia + 3.3 p.p.m. N as nitrate	16.5	16.6	3.3	3.4
4. Settled sewage	43.1	44.3	0	1.3
5. Settled sewage	51.1	49.5	0.5	0.4
6. Filter effluent	31.2	33.4	7.7	7.5
7. Filter effluent	31.5	30.2	9.0	9.3
8. Polluted river water	21.6	23.2	10.3	11.9

[1] Macro method: *NH_3:* Liquid + MgO distilled into N/140 H_2SO_4.
Oxidized N: Residue + Devarda alloy distilled into N/140 H_2SO_4.

[2] Micro method: *NH_3:* Liquid + NaOH incubated at 20° C. overnight and NH_3 absorbed in N/140 H_2SO_4.
NH_3 + Oxidized N: Liquid + NaOH + Devarda alloy incubated at 20° C. overnight and NH_3 absorbed in N/140 H_2SO_4.

analysis. Not more than 5 ml. sample and 0.3 ml. conc. H_2SO_4 are boiled in a 6-inch by 1-inch pyrex tube until the liquid blackens. Heating is continued until the solution is clear. When cool, the liquid is diluted, a few drops of phenol phthalein added and standard alkali added until the liquid is just pink. The solution is made up to a known volume—50 or 100 ml. or less if a photoelectric method of measurement is to be used, and the blue color which develops in the presence of phosphorus on addition of molybdic acid and stannous chloride is matched with the color obtained when standard phosphate solutions are treated similarly. Concentrations of phosphorus greater than 0.1 p.p.m. can be determined in 2 ml. samples using visual comparison. By the Spekker method the concentration must exceed 0.5 p.p.m. P if only 2 ml. of sample is available.

Determination of Dissolved Oxygen and Biochemical Oxygen Demand

The use of sodium azide in the determination of dissolved oxygen by the Winkler method was adopted for routine analysis in this Laboratory after it had been shown to give results which were as satisfactory as the Rideal-Stewart modification. The only occasion when azide has failed to react with nitrite in acid solution was when the temperature of the sample was 4° C. In working out a micro method for determining the dissolved oxygen in, and the B.O.D. of sewage, both the azide and Rideal-Stewart modifications were investigated. Difficulties had to be overcome in the iodine tritations, in finding a suitable type of bottle and in the conditions of incubation.

It was found that the slight volatilization of iodine which takes place from dilute solution is sufficient to affect the accuracy of results when 2 ml. portions are titrated with N/240 thiosulfate. The extent of volatilization depends upon the surface exposed and upon the time of exposure. The micro titration of iodine is accurate if it is carried out immediately in a narrow beaker, ¾ to 1 inch in diameter, using freshly diluted N/240 thiosulphate. For the standardization of the thiosulphate, N/240 chromate was found to be much more satisfactory than standard iodate solution. Typical results are given in Table 5.

Table 5(a).—*Effect of Exposing Different Areas of Iodine Solution During Titration with Thiosulfate*

Surface Exposed (Sq. In.)	Thiosulfate Required for 2.5 ml. Iodine Solution (Ml. N/240 Thio.)
1.37	0.545
1.96	0.542
2.75	0.524
3.93	0.512
4.71	0.509
6.28	0.500

Table 5(b).—*Loss of Iodine on Exposure Before Titration*

Time Exposed in Beaker Before Titration (Min.)	Thiosulfate Required for 2.5 ml. Iodine Solution (Ml. N/240 Thio.)
2	0.491
6	0.473
10	0.394
14	0.382
18	0.364

For the measurement of dissolved oxygen a special type of bottle had to be made, since improvised bottles such as small specimen tubes closed with rubber bungs or microscope cover slips were unsuitable for several reasons, such as the difficulty of excluding air, or of getting a good fit, etc. A suitable bottle is shown in Figure 5. The bottle must have a narrow neck so that when the stopper is removed from the filled bottle, the addition of one drop of reagent causes the bottle to overflow when the stopper is inserted. The bottle has a capacity of 3 to 4 ml. and has a ground-in pointed stopper, which prevents air being trapped. One drop of each reagent, added from a fine capillary tube, was sufficient to fix the dissolved oxygen. There was no advantage to be gained by using more concentrated reagents than those required for the ordinary macro methods. With the micro and macro methods the addition of oxalate in excess of that required to decompose the permanganate causes low dissolved oxygen values.

The micro determination of dissolved oxygen was compared with the results obtained in 300 ml. bottles. The water used was aerated for 2 hours, incubated overnight at 21° C., and then siphoned into six micro

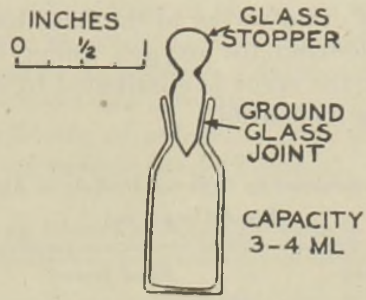

FIG. 5.—Bottle used for determination of D.O. and B.O.D. by micro methods.

and six 300 ml. bottles, which allowed dissolved oxygen to be found in duplicate by the following methods:

(a) Winkler method, without preliminary oxidation:

Micro Method: 1 drop $MnCl_2$ and 1 drop alkaline iodide (1 drop = 0.04 ml.).

Macro method: 1 ml. $MnCl_2$ and 1 ml. alkaline iodide.

(b) By Rideal-Stewart modification:

Micro method: 1 drop 50 per cent H_2SO_4 and 1 drop $KMnO_4$ allowed to stand for 20 minutes; 1 drop oxalate added or just sufficient to decolorize solution, then 1 drop $MnCl_2$ and 2 drops alkaline iodide.

Macro method: By the standard procedure.

(c) By the sodium azide modification (6):

Micro method: 1 drop $MnCl_2$ and 1 drop alkaline azide.

Macro method: 1 ml. $MnCl_2$ and 1 ml. alkaline azide containing iodide. After acidification, the solution is allowed to stand in the stoppered bottle for at least 5 minutes before titration.

In the micro method the bottles are restoppered after each addition of reagent and shaken several times. The manganese hydroxide precipitate takes about 10 minutes to settle. It is decomposed with 1 drop of conc. H_2SO_4. After shaking, 2.5 ml. are pipetted into a small beaker and titrated with N/240 thiosulphate delivered from a microburette. From Table 5 it is clear that the titration must be completed within one minute.

The results are given in Table 6 and show that, with nitrite-free water, the micro and macro methods gave similar values by the Rideal-

Stewart (b) and azide (c) modifications. The Winkler method (a) gave slightly higher figures for dissolved oxygen. In the presence of less than 1 p.p.m. N as nitrite, the values obtained were in fair agreement by all three methods, both on the micro and macro scale. The determination of dissolved oxygen by the unmodified Winkler method is unreliable in the presence of nitrite in excess of 1 p.p.m. N.

When the B.O.D. was carried out in the micro bottles applying the information already obtained, errors arose which were eventually traced to the leakage of air into the bottle during incubation and to the use of new bottles. Sealing the bottles with vaseline or paraffin wax did not eliminate this source of error owing to the fact that both these products have an appreciable demand for oxygen under the conditions of the B.O.D. test. However, the error is eliminated by submerging the micro bottles in water during incubation.

TABLE 6.—*Dissolved Oxygen Determined by Different Methods in Absence and Presence of Nitrite* (Results in p.p.m.)

Nitrite N Present p.p.m.	Winkler		Rideal–Stewart		Azide	
	Macro [1]	Micro [2]	Macro [1]	Micro [2]	Macro [1]	Micro [2]
0	8.3	8.6	8.2	8.6	8.0	8.5
1	8.2	8.7	8.1	8.8	7.9	9.1
5	9.3	9.5	8.0	8.4	8.15	8.6
10	10.5	9.8	7.8	8.4	7.9	8.6

[1] 300 ml. bottles used. [2] 3.5 ml. bottles used.

New bottles gave abnormal results. After autoclaving and immersion overnight in chromic acid, this source of error disappeared.

The standard British temperature of incubation of 18.3° C. for 5 days was compared with incubation for 3 days at 27° C., using the three methods outlined above. Results indicated that the micro determinations in each case corresponded with the macro values. The results of incubation at the two temperatures were also in fair agreement (Table 7). It is suggested that incubation for three days at 27° C. might be worth using where the time factor is important.

TABLE 7.—*Comparison of B.O.D. in 5 Days at 18.3° C. with 3 Days at 27° C.*

Method of Determining D.O.	Sample	B.O.D. (p.p.m.)			
		5 Days at 18.3° C.		3 Days at 27° C.	
		Micro	Macro	Micro	Macro
Winkler	Effluent 1	6.5	5.5	10.2	8.5
Rideal-Stewart	Effluent 2	17.5	9.5	22.7	21.5
Azide	Effluent 3	9.5	13.4	10.3	10.0

TABLE 8.—*Typical B.O.D. Results Obtained by Micro and Macro Methods—Azide Method Used for D.O. Determinations*

Sample	B.O.D. (p.p.m.)	
	Micro	Macro
Crude Sewage	257	250
Sedimentation tank effluent	237	190
Filter bed effluent	20	32
Filter bed effluent	8.7	8.5
Activated sludge effluent	8.1	9.2
Polluted river water	14.4	16.0

From the general application of the micro method to the determination of the B.O.D. of sewage, etc., it became evident that, *provided no coarse suspended matter is present, reliable results could be obtained (Table 8). Discrepancies are introduced by the presence of suspended solids, due to the difficulty of obtaining even distribution of the solids in the small volume of sample used (Table 9).*

TABLE 9.—*Errors Caused by Presence of Suspended Solids in Micro Determination of B.O.D.*

Method of Determining D.O.	Sample	Coarse Suspended Matter	B.O.D. (p.p.m.)	
			Micro Method	Macro Method
Azide	Sewage	Absent	304, 288, 285, 281, 286	285, 290
Azide	Effluent	Present	84, 67, 47, 69, 59	40, 39

GREASE IN SEWAGE SOLIDS

The routine method for grease determination used in this laboratory is to evaporate the sewage or sludge to dryness on a water bath and dry overnight in an oven at 60° C. The dry matter is extracted for 6 hours in a soxhlet with petroleum ether. The ether extract is filtered through paper into a test tube using gentle suction, and evaporated to dryness in a weighed dish. An alternative method is to evaporate the ether extract to dryness, weigh, extract the solid with ether and decant the settled extract, repeat the extraction twice, dry and re-weigh. The loss in weight is recorded as grease. This double extraction is used because fine particles of sludge may be carried over into the extract during siphoning.

The micro method described below was used for 0.1 g. samples, but it can be used for much smaller quantities if a microchemical balance is available. The 0.1 g. sample is extracted for 30 minutes in the pyrex apparatus shown in Figure 6, using 10 ml. of petroleum ether and heating so that the ether siphons over four times every minute. Electrical heating is preferable, although with gas heating the risk from fire is slight if the apparatus is partly immersed in a large beaker of water. After extraction, the ether is decanted into a small beaker, leaving behind any insoluble matter, and twice washed with 1 ml. portions of ether which are added to the beaker. The ether is evaporated off and dried for 30 minutes at 60° C. The dried beaker containing the grease and a dry, pyrex, micro filter stick are weighed. The grease is extracted with ether and removed by filtration through the filter stick and washed several times with ether, the washings being filtered off each time. The extract and washings can be collected in a weighed beaker and the grease determined by evaporation to dryness. The method the authors use is to dry the grease-free beaker and filter stick,

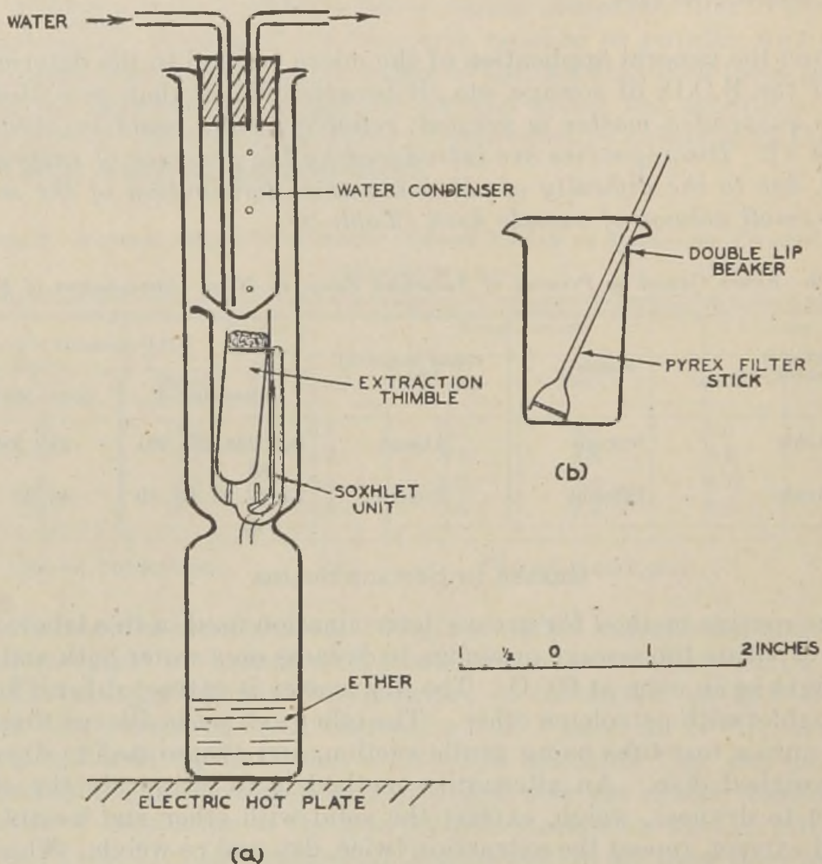

FIG. 6.—Micro Soxhlet extractor.

weigh and determine the grease by difference. The micro method gives reliable results if compared with the macro method, but it should be pointed out that the nature of the substances extracted from sewage or sludge is not known, nor is it clear why different organic solvents extract different amounts of "grease" from the same sample of sludge.

Summary

1. The applicability of certain methods of analysis to the examination of small volumes of sewage has been examined. The results are described in detail.

2. Distillation methods give satisfactory results for the determination of ammonia but tend to give unreliable estimates of the nitrate content.

3. The Conway microdiffusion technique was found to be suitable for the estimation of ammonia and oxidized nitrogen in sewage liquids and in solutions containing known amounts of ammonia and nitrate.

4. Several sources of error which may cause inaccurate results in the micro determination of dissolved oxygen and biochemical oxygen demand have been eliminated. A method is described which allows the dissolved oxygen content to be determined on 3 to 4 ml. of liquid.

5. A micro method is described for the determination of grease in small quantities of sewage solids.

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Discussion

By W. D. Hatfield

Chairman, Committee on Standard Methods of Sewage Analysis, F.S.W.A.

The micro methods of analyses suggested by Messrs. Dawson and Jenkins are not as revolutionary as they might appear and are, in fact, rather simple modifications of standard procedures applied to smaller samples and involving the use of micro equipment and weaker standard solutions. This paper is indicative of the general interest manifested by chemists in micro methods today.

Water and sewage chemistry has actually always been micro with respect to the quantities determined but, because of the great dilution, the quantities of sample taken have been macro in size.

The standard procedures, using larger volumes, will give more accurate results, and should be used wherever possible. The micro methods may find application, however, where it is necessary to work with samples of only 2 to 3 ml. There appears to be little justification for the determination of B.O.D. on raw sewage samples by the micro procedure because of the inherent sampling errors. In research on some homogeneous solutions, however, such methods may be advantageous in that incubator capacity would be greatly increased.

RELATION BETWEEN LOADING AND SUPERNATANT LIQUOR IN DIGESTION TANKS *

By Willem Rudolfs and Louis J. Fontenelli

Chief, Dept. Water and Sewage Research, New Jersey Agricultural Experiment Station and Chief Operator, Rahway Valley Sewage Treatment Plant, Respectively

Raw sewage sludge left standing quiescently concentrates with separation of solids from the liquor. The rate of separation of liquor is affected by various factors, chief of which are: initial concentration of sludge, time of standing, and temperature of the material. When raw sewage solids are placed in a digester, the same factors are of importance, but the material is disturbed by gas ebullition, mechanical mixing and addition of solids.

Rapid and effective separation of liquor in digesters is important in operation. Insufficient separation of liquid affects particularly: (1) The effective capacity of the digester. Since practically the same volumes of materials must be withdrawn from separate sludge digestion tanks as have been added, failure of liquor separation results in reduced storage time for the sludge, hence poorer digestion and less gas production. (2) Sludge concentration. When the liquor does not separate properly, the sludge remains thin and in effect becomes thinner than the original fresh solids, because a part of the organic matter is destroyed. (3) Handling of sludge. Poor separation of liquor results in handling larger volumes of sludge than anticipated, frequently resulting in more pumping and higher costs. (4) Drying of digested sludge. Larger volumes of thin sludge must be accommodated on the available sludge beds, leaving insufficient time for drying. Since about half of the water in the sludge drains out and the other half must evaporate, the thinner the sludge, the greater the quantity of water to be evaporated; therefore, the longer the drying time and the more trouble. When sludge is dewatered by mechanical means, the thinner sludge produces a thinner cake, hence more work and higher costs.

It is apparent, therefore, that the production of supernatant liquor is of prime importance in sludge digestion and, aside from difficulties for the operator, may mean success or failure of the process.

Much has been said and written about the effect of the character of supernatant liquor on other units of the plant, such as trickling filters, activated sludge aeration tanks, and sand filters, but little specific information is available on the quantity of supernatant to be expected under normal digestion conditions; and still less usable information is

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on hand in regard to overloaded digesters. To be sure, it is well known that a digester sometimes fails to produce clear supernatant liquor. It is also well known that an overloaded tank produces poor supernatant liquor or no liquor at all. The questions we wish to discuss, therefore, are: (1) How much supernatant liquor can we expect under normal digestion conditions in a given time, when the initial fresh solids concentration is constant? (2) How much supernatant should be produced in a given digestion time with varying concentrations of fresh solids added? (3) How important is the effect of temperature on liquor separation? (4) How high can we load a digester before interfering with effective supernatant production?

The results presented in this paper were obtained by laboratory experimentation and from the operation records at three sewage treatment plants. Only a small part of the laboratory results are included. The records from the Elizabeth Joint Meeting plant were used to show the sludge concentration and volumes of supernatant liquor which can be expected by storing fresh solids prior to barging, and the effect of temperature on supernatant production from raw sludge. The records of the Rahway Valley Joint Meeting two-stage digestion plant were used to show the variation in quantities of liquor drawn with the variation in loading of the digesters. No claim is made that the results presented and the conclusions reached hold for all types of sludges and all types of digestion plants under varying conditions, but we believe that the general pattern will be the same and that the results will vary only in detail at other plants.

Laboratory Experiments

Laboratory experiments were made with fresh solids, ripe sludges and digesting mixtures. Fresh solids and ripe sludges collected at the Rahway Joint Meeting plant were stored at different temperatures for varying periods of time. The effect of initial concentration of fresh solids on the separation of liquor after a period of 96 hours is shown in Figure 1. The percentage of supernatant which can be expected decreases with increased concentrations of fresh solids. The

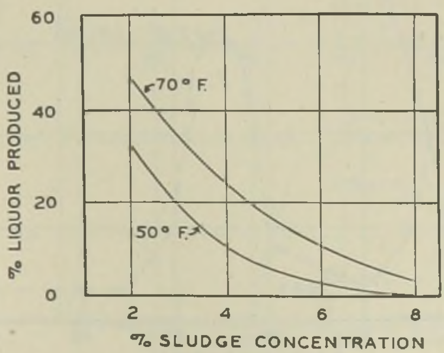

Fig. 1.—Effect of initial concentration of fresh solids and temperature on supernatant liquor production.

actual volume of liquor which can be withdrawn is much less with 6 per cent initial solids concentration than with a 4 per cent initial solids concentration. The effect of temperature is shown by the difference indicated by the two curves. The amount of supernatant is materially less at lower temperatures for each given initial solids concentration.

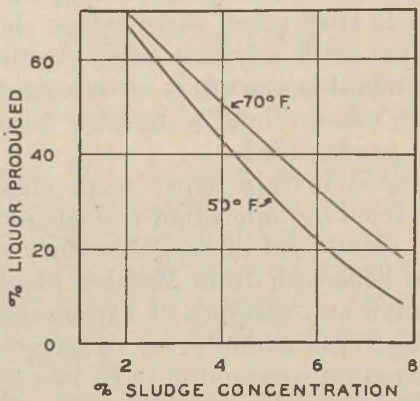

Fig. 2.—Effect of initial concentration of ripe sludge and temperature on the percentage supernatant liquor produced.

The effect of initial solids concentration and temperature on liquor separation from ripe sludge is similar to the effects on fresh solids (Figure 2). However, more liquor can be expected from ripe sludge with a given initial solids concentration and at varying temperatures than from fresh solids. The results shown are for rather short periods of 72 and 96 hours. When more time is allowed a greater separation of liquor takes place.

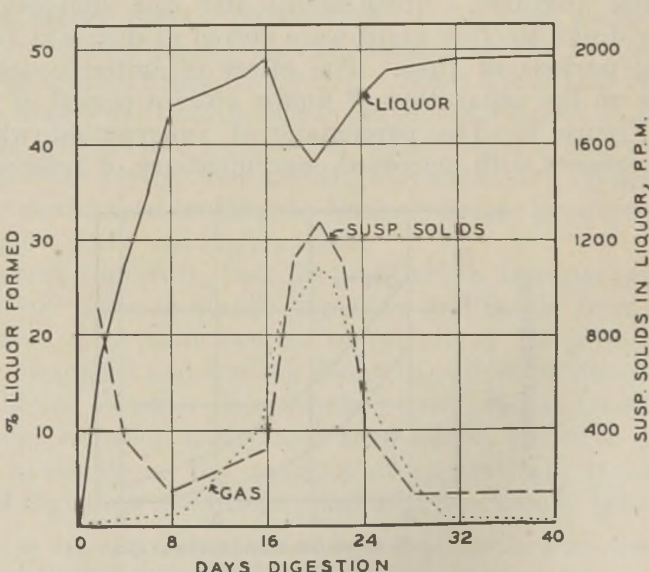

Fig. 3.—Liquor separation during digestion.

The question arises whether or not liquor separation varies during digestion. This is illustrated in Figure 3 as an example for properly seeded digesting material. The mixtures were stored in a tube 9 feet high, to facilitate observation. Analyses made showed the following:

Total solids, begin	7.3 per cent
Volatile matter	67.0 per cent
Volatile matter reduction	49.3 per cent
Liquid separation, end	49.0 per cent
Gas, per gram vol. matter added	492 ml.

The curve for liquor separation shows a steep rise during the first days when little gas production took place. At the peak of gas production considerable mixing occurred by the escape of gas bubbles, and the percentage liquid separation decreased. The mixing is also indicated by the increase in suspended solids in the liquor. After gas production decreased liquid separation increased again, remaining practically constant at 49 per cent for a number of days. The results show in general, a rapid separation of liquor, followed by a period of

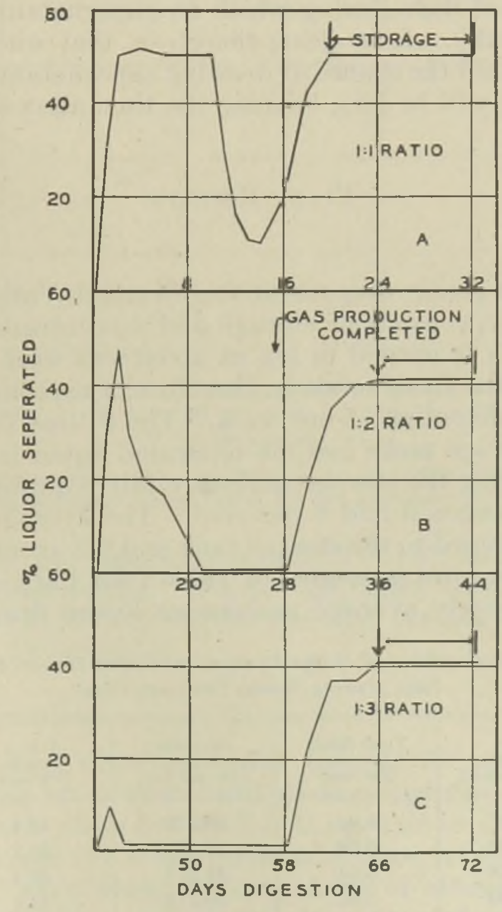

FIG. 4.—Effect of increasing load on liquor separation.

decreased separation when the digestion processes were most active and again followed by an improvement in liquid separation, so that about half of the original sludge could be discarded as supernatant liquor.

When the amounts of fresh solids added to the ripe sludge are increased, the separation of liquor is impaired. This is illustrated in Figure 4, obtained from another series of experiments in which the fresh solids were increased by 100 and 200 per cent on a volatile matter basis. It will be noted that in the properly seeded mixture (A) the liquor separation was rapid during the first few days, followed by a decrease caused by gas disturbance, and again followed by a rapid percentage increase in separation, producing at the end of the experiment 50 per cent supernatant. The ripe sludge loaded with twice the amount of fresh solids (B) required a longer time for digestion and followed the general pattern of experiment A, but there were a number of days that no supernatant was present and the separation was less complete at the end, amounting to about 41 per cent. When the load on the ripe sludge was trebled (C) a still longer digestion time was required and the number of days during which no supernatant could be drawn increased materially. It is clear, therefore, that when the load on a digester is increased the chance of drawing supernatant liquor decreases and the quantity will be less, because the time allowed for separation decreases.

Plant Results

Fresh Solids

The method of sludge disposal at the Elizabeth Valley Joint Meeting plant, New Jersey, consists of storage and concentration of the settled raw sludge, which is barged to sea at about two-week intervals. The storage time for the fresh solids is, therefore, a maximum of two weeks with an average detention of one week. The settled sludge is pumped daily into the storage tanks and the separated liquor is decanted. The fresh solids entering the storage tanks are fairly uniform in concentration and vary between 5 and 6 per cent. The average daily amounts of fresh solids pumped to the storage tank and the average daily quantities of liquor drawn are presented in Table I for the years 1939 to 1942 inclusive. The yearly average percentage liquor drawn varied from

Table I.—*Average Daily Quantities of Sludge Pumped and Liquid Drawn, Elizabeth (New Jersey) Joint Meeting Sewage Treatment Plant*

Year	Fresh Solids (Gal. per day)	Fresh Solids Concen. (Per cent)	Decanted Liquor (Gal. per day)	Liquor Drawn (Per cent)	Temperature Sludge (° F.)
1939	72,917	5.94	30,713	42.4	63
1940	70,700	5.08	25,504	36.2	62
1941	74,378	5.64	31,517	42.3	63
1942	91,620	5.80	39,713	43.4	62

36.2 to 43.4 per cent. Careful operation during 1943 increased the percentage liquor slightly, but with the facilities available no appreciable further reduction in volume can be expected. The plant operation results show that from 40 to 45 per cent of liquor may separate and, during certain periods of the year, liquor separation may be higher when the initial solids concentration varies from 5 to 6 per cent. The percentage separation of liquor in plant operation is higher than that obtained in relatively narrow vessels in the laboratory. Depth and friction may play a role.

The laboratory experiments showed that the temperature of the solids affects the percentage liquor separation. The average monthly results obtained for liquor decantation at the Elizabeth Joint Meeting plant have been plotted against the temperature of the sludge (Figure 5).

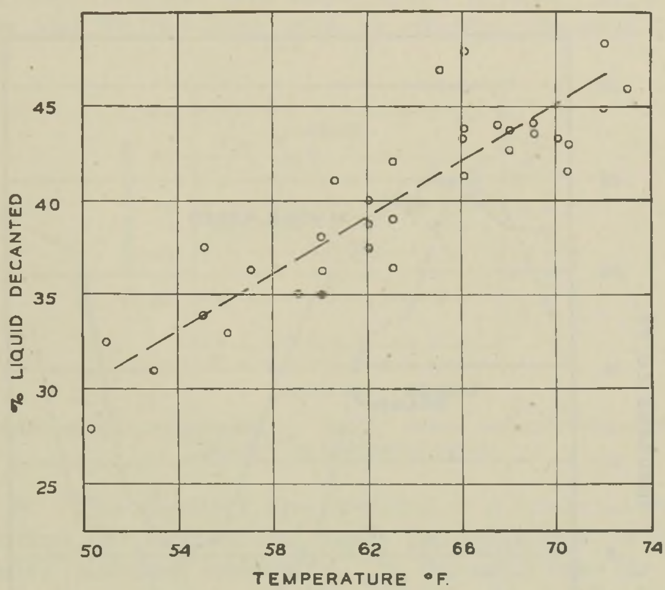

FIG. 5.—Effect of temperature on decanting fresh solids at the Elizabeth Valley Joint Meeting plant (original solids concentration 5–6 per cent; monthly averages).

The general statement that temperature affects liquor separation is substantiated by these results. Liquor separation with sludge temperatures of 72° to 74° F. is about 50 per cent greater than with sludge temperatures at 52° to 53° F.

Single Stage Digestion

Two single stage digestion tanks, kept at 68° to 72° F. and supposedly operating on a theoretical 45-day digestion schedule, had to handle considerably more fresh solids than could be accommodated. In order to make room for fresh solids additions, large quantities of so-called "liquor" were drawn. The volume of sludge added and subsequently the quantities of "liquor" drawn varied materially through the year (Figure 6). The total fresh solids added during the year and the liquor drawn as well as the average solids contents of the materials drawn were as follows:

Fresh solids added, cu. ft.	317,640
"Liquid" drawn, cu. ft.	180,100
Ripe sludge drawn, cu. ft.	34,835
Percentage "liquid" drawn	83
Total solids in liquid, per cent	2.92
Vol. solids in liquid, per cent	60.0
Total solids in sludge drawn, per cent	7.02
Vol. solids in sludge, per cent	54.6

The highest average monthly loadings amounted to 0.057 pound dry solids per cubic foot of effective digestion capacity per day, while the lowest average monthly loading during the year was 0.021 pound;

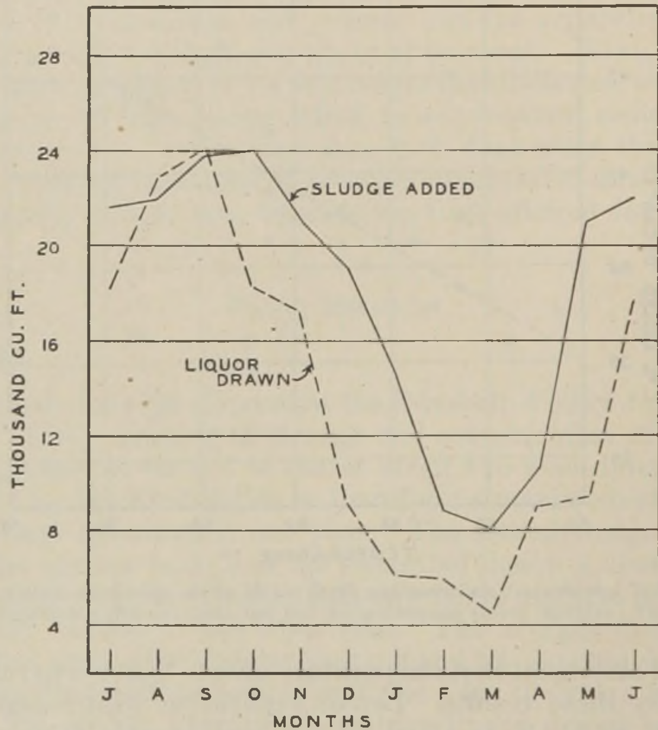

FIG. 6.—Relation between raw sludge added and "liquor" drawn in overloaded tanks.

with the highest and lowest loadings the percentage solids in the liquor amounted to 4.4 and 1.9 per cent, respectively. The average monthly minimum and maximum solids concentrations in the "liquid" were 1.81 and 4.36 per cent, respectively. In effect, the "liquid" was nothing but thin sludge. In general, the larger the quantities of "liquid" drawn, the higher the solids concentration. It is of interest to note that the volatile solids in the liquor averaged 60 per cent, indicating rather poor digestion. The relationship between the percentage of liquid drawn and the percentage solids concentration is shown in Figure 7. During a part of the year, overloading of the tanks was so severe that the "liquor" had nearly the same solids concentration as the fresh solids added. Even when the loading was reduced by two-thirds, liquor separation was poor. It is evident that overloading has an effect on liquor separation even after the loading has been reduced. Overloading reduces the effectiveness of the process in addition to leaving no time for liquor separation, which in turn affects the subsequent handling of the sludge. Instead of discarding some 40 per cent or more of the liquor, the whole mass must be handled by the sludge-drying facilities.

Two-Stage Digestion

At the Rahway Valley Joint Meeting plant, New Jersey, the sludge is digested in two stages. The two primary digesters are each 50 feet in diameter and 20 feet deep, with an effective digestion capacity of

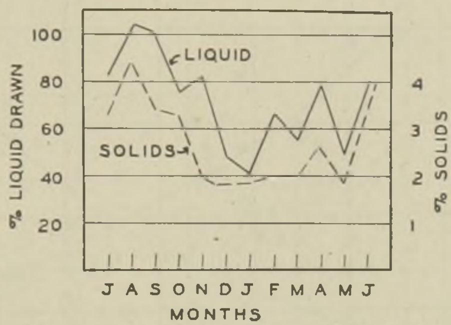

FIG. 7.—Relation between percentage "liquor" drawn and percentage solids in the "liquor" in overloaded tanks.

75,000 cu. ft. The digesters are operated at a temperature of 82° to 84° F. During the last several years the quantities of fresh solids collected have increased materially. At the same time the removal of supernatant liquor has become increasingly more difficult. Theoretically, the volumes of supernatant liquor should increase in direct proportion to the increase in quantities of fresh solids added to the primary tanks. However, examination of the records showed that the quantities of supernatant removal did not even remain constant with increased loading, but actually decreased. Plotting the average daily volumes of supernatant liquor removals for each month over a period of 27 months against the volumes of raw sludge added (Figure 8) the tendency of reduced supernatant liquor separation with increased loadings is clearly indicated. The monthly average total solids concentration of the raw sludge added to the primary digesters varied during this period between 5.8 and 8.2 per cent, with a general average of 6.9 per cent, and the volatile matter of the total solids between 61.8 and 74.9 per cent, with an average of 69.3 per cent. Possibly the loading on a volume basis was partially or entirely offset by the variations in volatile matter added and the actual loading on the digesters was not as indicated by the volumes of raw sludge added. When the pounds of dry volatile solids added daily (monthly averages) were plotted against the cubic feet of liquid drawn, the relationship between loading and supernatant removal was closer (Figure 9) than when the volumes of sludge additions were used as a basis. It should be stated here that the practice of operation has been to withdraw as much as possible of the supernatant liquid every day to make room for fresh solids. During the period under discussion, the average suspended solids in the supernatant liquor amounted to 2,000 p.p.m. When no more supernatant liquor could be removed the secondary digesters were used as primary tanks. However, the results during these periods have not been included. When still more sludge was received large storage basins were constructed to hold the sludge.

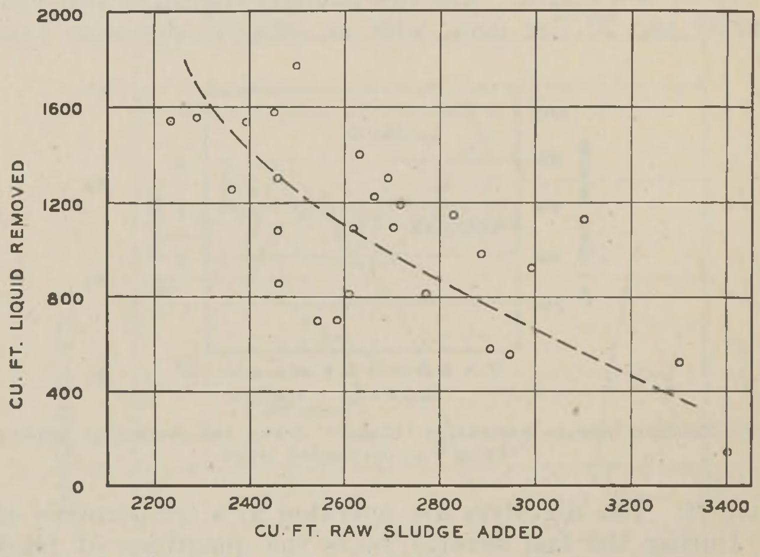

FIG. 8.—Supernatant liquor removal versus raw sludge added to primary digesters at the Rahway Valley Joint Meeting plant (monthly averages).

The percentage liquid drawn varied from only 2 per cent at the highest loadings to as much as 86 per cent at the lowest loadings. Considering that in all calculations the monthly averages were used, there is usually some carryover from a previous month in respect to supernatant liquor withdrawal. If a moving average of the volatile solids added and supernatant liquor withdrawn was plotted, the results would show still closer relationship between loading and supernatant removal.

The maximum percentage supernatant removal from fresh solids allowed to stand for one week is from 40 to 45 per cent. Laboratory experiments showed that with proper loading and several days quiescent standing after digestion had been completed, from 45 to 50 per cent supernatant liquor was formed. It would seem, therefore, that the quantity of good supernatant to be expected should be from 40 to 50 per cent. This checks rather well with the operation results obtained at the Rahway Valley plant.

In order to show the relationship between the loading of a given size digester, expressed in pounds volatile matter added daily for each 1,000 cubic feet of effective digestion capacity, and the volume as well as the percentage supernatant liquor produced, the Rahway Valley plant results have been calculated and are shown in graphical form in Figure 10. Reading from these curves, the optimum loading capacity for each 1,000 cubic feet of primary digestion capacity would be 100 pounds dry volatile matter per month, producing 50 per cent clear supernatant liquor. When the percentage of good supernatant is larger, the tanks

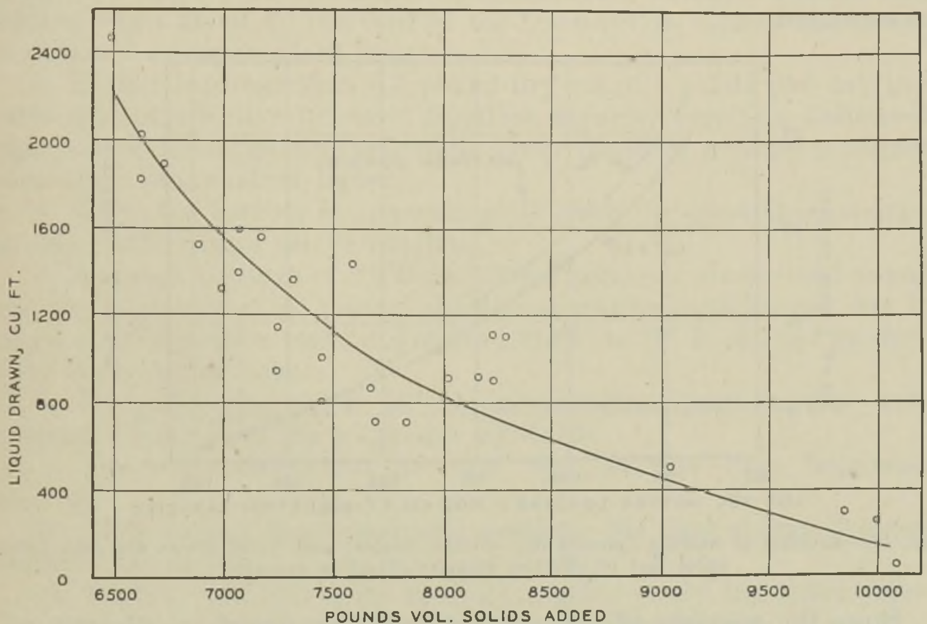

FIG. 9.—Relation between volatile solids loading of digesters and volumes of liquid removed (monthly averages).

could handle more fresh solids. To maintain sufficient room for the addition of fresh solids, the maximum loading allowed would be about 105 pounds volatile matter per 1,000 cubic feet of primary digestion capacity per month. This would produce about 40 per cent supernatant liquor, but when the percentage of supernatant drawn is lower, the fresh solids additions must be reduced or the sludge concentration will decrease with subsequent difficulties in digestion and sludge drying.

Expressing the maximum allowable loading differently, we may say that based on these results each cubic foot of effective primary digestion capacity could handle a maximum of 0.1 pound of volatile solids per day with the digestion tanks kept at a constant temperature of 82° to 84° F. Such a digestion capacity would not allow further compaction and concentration of sludge. As has been shown, compaction and concentration of sludge are greatly affected by time. To produce a thicker sludge, more time or rather more capacity is required. If we assume that the average amount of volatile solids retained from domestic sewage is about 0.1 pound per person a day, the minimum effective primary digestion capacity for the production of 40 per cent supernatant liquor would be 1 cubic foot per capita. This does not take care of any sludge from industrial waste or when the domestic solids production is higher. Additional capacity is required for storage of sludge and concentration of solids. If thicker sludge is required to reduce the load on drying facilities, the capacity must still be larger. In case industrial wastes are handled, which may interfere with the digestion processes or contain quantities of settleable solids, the effective digestion capacity must again be increased.

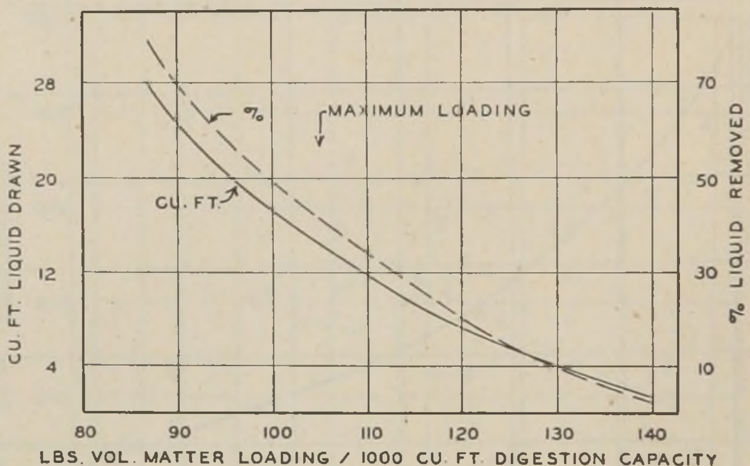

Fig. 10.—Relation of loading (pounds dry volatile matter) and liquid drawn for each 1,000 cubic feet of effective primary digestion capacity.

Since the amounts of supernatant liquor produced are directly related to the quantities of fresh solids added to the digesters, the fundamental problem is provision of either sufficient digestion capacity or adequate facilities for final sludge disposal. This may be a question of economics. However, from an operation standpoint, sufficient digestion capacity is preferred.

Summary and Conclusions

The volumes of supernatant which could be obtained from stored fresh solids, ripe sludge, and digestion mixtures were determined from laboratory experiments. The quantities of supernatant liquor produced from raw sludge, single and two-stage digestion were determined from plant operation records. The following conclusions are drawn:

1. Supernatant liquor production is affected by the initial concentration of raw sludge, the time of storage and the temperature of the sludge.

2. Supernatant liquor production is directly related to the quantities of fresh solids added to the digesters; in other words, supernatant liquor production is a function of the loading of the digesters. Production of 50 per cent supernatant liquor may be considered optimum.

3. Optimum loading of two-stage digesters appears to be about 0.1 pound of dry volatile solids per cubic foot of effective primary digestion capacity per day, if the digestion temperature is maintained at 82° to 84° F. The total digestion capacity (primary and secondary) required would be about 2 cubic feet for effective digestion and sludge concentration. When industrial waste is present, producing sludge, the total digestion capacity must be further increased.

4. Two-stage digestion tanks are considered to receive maximum loading when about 40 per cent of the fresh solids volume added can be obtained as supernatant liquor.

5. Higher loadings than 0.1 pound dry volatile solids per day per cubic foot of effective primary digestion capacity result in decreased supernatant liquor production, while lower loadings produce a higher percentage supernatant liquor.

6. When the loading is approximately twice the allowed maximum, no clear supernatant can be obtained.

7. Average loadings of 0.056 pound dry solids or about 0.042 pound volatile solids per cubic foot of effective digestion capacity per day in single stage digestion tanks maintained at 66° to 72° F. did not produce clear supernatant liquor.

8. The suspended solids in the supernatant liquor increase with loadings higher than the maximum allowable.

9. Operation difficulties increase with greater than maximum loadings.

10. With higher than maximum loadings the final sludge disposal facilities are taxed.

11. Higher than maximum loadings require either increased digestion capacity or greater facilities for final sludge disposal.

Sewage Works Planning

TRENDS IN SEWAGE WORKS PRACTICE IN GREAT BRITAIN *

By James H. Edmundson

President, Institute of Sewage Purification; General Manager, Sewage Department, City of Sheffield, England

I wish to thank the members of the Institute for the honor they have conferred upon me in electing me to the Presidential Chair for the ensuing year. I am not unmindful of my distinguished predecessors who, by their national and international reputations in the sphere of sewage purification, have added luster to the Institute. They have also given unstinted service and filled the office with dignity, which I shall endeavor to follow.

For some time I toyed with the idea, and I must confess that it was a wishful idea, that the exigencies of war might postpone the presentation of this address. My first reaction after all hope had vanished was to peruse a number of the addresses presented by your Past Presidents. The effect was very chilly; their surveys had been thorough.

I am a sewage works manager, responsible both for design and operation of sewage works, and for the past twenty years I have also had the additional responsibility of the contractor. This triple combination is an ideal arrangement for the local authority as they can easily place the blame for any defect that might develop. I mention this because it gives me a little wider range from which to draw my remarks.

During the full period of the war we have been compelled to practice austerity, and the past twelve months have been the most severe of all. The reasons are well known to everyone and the wonderful progress of the allied cause has fully justified the necessity. As a consequence, the proceedings of the Institute have been considerably curtailed, particularly with regard to the visitation and inspection of works and plants.

The activities of the Council and its committees, however, have been fully maintained throughout the year, and many important items affecting the Institute, and also the welfare of the individual member, have been under consideration. In addition to items of a domestic issue, two important and representative committees have recently been appointed; one to collaborate with the Water Pollution Research Board on matters appertaining to research in connection with sewage purification, and the other to confer with the Agricultural Research Council

* Presidential Address given by Mr. Edmundson at Annual General Meeting, Institute of Sewage Purification, Birmingham, England, December 7, 1944.

and discuss topics of interest in connection with the utilization of sewage sludge. I shall have occasion to refer to both these items later.

Many past addresses have contained complimentary references to the growth and development of the Institute, particularly in regard to quality rather than quantity, and I am in full agreement with all that has been written. In this respect I should like to refer to the high standing of the *Journal*,* which has been the subject of appreciative letters from our American friends. It is in great demand by all allied and kindred institutions at home and abroad and reflects great credit both to the contributors and the skill of the Editor.

The examination scheme continues to attract a steady flow of young men of good address and education, which is an encouraging sign for the future welfare and progress of the Institute.

It is pleasing to note from advertisements inviting applications for vacant sewage works appointments that an increasing number of local authorities are giving preference to corporate membership of the Institute. I commend this procedure to all local authorities when appointing sewage works managers and assistants. The modern sewage treatment plant is rather capricious and demands the attention of the skilled technician if efficiency and economy, in operation and maintenance, are to be achieved.

In company with my five immediate predecessors, I take office while the world is still convulsed in war, but I am a little more fortunate because the beginning of the end is now unmistakable. This has encouraged all organizations concerned with social services to produce and perfect their plans for postwar development and in this respect the Institute is fully prepared. No one supposes for one moment that all the idealistic schemes proposed can be put into hand forthwith; rather must the majority be looked upon as long termed policies to be gradually introduced over a number of years.

I know of no plan for reconstruction, however, which can be carried into effect with as little disruption and cost as the proposals contained in the "Memorandum" prepared by the Institute. When this point of view is taken into account together with the benefits that would accrue by its adoption, it is worthy of high priority for consideration by the authorities concerned. It is significant that kindred institutions and societies, interested in drainage or the prevention of rivers pollution, have issued recommendations which are in very close agreement with those outlined in the "Memorandum."

The suggestion to promote regional sewage authorities within well defined watersheds or drainage areas is not new. They have been in operation on the Continent for a number of years with outstanding success. In certain influential quarters, and, in fact, in the minds of the vast majority of the public, "regionalization" is viewed with some suspicion. It is opportune, therefore, to mention that the significance of

* See *This Journal*, 17, 2, 393 (March, 1945) for procedure in subscribing to the *Journal* of the Institute.

the word as used in the "Memorandum" bears no relationship to the present day accepted definition. The proposed regional sewage authorities can be likened to existing joint sewage or main drainage boards controlled by the local authorities concerned.

At the present time most members of the Institute will be more concerned with postwar domestic problems rather than with national policies, among which can be mentioned:

1. The consideration and possible adoption of the Public Health (Drainage of Trade Premises) Act of 1937.
2. The effect of the proposed Housing Development and redistribution of the population upon sewage treatment plants.
3. Repair and overhaul of plant which has been unavoidably neglected due to the urgency of war.
4. Extensions and additions to plant which were necessary prior to the war, or have developed during the war.

The consideration and possible adoption of the Public Health (Drainage of Trade Premises) Act will probably affect the majority of sewage undertakings. The Act has already been freely criticized, as far as it affects local authorities, by many members and visiting friends of the Institute, and it is not my intention to repeat or amplify any of the criticism on this occasion. There appears to be general agreement that the provisions of the Act should be drastically revised, but before this can be anticipated, the concerted action of local authorities, through their respective organizations, will be necessary.

The acceptance of trade effluent under agreement has been advocated as an alternative to the adoption of the Act. Although such agreements are subject to the provisions of the Act, they do give the local authority the opportunity of fixing permissible limits to harmful substances as they present themselves, and in this respect the proposal has definite appeal. On the other hand, any moral support that the Act may possess is lost.

The next item of topical interest is ancillary to the greatest of all problems facing the country—the lamentable shortage of houses. Everyone is in full agreement that the proposed "Housing Development" must take precedence over all other postwar developments, and the effect it will have upon sewage treatment must receive the same urgent consideration.

The development, in the majority of cases, will simply resolve itself into rehousing part of the existing population in the same drainage area and, consequently, the present arrangements for sewage disposal will not be affected. In other instances, the new housing estates will be planned as small satellite towns and many of these will extend into rural districts and fresh watersheds.

In such cases all services, including sewage purification, must keep in step with the development. If treatment plants are to be ready in time to serve the houses as completed, a high postwar priority for their construction will be necessary.

No one can say how long the "Housing Development" will continue before saturation point is reached but, on the assumption that it will extend over a number of years, there is much to be said in favor of designing the sewage works in two or more complete units. With this arrangement, one unit can be completed and in operation while the second unit is under construction, and the capital and maintenance charges incurred will increase in some reasonable proportion to the rateable value of the estates.

Sewage works designers, and those responsible for advising on schemes of extensions and reconstruction, have a number of well tried processes at their disposal. In addition, there are one or two new processes and applications of an older process ripe for development. At the conclusion of the last world war, the activated sludge system and sludge digestion were in their infancy, and in the interval between the two wars many fine examples of both processes have been constructed in various works in this country and abroad. There is no reason to doubt that they will enjoy popularity in postwar design.

In all probability, greater attention will be paid to the utilization of methane for the production of power, having regard to the great increase in the price of coal. In the majority of those works incorporating sludge digestion, sufficient methane will be available to produce the total power requirements of the sewage undertaking, particularly if oil-ignition gas engines are installed.

Of the new processes available for development, the various applications of the percolating filter are the most outstanding. They all aim at high rate dosing, and in the majority of cases produce, after settlement, final effluents of good quality. The percolating filter processes referred to are well known to members of the Institute and need no elaboration on my part. They include:

1. High rate primary or "colloidal" filter.
2. Double filtration with periodic change in order of operation.
3. The enclosed filter with forced aeration.
4. Recirculation or biofiltration.
5. Dilution with nitrated effluent prior to filtration.

At least two of the applications have emerged from the experimental stage, while the last mentioned process is about to be tried out on full plant scale lines. As far as experimental data can be relied upon, all the new applications will considerably increase the present day conception of percolating filter capacity.

Existing installations of percolating filters may benefit considerably by incorporating one or other of the new developments and it is probably in this direction that some of the applications will first receive attention. Most of the processes are still engaging the attention of many workers throughout the country and I predict that much more will be heard about them in the future.

Turning to the subject of sludge disposal, I have already suggested that digestion followed by drying on ash beds is still unrivalled in popularity. There are, however, some new processes which are being investigated and the results will be watched with great interest, particularly by those authorities who, having a restricted or congested sewage works site, are forced to consider an intensified process. The same applies to many northern towns, not forgetting those situated on or adjacent to the Pennine Range, where the seasonal drying weather is much shorter than in the South. It has been stressed on previous occasions that a more intensified method of dewatering sludge, a method unaffected by climatic conditions, is highly desirable, and I wish to emphasize the importance of continued investigation and experimentation in this direction.

The application of crude sludge to land has been practiced by some authorities over a number of years, but such final means of disposal for liquid digested sludge has not found similar favor. Having regard to the high manurial value of the liquid portion of the sludge, this means of disposal is worthy of consideration where sufficient land is available on, or adjacent to, the sewage works site.

The provision of a limited area of drying beds along with an area of agriculturally worked land appears to be an attractive combination; the land to take the sludge during the poor drying months and the beds to come into operation during the spring and summer when the land is under cultivation.

The utilization of sewage sludge for manurial purposes has attracted the attention of high agricultural authorities during the war years, and extensive experimental trials have been undertaken by the scientific officers of the Rothamsted Agricultural Experimental Station in collaboration with many members of the Institute. It is hoped that the results of the trials will enable some competent authority to place a market value on the various types of sewage sludge produced, both for the guidance of the farmer and of the local authority.

In addition to the material removed from drying beds and filter presses, there are two or three special preparations which can be produced in most sewage works and the reluctance to do so, in some instances, is simply a question of economics and an uncertain market. Composting, which is a case in point, has found favor during the war period. The process seems to be particularly well suited to the vagaries of the British climate, as it possesses an insatiable thirst for water. It appears to be generally agreed that the minimum economic price for straw-sludge compost is 15 shillings ($3.03) per ton, exclusive of transport. Although this may be within the limits of a wartime emergency, is it an economical proposition in peace time?

The preparation of a dry powdered fertilizer from activated sludge is another example. Admittedly, the process is rather "fickle" and will only respond when well conditioned liquid sludge is guided through the plant with a velvet glove. Nevertheless, when due regard is paid to the high class fertilizer produced, the effort would be well worth while provided the return was commensurate with the expenditure.

If some encouragement could be given by the Government, either in the form of a subsidy or a guaranteed market, particularly in the initial stages of production, local authorities would readily respond.

Much valuable information on the use of sewage sludge as a manure can be anticipated from the discussions now taking place between representatives of the Institute and the Agricultural Research Council. They appear to be making a most comprehensive survey of the subject and, in all probability, many of us will be asked to supply data relating to the various aspects of their deliberations.

This seems to be an age of collaboration, and while the Continental type is not very popular and the penalty awarded not very pleasant, we welcome the type developed in this country with enthusiasm. It is, therefore, a great pleasure to me to be afforded the opportunity of referring to two instances of collaboration between the Institute and important outside authorities.

The second case refers to the joint conference, about to take place, between the Water Pollution Research Board and representative of the Institute, to discuss matters appertaining to research in connection with sewage purification. I do not wish to anticipate their discussions or conclusions and will consequently confine my few remarks to research in general.

The Institute can be justly proud of the splendid efforts made by some of its past and present members in the field of research and experimentation, and it is not too much to say that the present day modern sewage treatment plant is a direct result of their work. Most of the research, however, was confined to the initiation and subsequent development of various processes, while the "reasons why" are still obscure. It is felt that if the fundamentals were available, much greater progress could be made, and it is with pleasure that we welcome the co-operation of the Water Pollution Research Board. They and other independent workers have already slightly lifted the veil in connection with the mechanism of the percolating filter, which has wetted our appetite for more.

The paramount importance of biological research has been exemplified by the work of the Water Pollution Research Board, just referred to, and also by independent work emanating from the Leeds University, but only the fringe of the subject has been touched upon and much more remains to be solved.

Nor is pure scientific investigation all that is required; one can instance the urgent need for an efficient grit separator for the smaller sized works so as to abolish the collection of that most objectionable material called detritus.

The present day trend of sewage purification requires much more from the designer and manager than the prevention of rivers pollution. The prevention of aerial nuisance is almost as important, whilst the aesthetic side of design and maintenance cannot be overlooked. Most of our older works leave much to be desired in one or more of these requirements, as pointed out by Mr. C. B. Townend in his contribution to the Institute, entitled "Democracy and Sewage Disposal":

> "Although . . . this Country led the world in sewage purification up to the last war, there is no question that today our works in general are 30 to 40 years old and becoming out-of-date. . . ."

We must not lose sight of the fact, however, that most things develop from the simple to the complex, from the plain and sometimes ugly to the pleasing and elaborate and, consequently, many of our older works are bound to be either simple or plain, while a number are both. The improved processes and methods of operation introduced since the early days of sewage treatment, along with the development of mechanical equipment, show considerable progress from the simple to the complex.

On the other hand, most of our modern works, including those of recent reconstruction, show to a very marked degree that sewage treatment plants can be made very pleasing in design and subsequent maintenance. The modern plant is a highly mechanized undertaking, providing, among other advantages, for the discharge of sludge under water, which in many instances remains unseen until all its powers to become offensive have been dissipated.

I do not feel guilty of exaggeration when I suggest that the expert designer, with the modern processes and plant at his disposal, can produce a sewage treatment plant which, in the hands of the skilled manager, can generally be operated and maintained without offending any of the senses possessed by man. This has been the aim and trend in sewage treatment for the past decade and will probably become the standard practice in postwar design. It is, incidentally, a trend only slightly in advance of public opinion which is now becoming conscious of the amenities of the countryside.

However perfect a sewage treatment plant becomes, the name will always be with us, and will continue to have a psychological effect upon the fanciful. It is probably on this account that one seldom hears the subject mentioned at any publicly convened meeting, notwithstanding that sewage disposal, coupled with main drainage, returns one of the best dividends in the country. When the annual national expenditure for the combined service is analyzed, the unit cost is only slightly in excess of one penny per person per week. Surely this achievement is worthy of much wider publicity, particularly when the benefits provided are compared with the unhygienic sanitary conditions of 60 years ago. Apparently, the general public is of the opinion that the subject, in which we find so much interest, is a very necessary job of work, but one that should not be talked about.

This gives me my cue to conclude this address by quoting a passage from J. C. Stobart's work—"The Glory that was Greece." When discussing the "Late Minoan" period of Crete, which is placed in the second millennium before Christ, Mr. Stobart states:

"The plumber will find a paradise in Knossos. There are lavatories, sinks, sewers and manholes."

After including a description prepared by Professor Burrows of the main and subsidiary sewers, he continues:

"Let no cultivated reader despise these details. There is no truer sign of civilization and culture than good sanitation. It goes with refined senses and orderly habits. A good drain implies as much as a beautiful statue. And let it be remembered that the world did not reach the Minoan standard of cleanliness again until the great English sanitary movement of the late nineteenth century."

We are in good company, with sculpture and all the other refined arts that contributed to "The Glory that was Greece."

Industrial Wastes

INDUSTRIAL WASTE DISPOSAL *

By George E. Symons, Ph.D.

Associate Editor, Water Works & Sewerage, New York, New York

The subject of industrial waste and its disposal has, within the last few years, reached the place of highest importance in the field of sanitary engineering. After many years of indifferent or complete lack of attention, followed by slowly awakening interest in this important problem, it appears that in the postwar period the disposal of industrial waste is to be the leading topic.

This trend, accelerated perhaps by the war, has become evident in many ways: In the programs of various technical organizations and societies; in the requests of engineering organizations to be addressed on the subject; in the report of the U.S.P.H.S. which makes an estimate of the amount of construction of remedial works to treat industrial wastes; in industrial advertising calling attention to the application of some product in industrial waste treatment; in the work of various stream control commissions in the United States and in Canada; in the work of the U.S.P.H.S. and the Ohio Stream Pollution Survey; in the calling of conferences on industrial waste by universities co-operating with state departments of health; in the continued research programs and the establishment of new ones by trade associations; and in articles appearing in the trade journals. Yes, it is evident that Industrial Waste Disposal is the problem of Today and its solution is the program of Tomorrow.

A problem of the complexity, magnitude, and variety of industrial waste disposal obviously cannot be presented in detail in any single paper. One can but hope to present certain broad aspects of the subject, and emphasize some generalities not usually considered in papers dealing with specific details of definite wastes and problems thereof.

One concept so frequently lost sight of in discussions of industrial waste is that disposal means "to get rid of" and, as far as industrial wastes are concerned, "disposal" may mean with or without treatment; in this paper that definition will be borne in mind.

Using an editor's prerogative, I have gathered for use here opinions and statements from persons who have had intimate contact with some phases of the problem.

Wastes—How Much and From What?

With this introduction, we may well ask, whence come these wastes? Obviously, if industry uses water in its processes one may, with surety,

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

expect the water to become contaminated in the process. It is this contaminated water that must receive treatment or else impose a pollution load on the receiving body of water. The tremendous quanti-

TABLE I.—*Industrial Water Requirements* *

A—Water Requirements for Selected Chemical Industries

1. Ammonia	31,000 gal./ton NH_3
2. Ammonium sulfate	200,000 gal./ton salt
3. Carbon dioxide	23,000 gal./ton CO_2
4. Caustic soda	21,000 gal./ton 11% solution
5. Cellulose nitrate	10,000 gal./ton nitrate
6. Corn refining	333 gal./ton corn
7. Glycerine	1,100 gal./ton glycerine
8. Gun powder	200,000 gal./ton powder
9. Hydrogen	660,000 gal./ton gas
10. Industrial alcohol	20,000 gal./ton grain
11. Lactose	220,000 gal./ton lactose
12. Magnesium carbonate	39,000 gal./ton salt
13. Paper	
a. De-inking paper	38,000 gal./ton paper
b. Paper board	14,000 gal./ton paper board
c. Strawboard	26,000 gal./ton strawboard
14. Phosphoric acid	7,500 gal./ton 35% acid
15. Soda ash	18,000 gal./ton 58% ash
16. Tanning	16,000 gal./ton hides

B—Water Requirements for Selected Food Industries

1. Beet sugar	2,600–3,200 gal./ton beets 20,000–25,000 gal./ton sugar
2. Canning	
a. Asparagus	7,000 gal./100 cases No. 2 cans
b. Beans	
(1) green	3,500 gal./100 cases No. 2 cans
(2) lima	25,000 gal./100 cases No. 2 cans
(3) pork and	3,500 gal./100 cases No. 2 cans
c. Corn—cream or whole	4,000 gal./100 cases No. 2 cans
d. Peas	3,000 gal./100 cases No. 2 cans
e. Sourkraut	300 gal./100 cases No. 2 cans
f. Spinach	16,000 gal./100 cases No. 2 cans
g. Tomatoes	
(1) products	7,000 gal./100 cases No. 2 cans
(2) whole	750 gal./100 cases No. 2 cans
3. Meat packing	
a. slaughter house	16,000 gal./100 hog unit
b. packing house	55,000 gal./100 hog unit
c. poultry	220 gal./100 lbs. live weight
4. Milk and milk products	
a. receiving and bottling	450 gal./100 gal. milk
b. butter	250 gal./100 lbs. butter
c. cheese	200 gal./100 lbs. cheese
5. Vegetable dehydration	
a. beets	1,870 gal./100 lbs. product
b. cabbage	750 gal./100 lbs. product
c. carrots	1,580 gal./100 lbs. product
d. potatoes	560–1,250 gal./100 lbs. product
e. rutabagas	1,520 gal./100 lbs. product
f. sweet potatoes	900 gal./100 lbs. product

TABLE I.—*Industrial Water Requirements—Continued* *

C—Water Requirements for Selected Textile Industries

1. Cotton	
a. processing	3,800 gal./100 lbs. goods
b. dyeing	1,000–2,000 gal./100 lbs. goods
2. Linen	10,000 gal./100 lbs. goods
3. Rayon	
a. "dissolving pulp"	9,500 gal./100 lbs. pulp
b. supra-ammonium yarn	8,000 gal./100 lbs. yarn
c. viscose yarn	10,000 gal./100 lbs. yarn
4. Wool-scouring	2,000–15,000 gal./100 lbs. raw wool

D—Water Requirements for Miscellaneous Industries

1. Air Conditioning	6,000–15,000 gal./person/season
2. Blast Furnace	4,000 gal./ton pig iron
3. Coal Carbonizing	3,500 gal./ton coal carbonized
4. Coal Washing	125 gal./ton coal
5. Electric Plant	120,000 gal./ton coal burned
6. Oil Fields	18,000 gal./100 bbl. crude oil
7. Oil Refinery	77,000 gal./100 bbl. crude oil
8. Rock Wool	5,000 gal./ton rock wool
9. Steel Plant	20,000–35,000 gal./ton steel
10. Sulfur Mining	3,000 gal./ton sulfur

* Compiled by Alex C. Burr, Director, No. Dakota Research Foundation

ties of water used in industrial processes are shown in Table I. Alex C. Burr, Director, North Dakota Research Foundation, compiled these data (1) and about them he writes (2),

"The figures cited are not mathematical averages nor are they necessarily typical. They do, however, represent the quantity requirements of operating plants. Requirements for a new plant of a given capacity will depend on design and water economy, and may vary greatly from the figures given. It should be noted that these figures do not include water for waste disposal.

"In many cases easily recognizable, a great portion of the water used will eventually find its way into the waste. This is especially true for those industries in which the steam and process water requirements are low.

"These figures have been obtained from a great variety of sources; some picked up from incidental references in literature, some based on inspection of plants. In every case the experience of at least three plants is involved and used in arriving at a figure.

"It goes without saying that these data should be used with caution. The main value is in emphasizing the quantity of water required."

Classification of Wastes

These values do emphasize the quantity of water required. They also emphasize the problem of waste disposal. Burr's tabulation offers, in a way, a classification of wastes. William S. Wise (3), Chief Engineer of the Connecticut State Water Commission, likewise has a classification of sorts in his list of industrial wastes in that state. From these two lists a broad classification of wastes has been made and is shown in Table II.

Even from this incomplete listing it is obvious that wastes containing both organic and inorganic compounds outnumber those predominantly organic or inorganic in nature.

Inorganic wastes require chemical or mechanical treatment or both, and will not respond to biological treatment. Organic wastes will respond to biological treatment and may or may not require chemical and mechanical treatment as well for complete purification. Mixed wastes may and probably will require both mechanical and chemical treatment as well as biological treatment, with special attention to various and many steps.

E. F. Eldridge (4) has made a slightly different classification under the headings Organic, Toxic and Inert. Generally, Eldridge's toxic wastes fall into the inorganic class, while his organic wastes embrace most of those listed here as mixed. (Most notable exceptions are the coke oven and gas wastes.)

TABLE II.—*Partial Classification of Industrial Wastes*

Inorganic	Organic	Mixed
Metallurgical	Vegetable Canning	Textile
Brass and Copper	Corn Products	Dyeing
Iron and Steel	Alcohol Production	Coke and Gas Wastes
Plating	Slaughter House	Paper Board and Allied
Sulfur	Dairy and Milk	Laundry
Sand Washing	Beet Sugar	Tanning
Acid Manufacturing	Citrus Fruit Canning	Cutting Oils
Salts	Brewery	Dye Manufacturing
Alkalies	Meat Packing	Petroleum
Coal Mines		Plastics
		Rubber Reclaiming
		Natural and Synthetic Rubber
		Explosives
		Vegetable Dehydration
		Wool Scouring

ECONOMICS OF WASTE DISPOSAL

Historically, the most common means of waste disposal has been by dilution. From earliest industrial development utilizing water power, it was the natural means of disposing of industry's waste.

While quantities of waste were small this method was satisfactory and acceptable. As waste quantities increased with industrial development the capacity of the streams to receive and purify these wastes was overtaxed. Streams formerly the source of fish and available for pleasure became fouled and an economic liability to the region. At the same time losses from industry became an economic factor to be reckoned with.

True, not all waste substances discharged are recoverable or have any economic value. On the other hand, the economic loss to some industries is evident. For example, Dr. C. S. Boruff (5), Technical Director, Hiram Walker and Sons, Inc., estimates that some 1,000,000 tons per year of recoverable materials have a value of $30,000,000, and comments, "From these figures one can obtain some idea of the economic loss, in the past, of discharging distillery residues to wastes."

Dr. Harry Gehm (6), Technical Advisor, National Council for Stream Improvement of the Pulp, Paper, and Paperboard Industries, quotes the U. S. Dept. of Agriculture estimate of $45,000,000 annually as the economic loss of the pulp, paper and allied industries.

Richard D. Hoak (7), Senior Industrial Fellow, Mellon Institute, has been working for three years on the problem of pickle liquor disposal from the steel industry and has estimated the loss of sulfuric acid "at 125,000 tons each year along with 500,000 tons of ferrous sulfate, if no recovery were practiced." Hoak (7) has also stated that before the mine sealing program of abandoned bituminous mines it was estimated that 2,700,000 tons of sulfuric acid were discharged annually into streams, obviously causing considerable economic damage. He continues, "Actually, considerable ferrous sulfate is recovered from pickle liquor, *but* if this compound were recovered from *all* of the liquor produced there would be a surplus of perhaps twenty (20) times the normal annual demand for ferrous sulfate."

In regard to the economic recovery aspect of this particular waste, Hoak continues,

"Development of processes for recovery of by-products from it has not been notably successful because of the low value and limited markets for compounds readily prepared from it. Treatment of pickle liquor has been a problem of economics rather than of technology; a variety of useful products can be derived from it, but transportation, operating costs, saturated markets, and other factors frequently make recovery processes more costly than wasting the liquor.

"The American Iron and Steel Institute maintains an industrial fellowship at Mellon Institute for research on steel mill wastes, and a number of processes have been developed which show promise. Until these processes can be studied on a pilot plant scale, however, their economic potentiality cannot be properly evaluated.

"Certain processes may be employed which will reduce the cost of treatment if they are operated on a sufficiently large scale, but it seems unlikely that any process will be developed which will yield a substantial net profit. Companies which produce only a few thousand gallons of waste liquor a week will probably find that time and/or limestone treatment will be the only practicable disposal expedient."

This statement points definitely to one important factor of the "economics of waste disposal," namely, that of markets for recovered by-products.

An extremely sane attitude on this matter has been expressed by Maurice LeBosquet, Jr., Principal Public Health Engineer, Sanitary Engineering Division, Water and Sanitation Investigations of the U. S. Public Health Service. LeBosquet (9) writes,

"I believe that an erroneous impression is created through the use of the phrases 'Economic loss from industrial wastes' and 'Value of recoverable waste products.' Such terms infer that industry, as a rule, is quite careless and accustomed to discharging materials of value into the sewer. Such instances are the exception rather than the rule and are usually found at the industry that does not sample its own sewers.

"It is true that there may be some value in the contents of industrial wastes, but, in the typical industry, this value is somewhat less than the cost of recovery. It is my feeling that while there remain further possibilities along the line of developing by-products, industry must first conduct extensive studies leading toward development of recovery processes and, in many cases, must also develop the markets to absorb the by-products after they become available.

Many industries now realize that they are confronted with an item of expense in abating pollution, even though part of this expense may come back through the sale of by-products. In the future, I believe all industries will come to this realization. In the meantime let us not place too much stress on the 'Value of recoverable waste products' even though, during the war period, the prospect of recovering war-needed items from industrial wastes is inviting."

One other factor must be considered in any evaluation of the economics of waste disposal. This factor of economic damage to receiving bodies of water cannot be evaluated, but judging from the vehement voices of sportsmen and conservationists it must be an appreciable value even in these days of war expenditures running into the billions.

While it is true that "economic loss from industrial wastes" creates an erroneous impression, it is likewise true that industries sometimes discharge waste to the economic detriment of themselves and their neighbors. We may cite the example of a city situated on an inland lake with several large industries on one part of the dredged stream forming a harbor. Some of the industries discharge sizeable amounts of acids with the result that at periods of low stream flow the harbor becomes quite acid. Industries using this water for cooling purposes have severe corrosion problems. So severe is the corrosion that one industry estimates a corrosion replacement of $50,000 per year is required while another spends $125 a day for lime neutralization during the summer months. This certainly is a highlight of economic loss from industrial waste disposal.

Pollution Abatement Programs

Two factors are paramount in the consideration or development of pollution abatement programs. First, to strike an economic balance between the extent of abatement and the capacity of the receiving body of water. Second, to develop individual abatement programs on a regional or drainage basin basis.

As to who will or should undertake the development of pollution abatement programs, the question has been answered generally by governmental action, municipal, state or provincial, regional, and Federal or Dominion departments of health and conservation. Of recent years, however, industry has itself undertaken programs that are designed to lead to the solution of the problems. Two notable examples are the American Iron and Steel Institute which for several years has been studying the problem of waste pickle liquor at Mellon Institute and the recent organization of a program for study of Paper and Pulp Wastes by The National Council for Stream Improvement.

This latter program has been set forth by Dr. Gehm (6) in a release as follows:

"In attacking its waste problem, the pulp, paper and paperboard industry has arrived at the stage where co-ordinated effort is imperative. Being one of the first industries to appreciate the need for research, it has reached the position before many other large industries. Never before has a waste problem been approached in so broad a manner, and in working out the procedure, the magnitude of the program has become increasingly evident.

"Before any large-scale laboratory projects can be initiated, the following information must be collected and assembled in abstracted form for guiding the technical planning and research groups in determining methods leading to a satisfactory solution of the problems with a minimum of duplicated effort:

1. Sanitary analysis of the drainage areas involved.
2. An investigation of prior art.
3. Industry's experience with treatment and recovery processes.
4. An assembly and analysis of the physical and chemical characteristics of the wastes involved in the manufacture of all grades of paper and paper board.

"In order that proper priorities may be assigned, actual conditions of the various plants in regard to stream pollution must be evaluated. This and the collection of industry experience will be the function of regional committees. Acting simultaneously, they will determine their most pressing needs and what contribution to the knowledge of waste treatment they can make to the industry as a whole. In order that a balance may be obtained, each grade of product manufactured in the region must be represented. The committee members, working with the chairman, will assemble the region's problems for submission by the chairman to the Technical Planning and Budget Committee meeting together with the chairman of other regions, the Council's staff, and representatives of the Mellon Institute, to decide on the general course of the work to be assigned to the research groups.

"When research results have reached the stage where they are ready for application by the industries, such data will be made available through the chairmen of the various regional groups. Assistance in applying the knowledge obtained will be rendered by the staff and such members of the research organizations as may be indicated."

Cost of Abatement Programs

The cost of industrial waste treatment to abate pollution in America will not be small. Research programs such as outlined above will require considerable expenditures in themselves.

A survey of industrial waste pollution in any drainage basin by a governmental agency likewise is not inexpensive, considering the necessity for investigation of individual industries, collecting and analyzing samples of various industrial waste and compiling data and information thereon.

The most recent large survey was that carried on in the Ohio River Basin by the Ohio Stream Pollution Survey of the U. S. Public Health Service from its Cincinnati office. About the extent and cost of this survey LeBosquet (8) writes,

"The complete Ohio River Pollution Survey and report cost about $600,000, of which about half was devoted to laboratory studies of the streams and half was devoted to collecting information on methods of sewage and industrial waste disposal and the preparation of the final report.

"The problem of collecting information on industrial wastes, including the preparation of Industrial Waste Guides, required more time than the problem of sewage disposal, so that possibly $200,000 was spent on the question of industrial wastes. This is about $100 per industrial plant included. The industrial waste investigations, however, did not include sampling and gaging studies, except in perhaps 20 cases. A sampling and gaging study might cost from $1,000 to $2,000 for one industry, depending on the complexity of the industry and the number of sewers involved."

Realizing that even the investigation of stream pollution will entail the expenditure of appreciable sums of money, one may well ask, what postwar future exists for industrial waste treatment? How large is the construction job of remedial measures to abate pollution? Three sources of information are available to give some idea of the financial expenditure involved in a comprehensive waste disposal program. These are the National Resources Committee publications "Water Pollution in the United States" (9), the report on "Ohio River Pollutional Control" (10) and the "National Inventory of Needs for Sanitation Facilities" (11).

LeBosquet (8) writes,

"The estimate for a comprehensive waste disposal program, first given in the National Resources Committee publication, is between $800,000,000 and $900,000,000, the annual cost being $200,000,000 to $250,000,000. The estimate is intended to be complete and to include disposal or treatment measures in industries not now generally practicing corrective measures. For example, in certain cases evaporation is assumed, whereas there are no evaporating plants installed at the present time. The estimate does not include any item of cost for rearranging sewer systems within industrial plants. This in itself might double the figure, as one instance has been recorded where an industry spent $250,000 simply for rearranging its sewer system in order to install phenol recovery facilities.

"The report on Ohio River pollution control . . . presents an estimate for treatment and other remedial measures for industrial wastes in the Basin, the total estimated cost being $13,580,000 and the annual charges being $4,265,000.

"This estimate differs from the National Resources Committee estimate in that the cost figure represents what could be spent today, with present knowledge, towards correcting and eliminating industrial waste pollution. It does not include an item of cost for correcting pollution where known successful methods are not now available. It does not include any item of cost for industrial wastes which in our opinion could be disposed of to best advantage in municipal treatment plants. It does not include any item of cost for rearranging sewer systems prior to installation of treatment works. It is apparent that any estimate of cost for industrial waste pollution abatement must be qualified with a statement as to what costs are not included.

"The most recent estimate on industrial waste pollution abatement costs was published in the Public Health Reports. I (M. LeB.) am familiar with the development of the estimates presented, having been connected with their preparation.

"The estimate is based largely on an expansion of the Ohio River Pollution Survey detailed data to cover the country as a whole. Estimated costs of independent industrial waste corrective measures total $160,000,000. In addition, the increased costs of municipal treatment works because of industrial wastes contributed to municipal sewer systems total $153,000,000, making the total cost of industrial waste disposal $313,000,000.

"As in the case of the Ohio River Pollution Survey, corrective measures are confined to those which can be taken now with present knowledge and do not include corrective measures which cannot be taken until after extensive studies have been made in regard to methods to be used. The estimate, again, does not include the cost of rearranging sewer systems preliminary to installing treatment works or other corrective measures.

"In view of the restricted nature of the estimate, it seems likely that the $313,000,000 U. S. Public Health Service estimate and the $800,000,000 to $900,000,000 National Resources Committee estimate are within reasonable agreement."

If one may estimate a similar per capita expenditure in Canada, then it becomes obvious that the construction of industrial pollution abatement may run for a period of years in the postwar period with expenditures of 75 to 100 million dollars a year.

Specific Waste Problems

In a general survey of the broad picture of industrial waste disposal, it is, perhaps, a mistake to attempt any mention of specific wastes, to the exclusion of others. On the other hand, mention has already been made of the extent of some specific waste problems, and it does seem wise to call attention to the complexities of at least two waste problems. When one speaks glibly for example, of the paper and pulp waste, one minimizes the problem out of all reason. The complexity of this waste problem, really several different wastes, is evident from Table III as furnished by Dr. Harry Gehm (6), Technical Advisor, National Council for Stream Improvement.

Table III.—*Types of Waste from the Pulp and Paper Industry*

Type of Waste	Type of Treatment
Sulfite Waste Liquor	By-products Manufacture: Vanillin Alcohol Yeast Others Lagooning, Precipitation Processes, Road Binder and Soil Stabilizer, etc.
Kraft Waste Liquor	Evaporation and Burning
Soda Waste Liquor	Evaporation and Burning
De-inking Waste	Precipitation, Filtration and Lagooning Sludge
White Waters	Precipitation, Flotation, Filtration, Centrifuging, Screening, Re-use of Fiber
Semi-chemical Waste Liquors	Barging, Lagooning, Recovery Processes in Development
Bleach Liquors	Precipitation, Lagooning

As another example of the complexity of wastes one may cite the canning industry. About this seasonal and highly varied industry, Wm. A. Ryan, (12) Industrial Waste Consultant of Rochester, N. Y., writes:

"Wastes from vegetables and fruits are chiefly organic in nature with small amounts of dirt or mineral matter from the washing process. The principal vegetables canned in most plants of New York State are tomatoes, corn, peas, beans, beets and cabbage. The principal fruits are apples, pears, peaches and cherries.

"During the past ten years many canneries have devoted more time to quick freezing and specialties such as soups, potatoes, milk, spaghetti, pork and beans, and baby foods. This practice tends to keep the plants operating the year around.

"Since the war a few plants have added dehydration and have specialized on potatoes, soup stock, tomatoes, etc. It makes little difference what is ultimately done with the fruit or vegetable, there is always wash water, blanching water, and wash down wastes to consider.

"Vegetable and fruit waste is not poisonous. In most cases the waste has an acid reaction and soon becomes putrescible. Peas and corn wastes are most objectionable to fish life due to dissolved organic matter such as sugars, starches, etc. One-third of the tomatoes as received leave the plant as waste. Pea, corn and lima bean ensilage juice should never be allowed to enter a stream or sewage plant. Pea vineries should be located in the country away from the plant.

"Introduction of the lye peel method (caustic soda plus hot water) for loosening the skins of potatoes, beets, carrots, etc., has increased the solids as well as the B.O.D. of the wastes. It is fortunate that this method of peeling has not been too popular.

"Vibrating or rotary screens are the first units to consider in treating canning wastes. Removal of waste from picking tables in plants in the form of garbage reduces the B.O.D. of liquid waste. Lagoons are most popular, after screening, for disposal of waste. Sodium nitrate is an aid in lagoons for keeping down odor and reducing B.O.D. Many large sewage treatment plants accept cannery waste, while small plants are easily overloaded.

"Flotation method for treating tomato waste has merit. Chemical treatment is not popular in New York State. Contact or Dunbar filters followed by riffles are used by many.

"Trickling filters require too long to become active for short season. Odors are a problem but nothing compared to reduction of oxygen in streams with resultant fish kill. Excess dosage of lime is not desirable, due to effect on stream life and fish life."

Not only are canning wastes seasonal and varied, but as Ryan concludes, "Every canning plant is an individual problem and must be studied separately."

Recovery of By-products

As pointed out by LeBosquet, recovery of saleable by-products from industrial waste is not the simple answer to the economics of industrial waste treatment. Not every waste contains a recoverable material that has a potential market sufficient even to pay a part of the waste treatment and recovery costs.

On the other hand, some industries do waste or have wasted valuable recoverable products. For example, about canning wastes, Ryan writes,

"Apple waste has the greatest possibility for recovery of by-products in the North. Pea vines and pods can be dehydrated and ground for feed admixtures, or fed as dry hay. Tomato seeds are recovered in New Jersey and clean tomato and beet waste can be dried and used as an admixture in dog food. In general, however, recovery of other vegetable or fruit waste as saleable by-products has little to offer."

An outstanding example of recoverable wastes has been in the corn products industry, with the recovery of cattle food and other materials from starch waste. Still another example with a highly dramatic story is that of the distillery waste problem, about which Dr. C. S. Boruff (5) writes:

"In pre-prohibition and early post-repeal days distillery residues were a waste disposal problem. This is no longer true; the problem is now one of recovery of valuable materials rather than disposal of a nuisance. Just prior to the war, recovery was at the rate of about 300,000 tons per year. This year there will be about 500,000 tons recovered, and equipment now in the process of being installed will lead to a recovery of 1,000,000 tons a year. This million tons will have a normal peace time value of some $30,000,000. From these figures you can get some idea of the economic loss, in the past, of discharging distillery residues to waste.

"Some plants recover only the material retained on screens. Others recover whole stillage by screening and evaporating the screened stillage. Both these products are used in dairy cattle rations. In 1940, Hiram Walker introduced the practice of drying separately on drum driers a portion of the concentrated (clarified by centrifugation) thin stillage. This product, distillers' dried solubles, is finding ready acceptance in poultry and swine rations because it contains high quality protein plus significant quantities of the water soluble B vitamins, found to be necessary in poultry and swine nutrition.

"As regards costs, I can say that in peace time, at normal prices, the recovery of by-products is a profitable business when modern recovery equipment and methods are employed."

In at least one instance it is the recovery of water itself which is the essential and controlling factor in the waste treatment. This situation exists at the famous Fontana (Cal.) steel plant of Henry J. Kaiser, where every drop of water is recovered for re-use. Saleable phenol recovered only partly pays for its own recovery, but the extreme shortage of available water makes complete treatment of waste and re-use necessary.

Local Industrial Waste Surveys

While governmental bureaus are generally staffed with personnel familiar with sanitary engineering problems, municipalities, particularly smaller ones, often face an industrial waste problem without an adequate idea of how to proceed.

How then should an industrial waste survey be conducted and toward what ends should it strive? In the first place the end in view must be abatement of pollution, not persecution of industry.

A good example of what not to do was done in Grafton, North Dakota, where the waste from a potato dehydrating plant had been extremely detrimental to the operation of the local sewage plant. Lack of forehand knowledge of these effects had led to the difficulty, but co-operative study of the problem was not utilized as the solution. On the contrary, the municipality adopted a motion prohibiting the dumping of the waste into the sewer system until the company indemnified the city against damage and damage claims, etc. The company closed the plant and moved to another city.

There are numerous examples on the other side of the ledger where co-operative study of the problems involved has resulted in benefit to both parties.

If a municipality has industrial waste problems and desires to eliminate or alleviate them, the first step is to release adequate and informative publicity to the general public, stressing the fact that co-operation and aid to the industry is the paramount consideration.

The second step is to list and classify all industries within the area to be covered by the survey. From these classes (breweries, chemical products, laundries, dairy products, tanneries, etc.) it is possible to divide the classes into two groups, according to the probability or knowledge of liquid wastes of other than sanitary nature. Industries not having liquid industrial wastes need not be investigated. Industries in the other group should be listed in order of their known relative importance and the survey is ready to begin.

Following the early publicity and classification of industries the next step is to notify each industry to be investigated by a letter asking for a conference with the technical representatives of the municipal authority. First contact should be aimed at establishing friendly understanding of the problems involved and the intent of the survey. This to be followed by a plant survey or investigation of sewers and wastes and, if indicated, sampling and analyses of wastes. In the latter case it is important to remember that sampling should be representative of plant operation and discharges.

Details of questions to be asked, information to be sought and analyses to be made depend largely on the local situation but a good guide to useful questionnaires may be found in the "Final Report to the Ohio River Committee—Supplement 'A', Collection of Data on Sources of Pollution." (13) "Supplement 'B', Organization and Methods of Laboratory Studies" (14) is likewise extremely helpful.

Thereafter the survey consists of interpreting the data and information in order that the co-operation of the industry may be obtained in reaching the desired end in view whether it be elimination of the waste, partial pretreatment of the wastes before discharge into the sewers, or payment by the industry of its fair share of the cost to the municipality for the treatment of the waste.

One interesting story of the need for education happened to the writer. The superintendent of the industry being interviewed said, "We don't have any waste to speak of—we obtain a 98 per cent yield of product." Quite true, but the 2 per cent loss could be 20,000 p.p.m. in his waste and the loss of reactants other than the products could be 95 per cent. In another instance a battery company was dumping a 3.2 per cent solution of sulfuric acid into the sewer at intervals. While 3.2 beer may not have much kick, 32,000 p.p.m. of sulfuric acid wreaks havoc on concrete sewers.

It is not the per cent loss that is important; it is the quantity loss in pounds and its effect on the stream, lake, or treatment works.

Payment for Treatment

As indicated above, in some cases it may be indicated that elimination of the waste is desirable and necessary, in others pretreatment before discharge into sewers, while in still other cases the simplest solution may be acceptance in the municipal sewers with treatment as a part of the city's sanitary waste. In the latter case it is entirely feasible that the industry pay its share of the cost of treatment.

The idea that industry pay the municipality for treating the industrial waste is not new, nor is the idea that payment should be on the basis of service rendered or strength, quantity and amount of waste treated.

Fifteen years ago Frank A. Marston (15) stated,

"Where the sewage is treated, the cost of operation and maintenance of the sewage treatment plant is influenced by the character of the sewage including industrial wastes, ground water and other leakage. Certain industrial wastes may add a considerable burden of expense because of their character; whereas relatively clean rinse waters, although of similar volume, would not involve a corresponding cost. To meet these conditions, it is possible to set up the following: A schedule of charges based not only on the volume of domestic sewage or industrial wastes, but also on the degree of pollution as measured by relative amount of suspended matter, the biochemical oxygen demand, or some other factor."

In a report on Sewer Rentals in Ohio some years ago, F. H. Waring (16), Chief Engineer, said,

"In making up a sewer rental schedule, special allowances . . . should be made for certain unusual premises served, for example,—industrial establishments where liquid wastes are admitted to the sewers. For the latter premises, variations in charges in accordance with the volume may be supplemented by further variation in accordance with the strength of the industrial sewage as compared with the domestic sewage."

One of the early municipal-industry agreements was that in Cedar Rapids, Iowa, where a packing company paid part of the cost of construction of the plant and pays a yearly sum toward operation costs. Other cities in the United States having some arrangements as to payment by industry for waste treatment in the past several years have been Sioux Falls, South Dakota (packing plants); Boulder, Colo. (creameries and laundries); Traverse City, Mich. (grain elevator, creameries and certain other industries); Phoenix, Ariz. (dairy waste); Orville, Ohio (food process industries); Hillboro, Ore. (separate sewer and treatment and special charge for all industry); Freehold, N. J. (special rate for industrial waste delivered to treatment works in separate sewer). There are several others.

Most of these agreements have been on the basis of yearly charge or some other negotiated basis. In the past two years, two municipalities have assessed sewer service charges on the basis of volume of waste, and strength of constituents which contribute to the cost of sewage treatment.

The first of these was Buffalo, N. Y., where, in 1942, this author and his associates developed a formula for charge, based on more than three years' study. The Buffalo service charge has been applied since February, 1943. The second city to make a similar basis of charge was New Brunswick, N. J.

The Buffalo industrial sewer service charge, as reported by Symons and Crane (17) in the March, 1944, issue of *Water Works and Sewerage,* was developed as applicable to all industries and is based on volume, and concentration of suspended solids and chlorine demand, as shown by the following formula (17):

$$R = FP_c\ (C - N_c) + FP_s\ (S - N_s)$$

"Where R = rate of special charge in cents per 1,000 cu. ft. of volume of waste.

F = factor for converting parts per million to lbs. per 1,000 cu. ft.

P_c = contract price of chlorine in cents per lb.

C = concentration, in parts per million, of chlorine demand of the waste.

N_c = normal dry weather chlorine demand of raw sewage in parts per million of sewage as received at the treatment works.

P_s = cost in cents for chemicals used in sludge conditioning and for power for disposal of solids resulting from one lb. of suspended solids received in the raw sewage at the sewage treatment works.

S = concentration, in parts per million, of suspended solids of the waste.

N_s = normal grit-free suspended solids in parts per million of raw sewage as received at the treatment works.

"The factor P_c may vary from year to year according to the contract price for chlorine and the factor P_s may vary according to the costs of chemicals and power involved in the disposal of solids as determined from operations for the previous year or previous two years. The factors C and S may be established by analyses (periodic or otherwise) to obtain average concentrations to be applied for any agreed length of period."

New Brunswick, N. J., decided on "treatment of all wastes at the municipal plant, without pretreatment by industry" and set up industrial waste charges by means of a city ordinance in February, 1944, in which it states:

"The charges for factory effluents or industrial wastes discharged into the city sewers or tributaries thereof, shall be fixed and determined according to flow, suspended solids and chlorine demand, according to the following schedule of rates:

$22 per million gallons.
$ 5 per ton sludge solids.
$ 5 per 100 lb. chlorine demand."

Experience at Buffalo to date has been successful in the application of such charges. Where questions of concentration were raised, co-operative study and friendly negotation were the means of solving the problem. The income from these special charges is an appreciable item in defraying that portion of the cost of operation attributable to the excess chlorine demand and suspended solids in the industrial waste.

About New Brunswick, Mayor Paulus (18) stated his belief

"that if industrialists are willing and do co-operate that most industrial wastes can be handled in adequately designed sewage treatment plants constructed for the treatment of domestic sewage, but, in this co-operation, the industrialists must be prepared to pay their full share of the cost of plant enlargement and plant operation."

Summary

In a broad review of a problem of the size and complexity of that of industrial waste disposal, the discussion of details must perforce remain subordinated. Even so, the presentation may run to some length. It is well, therefore, to recapitulate certain salient points worth bearing in mind.

Not only may waste discharges involve economic loss to the industry in some cases, but damage to receiving bodies of water may constitute an economic loss.

Pollution abatement programs will involve the expenditure of several hundred million dollars in the postwar period. These programs may be initiated generally by surveys conducted by governmental bureaus or political subdivisions thereof. Studies by trade associations will aid materially in the abatement programs.

Pollution abatement should be given first consideration on the basis of drainage basin or other hydrologic region, but municipalities may wish to undertake the solution of their own problems. In making an industrial waste survey, a municipality must consider that (1) each industry may have a variety of specific problems, (2) co-operation with industry is essential, (3) by-product recovery is not always the solution, and (4) final solution of the problem may involve complete elimination of the waste, pretreatment of the waste before discharge into the city sewers, or acceptance of the waste for treatment by the municipality.

If industrial wastes are accepted in the sewers for treatment at the municipal plant, it is both fair and equitable that industry should pay its share of the cost of such treatment. Equitable means of charging industry can be developed on the basis of volume and concentration of constituents.

Industrial Waste Disposal is the problem of Today; its solution should be a definite part of the postwar planning for Tomorrow.

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Stream Pollution

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

I. Surveys

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Certain of the lakes at Madison, Wisconsin, especially those receiving storm and sanitary sewer drainage, have become notorious because of their algal blooming, resultant offensive odor conditions, and the methods of control which have been practiced. Attention was directed to Lake Monona at an early date. Copper sulfate treatment of that lake was begun in 1918 and has been continued each season since. Lakes Waubesa and Kegonso have been of considerable concern during the past 10 years and have received treatment with copper sulfate since 1935.

Sewage Treatment at Madison, Wis.

The City of Madison is served with a separate sanitary system, the construction of which was started in 1886. Raw sewage was disposed of in Lakes Monona and Mendota, mainly the former, until 1899. From 1899 to 1902 chemical treatment of the sewage was practiced and the effluent disposed of in Lake Monona. A septic tank-filter bed combination was used in the period 1902 to 1914, with Lake Monona receiving all the effluent. From 1914 to 1926 the sewage was treated by plain settling and contact beds followed by trickling filters (Burke Plant), the unsettled filter effluent going directly to Lake Monona. In 1926 the first unit of the present Nine Springs Plant employing an Imhoff-trickling filter system, with drainage to Lake Waubesa, was put into operation to relieve the much overloaded conditions at the Burke Plant. In 1936 the Burke Plant was closed and all sewage was sent to the Nine Springs Plant which had been enlarged with activated sludge facilities for treating the additional load. Since 1936 all treated sewage of the metropolitan area has been discharged to Lake Waubesa. Additional activated sludge facilities were completed at the Nine Springs Plant in 1940.

During 1942 the U. S. Army leased the abandoned Burke Plant and remodeled it for use in treating the wastes from Truax Field, an A.A.F.T.S. The plant was placed in operation during October, 1942, and has been discharging its effluent into Lake Monona.

Fig. 1.—Map of Madison lakes.

Figure 1 is a map which shows the Madison Lakes Area and the location of the sewage treatment plants now in operation.

Legislation

During the last 30 years, there has been a growing conviction among the lake shore residents of Lakes Monona, Waubesa and Kegonsa that much of their lake odor problem was related to the disposal of treated and untreated sewage in those bodies of water. By 1941 the lake shore residents, through the medium of the Southern Wisconsin Lakeland Assoc. and local improvement associations, had become well enough organized to introduce and have passed by the Wisconsin legislature a bill designed to make it unlawful for the Madison Metropolitan Sewerage District to dispose of sewage or treated sewage in Lakes Monona, Waubesa, or Kegonsa, the lakes in the drainage area below the City of Madison.

The bill, as passed by the legislature, was vetoed by the Governor, but only after he had secured a fund of $10,000 from the Madison Metropolitan Sewerage District to finance an investigation of the lake nuisance. In due time, a Committee was appointed by the Governor, that met with the approval of all parties, to direct the course of the investigation and to report the findings to the Governor.

Nature of the Investigation

The Governor's Committee chose as the first phase of their investigation to make a one-year survey of the sources and quantities of all fertilizing matters entering Lakes Monona, Waubesa and Kegonsa. This decision was based mainly on the belief that at least 95 per cent of the odor nuisances created by the lakes were a direct result of decomposing algal deposits along the shorelines and that these growths were largely a direct result of food material entering the lakes in the form of fertilizing minerals, nitrogen, phosphorus, potassium, etc. Consequently, gaging and sampling of all significant tributary waters were instituted. Samples for chemical analysis were collected from all tributaries once each week. During the last six months of the survey, daily samples were taken from three of the main tributary creeks, Door, Nine Springs, and Starkweather. The location of gaging and sampling stations is given in Figure 1. The survey was started in July, 1942, and continued through June, 1943.

Biological studies on the lakes were begun in December, 1942, and have been continued over a period of sixteen months. These studies

Table I.—*Physical and Chemical Characteristics of Certain Southeastern Wisconsin Lakes*

Lake	Direct Drainage Area (sq. mi.)	Lake Area (sq. mi.)	Mean Depth (feet)	Alkalinity (Range) (p.p.m.)	Inorganic Nitrogen		Inorganic Phosphorus	
					Summer Minimum (p.p.m.)	Winter Maximum (p.p.m.)	Summer Minimum (p.p.m.)	Winter Maximum (p.p.m.)
Mendota *	264	15.20	39.7	145–180	.06	.36	<.01	.03
Wingra *	6	.75	8.9	144–250	.07	.53	<.01	.02
Monona *	32	5.44	27.5	155–194	.07	.91	<.01	.10
Waubesa *	45	3.18	16.1	150–230	.19	2.49	.24	.57
Kegonsa *	71	4.91	15.1	150–236	.07	2.03	.16	.35
Como	9	1.45	<6.5	178–261	.09	.19	<.01	.01
Delevan	35	2.83	26.2	126–182	.06	.87	<.01	.07
Geneva	36	8.76	64.7	118–182	.05	.14	<.01	<.01
Koshkonong	2,533	14.80	—	119–292	.12	1.32	<.01	.06
La Belle	14	1.77	10.8	168–203	.07	.26	<.01	<.01
Lauderdale (Mill)	12	.46	8.2	150–212	.06	.20	<.01	<.01
Nagawicka	46	1.43	36.1	144–218	.08	.88	<.01	.03
Nemahbin (Upper)	—	.42	29.5	160–199	.05	.65	<.01	.02
Oconomowoc	3	1.27	29.8	161–196	.04	.15	<.01	.01
Okauchee	10	1.65	39.6	143–206	.05	.21	<.01	.01
Pewaukee	20	3.59	12.8	165–215	.06	.21	<.01	<.01
Rock	11	1.91	20.0	151–182	.07	.11	<.01	<.01

* Madison, Wisconsin lakes.

were initiated to ascertain whether or not any correlation existed between fertilization, nature of algal blooms, and productivity in general.

For comparative purposes, 12 other lakes of southeastern Wisconsin, all hardwater lakes, have been studied from a chemical and biological viewpoint. Samples have been collected from these 12 lakes on an average of once every five weeks since April, 1943. Table 1 is presented to show how the surface waters of these lakes compare with those in the Madison group.

Results of Lake Fertilization Survey

The objective of the survey was to settle, if possible, a time-worn argument as to whether domestic wastes or agricultural drainage was the principal contributor of the fertilizing elements, nitrogen, phosphorus, potassium and sulfur entering Lakes Monona, Waubesa and Kegonsa.

The studies on sulfur were short-lived because it was soon established that all the local lake waters contained a considerable excess of this element, usually in concentrations greater than 6 p.p.m., even during the summer growing period. Potassium determinations were made at intervals throughout the year survey and rarely did the concentration drop below 1.5 p.p.m., and no consistent depletion occurred in all the lakes during the growing season. In view of these facts, it did not appear feasible that the addition of large quantities of these two elements in sewage or sewage effluent could be an important factor in increasing the blooming of the Madison lakes.

On the other hand, all of the lakes studied showed a marked reduction in available nitrogen (inorganic forms) in the surface waters during the seasons of rapid growth. In practically all cases the concentration decreased to values less than 0.10 p.p.m. sometime during the summer. The results obtained for inorganic phosphorus were quite different, however. In lakes receiving little or no sewage pollution, the concentration seldom exceeded 0.01 p.p.m. during the warm months, while in Lakes Waubesa and Kegonsa, which receive all the drainage from the City of Madison, directly or indirectly, the concentration normally exceeded 0.20 p.p.m. during the summer months. It may be concluded, therefore, that lakes receiving domestic sewage or biologically treated domestic wastes, to any marked degree, will never lack for phosphorus.

Since it appeared that nitrogen and phosphorus were two of the critical elements which could act as limiting factors in the plankton productivity of the lakes, the survey included measurement of these elements in all significant forms.

The results obtained during the year for inorganic nitrogen (ammonia, nitrite and nitrate nitrogen) are shown in Figure 2. The outstanding fact to consider is the large percentage of the contribution to Waubesa made by the Madison sewage plant effluent, 76.9 per cent or a total of 660,000 lbs. Lake Kegonsa received 67.2 per cent of its inorganic nitrogen in the drainage from Waubesa, via the Yahara River. This is reasonable since large quantities carry through Waubesa during the winter months when biological usage is restricted by low temperatures as will be discussed later.

Starkweather Creek had its contribution of inorganic nitrogen augmented during May and June by sewage effluent from Truax Field. Nine Springs Creek carried seepage wastes from a rendering plant and wastes from a large dairy. These industrial wastes were generous contributors of phosphorus, also.

The only creek which was a large contributor of inorganic nitrogen, and which to our knowledge carried no domestic or trade wastes, was

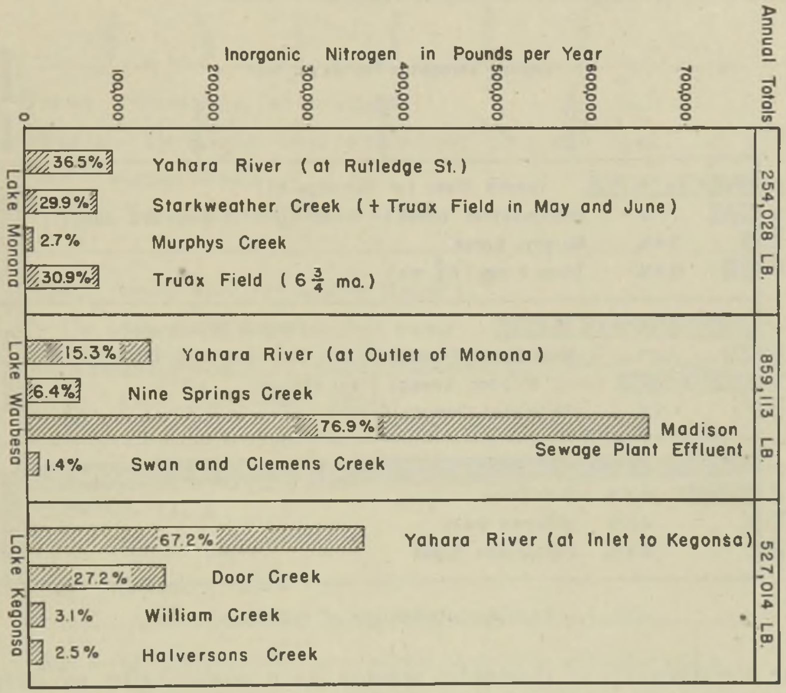

FIG. 2.—Annual contributions of inorganic nitrogen to Madison lakes.

Door Creek. It should be mentioned that this creek drains a very well developed marsh agricultural area as well as a highland agricultural area. During the non-growing season, especially during February and March, of this particular year when soil percolation was at a maximum due to unfrozen ground conditions, the nitrate nitrogen in the creek water often exceeded 10 p.p.m. Thus, it appears that such well developed marsh areas can be large sources of nitrogen for fertilizing lakes and streams, during the winter months.

The story regarding organic nitrogen is very much different and is shown in Figure 3. From this, it will be noted that the drainage from lakes is the most important source of this secondary fertilizing material and that Monona and Waubesa each released more organic nitrogen than they received. Since it is generally recognized that a large proportion of the plankton organisms formed in a lake eventually die and settle to the bottom, it becomes readily apparent that a tremendous conversion of inorganic nitrogen to organic nitrogen takes place during the growing season. Furthermore, these data show that sewages, even after biological treatment and secondary clarification, are also important sources of organic nitrogen. During the course of the year, the waters flowing from Monona carried approximately 144,000 lbs. of organic nitrogen and the waters from Waubesa carried approximately 328,000 lbs. This increase is much greater than the increase in lake water discharge from the two lakes and indicates that Waubesa is at least twice as productive as Monona.

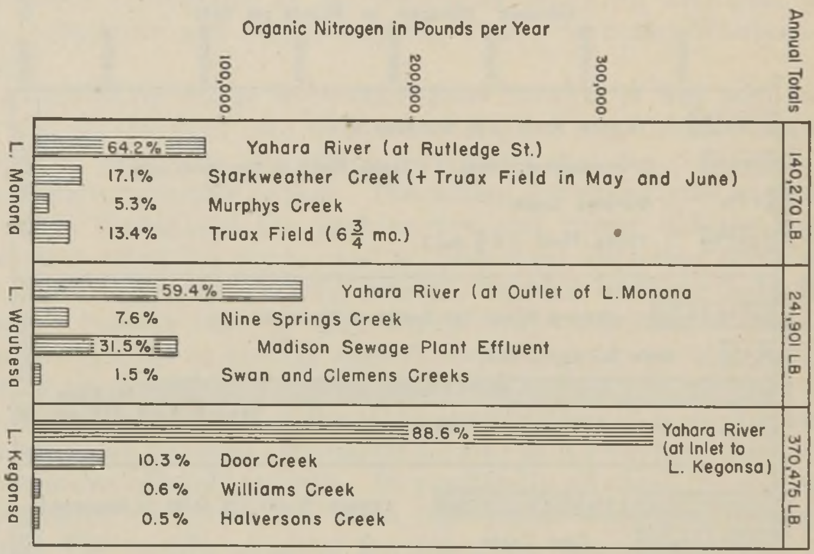

Fig. 3.—Annual contributions of organic nitrogen.

The significance of domestic wastes as a contributor of inorganic (soluble) phosphorus is shown in Figure 4. During the eight and one-half months that the Truax Field sewage effluent entered Monona, it contributed approximately 75 per cent of the inorganic phosphorus which entered the lake during the entire year. 89.2 per cent of the inorganic phosphorus entering Waubesa originated from the Madison sewage plant, and 98.2 per cent of the phosphorus entering Kegonsa was from Waubesa. It should be noted that Door Creek, which was a generous contributor of inorganic nitrogen, was a relatively poor contributor of inorganic phosphorus. Thus, it may be concluded that agricultural drainage in the Madison area is normally an unimportant source of this important fertilizing element.

No measurement was made of the quantities of fertilizing minerals entering Mendota, Wingra or the other 12 southeastern Wisconsin lakes under observation. Of these 14 lakes, Koshkonong is the only one which receives appreciable amounts of fertilizing minerals from sewage. Geneva, Mendota, and Nagawicka receive creek or river waters containing sewage from small villages and cities. The data given in Table 1 shows that none of these lakes can be compared on a basis of fertilizing mineral content with Monona, Waubesa or Kegonsa, especially during the winter months. It should also be noted that the soluble phosphorus content of all the lakes except Waubesa and Kegonsa falls to values less than 0.01 p.p.m. during the summer months. There has been very little agitation for chemical treatment to control

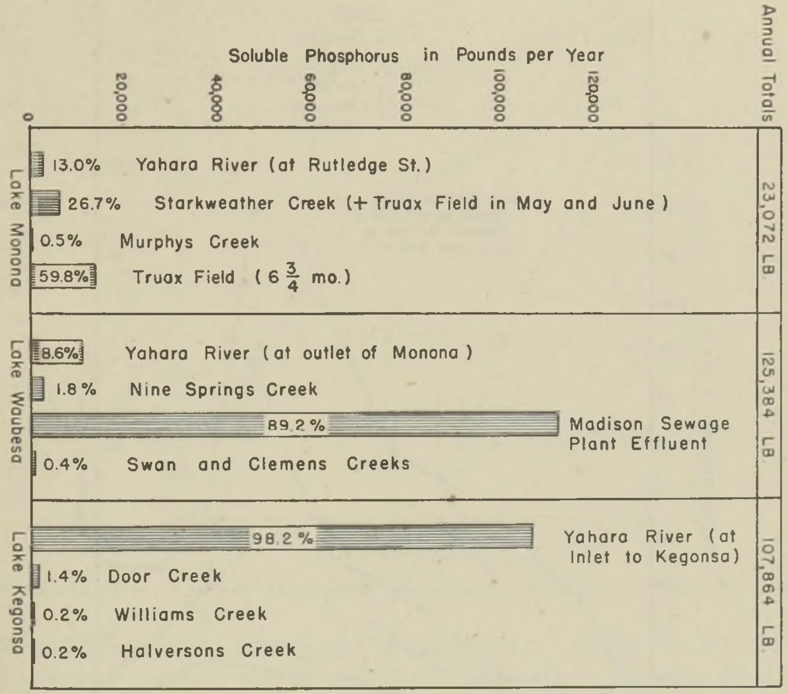

FIG. 4.—Annual contributions of soluble phosphorus to Madison lakes.

algal growths in the lakes with low phosphorus and nitrogen concentrations, Delavan, Nagawicka and Pewaukee being the only exceptions.

Biological Utilization of Inorganic Nitrogen

Although it has been known for some time that the concentration of nutrient elements in lake waters increases during the winter months and decreases during the summer months, it has not always been conceded that this change is a result of varying biological activity. Figure 5 is a presentation of data obtained over the course of one year which show that minimum concentrations of inorganic nitrogen were always encountered during periods of greatest biological activity, as measured by suspended organic matter in the lake waters. This figure also shows in graphic manner the relative potency of the different

Madison lake waters from the viewpoint of fertilizer content, during the various seasons of the year.

The data shown in Figure 6 are more specific than those in Figure 5 and demonstrate that marked quantities of inorganic nitrogen are used during periods of algal blooming. The data also show that the greatest reduction in inorganic nitrogen occurred in the waters near the surface and that the deeper waters serve as an enormous reservoir for furnishing additional inorganic nitrogen to support blooms later in the season.

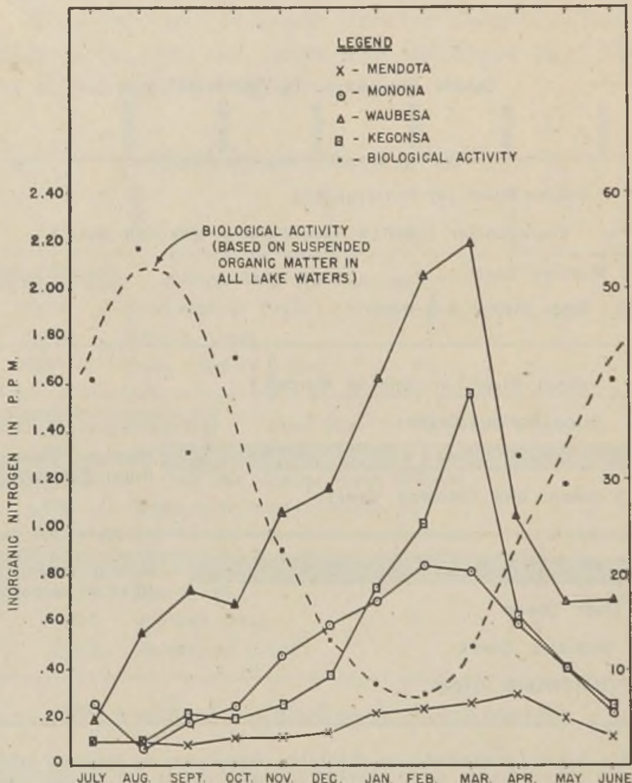

FIG. 5.—Relationship between biological activity and inorganic nitrogen content of effluent waters from the Madison lakes.

Discussion

The great productivity of Lakes Monona, Waubesa and Kegonsa has been a vexing problem to many. The continued blooming of Monona even after the transfer of the major portion of the domestic wastes to the lower lakes has proven even more vexing. To those familiar with the abuses to which Monona has been subjected and with the fertilizing potency of ordinary sewage, sewage effluents, sewage sludges and certain industrial wastes, this problem is not so perplexing. A consideration of the amounts of inorganic nitrogen and phosphorus which reaches each lake per acre of area is quite revealing. These data are shown in Table II.

A normal application of nitrogen and phosphorus to farm lands seldom exceeds 30 and 12 lbs. per acre, respectively, and such applications are not usually made more than once every 3 or 4 years. Thus, it can be deduced that the Madison lakes are being fertilized from 2.5 to 15 times as heavily as ordinary farm land. Swingle and Smith (1) have reported that an application of 8 lbs. of nitrogen per acre per month is optimum for fish production and that applications in excess

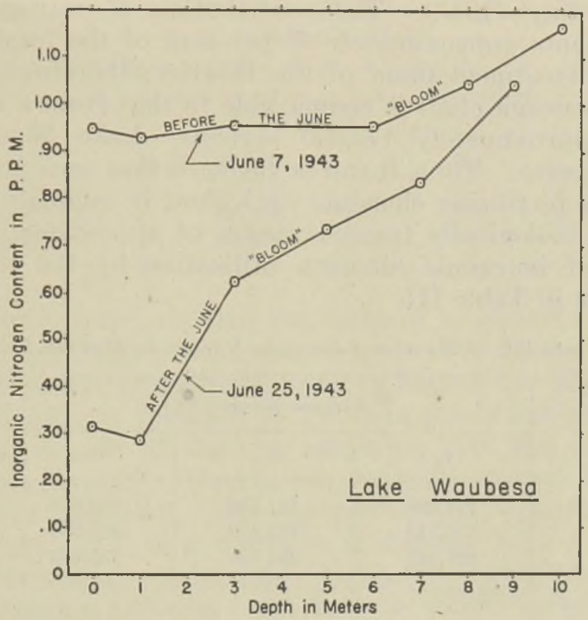

FIG. 6.—Relation of Algal "blooming" to reduction of inorganic nitrogen content.

of this value result in decreased productivity. With the 6- to 7-month active growing season which exists at Madison, it appears that a loading of about 50 lbs. per acre per year would be optimum. On this basis, the Madison lakes receiving domestic and industrial wastes are being fertilized from 1.5 to 8.5 times as heavily as would be recommended for maximum fish production. None of these bodies of water are considered good fishing places at the present time. What part copper sulfate treatment has had in influencing fish development is open to question. It is significant that Waubesa, the most heavily fer-

TABLE II.—*Fertilization of Madison Lakes*

Lake	Inorganic Nitrogen (lbs. per year)		Inorganic Phosphorus (lbs. per year)	
	Per Lake	Per Acre	Per Lake	Per Acre
Monona	254,028	73	23,072	6.6
Waubesa	859,113	422	125,384	62.2
Kegonsa	527,014	168	107,864	34.2

tilized of all the lakes studied, is the most productive of algal blooms. Extensive blooms even occur on occasion under the ice in Waubesa and Kegonsa.

Another way of illustrating the extent of fertilization of Waubesa is to estimate the population loading per acre of area. The Madison Metropolitan Sewerage District serves a population of approximately 100,000 people in addition to accepting the partially treated wastes from a packing plant with an average kill in excess of 5,000 hog units per working day (1943). The contribution of nitrogen from this source represents approximately 30 per cent of the total nitrogen received at the treatment plant of the District; therefore, the nitrogen reaching the sewage plant is comparable to that from a domestic population of approximately 143,000 persons. Lake Waubesa has an area of 2,040 acres. Thus, it can be deduced that each acre of the lake is enriched by fertilizing elements equivalent in quantity to those contained in the biologically treated wastes of approximately 70 people.

A study of inorganic nitrogen utilization by the three Madison lakes is shown in Table III.

TABLE III.—*Utilization of Inorganic Nitrogen by Madison Lakes*

Lake	Inorganic Nitrogen (lbs.)			Per Cent Used
	In	Out	Used	
Monona	254,028	131,350	122,678	48
Waubesa	859,113	423,413	435,700	51
Kegonsa	527,014	284,350	243,664	46

It will be noted that although the loadings on the three lakes varied in the ratio of approximately 1:3:2, the percentage of the nitrogen utilized was surprisingly constant. This would seem to indicate that none of the lakes was over fertilized to such an extent that the food material present could not be utilized to full advantage during the growing season. The fact that only about one-half of the nitrogen was used requires some sort of justification. The explanation is offered that the per cent utilization is governed by the climatic conditions at Madison, which allow nearly complete usage in the summer and little usage in the winter. See Figure 5 for further explanation.

Since Waubesa has an area of 3.18 sq. mi. and Monona an area of 5.44 sq. mi., the data in Table III indicate that Waubesa is about 6 times as productive as Monona. Suspended organic matter and organic nitrogen data show Waubesa to be from 3 to 3.6 times as productive as Monona.

A comparison of the amounts of inorganic nitrogen released by each of the lakes to the next one in the chain is shown in Table IV. These data show the marked influence of sewage fertilization on the lakes receiving domestic wastes and the carry over effect from one lake to the next one in the chain. The fact that Monona released 3.5

times as much inorganic nitrogen as Mendota indicates that it is still quite heavily fertilized, as was found to be the case during the course of the survey, but that it in no way compares to Waubesa which released 11 times as much inorganic nitrogen as Mendota and over 3 times as much as Monona. The effluent waters of Kegonsa carried considerably less inorganic nitrogen than did those from Waubesa. The latter demonstrates the protective action of each lake in a chain to succeeding members.

TABLE IV.—*Inorganic Nitrogen Released from Madison Lakes (July, 1942 to July, 1943)*

From	Inorganic Nitrogen (lbs.)	Avg. Lake Discharge (c.f.s.)	Inorganic Nitrogen (lbs. per c.f.s. per yr.)
Mendota to Monona	37,600	92	410
Monona to Waubesa	131,350	121	1,085
Waubesa to Kegonsa	423,413	172	2,460
Kegonsa to Yahara R.	284,350	205	1,390

It should be pointed out that the value of inorganic nitrogen given in Table IV for Mendota does not correspond with the value for the Yahara River contribution to Monona in Figure 2. The latter value represents the amount released by Mendota plus additions from storm and industrial sewers of the city emptying into the river along its course through the city. During the year, the sewers accounted for 59.5 per cent of the total. The contribution of Monona to Waubesa is, of course, greater than it would be if Monona did not receive storm water, sanitary sewage and industrial wastes. Another factor in the release of inorganic nitrogen from Monona which tends to increase it somewhat is the restricting action of copper sulfate treatment on biological growths in the lake.

TABLE V.—*Retention of Nitrogen in Madison Lakes*

Lake	Total Nitrogen (lbs.)			Per Cent Retained
	In	Out	Retained	
Monona	394,298	274,500	119,798	31
Waubesa	1,101,014	433,700	667,314	61
Kegonsa	897,489	620,150	277,339	31

A study of the total amount of nitrogen leaving a lake as compared to the amount entering the lake in all forms should give valuable information in regard to the rate at which bottom mud deposits are enriched by deposition of nitrogenous matter. A comparison of the three lakes is shown in Table V. These data show that over 5 and 2 times as much nitrogenous matter is deposited in Waubesa and Kegonsa, respectively, as is deposited in Monona. When corrections are made for lake areas (Table I), the data show that the bottom deposits are being enriched in the ratio of approximately 1:3:10 for Monona, Kegonsa and Waubesa. With such tremendous deposits of unstable nitrogenous matter as are occurring annually in Waubesa and Kegonsa, it seems logical to conclude that such deposits will serve to furnish large amounts of fertilizing minerals to the overlaying waters for several years to come. Thus, it seems likely that Monona is being fertilized to a large extent at the present time from deposits laid down during the many years it was the recipient of the sewage of the city of Madison. Therefore, even though all sewage be diverted elsewhere, it seems likely that extensive blooming of Waubesa and Kegonsa will occur annually until the bottom deposits have become well stabilized. Whether this will require 1, 5 or a greater number of years, no one has yet determined.

The importance of lake shore residences as sources of lake fertilization was investigated. A survey was conducted during the winter months to determine the number of cottages that could be considered occupied 12 months of the year. All others were assumed occupied 4 months of the year and the number of occupants taken as 3 each. On this basis, the cottage contribution to Monona was estimated at 5 per cent of the quantity contributed by Truax Field and the contributions to Waubesa and Kegonsa at less than 1 per cent of the total input to each lake.

Much significance has been attached to storm sewer drainage as a source of fertilization in Lake Monona. The investigation showed that storm sewer drainage was comparable to ordinary surface runoff from agricultural lands, being quite high in silt and inert material. The samples collected during the first 6 months of the survey (fall season) were richer in soluble phosphorus than those collected during the last 6 months. This difference was attributed to the practice of burning leaves in the streets during the fall, as much of the ash from the leaves was washed to the storm sewers before cleanup crews arrived.

The discussion of this point has made no reference to the possibility of nitrogen fixation from the atmosphere by certain algal forms. In lakes which are as richly fertilized with all the essential fertilizing minerals as the Madison lakes, it seems highly probable that such reactions may proceed simultaneously and enrich still further the bottom deposits in the lakes. On the other hand, the lakes which do not receive sewage pollution to any appreciable degree such as Geneva, Okauchee, Oconomowoc, La Belle, Lauderdale, Nehmahbin and Rock do not produce troublesome blooms of blue-green algae, the nitrogen fixers. Therefore, it would seem logical to conclude that the Madison lakes in time, in the absence of sewage pollution, would shed their ability to produce such heavy blooms of these troublesome algae.

It is recognized that domestic sewage contains certain organic substances which may act as stimulators to plant growth, especially when such a rich medium is involved. No attempt was made to ascertain the amounts of these substances contributed from the various sources, it being held that such substances in the absence of plentiful supplies of the basic nutrients, nitrogen and phosphorus, would be impotent in producing algal blooms.

Summary

A twelve-months fertilization survey of three Madison, Wisconsin, lakes has shown non-agricultural drainage to be the major contributor of inorganic nitrogen and inorganic phosphorus. For instance, Lake Waubesa received 76.9 and 89.2 per cent of these fertilizing elements, respectively, from the effluent of the Madison sewage treatment plant.

Lakes Monona, Waubesa and Kegonsa received 73, 422 and 168 lbs. of inorganic nitrogen per acre, respectively, from inflowing waters during the year of survey.

The net conversion of inorganic nitrogen to organic forms varied from 46 to 51 per cent in the three lakes under study.

The concentration of inorganic nitrogen in the surface waters of the lakes was found to be related to the biological activity, as influenced by temperature and light intensity. Algal blooming was shown to reduce inorganic nitrogen concentrations markedly.

Lakes receiving appreciable amounts of raw or biologically treated sewage are characterized by plentiful supplies of inorganic phosphorus during all seasons of the year. Lakes receiving limited amounts of sewage show abnormal concentrations during the winter months only.

Results of studies on 12 additional southeastern Wisconsin lakes correlated very well with the findings obtained on the five lakes at Madison, Wisconsin.

Reference

1. Swingle, H. S., and Smith, E. V., "Fertilizers for Increasing the Natural Food for Fish in Ponds," *Trans. Amer. Fisheries Soc.*, 68, 126–134 (1938).

STREAM POLLUTION CONTROL IN PENNSYLVANIA *

By Dr. A. H. Stewart

Secretary of Health and Chairman, State Sanitary Water Board, Harrisburg, Pa.

It is a great pleasure to meet with the Federation and to present some of the problems confronting us in Pennsylvania in connection with stream pollution control. The Pennsylvania Department of Health has had an interest in the Federation of Sewage Works Associations from the time of its organization. Seventeen years ago the Department fostered the creation of the Pennsylvania Sewage Works Association, the host for this convention, and has maintained a constant interest in its activities. It was felt that such an organization was greatly needed in the sewage treatment field and this has been amply justified by its accomplishments. The Federation in a larger way has followed the same principle and co-ordinated similar efforts throughout the United States, Canada, and abroad. Its success has been phenomenal and I extend my congratulations for the excellent work done and my best wishes for continued success.

Wherever you have communities there are problems of waste disposal. These become more complex as the population increases. Pennsylvania with its 10,000,000 population ranks second in size among the states, only New York exceeding it. It is rectangular in shape, being 300 miles long east and west, and 160 miles wide, north and south. It contains 45,000 square miles of land area and in 1940 had a population density of 219.8 per square mile, being the sixth state in that respect. Its topography is quite varied, a dominant feature being the Allegheny Mountains, whose ranges are vast and in many instances rugged. They extend diagonally approximately through the center of the state from the northeast to the southwest and serve as a divide between the Susquehanna River basin on the east and the Ohio River basin lying to the west.

Pennsylvania is unusually well blessed with streams. If all of the named streams in the state were placed end to end they would form one stream 100,000 miles long, or the equivalent of four times the circumference of the earth. These range from the small mountain brook to mighty rivers, on some of which the commerce of the nation is carried.

There are six principal drainage basins in Pennsylvania. On the east lies the Delaware River basin, the river forming the dividing line between Pennsylvania and New Jersey, and draining 15 per cent of the state's area. Adjoining it on the west is the Susquehanna River basin, the largest in the state and draining nearly 50 per cent of its area. The western edge of the basin lies in the Allegheny Mountains, west of which is the Ohio River basin accounting for about 35 per cent

* Presented at 17th Annual Meeting, F.S.W.A., Pittsburgh, Pa., October 13, 1944.

of the state's area. Three others comprise the Potomac River along the southern border, the Genesee draining to New York State, and the area tributary to Lake Erie in the northwestern corner; all quite small.

Each of the main rivers has important tributaries, which are large rivers in their own right. For example, the Schuylkill and the Lehigh Rivers in the Delaware basin; the North and West Branches of the Susquehanna River; the Allegheny and Monongahela Rivers which form the Ohio River at Pittsburgh and the Beaver River entering the Ohio near the state line. All told, there is a vast network of streams constituting a natural resource of untold benefit to the citizens of Pennsylvania.

Along the banks of these streams and scattered over their watersheds are the nearly 1,000 incorporated municipalities in Pennsylvania. These comprise 49 cities, 935 boroughs and one incorporated town. In addition, there are numerous densely populated sections of townships. In these communities and on the farms of the state, reside Pennsylvania's 10,000,000 citizens, whose lives are so intimately connected with the streams of the state.

It is the task of the Department of Health and the Sanitary Water Board practically and wisely to control stream pollution in order that this invaluable natural resource may be preserved for the benefit of all. Its particular duty is to keep clean streams clean and to improve the condition of those already polluted.

All of our cities, most of the larger boroughs and many of the township communities are sewered, and through these systems are daily discharged millions of gallons of sewage, much of it untreated, into state waters. Less than 300 sewage treatment works have been built in Pennsylvania and a large proportion of these are to be found in the smaller communities. Consequently, the great centers of population together with their satellite communities are the chief offenders in the matter of stream pollution. This does not signify that communities of smaller size have less relative responsibility to care for their own particular wastes, but is merely cited to show the scope of the problem confronting the state.

A somewhat similar situation exists with regard to industrial wastes, of which there is a great variety, and some extremely harmful to our streams. Considerable has already been done to alleviate this condition, but there is sufficient task ahead to challenge the efforts of everyone concerned. For some of these wastes known processes of treatment are at hand, while for others somewhat less is known and study is being made to devise practical means of treatment. It is all part of the general problem of stream pollution and must be faced frankly and fearlessly.

Aside from the mere fact that streams should be clean, there is in Pennsylvania a more urgent reason and that is the fact that the sources of public water supply for the 1,000 public water works in the state are usually the surface streams. Relatively, Pennsylvania does not rely much upon underground supplies but makes use of the streams with which the state is plentifully endowed; hence, it is of vital moment to protect these sources of supply used by 8,000,000 Pennsylvania citizens. Of course, the water supplies are safeguarded by filtration and chlorination, some 6,000,000 people receiving water both filtered and chlorinated, and about 2,000,000 being served with water not at present needing filtration, but which is chlorinated. Thus, if for no other reason, we should have clean streams.

History of Stream Pollution Control

A brief review of the background of stream pollution control will be of interest. Efforts for such control date back many years but not until 1905 was there legal backing. In that year the Purity of Waters Act was passed coincident with the organization of the Department of Health, giving the Department jurisdiction over the discharge of sewage into state waters. It should be noted that there was no similar control over trade wastes produced by industry. Such legal control was not granted until 1937. The 1905 Act required all municipalities to file a report and plans of existing sewer systems. These basic data have been added to in subsequent years by the submission of other plans and reports and now constitute a record of great volume.

Under the provisions of the Purity of Waters Act, no sewer system could be built or existing system extended, or additional discharge of sewage be made without first securing a permit from the Department of Health. Such permits were issued by the Commissioner of Health, later called the Secretary of Health, upon unanimous consent of the Governor, the Attorney General and the Commissioner of Health. Later, the procedure was changed and this power was vested in the Sanitary Water Board.

In 1923 reorganization occurred for the conduct of the work of the Commonwealth, and in connection therewith the Sanitary Water Board was created and placed in the Department of Health. As at present constituted it is the administrative board within the Pennsylvania Department of Health having jurisdiction over all matters relating to the pollution of state waters. It comprises three ex-officio members, the Secretary of Health, as Chairman, the Secretary of Forests and Waters, the Commissioner of Fisheries, and three members appointed by the Governor. The Board's personnel today consists of Dr. A. H. Stewart, Secretary of Health, Chairman; James A. Kell, Secretary of Forest and Waters; Charles A. French, Commissioner of Fisheries; Dean Elmer A. Holbrook, and H. Rhea Klahr.

The Board is charged with the enforcement of the laws relating to the pollution of state waters, and with the investigation and report upon ways and means of preventing and eliminating such pollution. It administers the relevant portions of the Purity of Waters Act, the Stream Pollution Law of June 22, 1937, the Fish Law of 1917, and the Advisory Health Board's rules and regulations as these relate to stream pollution.

Whereas the Purity of Waters Act had as its objective the control of sewage discharge, the Act of 1937 upon which the Board mainly bases its activities for pollution control, goes far beyond the original 1905 Act. First of all it provides equal control over the discharge of trade wastes from industry, a power which was lacking in the earlier Act, but the scope of the law is more far reaching and includes additional features of stream life. This is well set forth in the definition of the term "pollution" which is defined to mean "noxious and deleterious substances rendering unclean the waters of the Commonwealth to the extent of being harmful or inimical to the public health, or to animal or aquatic life, or to the use of such waters for domestic water supply, or industrial purposes, or for recreation."

It should be noted that the definition uses the word "unclean," makes the powers of the Act applicable not only to public health but to "animal or aquatic life," and takes cognizance of the use of the Commonwealth's waters for "recreation." The earlier conception confined the Act exclusively to the purity of the waters of the state for the protection of the public health. This changed point of view is a reflection of the demands of the public that their streams shall be free from discharges harmful to animal or aquatic life or to their use for recreational purposes. In my opinion, this constitutes a distinct advance in the thinking of the general public, which demand was first of all that its health should be protected, and after that an insistence that other phases of stream use shall likewise be given consideration.

Growth of Sewerage

When the Department of Health was organized in 1905 most of the towns and cities in this Commonwealth were deficient in sewerage; even some large cities relied upon cesspools for disposal of household wastes. Allentown, having then a population of 40,000, and Lebanon with some 20,000 population disposed of their sewage in underground formations. Subsequently, many new systems were built and existing ones extended so that today there is scarcely a town of 2,500 population unprovided with sewers, and in fact, many places much smaller have public systems.

Some years ago an estimate was made of the total mileage of Pennsylvania's sewer system in use. Fancifully, it was stated that this total was equivalent to a fence four rails high around the entire border of the state, a distance of approximately 1,000 miles. Today, undoubtedly, this total is much larger, perhaps sufficient to add a fifth rail to the fence.

There has likewise been a growth in sewage treatment works, although not paralleling that of sewer systems. Again referring to 1905, there were then some 15 sewage treatment works in the entire state. Only three were in incorporated municipalities, the remainder being found in smaller communities and at institutions. Today, there are approximately 300 plants, both large and small. Nevertheless, there are many million gallons of untreated sewage discharged to the Commonwealth's streams, some of which are heavily polluted.

Added to the sewage load is that imposed by trade wastes from industry. Pennsylvania is highly industrialized and trade wastes are varied and contribute a very considerable burden upon already polluted streams. For example, we have the wastes from coal mines, collieries and washeries, quarries, steel mills, pulp and paper mills, tanneries, distilleries, T.N.T. plants, synthetic rubber plants, canneries, milk plants, textile mills, dye houses and many others.

It is true that many industries are treating their trade wastes but much remains to be done in that field, as well as in the treatment of sewage. This latter waste not only pollutes the streams but is dangerous to health because of the possible presence of disease producing germs.

Previous mention has been made of the issuance of permits, authorizing the discharge of sewage, and latterly of industrial wastes under conditions prescribed first by the Department of Health and since 1923 by the Sanitary Water Board. In sequence, an application is filed for the project in hand, an engineering study and report are made and the case is then presented to the Sanitary Water Board with suitable recommendations upon which, at the Board's option, a permit is either issued or denied.

Earlier in the existence of the Sanitary Water Board, in an attempt to solve in a practical manner the problems of stream pollution, a plan was devised for the classification of state streams. This plan later was abandoned but in a measure the principles then erected are still being applied. This classification was based upon a recognition of the facts and equities of existing conditions. Streams were placed in three categories, namely; Class A, B, and C, and they were so designated by official action of the Board after which they were placed with proper designation upon drainage maps.

Class A streams were those virtually in their natural state, free from artificial pollution and subject only to the surface washings from fields and forests and to such casual and minor contamination as is quickly dissipated by the stream.

Class B streams were those which are more or less polluted but capable of reclamation. Those remaining, or the Class C streams, were those so polluted as to be unusable for public water supplies; incapable of supporting fish life; not used for recreational purposes and where it would be extremely difficult or inadvisable to attempt to restore them to a clean condition. Notable in this class, are the streams in the coal fields, at present unusable because of their contamination by silt and acid drainage from coal operations.

At that time the policy of the Board was somewhat radical, but represented an advance in the field of stream pollution control and, as previously stated, the principles thus established are in effect today, and to some extent govern the action of the Board.

Future Plans

So much for the past; now let us consider the future, for the Board has very definite plans in this respect. The Sanitary Water Board believes that this is an opportune time to attack the problem on a state-wide basis. Whatever is accomplished along this line will have a bearing upon the health and welfare of the public. Moreover, the projects necessary to attain this end will fit in admirably with postwar work and provide employment immediately after the close of the war. We have strongly urged that municipalities and industries undertake the preparation of plans in order to be prepared for the day when the war ceases.

The Sanitary Water Board proposes that all sewage, before discharge to state waters, shall receive a minimum of "primary" treatment, consisting of quiescent sedimentation or its equivalent. This should remove about thirty-five per cent of the polluting matter. If conditions indicate the need, then complete treatment will be required, and such treatment should remove approximately eighty-five per cent of the pollution load. For intermediate conditions, intermediate degrees of treatment will be called for. Exception will be made in the case of those streams now receiving such large quantities of acid drainage as to render treatment of sewage of no public value at the present time.

Correspondingly, industrial wastes are to be treated to an equivalent degree. Likewise, the coal operators have been called upon to cease the discharge of silt to the streams.

In order fully to acquaint the public with these matters and to afford an opportunity for those interested to be heard, the Sanitary Water Board has conducted a series of ten hearings throughout the state. Prior to the date of a hearing, official notice of the time and place was given through advertisements in newspapers and legal journals and by means of registered mail to holders of permits issued by the Board. At the outset of each hearing, the Chairman of the Board explained in detail its purpose and plans, after which opportunity was afforded interested persons to present their views on the subject in order that the Sanitary Water Board might be guided in reaching a reasonable and equitable decision on what things had to be done to protect the waters of the Commonwealth.

Having reached final decision, the Board is preparing to issue orders to those responsible for the discharge of sewage and industrial wastes, informing them of the degree of treatment to be required of the sewage and industrial wastes before discharge into the waters of the state, and requiring the preparation and submission of plans for the treatment of the same. Judging by the interest with which these matters were received, the Board is inclined to believe that, in general, the public is convinced of the need for such a state-wide program and is hopeful that this interest will be translated into actual accomplishment.

It is difficult to estimate accurately the full scope of this work but it is believed that of the approximately 1,000 incorporated municipalities in Pennsylvania, some 500 of them will be affected, as well as several hundred industries. One good feature of the plan is that uniformity of requirements can thus be inaugurated for all communities and industries on a given watershed, or for specific parts of any stream. It is not the purpose of the Board to place intolerable burdens either upon municipalities or industries, but with a full realization that the time has arrived for concerted action, the Board will expect each municipality, industry or person responsible for the pollution of the state's streams, to do what is reasonable and practicable to improve their condition.

Policy on Coal Mine Wastes

Practically all the anthracite coal in the United States is located in Pennsylvania. Much of the western third of the state is underlain with bituminous coal. Mining and processing of coal produce acid waters and silt, more commonly known as culm. The disposal of silt is a problem which chiefly concerns the anthracite district, although in the bituminous district there is a somewhat similar problem arising from present day methods of processing. Over possibly a hundred years this silt has been discharged into state waters and some idea of its magnitude may be had when it is considered that in the Schuylkill River alone, there are 26,000,000 tons of silt, according to an estimate of the Army Engineers. In addition, there are vast mountains of silt throughout the entire anthracite district and enormous quantities are produced daily by the collieries and washeries.

As a part of the stream pollution control program, but constituting a distinct phase, the Sanitary Water Board has established a policy to govern the discharge of coal mine wastes into state waters. The Stream Pollution Law of 1937 definitely granted an exception from the general provisions of the Act for acid mine drainage and silt until such time as the Board arrived at the opinion that practical means for the removal of the polluting properties of such drainage had become known. After a careful and intensive study of this subject by the Engineers of the Department of Health, both in the field and the laboratory, and following conferences with the coal operators, the Board took official action declaring that practical means were known for the removal of silt from coal mine wastes, at the same time stating that at this time the Board knows of no practical method of general applicability for removal of the acid properties of mine drainage.

However, in this regard the Board recognizes the value of mine sealing, in which an extensive program was carried out in Pennsylvania. But the application of this method is to abandoned mines and not to active workings. Within limits, much can be accomplished in this field provided funds are made available.

Shortly following the enunciation of this policy, the Board adopted resolutions covering the details for the removal of silt in which definite dates are stated for the filing of data, and the preparation and submission of plans for works for the treatment of the silt wastes, all with the idea that the preliminaries in connection with this problem shall be undertaken without delay and the actual works constructed as soon as materials and labor become available.

Conclusion

To conclude, let me say that people have the right to clean streams. Numerous court decisions have upheld this right, which is well set forth in a recent decision of the Court of Common Pleas of Philadelphia County, Pennsylvania, in a case concerning the alleged pollution of the Schuylkill River. In this, the court said *inter alia:*

> "And nothing is more fundamental than the right of the people to have the public streams from which they draw their water supply, free from pollution. That right is supreme, for the simple reason that health and life itself depend on it. The people have the absolute right to have the 'ancient purity' of their streams preserved against all other considerations."

To this doctrine we heartily subscribe and the Sanitary Water Board will exert its best efforts to attain this goal, realizing that the problem can only be solved by the exercise of wise judgment and with justice to all concerned, and more than all, with the entire co-operation of all the citizens of the state.

THE OPERATOR'S CORNER

UNIFORMS FOR OPERATORS

A recent issue of *Sanitary Engineering News,* a fact packed newsletter edited by Prof. Don E. Bloodgood for the Purdue University School of Engineering, contains a brief editorial which is considered appropriate for repetition here. The editorial recommends that operation personnel in sewage and water works wear uniforms—a practice which has impressed us most favorably where we have seen it used:

> There are those who say that in time of war all uniforms have a certain amount of glamour and that there are tendencies for many to wish to wear some form of standardized dress, but this feeling is not the prompter of the following comments. Perhaps this is not an opportune time to discuss the matter of uniforms for employees of sewage purification and water treatment plants, but there are many good reasons why employees in these plants should dress uniformly, so why not talk about it now? In the first place, it is a badge of loyalty to the organization for which the employee works. For the employee it can be a satisfactory method of obtaining a good quality of clothing at a reduced price because of purchases in quantities. There are a few plants that now have their personnel wear uniforms. It impresses one favorably when visiting such a plant to see the employees well dressed and neat. It no doubt gives the employee a feeling of prestige that he would not have otherwise. Any attempt at improvement in appearance of either employee or plant surroundings or equipment tends to improve the efficiency of the work being done by the plant.

In war or peace, uniform dress by personnel engaged in public service functions has much to commend it. The principle advantages accrue in the way of public relations and, as pointed out by Prof. Bloodgood, they can be achieved at no cost or even with some saving in clothing costs to employees. When the public visits the treatment works, uniformed personnel impart an air of good organization and efficiency to the surroundings and anything that leaves the taxpayer with such an impression is unquestionably worthwhile! When the operation crew visits the public, as during sewer inspection and maintenance work, the fact that pride is taken by them in dress and appearance brings an equally desirable reaction.

This topic brings to mind a personal experience of some years ago when a sewage treatment plant was visited in an official capacity. The sight of an operator cleaning a bar screen in a freshly laundered white laboratory coat, obviously donned but minutes before, was such a transparent endeavor to make a favorable impression that it was amusing. A matched jacket and trousers in a practical blue, gray or tan, as commonly worn by filling station attendants, would be most appropriate, although a coverall type of garment in similar colors would be more suitable for "messy" jobs. The service being rendered is best identified by having the name of the municipality and department stitched into the cloth as a breast pocket ornament.

Why not give the idea a trial?

W. H. W.

STEEL PURCHASES FOR MRO TEMPORARILY LIMITED

M. D. Sullivan, Chief of the Sewerage and Sanitation Section of WPB, recently released Direction No. 1 to WPB Order P–141, which provides that orders for steel used in maintenance, repairs and operation must be reduced in the second quarter of 1945. The amount of steel which can be ordered by an operator during the second quarter of 1945 is limited to 80 per cent of the steel purchased for MRO during the same period of 1944. Release from the limitation may be granted under unusual circumstances.

The temporary limitation directive follows:

WAR PRODUCTION BOARD

PART 3287—GOVERNMENT SERVICES

[Preference Rating Order P–141, Direction 1]

TEMPORARY LIMITATION ON THE PURCHASE OF STEEL FOR MRO DURING THE SECOND QUARTER OF 1945

(a) Because of a shortage of steel in controlled material form during the second calendar quarter, the War Production Board urges operators to defer all MRO that is possible, and in doing necessary MRO, to use steel out of existing inventories to the greatest extent possible. In the absence of circumstances which cannot now be foreseen, this limitation will apply only in the second quarter and will not be extended beyond.

(b) No operator shall use the CMP Allotment Symbol MRO–P–141 to place orders for steel for delivery in the second calendar quarter of 1945, in excess of 80% of the steel he purchased for MRO during the second calendar quarter of 1944. Any operator who has already placed authorized controlled material orders by use of the MRO symbol for delivery in the second quarter of 1945 in excess of 80%, must cancel or reduce such authorized controlled material orders by the amount of the excess. This cancellation or reduction must be made at once, unless the operator finds it necessary to apply for relief in accordance with paragraph (c). Such application for relief must be made within 5 days of the date of this direction, and upon receipt of grant or denial of the application by the War Production Board, the cancellation or reduction, if any, then required, must be made at once.

(c) Any operator who has to do essential MRO during the second quarter which cannot be postponed, and who is prevented from doing so by this direction, may apply to the War Production Board, Washington 25, D. C., for permission to buy additional quantities of steel. The application may be made by letter, Ref: Direction 1 to Preference Rating Order P–141, and should state: (1) the amount of steel he is permitted to buy and amount and type of steel he requires in addition; (2) the reasons why the maintenance, repair or operation must be continued, cannot be deferred, and cannot be supplied out of inventory; and (3) why other maintenance, repair or operation cannot be deferred to provide the needed steel.

(d) This direction does not apply to any operator who will order for delivery less than 10 tons of carbon steel and less than 2 tons of alloy steel during the second quarter of 1945.

Issued this 28th day of March 1945.

WAR PRODUCTION BOARD,
By J. JOSEPH WHELAN,
Recording Secretary.

TRICKLING FILTERS—A DISCUSSION *

BY J. T. FRANKS

Chief, Water and Sewage Unit, Seventh Service Command, Omaha, Neb.

The past ten years have witnessed the renaissance of the trickling filter. About 1934 and 1935, the activated sludge process threatened

* Presented at Eighth Annual Meeting, Rocky Mountain Sewage Works Association, Denver, Colo., September 20, 1944.

to push other secondary treatment processes out of the picture. In the critical review of the literature of 1935 in the March, 1936, issue of *Sewage Works Journal,* the statement was made: "It is significant of the trend of the times that *This Journal,* including the Review Section, lists for 1935 only one reference to a sewage filter and this merely to methods of collecting samples." But during this period, men such as Halvorson, Savage and Piret in Minnesota; Mohlman and Wisely in Illinois; Levine, Luebbers, Galligan, and Vaughn in Iowa; Jenks in North Carolina and California; and others, did not share the belief of some that the trickling filter was through. In fact, they felt that the filter had never been used to its maximum capaciy and proceeded to carry on experiments in methods of distribution, application rates, recirculation, and types of media. These investigations brought out some very enlightening new information and revived some half-forgotten facts gleaned over the past forty years. During these last ten years considerable additional knowledge and some understanding has been accumulated but we do not know all the answers even now.

Before starting a discussion of any sort, it is well to define the topic, in order that we may be assured that we are all discussing the same thing; review the literature and books on the subject, so that we may avail ourselves of the knowledge of preceding investigators; and summarize the matter in a general way, thus providing a basis and starting point for discussion without needless repetition and delay.

A trickling filter, which is not a filter in the usual sense, may be defined as a bed of filtering media of various kinds, sizes, and shapes; and of varying depths and areas; over which settled sewage is distributed by diverse means and at difference rates; and where the sewage, upon trickling through, is so altered in character by complex biotic, chemical, and physical means as to render it sufficiently stable to be innocuous to health and to prevent nuisance downstream. As will be noted, this definition is very broad, but any attempt to make it more specific places upon it limitations which are subject to numerous differences of opinion.

Among the kinds of filtering media that have been and are being used are lath, coke, slag, tile or ceramic and rock. Each of these has been touted as being the ideal, or the nearest to the ideal, media. Experience has shown that they all have their advantages and disadvantages. The size of the material varies from one-quarter inch to six inches or larger; here again each size has its advantages and disadvantages. All have been used successfully. The shape of the media has also been the subject of considerable discussion but no really conclusive evidence one way or another has been presented. Filters vary in depth from 2½ ft. to in excess of 10 ft.—some have been reported up to depths of 19 ft. The area of the individual filter is dictated by the kind and amount of waste to be treated, the method of distribution, and the type of treatment required. Distribution is divided into two general kinds: fixed nozzles and various kinds of moving distributors. In this country the rotary type has become very popular. One of the major reasons for this trend has been the advent of the so-called capacity filter.

Inasmuch as most of the investigation of recent years has concerned high capacity filters, it may be well at this point to attempt to distinguish between the standard and high capacity type. The difference is sometimes hard to discern. In a general way, the difference lies in the method and rate of application of the sewage per unit of filter area. In order to clarify some of the differences, a method similar to that suggested by Dr. Montgomery in *Sewage Works Journal* of September, 1941, can be used advantageously.

In the first group occurs the "low daily capacity" or "standard" filter, generally consisting of a bed of media five or more feet in depth, onto which the settled sewage is discharged by means of either fixed nozzles or rotary distributors from a dosing chamber or pumps, at a daily average rate of from 0.5 to 5 or 6 m.g.a.d. The higher rates are generally maintained by recirculation of the final effluent to some point ahead of the filter. The sewage is dosed at a relatively high instantaneous rate per unit of surface area, with a rest period between dosing tank discharges or rotations of the distributor arms.

In the second group are the high capacity filters which are divided into three general types, all having, or claiming to have, some patented features. Each of the different types of high capacity filters has its proponents, with each group endeavoring to demonstrate with appropriate data the particular advantages to be gained by that particular process. It is not intended here to enter into any discussion of the relative merits of each method, but merely to bring out some of the purported differences of all the various kinds.

The "high daily capacity" filters are divided into two major types, these having high instantaneous dosing rates and those having low instantaneous dosing rates per unit of filter surface, depending on the method of distribution. Those with high instantaneous rates have brief rest periods between rotations of the distributor; those having low instantaneous rates have little, if any, rest periods, the sewage being applied in an almost continuous fine spray. The high instantaneous rate type is further divided into the "Biofilter" which is as a general rule relatively shallow (2½ to 4 ft.) and the "Accelo-Filter," which is generally 5 to 6 ft. in depth. The sewage to both is distributed by a two- to four-arm distributor at daily average rates of from 10 to 40 m.g.a.d. made up by heavy recirculation taken from almost any point past the filter effluent and returned to almost any point ahead of the filter. The low instantaneous rate type, or the "Aero-Filter," may be of any depth, and is dosed at rates of from 10 to 40 m.g.a.d. by means of either of two types of distributors; the motor-driven disc type for filters up to 35 feet in diameter or the multi-arm type for filters of greater diameter. The dosing rate is generally maintained by light recirculation.

Filters similar to these and various modifications of all four types have been built and are in operation. Some of the major differences in the various types of filters have been brought out, but what happens to the sewage as it passes through them and what, if any, is the difference in the effluent?

Regardless of the type of filter, the action inside is somewhat the same. Briefly, it comprises a complex physical and biochemical process whereby the settled sewage solids, consisting largely of organic material either dissolved or in suspension (the latter divided into either pseudo colloids, colloids or residual settleable solids not removed by sedimentation), in passing through the filter, become entrapped either by adsorption, absorption or adhesion by the zoogleal film on the filter media. In the presence of free oxygen these solids are acted upon by the various organisms and their enzymes to alter the material from a high to a less putrescible state. This action has been studied by a number of investigators. Their findings have been numerous and at times in seeming variance, however, there is general agreement about most of them, albeit some have been subjected to different interpretations to fit different theories.

It is not intended, nor is there time, to go into details regarding the biology of the trickling filter. However, to round out the picture, the following is quoted from Wilson's "Supplementary Biological Investigations" of "High Daily Rate Trickling Filter Performance" made under the direction of the State Health Commissioners, Upper Mississippi River Sanitation Agreement, published in March, 1943:

> "The composition of trickling filter growth is varied and complex. It is an amazing assemblage of living organisms, from minute bacteria (and probably viruses) to insect larvae over two inches long (crane fly larvae). Between these extremes of size there are many representatives from both the plant and animal kingdoms, including filamentous bacteria, fungi, algae, protozoans of many kinds, and metazoans and even certain adult insects (Collembola). Each of these groups of organisms performs certain functions in the filter; each occupies its niche in the biological community."

There are certain differences in the action of the filter as the dosing rate is increased. It has been determined that the amount of film and not the surface area of the film determines the contact time. Inasmuch as it is believed that the changes in the character of the sewage are a contact phenomenon, the contact time is certain to have a bearing on the kind and amount of purification. Goldthorpe,* in conducting some experiments with high rate filtration in concrete pipes 8 feet deep and 2 feet in diameter, using a 2- to 4-inch clinker, found that the contact time was 20 to 25 minutes at 10 m.g.a.d., and 7 to 9 minutes at 20 m.g.a.d. In a standard rate filter, the film is relatively thick and some of it tends to digest in the filter and unload twice a year. This sloughing, or humus, is comparatively stable and settles readily. As the rate through the filter increases, the film becomes thinner, less and less digestion takes place, the sloughing becomes continuous and flocculent—because of both the flushing action of the sewage and the activities of the biotic life—and is less readily settleable. Because very little, if any, digestion takes place in the high rate filter, the floc is still

* *The Surveyor*, 102, 177, 243 (1943).

highly putrescible and should be removed from the settling tank as soon as practicable. It has become an almost universal practice to follow any filter with an adequate sedimentation tank. In fact, most engineers prefer to consider secondary treatment as a single unit consisting of an oxidizing unit plus a sedimentation tank.

At this point, some mention should be made of recirculation and its effect upon purification. Experiments seem to demonstrate that biological purification in a filter is approximately unimolecular, that is, as the sewage passes through the filter the B.O.D. removal decreases proportionally to the amount of organic material present. Thus, as the number of recirculations is increased, the amount of material removed with each passage through the filter diminishes, although the cumulative removal increases. With no limiting factors, the B.O.D. removal would approach 100 per cent if the number of recirculations were increased infinitely. However, this is obviously impossible.

The findings of independent investigators regarding all types of filters may be summarized briefly as follows: (a) The higher the dosing rate the smaller the percentage of B.O.D. reduction but the more pounds of B.O.D. removed. (b) With recirculation, the percentage of removal increases to an optimum point and then rapidly decreases. The point varies with each sewage. (c) In high rate filters, the results obtained without recirculation are never as good as those obtained with recirculation. (d) In high rate filters, increasing the depths of the filter beyond 6 feet has little, if any, advantage. (e) The advantages of recirculation through the primary settling tank have not yet been clearly demonstrated. (f) The so-called seeding effect of recirculation has not been successfully proven. (g) The effluent from a standard rate filter is generally well nitrified. Nitrification and the quality of the effluent deteriorate as the loading and dosing rate is increased. (h) The bacterial count in the effluent of a high rate filter is generally higher than in that of the standard rate filter.

Let us now consider some of the factors affecting the performance of all kinds of filters. They are (a) distribution of sewage onto the filter, (b) size and kind of media, (c) depth of filter, (d) temperatures of air and sewage, (e) ventilation, (f) organic loading and (g) condition of filter influent.

Kinds of distributors have been mentioned previously and only this need be added. It is desirable to obtain the best distribution ratio possible, that is, uniform coverage per unit of surface area; however, conclusive proof of the need for elaborate means of distribution is lacking.

In general, the smaller the media, the larger the surface area possible. The percentage of voids remains almost constant. There are numerous other factors to be considered and the efficiency of equal depth filters remains very nearly the same over wide variations of media and material. The availability and cost of the material remain as major controlling factors.

The filter depth has been previously mentioned. In a general way, the deeper the filter the better the quality of the effluent; however, with a high rate filter, this is not true. The limiting depth here has not been determined. Obviously, a very shallow filter will require more recirculation than a deeper filter. Construction costs and economy of operation must be considered.

The effect of the temperatures of the air and sewage on filter efficiency has been studied rather extensively. The findings are conflicting but, obviously, filter action being biotic, the temperature plays an important part. Low temperatures result in less nitrification and poorer B.O.D. reduction.

The effect of ventilation on filter efficiency has not yet been completely determined. Air to furnish free oxygen is necessary, but it is generally believed that artificial, or forced ventilation, is of doubtful value. The possible exception to this is where there is no rest period, such as occurs in the "Aero-Filter." Here forced ventilation is probably very necessary.

The direction of the flow of sewage through the filter has little influence on air flow. Difference in temperature between the sewage and air is the controlling factor. The greater the difference between these two temperatures, the larger the amount of air flow. When the air is warmer than the sewage, the flow is downward and vice versa. Well designed and well constructed underdrains will generally furnish all the ventilation necessary.

Obviously, the amount and strength of the sewage to be treated will influence the size of the filter. There are various ways of stating this loading, all of which leave something to be desired. This is because both rate of flow and B.O.D. load must be considered simultaneously. That is, million gallons per acre per day and pounds of B.O.D. per acre foot, or their equivalent expressions. The term million gallons per acre per day is the most common method of stating dosing rate. The amount of B.O.D. loading is still the subject of some speculation; however, present day designers consider 600 lbs. per day of B.O.D. per acre foot for standard filters and 3,000 lbs. per day of B.O.D. per acre foot for high capacity filters to be not excessive. These figures are very arbitrary and are subject to wide variations, depending on the problem at hand.

It is well known that the condition of the sewage just prior to its application to any form of secondary treatment is very important. Trade wastes or septic sewer hinder the effective operation of any form of secondary treatment, albeit the trickling filter seems better able to withstand such shocks. The presence of dissolved oxygen in the filter influent is very important. Horton, Porges and Baity showed an improvement of approximately 10 per cent in B.O.D. reduction where D.O. was present in the filter influent. It is the author's belief that the oxidation-reduction potential is one of the determining factors in filter efficiency and that it is the D.O. in recirculated effluent that is sometimes mistaken for the so-called seeding effect.

The design of filters is very ably and thoroughly covered in several standard texts and is out of the ken of this paper; however, it has been the writer's experience that in designing and constructing any type of filter, two things above all else should be considered. First, the media should be chosen with great care, the specifications made very definite, and the inspection thorough; second, the underdrain and ventilation system made adequate plus a larger safety factor. Too many filters have failed both physically and in performance on account of poor or slip-shod engineering attention at these points.

The operation of a filter is largely fixed by the design and is confined to more or less routine matters such as cleaning nozzles, controlling ponding and filter flies, lubricating and maintaining equipment. All of these have been covered in various publications and will be discussed by qualified men here today, so no further mention relative to operation will be made except to suggest that the manufacturer's recommendations regarding care of equipment be carefully followed.

It has been the writer's privilege during the past two years to observe the performance of some 50 trickling filters of most types and sizes, located at Army posts at points all over the central west. In this area, great extremes of climate, elevation and population obtain. Unfortunately, complete operation data are not available, and the following comments and opinions are based on personal observations, plus a perusal of available literature. It is realized that no one will agree with them in their entirety, and some will agree with few, if any, of them. It is also realized that there is very little which is original or particularly new about them.

Temperature, climate and possibly elevation affect the operation of the filter. The size, kind and shape of the media are not as important as uniformity of size and quality. Most of the ponding and unsatisfactory performance have been directly attributable to faulty design and inspection. Good natural ventilation is an absolute necessity.

Standard capacity filters in depths exceeding 8 ft. are not economically justified. Let us not forget that the removal of the last few pounds or p.p.m. of B.O.D. is dearly paid for.

Depths of over 6 feet in high capacity filters are not justifiable with the results obtained.

The type of distributor and the rate of application are not as important as that the distributor chosen distribute the sewage equally over the entire surface and at a rate in keeping with the results desired. Nitrification drops off and the effluent becomes less stable as the load per unit of volume of media is increased.

More independent study should be made of the various types of high capacity filters to determine the economics involved. The writer considers that some optimum point must exist relative to the depth of filter, method of distribution, and amount of recirculation. Too much distinction is being made between the different types of filters, losing sight of the fact that a trickling filter is still a trickling filter regardless of the somewhat confusing terms used. All are similar in construction and perform the same job in varying degrees, depending upon the requirements of the receiving stream or subsequent treatment. There is a paucity of data pointing to the superiority of any particular kind of the so-called high capacity types. Further biochemical investigation should be encouraged with especial emphasis placed on the possible benefits to be gained by the presence of D.O. in the filter influent.

Finally, bearing in mind that they can become burdensome things in very large installations, trickling filters can be designed and built to suit any kind of treatment need, and this need should be carefully determined beforehand. There has been too much sewage plant designing done with knowledge but without understanding. Too few designers have had the doubtful pleasure of falling into a clarifier while trying to clean out a particularly bad hydraulic monstrosity. Too many plants have been built without due regard being given to the needs of the stream and the community.

In conclusion, it is suggested that, while trickling filters may not be the ultimate in secondary sewage treatment method, they do have a high place in the future of sewage treatment and when properly adapted to conditions, they are economical and always reliable.

OPERATION OF TRICKLING FILTERS *

By T. C. Schaetzle

Superintendent of Sewage Treatment, Akron, Ohio

Among the oldest and yet most modern sewage treatment devices is the trickling filter. It has been modified from time to time but in general principle has remained the same and continues to do a good job under proper conditions of loading. It definitely retains a prominent position in the field of sewage treatment.

The Standard Filter

Considerable has been written about the size of media, depth of filter and form of distribution. The original experiments in this country were conducted by Hazen in 1892. In 1909, Rudolph Hering combined the three variables of bacterial surface, air supply, and time of liquid passage through the beds into a formula giving the degree of purification. His reasoning still holds in that the media size affects the area of bacterial film and both size of media and depth of filter are directly related to the time of passage.

My own experience at both large and small plants has indicated that with similar sewages, limestone, slag and trap-rock have produced

* Remarks Introducing Forum Discussion at 18th Ohio Conference on Sewage Treatment, Marion, June 21–22, 1944.

equally good results as long as the size was not less than one inch, and that depths of six feet or more have proved equally satisfactory. The disintegration or cementing of the media has varied with the type of material used.

I should like to know the reason for the variations in the growth on different beds. In some plants the film is light but with a distinctly reddish cast, at others it is a deep blue-green and at still others a black, partially curled up, tough growth. At one plant with which I am familiar, the growth completely encases every stone near the surface of the bed. This growth is like a shell, varies from 1/8 to 1/4 inch thick and is quite tough. The sewage at this plant contains better than 1,900 p.p.m. chlorides as an average. The range is 250 to 7,900 p.p.m. Forty-five hundred p.p.m. is not uncommon. Why these variations in the type of growth?

All of you are familiar with the various types of fixed nozzles and the more common rotary distributors but I imagine that few of you have had experience with the straight line type in use at Oberlin. Each has its advantages and disadvantages. It has been my experience that there is as much trouble with nozzle clogging at the rotary distributors as at the fixed nozzle types. At Oberlin, very little nozzle clogging occurs but slippage of the drive wheels on the rail, maintenance of gears and ice on the rail and trolley wires are sources of considerable trouble.

High Rate Filters

Although I have had no operating experience with high rate filters I do believe that some one here can present some worthwhile information.

The multiple arm and disc distributors are interesting developments. I have seen but one disc distributor in operation and, at the time, it was giving excellent coverage and producing a very fine spray. Perhaps some one connected with the Orrville plant will say a few words on this subject.

Problems Common to Both Types

Common to both of these are psychoda alternata. The high rate filter seems to minimize their presence. One advocate of the high rate filter does not claim the absence of the gnat but refers to their inability to leave the filtering media because the stone is kept wet at all times.

Referring again to Oberlin, I have been much impressed by the very small number of gnats at any time. Why should there be a difference in this respect between the straight line and rotary distributor?

In the standard filter I have found chlorination of little value for psychoda control but very effective for relief of ponding, yet much more expensive than harrowing every second year.

At Akron, flooding has proven quite satisfactory. At a certain plant which is designed for approximately 2.25 m.g.d. and which is operating under climatic conditions very similar to those at Akron, good gnat control was not obtainable when the interval between floodings exceeded seven days. Right here we come up against a problem not yet solved as far as I know.

For a small plant with but one filter and with no means of gnat control other than by flooding, the operator is confronted with the problem of tolerating the psychoda or discharging unfiltered sewage to the receiving body of water for approximately 24 hours every seven days. Even where there are two filters, while one is being held in a flooded condition whenever the sewage flow exceeds the capacity of the operating filter, unfiltered sewage must go to the stream. To provide excess filter capacity is too expensive.

Another experience worthy of mention is that in connection with odors. At Akron, if a bed is left out of service for more than three days in hot weather the odor is exceedingly offensive and nauseating to some of the employees. The best remedy is to wet the stone.

Analyses

I presume that we are all in agreement that the methylene blue stability test is still the best available determination for small plants without laboratory facilities or technical personnel. But what of the value of ammonia nitrogen, nitrites and nitrates where facilities are available for these determinations?

We will agree, I am sure, that D.O. and B.O.D. are our most reliable servants. The State Health Department states that 250 pounds of B.O.D. per acre foot is the limit for a safe filter loading. Akron's experience certainly confirms this. From 1930 to 1938, inclusive, the B.O.D. loading was 210 or less and nitrates ranged between 4 and 8 p.p.m. From 1939 to 1943 there was a very sharp decline in nitrates as the loading increased. A definite break to less than 4 p.p.m. occurs at 250 pounds of B.O.D. per cubic foot with a drop to as low as 1 p.p.m. when the B.O.D. reached approximately 600 pounds per acre foot.

With a normal domestic sewage the following effluent analysis is considered satisfactory:

Suspended Solids	not more than 42 p.p.m.
B.O.D.	not more than 25 p.p.m.
D.O.	not less than 5 p.p.m.
Nitrates	not less than 6.5 p.p.m.
Relative Stability	not less than 90 per cent

Conclusion

Finally, I offer three questions to initiate discussion:

(1) Is it practicable and economical where standard filters are used to provide a means of shutting off or turning on additional filters as the sewage flow varies?

(2) How high can chlorides run without detriment to a trickling filter?

(3) How can chlorides be controlled?

In conclusion, let me suggest that this paper touches only a few of the items in connection with trickling filter operation and is not intended as a treatise on the subject. It is intended only to stimulate discussion.

BARK FROM THE DAILY LOG

By Walter A. Sperry

Superintendent, Aurora Sanitary District

March 1—Wednesday, and the month off to a good start. Gas and tire restrictions have almost eliminated the occasional pleasant and profitable hour with a visiting operator but today P. H. Schroeder, Sanitary Engineer for the Dixon (Ill.) Ordinance Plant, came to call. It is always an inspiration to walk about one's plant with a brother operator and "talk shop." Did you ever note how many good ideas are suggested at such times? Wm. R. Copeland, formerly of the Connecticut State Department of Health, had a familiar phrase for it: "Always make the visitor pay his way."

March 3—Flushing out the filter nozzle riser pipes today. It was a must job. The surface of the filters was covered with gray grease balls—a strange sight. The balls were surprisingly round and firm and ranged in size from one-half inch to nearly two inches in diameter. Some of the risers were packed so tightly with assorted sizes of balls as to almost cut off the flow. The phenomena lasted for several weeks and then disappeared. This condition had not been observed before or since. Nothing connected with the operation of the clarifiers gave any clue as to the origin of the grease nor was the condition even suspected till the reduced flow from the nozzles demanded our attention. An unsolved mystery.

March 4—The telephone again. It always rings in the middle of some laboratory operation but it is always an adventure and one never knows what to expect. This time a distressed voice informed us that he had just dropped a ten-dollar bill in the toilet and would we please watch out for it? We gave him no encouragement. At that, once in a "blue moon," a bill does come through and one of the operators has had a lucky day.

March 7—Bought a fine large safe with a combination lock for the office today. Picked it up at a bargain price from a defunct hotel. In it was a removable section of forty steel drawers, each with a label pocket and a lock. It cost someone a lot of money and had been used for storing valuables of hotel guests. This outfit gave Willard, our valued assistant, a good idea which was promptly adopted. The removable part was converted to use for the storage of small supplies and repair parts, such as switches, spark plugs fuse links, thermal relays, valve packings and the like. The drawers were labeled and now provide a place for things difficult to store and easily lost track of. It gives us an inventory at a quick glance and helps maintain supplies at a safe level.

March 10—Two things around a plant can quickly make trouble—a miscalculated paycheck and the time. It's odd about the pay checks. No matter how unskilled with figures a man may be, it is always a matter of amazement how quickly he senses a "short" check.

As to time-keeping, when we cut off the public utility power supply and began to depend wholly on our own gas generated current, our electric clocks went wild. One of the generators ran the clocks too fast and the other one too slow. Lunch time and quitting time were never right with the men's watches and trouble began to brew. We were not running the generators primarily to operate clocks and so did not provide delicate voltage regulators. A near riot was averted by buying a good old-fashioned pendulum clock with the familiar octagonal frame. It keeps almost regulator time and every one is happy again.

March 12—Trouble on the big 69-inch interceptor today. It runs along the river through the village of Montgomery and, for the third time, one of the manhole covers has been recovered from the river and replaced. The kids again. Today we sent down a crew of men and pulled out about a half ton of stones with a bucket and rope—more kids having fun. This time we struck upon the idea of a simple fix by cap-screwing a plate on the underside of the cover and over the finger hole. We have had no trouble since. The youngsters cannot pry off the cover with a stick. Seems to be simple and effective.

March 24—Just another typical day:

Routine laboratory work on Thursday's composite samples:
  Free amonia, nitrates, pH, stability tests, D.O's, 5-day B.O.D's, suspended solids and Imhoff cone determinations.
Weekly Orsat test of the gas and B.T.U. values calculated.
Downtown pumping stations inspected.
Greasing routines for all machines.
Mowers sent to the shop for annual overhaul.
Two men working on the sludge beds.
Sewer connection inspected in the South Park District.
Working on the river rating chart.
Working on the filter nozzles.

March 27—Paper mill test day. Chapter Three of the Paper Mill Story. After the sampling arrangements had been planned and the various gadgets made and assembled came the problem of where and how to get a measure of the volume of flow leaving the mill. The best way would have been to place a 90-degree, V-notch weir in a manhole at a point just before the waste entered the District interceptor. This manhole, however, was across the street and, while this arrangement would have given an accurate flow measure, it was far too inconvenient to be considered. Meantime, there was a rectangular channel twelve inches wide and about eighteen inches deep meandering through the mill into which all the mill wastes found their way. At a selected point in this channel, a board with a thin metal weir crest was placed to form a twelve-inch rectangular weir. A stick with a sharp nail in the end made a good hook gage. On the other end a section of a rule was placed to be read against the sharp edge of a board placed above the weir. This arrangement was convenient but not too accurate. Sand accumulated back of the weir and there was not sufficient vertical height to give a free fall over the weir. It did give us a reasonably comparable record, easily computed from tables. Later, a V-notch weir was placed in the manhole and an occasional set of readings was taken simultaneously over the two weirs to obtain a correction factor. This proved to be about 18 per cent low on the rectangular weir. (To be continued.)

March 28—Another very pleasant day. We were happily surprised to have Walter Kunsch, the newly appointed superintendent of the Urbana-Champaign (Ill.) Sanitary District, drop in for a get-acquainted chat. He had come up to Aurora on a pump repair errand. Walt comes to the Middle West from the New England States and looks so much like C. R. (Chuck) Velzey that the writer has been "red-faced" with embarrassment more than once by mistaking one for the other. Here in Illinois we like him and hope he learns to like us.

The Fox River is in flood following a 2.7-inch rainfall. Three and a quarter feet of water is running over the chest of the Main Street dam, the highest since 1938 when there was a crest flow of four feet. This flow was not enough to top the secondary tanks as it did in 1938 but the clarifier overflow chamber had to be sandbagged. In 1938 the secondary tanks were submerged ten inches and trapped about two wheelbarrow loads of fish. They were finally caught by bypassing the flow when the resulting lack of oxygen drove the fish to the surface. How the word got about among the negros who fished for carp at the plant we never found out, but they came and got the fish.

April 1—April Fool's Day but a good one. Collected $100 for a factory sewer connection in the Hercules Park District. A regulation house connection costs $40 but this one was special and the fee was determined by the Trustees.

Had a caller this afternoon with a new and interesting query as to whether sludge would make good bedding soil for growing mushrooms. This was unusual. We once had a friend who put his son through the university with the money earned from mushroom beds in a gypsum mine. He used the manure accumulating from the mine mules. Imitators tried it in their basements but the swarms of flies developed rivaled the insect plagues of the days of Moses and the Pharaohs. Manure is now hard to find, however, and sludge might be a good substitute. We told him as much as we could about sludge and he went away promising to try some experimental beds to be set up in the basement of the old Aurora Brewery. Some will not agree as to whether this is the best use for a brewery but, if it works, a lot of sludge will be used.

April 5—Here is a bit of borrowing philosophy. A neighbor came across from the nearby cottages to say he was in trouble with a plugged sewer and asked us to loan him a sewer tap. We reluctantly let him take a small tap but it did not come back when promised nor for several days thereafter. Finally, after a second call we found him at home. He acknowledged the loan and brought the tap back the next day. Fortunately it was not needed but such things are irritating to a good willed lender and the next time we will hesitate before allowing the loan. We have boasted of our ability to borrow anything we needed from anywhere at any time—the secret is to return the item in good order and on time as promised.

April 10—Have been working on the plant highway sign. For several years its appearance has been restored by retracing the letters with fresh paint but the results were getting less and less satisfactory. Then we got the idea for a more permanent lettering scheme. All the letters were cut out of Masonite, giving a raised letter effect. Next the same letters were cut out of stainless steel with a chisel and a pair of snips. These were then run through the enamel-baking ovens of a nearby industry. The black, stainless steel letters were mounted on the Masonite letters and the combination screwed to the sign board. The effect was excellent. Now the letters are easily removed and replaced when the board needs painting and it always has a well groomed appearance.

April 13—Friday and an unlucky day for the State Highway Department. A little neighbor girl we always call "Sally" came running breathlessly to tell us that the asphalt barrels stored at the highway were afire. Sure enough, we could see the smoke and flame and our men put it out. The local highway supervisor was called and Sally got a box of candy at our suggestion. It was during the spring vacation from school and the youngsters were on a rampage.

April 20—Plenty of trouble at the screen house and about the clarifiers for the last three days. Periodically, large gobs of a super-slippery, green-yellow grease of butter-like consistency has been coming down the interceptor. From whence it came we could not guess. The floor of the screen house was dangerously slippery and the use of a hose and broom did not phase it. Sand had to be used to give a safe footing. It clung to the tools and made a dangerous fire in the incinerator. The men's clothes were being ruined and their tempers were getting decidedly short. It looked like a cutting oil or soap and tested strongly of copper.

About this time the City Engineer and the City Sewer Inspector called for a conference at a manhole downtown. The manhole, as well as several blocks of sewer, were found to be caked with the stuff. The Sewer Inspector was breathing "fire and brimstone" since his men were refusing to work any longer with the sewer. We then determined the source of the grease to be a local brass shell-case plant. At first, the plant superintendent denied strenuously that it came from his plant but later he calmed down and allowed us to inspect and study the place. Before long, a few laboratory tests clearly showed the material to be coming from the shell washing machines. Individual grease traps improvised from steel oil drums and some piping completely solved the problem and there has been no grease trouble since.

There is a moral to this story. The superintendent knew the source of the trouble but was irritated by heated words and argument. A sincere and quiet try at finding the difficulty and suggesting a solution brought the needed co-operation.

April 25—The night man became the proud father of a baby boy today, his first. Mighty good cigars!

ACTIVATED SLUDGE ROUND-TABLE *

Chairman George Martin (*Green Bay, Wis.*)—We now come to the "2A over C minus 1" part of the program. The only reason I can give you for my being assigned to preside over this session is that my plant does not include activated sludge treatment and that I know absolutely nothing about it. At least, I shall be neutral!

Mr. Larson has a question.

C. C. Larson (*Springfield, Ill.*)—I would like to take issue with Prof. Bloodgood (see *This Journal*, **16**, 5, 913 (1944)) in regard to his proposed yardstick for rating activated sludge plant operation. It strikes me that his basis of m.g.d. treated per m.g. of tank capacity is more of a design criteria than an operational one. I would like to see more operators report on the cubic feet of air per pound of B.O.D. removed, which is, to me, the best measure of operating efficiency we have. I cannot visualize or think in terms of Prof. Bloodgood's method of rating.

Prof. Bloodgood (*Lafayette, Ind.*)—I contend that the evaluation of activated sludge operation on the basis of m.g.d. treated per m.g. of aeration tank volume is not a designing engineer's figure and believe that it is wrong to say you can measure the amount of B.O.D. removal by the cubic feet of air applied. It is my opinion that we actually know very little as yet about the application of air to activated sludge; we must take the broadest possible view of the process and use only the very fundamental facts, such as the volume of the tank.

Mr. Larson—Is not air application a fundamental function?

Prof. Bloodgood—Yes, but you can not tell whether a cubic foot of air is used as efficiently under one set of conditions as under another.

W. W. Mathews (*Gary, Ind.*)—No matter what type of diffusers you are using, if your plant is performing properly you need only about 700 cubic feet of air to remove one pound of B.O.D. This is certainly more efficient and economical operation than if 1,000 cubic feet of air is required to do the same work.

In the winter we carry more solids in the mixed liquor than in the

* Forum Discussion, Seventeenth Annual Meeting, Central States Sewage Works Association, Oshkosh, Wis., June 23, 1944. Led by George Martin, Superintendent, Green Bay Metropolitan Sewerage District, Green Bay, Wis.

summer. If you have the capacity, try operating with low and high solids contents in the mixed liquor with uniform use of air. We have a peculiar condition at Gary. The blowers are operated at a fixed rate for several months and there will be a natural variation in the efficiency of B.O.D. removal during that period. There are several variables that may cause the efficiency to change, such as solids content, rate of sludge return and rate of waste. Prof. Bloodgood mentioned that there was about a month's lag. There is always a certain amount of lag and it is only possible to deal with averages. A day-to-day determination is only an indication of the trend of the treatment process.

J. C. Mackin (*Madison, Wis.*)—With reference to Mr. Mathews' remarks about the variation in mixed liquor solids, I presume that such variation was by intent and not by accident. If it was by intent, I would like to know why the solids go up in the winter and down in the summer, and why he risked reducing the air last month to such a low figure?

Mr. Mathews—You have heard Dr. Sawyer discuss the slowing up of the bacterial action during the winter (see *This Journal*, **16**, 5, 925 (1944)), which indicates that you need more solids in the aeration tanks to obtain the same results that are obtained by less solids in warm months. The reason the applied air was reduced last month was because the tubes were partially clogged. Since there was an excess of D.O. at the end of aeration it was safe to reduce the amount of air applied so as to reduce the pressure at the blowers.

During the winter months, mixed liquor solids may run as high as 1,800 p.p.m. while in summer they are held to about 1,000 p.p.m. The sludge index was low in January, about 55, while at present it is about 120, showing a gradual rise with increasing raw sewage temperature. This does not check with our experience one winter when the sludge index went to a high of 495 in 10 below zero weather. There was no bulking present in the sense that large quantities of solids were passing over the weirs of the final tanks, for the effluent suspended solids never exceeded 10 p.p.m.

Mr. Mackin—Then you did adjust the solids concentration by intent and to serve a purpose; you pointed out that the organisms may be less active, suggesting a need for higher solids in the winter, but did you find the B.O.D. load to vary—to show a rise in the summer and drop in winter?

Mr. Mathews—Operation was being controlled merely to be sure that the quality of the plant effluent stayed where we wanted it, paying no attention to the load coming over from the primary clarifiers.

Mr. Mackin—I think that point should be stressed. The Gary plant is in very fortunate circumstances in regard to loading and is not afflicted with the bulking that occurs when the secondary treatment process is overloaded at other plants.

James Brower (*Milwaukee, Wis.*)—While we are talking about air application, I would like to say something about getting air through diffuser plates under summer conditions. In 1928 we started to study the effect of moisture on the efficiency of diffusers and we have found conclusively that conditioning the air has an appreciable effect on diffusion results.

A great many operators, if they were asked if they had noticed an increase in air pressure in summer, would say no, but I have never yet gone through the summer period without observing that the air capacity did not fall off and that the pressure went up. In fact, it costs us about $84 per day more in the summer months to supply our full capacity of about 195 million cubic feet of air per day at the Milwaukee plant.

I have here a chart which shows that at 90 per cent relative humidity, a total of 18.45 pounds of water per day will be put into a single container of 9 plates discharging one c.f.m. per plate. Since the sewage is a great deal cooler in summer, the moisture contained in the air under pressure is condensed in the container and must be blown out. The capacity of the plates will fall off 30 to 50 per cent under these conditions.

Our 1928–29 studies were made on new, clean plates in a research set-up. Tests of efficiency were made under different conditions of relative humidity and barometric pressure. If anyone is interested in our report on this work I will be glad to have them get in touch with me. I think these studies resulted in the adoption of the present system of testing by plate manufacturers whereby the plate capacity is expressed at a stated temperature and barometric pressure.

W. D. Hatfield (*Decatur, Ill.*)—My experience is absolutely in agreement with that of Mr. Brower's. We have a special condition at Decatur because our sewage is of higher temperature than in most places, but our blowers almost stop entirely just before a storm and when the humidity is high. With a low barometer and high humidity, the pressure at our blowers will increase 1 to 1.5 pounds per square inch and it is almost impossible to get the air through the plates. At such times we must vent the air to the atmosphere.

There is no question but that the containers or plates will become filled with water under certain humidity and temperature conditions.

M. Starr Nichols (*Madison, Wis.*)—I have heard of people with rheumatism predicting humidity and storms, etc. Perhaps Mr. Brower might get in touch with the meteorologists in the hope that he could help them predict the weather more accurately.

Mr. Brower—I do not know if it is arthritis or rheumatism but it is a nuisance and, as far as taking it up with the weather man, we have enough problems of our own.

The Milwaukee plant is located on the shore of Lake Michigan where the humidity is very high and have had a lot of trouble keeping the air pressure down and in supplying air to the tanks. We first thought that our containers, located far below the lake level might be leaking because we found them almost full of water, which we removed with a pump. Our engineers assured us that these containers were made of very dense concrete and were water-tight.

Finally catching on that the weather conditions played havoc with the operation of the diffusers, we constructed a large pipe in such a manner that we could condition the air passing through it and produce humidities comparable to those existing in the outside atmosphere. This apparatus was equipped with a certified gas meter, manometer, and wet and dry bulb thermometer in the pipe line passing the air to the plate container. New plates of known porosity were tested and the results checked our findings under actual operating conditions—the capacity falling off as much as 30 per cent in some cases.

This work convinced us that high relative humidity with certain temperature of the sewage caused the air to reach its dew point, creating an increase in pressure and a reduction in volume passed through the plates. From an economic standpoint, this becomes a serious matter, especially in large plants where huge volumes of air are applied. Very little has been published about this phase of plant operation.

It was surprising to me to read in *Sewage Works Journal* that diffuser plates at Cleveland lasted only about a year and a half. We have plates which have been in operation since 1925 and, although we burned them down once and smoothed them with a carborundum stone, they now show only a slight increase in pressure over plates which were installed in 1937. The plates in the old plant have permeability ratings of only 8 to 12 as compared to the permeability of 30 to 36 in the new plates. Today many plants are equipped with plates of 60 to 80 permeability and encounter serious troubles. One begins to wonder if it is the proper thing to go to such course plates although, of course, it is necessary to use plates of large capacity where it is desired to limit the number of diffusers to a minimum.

Steam driven blowers are used at Milwaukee, each requiring about 2,100 horsepower. The pressure can build up to a certain limit after which the blowers will drop off the line. In order to put them back in service it is necessary to reduce the air pressure over the entire plant. In our case, a pressure increase of 1 to 2 pounds costs about $84 daily.

We have been talking about the above problem for some years and I have met only one operator who experienced the same conditions from June to September and he reported that plates were actually blown out of the containers because the pressure became so high. I believe that this problem is of vital importance to every diffused air activated sludge plant and hope that research will be initiated.

Prof. Bloodgood—The same difficulty is experienced at Indianapolis.

Mr. Brower—I am interested to hear that.

Leland Bradney (*Sioux Falls, S. Dak.*)—I can add nothing to this discussion on diffuser plates but we have one of the most serious activated sludge problems in the country at Sioux Falls. We are handling a mixture of sewage and of packing house wastes, the latter after preliminary treatment on trickling filters. For some time we have been troubled by rising sludge in the final settling tanks. The discouraging thing about it is that the condition only occurs when we have what we consider a good activated sludge but the stuff just will not stay down in the bottom of the tank. We have also found that the loading of the process has no effect on this rising sludge condition; the B.O.D. of the influent sewage to the aeration tanks has varied from 65 to 350 p.p.m. and the rising sludge occurs through the entire range. Another thing, the dissolved oxygen concentration does not seem to make much difference. We get above 0.5 p.p.m. in the aerated mixed liquor and the sludge doesn't rise any worse with 0.5 p.p.m. than it does with 2 p.p.m. I am interested to know if anyone else has encountered a similar condition.

Prof. Bloodgood—We have had trouble with rising sludge and have been able to correct it by increasing the loading, that is increasing the m.g.d. treated per m.g. of aeration tank capacity.

K. V. Hill (*Chicago, Ill.*)—I think the problem at Sioux Falls is a very special case. With reference to Prof. Bloodgood's suggestion that he has corrected the difficulty at Indianapolis by boosting the load on the aeration tanks, we have analyzed the loading on the basis of pounds daily of applied B.O.D. per thousand cubic feet of aeration tank capacity and have found that it varies from 27 to about 100 pounds per day per thousand cubic feet.

I would also like to bring out that this rising sludge occurs even following the second stage trickling filters. The effluent from the second stage of filtration, upon settling, produces the identical condition.

Mr. Mackin—I question Mr. Hill's interpretation. I am not sure it is the same condition. It seems to me that the sludge is going septic and I know that on occasion a rising sludge in the aeration system can be a well oxidized sludge, so I do not think they are of the same type.

Mr. Hill—The effluent from the second stage of filtration frequently contains 2 p.p.m. of dissolved oxygen and some 10 to 17 p.p.m. of nitrate.

Mr. Mackin—Have you examined the trickling filter sludge under a microscope to determine if it appears to be similar to activated sludge?

Mr. Hill—No.

Mr. Bradney—We have taken activated sludge that rises very rapidly and placed it in a flocculator. Once the nitrate is used up, which takes about 4 hours, that sludge does not rise at all in 8 or 10 hours. We did the same thing with sludge from the secondary trickling filter with the same result.

Chairman Martin—May I suggest that we give some of the time in this discussion to the Mallory Oxidized Sludge Process. Mr. Mackin has been operating the Madison plant for several months under this method of control. Suppose we invite questions along these lines and ask Mr. Mackin to answer them on the basis of his experience.

Prof. Bloodgood—Mr. Mackin, how much have you increased the loading in your plant since converting to the new method of control?

Mr. Mackin—We have increased the loading about 1.0 to 1.5 m.g.d. The plant now treats some 8.5 to 9.25 m.g.d.

The B.O.D. of the sewage is very similar to that formerly received although we had 3 or 4 inches above normal rainfall in June and the total rainfall for the year thus far is 2 or 3 inches above normal. Furthermore, I have noticed that the Madison sewage has shown a tendency to increase in strength. I do not know if this is a result of the concentrated housing conditions because of the fact that we have a sizeable camp nearby or whether it is a normal wartime experience, but I have definitely noticed that the strength of the sewage is going up. We have increased the air under heavy loads as in the past winter when we had a very critical condition brought about by the unusually heavy kill at the Oscar Mayer packing plant.

P. W. Riedesel (*Minneapolis, Minn.*)—As an operator of a plant using the oxidized sludge system, have you found the method of control to be practical? I think that is the point which is bothering many people.

Mr. Mackin—Yes, I do consider it a practical method of control. There are other places in which the application would be much more simple than at Madison because of the variable load that we have; for example, where there is a fairly normal, uniform load without any severe shocks. I can sympathize with Dr. Hatfield of Decatur, because, his plant receives some tremendous shocks, but where these are absent oxidized sludge control is most satisfactory.

Dr. Hatfield—What is the extent of the shock load that your plant can take?

Mr. Mackin—An overload of about 50 per cent for 4 hours and 10 per cent for 24 hours, only providing a normal load is not exceeded for the next day or two. Mr. Mallory has a method for rating the plant. The Madison plant is rated at 15,000 pounds per day.

Mr. Mathews—How much did you increase the mixed liquor solids and the applied air?

Mr. Mackin—We tended to decrease the solids. We increase the air only during the winter time.

Mr. Mathews—Are you trying to maintain uniform operations or do you make adjustments in the 24 hours?

Mr. Mackin—Very definitely not uniform. We vary the control in accordance with the demands that are established from the charts which Mr. Mallory provides. We check these items six times a day and make necessary adjustments to keep the process in balance after each test.

Mr. Larson—Where do you get the men to do that?

Mr. Mackin—Only one man is required.

Mr. Mathews—How much do you vary the concentration of solids in the mixed liquor?

Mr. Mackin—We haven't analyzed the suspended solids in the aeration tanks on each shift but I would estimate that the variation would not exceed 200 to 500 p.p.m., ranging from 1,200 to 1,700, as an example. The solids concentration has varied from about 500 to 2,400 p.p.m. in our seven months of experience to date.

Mr. Larson—Do you find that such variation gives you better results than when you operate at a uniform concentration of 3,000 p.p.m.? Is not the air consumption greatly increased?

Mr. Mackin—The more solids that must be carried in the aeration tanks the more air that must be supplied. Hence, where our control tests call for high solids in the aeration tanks, the air costs are going to be high. These conditions will prevail when there is a heavy B.O.D. load on the secondary treatment units.

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As an illustration, let us take the Madison plant with all of the aerators and clarifiers in service. According to our method of rating, this is a 46 per cent return sludge plant designed to treat a sewage of 200 p.p.m. Now let us take one clarifier out of service and the plant characteristics have been altered to a 26 per cent return sludge rate to treat a sewage of 235 p.p.m. B.O.D. In this case, there is less dilution for a stronger sewage.

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INTERESTING EXTRACTS FROM OPERATION REPORTS

CONDUCTED BY LEROY W. VAN KLEECK

Annual Report of the Sewage Disposal Commission of the City of New Britain for the Year Ending March 31, 1944 *

BY JOHN R. SZYMANSKI, SUPT.

This plant began actual operations on May 1, 1937. It employs the Guggenheim biochemical process of treatment. The successive stages in the path of the main sewage flow are: bar screens having one-inch

* For a previous extract see: *This Journal*, 10, 770 (1938).

clear openings, a dosing tank used as a grit settler, primary settling tanks, chemical dosing tank, mixing tanks, and final settling tanks.

Design Data

Population in 1950	80,000
Average dry weather flow	9 m.g.d.
Maximum rate of dry weather flow	13.5 m.g.d.
Maximum rate subject to complete treatment	18.0 m.g.d.
Maximum rate subject to primary sedimentation	25.0 m.g.d.
Detention periods for tanks at 9.0 m.g.d. flow:	
Dosing tanks, each	4.0 mins.
Primary tanks, all three	1.0 hrs.
Mixing tanks, all four	1.5 hrs.
Final settling tanks, all four	2.0 hrs.

Extensive Repairs Made to Sludge Incinerator

The following work was done on the incinerator during the past year:

(a) Hearths Nos. 1, 2, 3 and 4 were rebuilt.
(b) The side wall between hearths No. 1 and No. 2 was rebuilt.
(c) Eight new rabble arms were installed with new teeth.
(d) The arms in the upper six hearths were insulated.
(e) The shaft was insulated from hearths No. 1 to No. 6 inclusive.
(f) All thermocouples were replaced.
(g) Burner boxes No. 2, No. 4, and No. 6 were rebuilt.
(h) All burners were thoroughly checked and cleaned.

General

As a result of numerous conferences with state officials, a definite program was finally instituted whereas the Commission is going to have a detailed survey made of the plant as well as the storm water stream by a competent engineering firm. The money for this survey was set aside by the City Council.

A detailed investigation is in progress on the advisability of converting the sludge cake into fertilizer or soil conditioner.

The incinerator has been rebuilt and is operating satisfactorily.

Following is a summary of operating data for the plant during the period:

Summary of Operating Data at New Britain, Conn. (1944)

Item	Average
Sewage flows, m.g.:	
Daily maximum	13.14
Daily minimum	6.36
Daily treated	10.29
Total by-passed after primary treatment, year	200.0
Screenings, c.f.:	
Total for year	16,002.0
Per m.g. sewage	4.4
Grease, c.f.:	
Total for year	13,411.0
Per m.g. sewage	3.6

Summaay of Operating Data at New Britain, Conn. (1944)

Item	Average
Mixed sludge removed for disposal:	
Total for year, m.g.	10.08
Per cent solids	7.59
Chemicals and air used for sewage treatment:	
Copperas, total lbs. for year	566,205.0
Ferrisul, total lbs. for year	62,457.0
Chlorine, total lbs. for year	76,022.0
Air, c.f. per gal. of sewage	0.146
Returned sludge wasted to primaries:	
Million gals. total	38.05
Per cent solids	0.78
Sludge disposal:	
Total filter hours for year	7,957.74
Lbs. ferric chloride for year	183,607.0
Lbs. Prestolime for year	2,010,958.0
Lbs. dry solids filtered for year	6,348,849.0
Lbs. dry solids per sq. ft. per hr. (filters)	4.0
Suspended solids, p.p.m.:	
Raw	251.0
Final effluent	35.0
5-Day B.O.D., p.p.m.:	
Raw	195.0
Final effluent	48.0
Per cent solids:	
Return sludge	0.78
Raw sludge	7.59
Filter cake	30.2
Total iron, p.p.m.:	
Raw	27.0
Effluent	5.0
Cost of treatment in 1944, dollars:	
Chemicals	14,767.71
Supervision and labor	34,239.50
Light, power and gas	10,117.19
Fuel and supplies	3,680.44
Maintenance	3,131.97
Building maintenance	367.80
Total cost of operation and maintenance	66,304.61
Cost per m.g.	17.43

Eleventh Report of the Minneapolis–Saint Paul Sanitary District for the Year 1943 *

By George J. Schroepfer, Superintendent and Chief Engineer

Rules for Promotion—Grievance Committee

Difficulties which ordinarily occur as a result of poor working conditions, pay, or lack of understanding between employer and employee, have never been a source of concern to the District.

The Board of Trustees has consistently promoted good labor relationship in the knowledge that both management and employee accrue

* For previous extracts see: *This Journal*, 11, 1078 (1939); 14, 199 (1942); 16, 632 (1944).

many benefits, as a result the Board believed it would be well to establish a plan for making promotions based on seniority and qualifications, uniform in all respects to each and every employee. The employees select a committee of their own, known as the Grievance Committee, which meets with the Board's Committee for the purpose of studying proposed plans for making promotions and other matters of concern to them.

Sludge Fertilizer

The experimental work involving the use of sludge cake as a fertilizer was continued by both the District and the University Farm School. An exhibit was held at the Minnesota State Fair again and the District is indebted for exhibit space. Samples displayed were those taken from the State University Farm Experimental fields. That the exhibit at the Fair is considered well worth while is borne out by the fact that additional information as to the use of sludge cake as a fertilizer with a corresponding increase in demand for sludge cake itself was requested especially by farmers living in the vicinity of the Twin Cities. It is interesting to point out the steady increase in the quantity of filter cake used as a fertilizer. In 1939 this quantity was 21 tons; in 1940, 2,756.8 tons; in 1941, 3,678.3 tons; in 1942, 6,867.3 tons. For the year, 1943, this quantity has risen to 11,580.1 tons or approximately twelve per cent of the total annual production.

Inoculations

Continuing its policy of safeguarding the health of its employees, the Board of Trustees authorized re-inoculation of all employees against typhoid fever and paratyphoid. This work was done at the District's expense in December.

Screen and Grit Chambers

Provision is made for ventilation of the screen and grit chambers, the superstructure over these units, and the incoming sewer by means of a 20,000 cu. ft. per minute fan.

In the 1941 report mention was made of the fact that difficulties and the cost of removing screenings from the coarse bar screens with six-inch openings had resulted in the carrying out of an experiment leading to the actual removal of the coarse bar screens in October of 1941. In more than two years of continuous operation with the screens removed, it has been determined that operation savings of some magnitude have been effected by the elimination of these racks, which have more than offset the small increase in maintenance costs of the one-inch, mechanically-cleaned bar screens which has resulted.

Settling Tanks

Sludge is pumped once each shift and a determined effort is made to secure as concentrated a sludge as possible. That such efforts have been successful is shown by the fact that for the entire year solids concentration in the raw sludge pumped from the settling tanks averaged 8.29 per cent as compared with 7.79, 8.07, 8.00 and 8.61 per cent, respectively, in 1939, 1940, 1941 and 1942. As an aid in the increasing sludge concentration, weighing of sludge samples during the pumping period was continued during the year 1943.

Again during the year 1943, the automatic scum removal mechanisms were operated only during the warmer months of the year, their use being dispensed with in the winter months, when the work of maintaining this equipment in operation for mechanical removal of skimmings proved to be much more of a problem than hand skimming. The skimmings removed from the settling tanks are ejected to an area south of the plant where they are covered with incinerator ash without nuisance.

Effluent Filters

The operation of these filters was not required during the year.

Vacuum Filtration

Continued reduction in the quantity of conditioning chemicals was effected. During the year 1943 the quantity of ferric chloride required was 1.12 per cent of the weight of the dry sewage solids, and the quantity of lime expressed on a calcium oxide basis was 3.05 per cent. Comparable figures for the year 1940 were 1.92 and 4.76 per cent, respectively, and during 1939 were 2.1 and 5.68 per cent, respectively.

During the year 1943 the use of hydrochloric acid containing an inhibitor in the cleaning of the drums and screens of the vacuum filters, and for prolonging the life of filter cloth was continued. The life of the cloth was extended to an average of approximately 450 hours by cleaning the cloth with acid after approximately 300 hours of use.

In the past some difficulty has been encountered because of the build-up of calcium carbonate in the sludge distribution lines from the conditioning tanks to the vacuum filters. This carbonate deposit has also occurred in the vacuum lines on the individual filters and on the woodwork and screens forming the drum of the filter. In April, 1943, a device was installed to feed hexametaphosphate continuously to the sludge along with the lime and ferric chloride as a means of attempting to eliminate the build-up of lime. This experiment was continued for two months with negative results, possibly due to its absorption by the organic material in the sludge. Upon the failure of this effort to control the build-up of carbonate deposits, the next effort in this direction was the control of the pH nearer the stability point, so as to eliminate carbonate deposits on the one hand or corrosion of the metal parts on the other. As shown in the following tabulation, the pH of the filtrate has been gradually reduced from 11.7 in 1938 to 8.9 for the last half of the year 1943.

Finally catching on that the weather conditions played havoc with the operation of the diffusers, we constructed a large pipe in such a manner that we could condition the air passing through it and produce humidities comparable to those existing in the outside atmosphere. This apparatus was equipped with a certified gas meter, manometer, and wet and dry bulb thermometer in the pipe line passing the air to the plate container. New plates of known porosity were tested and the results checked our findings under actual operating conditions—the capacity falling off as much as 30 per cent in some cases.

This work convinced us that high relative humidity with certain temperature of the sewage caused the air to reach its dew point, creating an increase in pressure and a reduction in volume passed through the plates. From an economic standpoint, this becomes a serious matter, especially in large plants where huge volumes of air are applied. Very little has been published about this phase of plant operation.

It was surprising to me to read in *Sewage Works Journal* that diffuser plates at Cleveland lasted only about a year and a half. We have plates which have been in operation since 1925 and, although we burned them down once and smoothed them with a carborundum stone, they now show only a slight increase in pressure over plates which were installed in 1937. The plates in the old plant have permeability ratings of only 8 to 12 as compared to the permeability of 30 to 36 in the new plates. Today many plants are equipped with plates of 60 to 80 permeability and encounter serious troubles. One begins to wonder if it is the proper thing to go to such course plates although, of course, it is necessary to use plates of large capacity where it is desired to limit the number of diffusers to a minimum.

Steam driven blowers are used at Milwaukee, each requiring about 2,100 horsepower. The pressure can build up to a certain limit after which the blowers will drop off the line. In order to put them back in service it is necessary to reduce the air pressure over the entire plant. In our case, a pressure increase of 1 to 2 pounds costs about $84 daily.

We have been talking about the above problem for some years and I have met only one operator who experienced the same conditions from June to September and he reported that plates were actually blown out of the containers because the pressure became so high. I believe that this problem is of vital importance to every diffused air activated sludge plant and hope that research will be initiated.

Prof. Bloodgood—The same difficulty is experienced at Indianapolis.

Mr. Brower—I am interested to hear that.

Leland Bradney (*Sioux Falls, S. Dak.*)—I can add nothing to this discussion on diffuser plates but we have one of the most serious activated sludge problems in the country at Sioux Falls. We are handling a mixture of sewage and of packing house wastes, the latter after preliminary treatment on trickling filters. For some time we have been troubled by rising sludge in the final settling tanks. The discouraging thing about it is that the condition only occurs when we have what we consider a good activated sludge but the stuff just will not stay down in the bottom of the tank. We have also found that the loading of the process has no effect on this rising sludge condition; the B.O.D. of the influent sewage to the aeration tanks has varied from 65 to 350 p.p.m. and the rising sludge occurs through the entire range. Another thing, the dissolved oxygen concentration does not seem to make much difference. We get above 0.5 p.p.m. in the aerated mixed liquor and the sludge doesn't rise any worse with 0.5 p.p.m. than it does with 2 p.p.m. I am interested to know if anyone else has encountered a similar condition.

Prof. Bloodgood—We have had trouble with rising sludge and have been able to correct it by increasing the loading, that is increasing the m.g.d. treated per m.g. of aeration tank capacity.

K. V. Hill (*Chicago, Ill.*)—I think the problem at Sioux Falls is a very special case. With reference to Prof. Bloodgood's suggestion that he has corrected the difficulty at Indianapolis by boosting the load on the aeration tanks, we have analyzed the loading on the basis of pounds daily of applied B.O.D. per thousand cubic feet of aeration tank capacity and have found that it varies from 27 to about 100 pounds per day per thousand cubic feet.

I would also like to bring out that this rising sludge occurs even following the second stage trickling filters. The effluent from the second stage of filtration, upon settling, produces the identical condition.

Mr. Mackin—I question Mr. Hill's interpretation. I am not sure it is the same condition. It seems to me that the sludge is going septic and I know that on occasion a rising sludge in the aeration system can be a well oxidized sludge, so I do not think they are of the same type.

Mr. Hill—The effluent from the second stage of filtration frequently contains 2 p.p.m. of dissolved oxygen and some 10 to 17 p.p.m. of nitrate.

Mr. Mackin—Have you examined the trickling filter sludge under a microscope to determine if it appears to be similar to activated sludge?

Mr. Hill—No.

Mr. Bradney—We have taken activated sludge that rises very rapidly and placed it in a flocculator. Once the nitrate is used up, which takes about 4 hours, that sludge does not rise at all in 8 or 10 hours. We did the same thing with sludge from the secondary trickling filter with the same result.

Chairman Martin—May I suggest that we give some of the time in this discussion to the Mallory Oxidized Sludge Process. Mr. Mackin has been operating the Madison plant for several months under this method of control. Suppose we invite questions along these lines and ask Mr. Mackin to answer them on the basis of his experience.

Prof. Bloodgood—Mr. Mackin, how much have you increased the loading in your plant since converting to the new method of control?

Mr. Mackin—We have increased the loading about 1.0 to 1.5 m.g.d. The plant now treats some 8.5 to 9.25 m.g.d.

The B.O.D. of the sewage is very similar to that formerly received although we had 3 or 4 inches above normal rainfall in June and the total rainfall for the year thus far is 2 or 3 inches above normal. Furthermore, I have noticed that the Madison sewage has shown a tendency to increase in strength. I do not know if this is a result of the concentrated housing conditions because of the fact that we have a sizeable camp nearby or whether it is a normal wartime experience, but I have definitely noticed that the strength of the sewage is going up. We have increased the air under heavy loads as in the past winter when we had a very critical condition brought about by the unusually heavy kill at the Oscar Mayer packing plant.

P. W. Riedesel (*Minneapolis, Minn.*)—As an operator of a plant using the oxidized sludge system, have you found the method of control to be practical? I think that is the point which is bothering many people.

Mr. Mackin—Yes, I do consider it a practical method of control. There are other places in which the application would be much more simple than at Madison because of the variable load that we have; for example, where there is a fairly normal, uniform load without any severe shocks. I can sympathize with Dr. Hatfield of Decatur, because, his plant receives some tremendous shocks, but where these are absent oxidized sludge control is most satisfactory.

Dr. Hatfield—What is the extent of the shock load that your plant can take?

Mr. Mackin—An overload of about 50 per cent for 4 hours and 10 per cent for 24 hours, only providing a normal load is not exceeded for the next day or two. Mr. Mallory has a method for rating the plant. The Madison plant is rated at 15,000 pounds per day.

Mr. Mathews—How much did you increase the mixed liquor solids and the applied air?

Mr. Mackin—We tended to decrease the solids. We increase the air only during the winter time.

Mr. Mathews—Are you trying to maintain uniform operations or do you make adjustments in the 24 hours?

Mr. Mackin—Very definitely not uniform. We vary the control in accordance with the demands that are established from the charts which Mr. Mallory provides. We check these items six times a day and make necessary adjustments to keep the process in balance after each test.

Mr. Larson—Where do you get the men to do that?

Mr. Mackin—Only one man is required.

Mr. Mathews—How much do you vary the concentration of solids in the mixed liquor?

Mr. Mackin—We haven't analyzed the suspended solids in the aeration tanks on each shift but I would estimate that the variation would not exceed 200 to 500 p.p.m., ranging from 1,200 to 1,700, as an example. The solids concentration has varied from about 500 to 2,400 p.p.m. in our seven months of experience to date.

Mr. Larson—Do you find that such variation gives you better results than when you operate at a uniform concentration of 3,000 p.p.m.? Is not the air consumption greatly increased?

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Maximum rate subject to primary sedimentation	25.0 m.g.d.
Detention periods for tanks at 9.0 m.g.d. flow:	
Dosing tanks, each	4.0 mins.
Primary tanks, all three	1.0 hrs.
Mixing tanks, all four	1.5 hrs.
Final settling tanks, all four	2.0 hrs.

Extensive Repairs Made to Sludge Incinerator

The following work was done on the incinerator during the past year:

(a) Hearths Nos. 1, 2, 3 and 4 were rebuilt.
(b) The side wall between hearths No. 1 and No. 2 was rebuilt.
(c) Eight new rabble arms were installed with new teeth.
(d) The arms in the upper six hearths were insulated.
(e) The shaft was insulated from hearths No. 1 to No. 6 inclusive.
(f) All thermocouples were replaced.
(g) Burner boxes No. 2, No. 4, and No. 6 were rebuilt.
(h) All burners were thoroughly checked and cleaned.

General

As a result of numerous conferences with state officials, a definite program was finally instituted whereas the Commission is going to have a detailed survey made of the plant as well as the storm water stream by a competent engineering firm. The money for this survey was set aside by the City Council.

A detailed investigation is in progress on the advisability of converting the sludge cake into fertilizer or soil conditioner.

The incinerator has been rebuilt and is operating satisfactorily.

Following is a summary of operating data for the plant during the period:

Summary of Operating Data at New Britain, Conn. (1944)

Item	Average
Sewage flows, m.g.:	
Daily maximum	13.14
Daily minimum	6.36
Daily treated	10.29
Total by-passed after primary treatment, year	200.0
Screenings, c.f.:	
Total for year	16,002.0
Per m.g. sewage	4.4
Grease, c.f.:	
Total for year	13,411.0
Per m.g. sewage	3.6

Summaay of Operating Data at New Britain, Conn. (1944)

Item	Average
Mixed sludge removed for disposal:	
Total for year, m.g.	10.08
Per cent solids	7.59
Chemicals and air used for sewage treatment:	
Copperas, total lbs. for year	566,205.0
Ferrisul, total lbs. for year	62,457.0
Chlorine, total lbs. for year	76,022.0
Air, c.f. per gal. of sewage	0.146
Returned sludge wasted to primaries:	
Million gals. total	38.05
Per cent solids	0.78
Sludge disposal:	
Total filter hours for year	7,957.74
Lbs. ferric chloride for year	183,607.0
Lbs. Prestolime for year	2,010,958.0
Lbs. dry solids filtered for year	6,348,849.0
Lbs. dry solids per sq. ft. per hr. (filters)	4.0
Suspended solids, p.p.m.:	
Raw	251.0
Final effluent	35.0
5-Day B.O.D., p.p.m.:	
Raw	195.0
Final effluent	48.0
Per cent solids:	
Return sludge	0.78
Raw sludge	7.59
Filter cake	30.2
Total iron, p.p.m.:	
Raw	27.0
Effluent	5.0
Cost of treatment in 1944, dollars:	
Chemicals	14,767.71
Supervision and labor	34,239.50
Light, power and gas	10,117.19
Fuel and supplies	3,680.44
Maintenance	3,131.97
Building maintenance	367.80
Total cost of operation and maintenance	66,304.61
Cost per m.g.	17.43

Eleventh Report of the Minneapolis–Saint Paul Sanitary District for the Year 1943 *

By George J. Schroepfer, Superintendent and Chief Engineer

Rules for Promotion—Grievance Committee

Difficulties which ordinarily occur as a result of poor working conditions, pay, or lack of understanding between employer and employee, have never been a source of concern to the District.

The Board of Trustees has consistently promoted good labor relationship in the knowledge that both management and employee accrue

* For previous extracts see: *This Journal*, 11, 1078 (1939); 14, 199 (1942); 16, 632 (1944).

many benefits, as a result the Board believed it would be well to establish a plan for making promotions based on seniority and qualifications, uniform in all respects to each and every employee. The employees select a committee of their own, known as the Grievance Committee, which meets with the Board's Committee for the purpose of studying proposed plans for making promotions and other matters of concern to them.

Sludge Fertilizer

The experimental work involving the use of sludge cake as a fertilizer was continued by both the District and the University Farm School. An exhibit was held at the Minnesota State Fair again and the District is indebted for exhibit space. Samples displayed were those taken from the State University Farm Experimental fields. That the exhibit at the Fair is considered well worth while is borne out by the fact that additional information as to the use of sludge cake as a fertilizer with a corresponding increase in demand for sludge cake itself was requested especially by farmers living in the vicinity of the Twin Cities. It is interesting to point out the steady increase in the quantity of filter cake used as a fertilizer. In 1939 this quantity was 21 tons; in 1940, 2,756.8 tons; in 1941, 3,678.3 tons; in 1942, 6,867.3 tons. For the year, 1943, this quantity has risen to 11,580.1 tons or approximately twelve per cent of the total annual production.

Inoculations

Continuing its policy of safeguarding the health of its employees, the Board of Trustees authorized re-inoculation of all employees against typhoid fever and paratyphoid. This work was done at the District's expense in December.

Screen and Grit Chambers

Provision is made for ventilation of the screen and grit chambers, the superstructure over these units, and the incoming sewer by means of a 20,000 cu. ft. per minute fan.

In the 1941 report mention was made of the fact that difficulties and the cost of removing screenings from the coarse bar screens with six-inch openings had resulted in the carrying out of an experiment leading to the actual removal of the coarse bar screens in October of 1941. In more than two years of continuous operation with the screens removed, it has been determined that operation savings of some magnitude have been effected by the elimination of these racks, which have more than offset the small increase in maintenance costs of the one-inch, mechanically-cleaned bar screens which has resulted.

Settling Tanks

Sludge is pumped once each shift and a determined effort is made to secure as concentrated a sludge as possible. That such efforts have been successful is shown by the fact that for the entire year solids concentration in the raw sludge pumped from the settling tanks averaged 8.29 per cent as compared with 7.79, 8.07, 8.00 and 8.61 per cent, respectively, in 1939, 1940, 1941 and 1942. As an aid in the increasing sludge concentration, weighing of sludge samples during the pumping period was continued during the year 1943.

Again during the year 1943, the automatic scum removal mechanisms were operated only during the warmer months of the year, their use being dispensed with in the winter months, when the work of maintaining this equipment in operation for mechanical removal of skimmings proved to be much more of a problem than hand skimming. The skimmings removed from the settling tanks are ejected to an area south of the plant where they are covered with incinerator ash without nuisance.

Effluent Filters

The operation of these filters was not required during the year.

Vacuum Filtration

Continued reduction in the quantity of conditioning chemicals was effected. During the year 1943 the quantity of ferric chloride required was 1.12 per cent of the weight of the dry sewage solids, and the quantity of lime expressed on a calcium oxide basis was 3.05 per cent. Comparable figures for the year 1940 were 1.92 and 4.76 per cent, respectively, and during 1939 were 2.1 and 5.68 per cent, respectively.

During the year 1943 the use of hydrochloric acid containing an inhibitor in the cleaning of the drums and screens of the vacuum filters, and for prolonging the life of filter cloth was continued. The life of the cloth was extended to an average of approximately 450 hours by cleaning the cloth with acid after approximately 300 hours of use.

In the past some difficulty has been encountered because of the build-up of calcium carbonate in the sludge distribution lines from the conditioning tanks to the vacuum filters. This carbonate deposit has also occurred in the vacuum lines on the individual filters and on the woodwork and screens forming the drum of the filter. In April, 1943, a device was installed to feed hexametaphosphate continuously to the sludge along with the lime and ferric chloride as a means of attempting to eliminate the build-up of lime. This experiment was continued for two months with negative results, possibly due to its absorption by the organic material in the sludge. Upon the failure of this effort to control the build-up of carbonate deposits, the next effort in this direction was the control of the pH nearer the stability point, so as to eliminate carbonate deposits on the one hand or corrosion of the metal parts on the other. As shown in the following tabulation, the pH of the filtrate has been gradually reduced from 11.7 in 1938 to 8.9 for the last half of the year 1943.

Table Showing Filtrate pH, Lime, and Ferric Chloride Doses

Year	pH	% $FeCl_3$	% CaO
1938 average	11.7	3.17	10.30
1939 average	11.6	2.10	5.68
1940 average	10.5	1.92	4.76
1941 average	10.0	1.53	3.77
1942 average	10.4	1.20	3.44
1943 (Jan.–June)	10.2	1.07	2.98
1943 (July–Dec.)	8.9	1.19	3.16

An inspection of the piping after six months of operation with lower pH values revealed considerably less build-up than had formerly occurred. This statement applies as well to the accumulation on the screens and woodwork of the filters. However, with the reduction of the lime build-up on the filters another problem presented itself: namely, the accumulation of a gelatinous coating on the filter drums and screens, efforts toward the control of which are now under way.

Realizing the inherent accuracy of the yard-stick for filtration generally employed, namely, pounds per square foot per hour, counters were installed on all filters in the latter part of 1941, so as to permit the determination of the actual area of filtering service used in any given period of time. While the conventional basis of expressing filtration rates is still being calculated, it has been found that the new yardstick, based upon the pounds per square foot of filtering area actually used, measures more accurately the work performed by filters, since the conventional basis does not take into account several factors affecting filtration, more particularly the speed of rotation of the drum and, therefore, the filtering area in a given period of time.

During October of 1943 two of the three conditioning tanks and one of the two bucket elevators were elevated a total of three feet. The purpose back of this improvement was to permit the flow of heavier sludge from the conditioning tanks to the filter pans by approximately doubling the head available between those two points. This change has definitely been successful as shown by the fact that previously sludge containing as low as 8 per cent solids would have to be diluted with water to permit of its flow to the filter pans. The use of dilution water for this purpose has practically been eliminated except for its occasional use when the sludge distribution lines have become partially fouled.

Incinerators

In earlier reports mention has been made of the fact that it was planned to remove the preheaters and hot air fans from the incinerators so as to effect economies in operation and maintenance of these units. Removal of the preheaters in one incinerator was completed during May of 1941, the second unit during March, 1943, and the last unit during December of 1943. Operation under the improved arrangement shows that the expected economies can more than be fulfilled. As an example, the power requirements have been reduced from an average of 17 kilowatt hours per dry ton, in both the years 1939 and 1940 to 14 kilowatt hours per dry ton in 1941, to 8.8 kilowatt hours in 1943 and to 4.7 kilowatt hours in 1943 after all units were converted. When it is remembered that power during the year 1943 cost an average of 1.20 cents per kilowatt hour, the magnitude of such savings will be apparent.

Sampling Methods

Laboratory results are only as reliable as the samples on which the determinations are made. The samples should be as representative of the sewage, sludge, and other materials being sampled as is reasonably practicable and as their importance justifies. There follows a brief description of the sampling methods in use, together with the frequency of sampling:

The screenings and grit removed from the sewage in the Screen and Grit Chamber Building were sampled daily, with 24-hour composite samples made up from grabs off the conveyor belts. The grab samples are placed in pails with perforated bottoms to permit drainage of any excess water, after which the unit weight per cubic foot is determined. The daily quantities in cubic feet are computed from the number and estimated size of truckloads hauled to the dump. The moisture and volatile matter contents are determined in the laboratory.

Samples of the sewage from the various plant units consisted of daily 24-hour composite samples collected by automatic samplers which proportion the sample to the rate of sewage flow. Once a shift the one-gallon aluminum sample cans are removed from the automatic samplers and placed in a refrigerator. The pipe lines to the automatic samplers are backwashed once a shift with plant effluent under pressure. Once a week the sampler parts are brushed and washed with copper sulfate solution and the raw sewage sampler lines are blown back with compressed air. The samplers are checked periodically for proper proportioning and mechanical operation.

The raw sludge samples were daily 24-hour composites of grabs from sampling cocks on the sludge pumps. From each pump operating, a sample is taken fifteen minutes after starting, every fifteen minutes during the pumping, and one when the pump is stopped, allowing the sludge to flush through the sampling pipe before collection of each sample.

The supernatant liquor pumped back to the raw sewage from the sludge concentration tanks was sampled by collecting two 100-ml. ladles every fifteen minutes during pumping.

The concentrated sludge samples were daily 24-hour composites of the sludge going to the conditioning tanks, obtained by taking two 100-ml. ladles per hour from a bucket of each bucket elevator operating. One to two gallons of composite sample were thus obtained.

The filter cake samples were daily 24-hour composites collected by applying a cookie cutter to the discharge side of the vacuum filters. One "cookie" was collected per filter operating per hour. The sludge and filter cake samples are deposited in milk cans having tight fitting covers to minimize loss of moisture by evaporation during the sampling day.

The sludge filtrate samples were daily 24-hour composites of hourly grabs collected from the filtrate receivers.

Toward the end of each shift, the samples collected during each 8-hour period of operation were all brought to the laboratory and placed in the refrigerator to await compositing by the chemist on duty the following morning.

Samples for dissolved oxygen were grab samples collected once a week.

Mississippi River Data

The river discharges and a total of 905 river samples were collected during 1943. The river water samples were subjected to the following determinations: temperature, dissolved oxygen, pH, turbidity, one-, five- and ten-day biochemical oxygen demand, total bacterial count and coliform organisms. In addition to the analytical determinations, field observations were recorded on weather conditions at the time of sampling, existence of floating material or gassing, extent of ice coverage, algae, midge flies, and other conditions which might aid in interpreting the analytical data.

Following is a table summarizing the operating data for 1943:

Summary of Operating Data, Minneapolis—Saint Paul Sanitary District (1943)

Item	Average
Sewage flow, m.g.d.	119.1
Estimated tributary population	826,000.0
Screenings:	
Cu. ft. per m.g.	0.90
Wet lbs. per cu. ft.	33.3
Total solids, per cent	16.5
Volatile solids, per cent	88.6
Grit:	
Cu. ft. per m.g.	3.9
Wet lbs. per cu. ft.	85.8
Total solids, per cent	88.0
Volatile solids, per cent	5.9
Sewage temperature, degrees F:	
Raw	63.0
Effluent	61.0
Settling tank detention, hours	1.2
Sewage analyses:	
B.O.D.—5-day	
Raw, p.p.m.	170.0
Settled, p.p.m.	105.0
Per cent removal	39.5

Summary of Operating Data, Minneapolis—Saint Paul Sanitary District (1943)—Continued

Item	Average
Suspended solids:	
Raw, p.p.m.	265.0
Settled, p.p.m.	95.0
Per cent removal, settling tanks	64.3
Per cent removal, total incl. sc. & grit	68.4
Settleable solids:	
Raw, ml. per liter	6.5
Settled, ml. per liter	1.3
Per cent removal, settling tanks	79.1
Analysis of sludge:	
pH:	
Raw sludge	6.2
Thickened sludge	6.0
Filtrate	9.6
Total solids, per cent:	
Raw sludge	8.29
Thickened sludge	9.47
Filtered sludge (sludge cake)	33.4
Volatile solids, per cent:	
Raw sludge	66.1
Thickened sludge	64.5
Sludge cake	61.3
Analysis of filtrate:	
Total solids, p.p.m.	3,100.0
Suspended solids, p.p.m.	91.0
Raw sludge:	
Gallons daily	315,000.0
Dry tons daily	111.2
Thickened sludge:	
Gallons daily	225,700.0
Dry tons daily	92.2
Conditioning tanks detention, mins.	8.0
Conditioning chemicals:	
Per cent CaO	3.05
Per cent ferric chloride	1.12
Filter cake:	
Wet tons daily	277.5
Dry tons daily	92.8
Filter rate:	
Wet lbs. per sq. ft. per hr.	10.4
Wet lbs. per sq. ft. of area used	0.86
Filter cake used for fertilizer, dry tons, total for yr.	3,623.3
Filter cake incinerated, dry tons daily	82.4
Ash, dry tons daily	31.9
Power used, k.w.h. per ton dry solids	4.7
Fuel oil used, gals. per ton dry solids	2.54
Cost data, dollars:	
Total operation and maintenance cost	280,345.50
Light and power cost	20,232.62
Materials and supplies	40,074.14
Chemicals for sludge conditioning	23,416.10
Chemicals per dry ton	0.71
Salaries and wages	192,704.59
Per million gallons sewage treated	6.29

Thirteenth Annual Report on the Sewage Treatment Plant of the Aurora Sanitary District, Aurora, Ill., for the Year 1943 *

By Walter A. Sperry, Superintendent

Saving Through Use of Plant Produced Power

December 31, 1943, completed three years and one month of complete dependence on plant produced power and independence from the local power utility. There were no substantial power interruptions and only a few minor breakdowns. Eight hundred and twenty-three gallons of gasoline were used to bridge deficient gas supply in the months of February, March, April and May. With purchased power the total operating cost would have been $33,008 instead of $26,149, a reduction due to plant produced power of 20.8 per cent.

Postwar Program

Agreeable with good policy and by government request a well considered postwar program is under study. It is not expected that this program will be completed in any one year, but that it will proceed as funds are available and somewhat in the order listed.

Included among the projects are two of general interest:

1. The installation of four aeration-flotation units in Clarifier No. 1 for the pretreatment of raw sewage and primarily for the removal of hydrogen sulfide to gain better odor control. Some increase in clarifier efficiency is anticipated.
2. The consideration of an intermediate receiving tank for transfer sludge which will solve a sampling problem and allow for sufficient concentration and decantation of supernatant liquor as may materially effect the operation of the second stage digesters.

A Few General Notes

The plant redesigned a highway sign announcing the qualities of sludge as a permanent advertisement that sludge was here for the asking. Due to the distance from the city, the prohibition on tires and gasoline and the high percentage of men employed, practically no sludge was removed in 1943.

Operator's note: "Installed screens on the louver of the pump room to exclude sparrows who persisted in making a 'Sanitary District' of the engine room."

Installed a pendulum clock in the main pump room. Normally, with utility power, an electric clock would be used. At the time of installing the gas generators, the electric clock, then in use, began to "race," and the District was the butt of some joking by the utility men. It was pointed out, however, that the generators were not purchased to operate clocks and it was not possible to regulate the 35-kilowatt machines closely enough for clock operating purposes.

* For previous extracts see *This Journal*, 8, 659 (1936); 13, 1242 (1941); 15, 949 (1943).

Gross Totals of Suspended and Soluble Solids Received and Removed

In the table summarizing the operating data for 1943 are given the usual figures for B.O.D. and suspended solids removal by this plant. In tables A and B directly below, however, are tabulated the gross totals of suspended and soluble solids received and removed by the plant during 1943. These figures were compiled from meter and laboratory data. While these figures may be open to some discussion as to their absolute correctness, they are nevertheless based on careful observations, which makes them a valuable comparison from year to year as to the overall work accomplished. This abstractor recom-

TABLE A.—*Suspended Solids Data*

Total pounds of suspended solids brought down by raw sewage	4,381,460
Total pounds of suspended solids removed by plant	3,702,740
Total pounds screenings removed	30,560
Total pounds grit removed	266,700
Total pounds grease-scum removed	43,600
Total pounds sewage solids removed by settling tanks	2,199,300
Total pounds sewage solids removed by filters	814,300
Total pounds sewage solids removed by secondary tanks	348,280
Total pounds sewage solids discharged to Fox River	678,720

TABLE B.—*Soluble Solids Data*

Total pounds "oxygen demand" of raw sewage	2,580,920
Total pounds "oxygen demand" reduced	2,168,620
Oxygen demand reduced by settling tanks	922,720
Oxygen demand reduced by filters	1,092,760
Oxygen demand reduced by secondary tanks	153,140
Total pounds "oxygen demand" discharged to Fox River	412,300

Summary of Operating Data, Aurora Sanitary District, Aurora, Illinois (1943)

Item	Average
Sewage flow, m.g.d.	7.8
Estimated population served	51,000.0
Screenings, cu. ft. daily	9.8
Grit. cu. ft. daily	23.4
Skimmings from settling tanks, cu. ft. daily	2.7
Settleable solids, ml. per liter:	
Raw sewage	5.9
Tank effluent	0.8
Filter effluent	0.3
Final effluent	0.2
Chemical analysis of sewage:	
B.O.D.—5-day, p.p.m.:	
Raw sewage	111.0
Settled sewage	70.0
Filtered sewage	22.0
Final effluent	13.0
Relative stability, final effluent, per cent	96.0
Suspended solids, p.p.m.:	
Raw sewage	174.0
Settled sewage	78.0
Filtered sewage	41.0
Final effluent	25.0

Summary of Operating Data, Aurora Sanitary District, Aurora, Illinois (1943)—Continued

Item	Average
Dissolved oxygen in Fox River, p.p.m.	10.5
Fox River flow, c.f.s.	950.0
Lbs. oxygen available daily in Fox River	70,400.0
Lbs. oxygen demand of plant effluent, daily	950.0
Primary sludge to first stage:	
Per cent solids:	
Maximum	14.0
Minimum	1.6
Average	4.7
Per cent volatile matter	73.1
Dry lbs. daily	6,750.0
Secondary sludge to second stage:	
Per cent solids:	
Maximum	8.3
Minimum	3.0
Average	5.7
Per cent volatile matter	62.4
Dry lbs. daily	690.0
Transfer sludge (first to second stage):	
Average per cent solids	2.2
Per cent volatile matter	57.1
Digester temperatures, F°:	
Digester No. 1	82.0
Digester No. 2	87.0
Digester No. 3	87.0
Per cent of sludge gas from first stage	60.6
Total cu. ft. of gas, daily	48,740.0
Cu. ft. gas per m.g. sewage	6,300.0
Cu. ft. gas per lb. volatile matter added	8.4
Cu. ft. gas per capita daily	0.95
Lbs. dry solids removed by settling tanks (primary) per m.g. sewage	860.0
Lbs. dry solids removed by primary tanks per capita	0.132
Lbs. dry solids removed by secondary tanks per m.g. sewage	180.0
Cost of operation, dollars:	
Total for administration and operation	31,548.91
Per million gallons	11.06
Per capita per year	0.62

mends that other plants consider the publishing of similar data not only for the yearly comparison of plant accomplishments, but also because of the popular appeal of such figures for newspaper articles, public talks and general appreciation of plant performance by the layman.

Sewage Treatment Plant at Cortland, New York. Operating Report for the Year 1943 *

By Uhl. T. Mann, Superintendent

This plant was placed in operation on May 1, 1940. It serves an estimated population of 15,000 and had a mean daily flow in 1943 of 6.04 m.g.

* This report won the rating award of the New York State Sewage Works Association for 1944.

The treatment processes, in the sequence of sewage flow, are:

Pre-chlorination chamber
Mechanically cleaned bar screen
Two hand cleaned bar screens
Screenings grinder
Four sewage pumps
Duplicate grit chambers
Parshall flume for measuring flow
Duplicate sedimentation tanks with collectors
Post chlorination chamber
Outfall to river

The sludge treatment and accessory processes are:

Duplicate heated sludge digestion tanks
Gas holder
Three sludge pumps
Two vacuum filters
Duplicate batch-mix conditioning tanks
Continuous mix tank
Belt conveyors for dried sludge
Gas and oil boiler

Following is a table giving a summary of operating data for the year 1943:

Summary of Operating Data, Cortland, N. Y. (1943)

Item	Average
Estimated population served	15,000.0
Sewage flow, m.g.d.	6.04
Grit, cu. ft.:	
Per month	113.0
Per m.g.	0.76
Screenings, cu. ft.:	
Per month	661.0
Per m.g.	3.78
Settling tanks, detention, hrs	2.0
Primary sludge removed, cu. ft.:	
Per month	31,713.0
Per m.g.	183.7
Settling tank skimmings, cu. ft.:	
Per month	578.2
Per m.g.	3.14
Settleable solids, ml. per liter, 1 hr.:	
Influent	3.15
Effluent	0.09
Chlorine used, lbs. per m.g.	68.8
Chlorine residual, p.p.m.	0.5
Sludge temperature in digesters, F°:	
Digester No. 1	87.4
Digester No. 2	89.9
Sludge pH in digesters:	
Digester No. 1	7.0
Digester No. 2	6.9

Summary of Operating Data, Cortland, N. Y. (1943)—Continued

Item	Average
Digested sludge drawn, cu. ft.:	
Per month	6,475.0
Per m.g.	35.2
Dry solids in sludge, per cent:	
Primary sludge	2.61
Digested sludge	9.98
Sludge cake from vacuum filters	38.5
Sludge conditioning chemicals:	
Lime, per cent dry basis	10.24
Ferric chloride, per cent dry basis	3.01
pH unconditioned sludge	6.9
pH conditioned sludge	10.9
Filter rate, dry lbs. per sq. ft. per hr.	9.3
Gas production, cu. ft.:	
Per day	14,257.0
Per capita daily	0.95
Carbon dioxide in sludge gas, per cent	30.4
Sewage analysis:	
B.O.D., 5-day, p.p.m.:	
Bar-screened sewage	384.1
Tank effluent	184.5
Suspended solids, p.p.m.:	
Bar-screened sewage	144.0
Tank effluent	53.2
Receiving stream:	
Average flow, c.f.s.	498.0
B.O.D., up-stream, p.p.m.	3.15
B.O.D., down-stream, p.p.m.	8.93
Dissolved oxygen, up-stream, p.p.m.	10.3
Dissolved oxygen, down-stream, p.p.m.	8.57
Relative stability, up-stream, per cent	97.0
Relative stability, down-stream, per cent	97.0
Cost of plant, dollars	190,101.30
Power and light costs in 1943	1,747.55
Chemical costs in 1943	1,682.83
Total operation and maintenance costs, 1943	13,589.72
Cost per m.g. treated, excl. amortization and interest	6.16

WARTIME MAINTENANCE PROBLEMS *

By Paul Winfrey

Operating Engineer, Des Moines, Iowa

Maintenance of sewage plant equipment is always a problem—a problem of finances, manpower and the supervisor's personal time and energy. Maintenance in time of war has become more of a problem because of the added worries of limited supply of critical materials and of the inability of the manufacturers to make and deliver repair and replacement parts with any promptness. When parts are ordered in December and received the next September or, as sometimes happens, the company does not bother to acknowledge receipt of the order, those

* Presented at the Twenty-fifth Annual Meeting of Iowa Wastes Disposal Association, Ames, September 15, 1944.

in charge of plant operation take maintenance for the prevention of breakdowns more seriously.

Sewage plants have been given, and rightly so, a high priority rating by the War Production Board. The present rating of AA–1 is sufficient to purchase if a seller who can deliver can be found. Early in the war there was, I believe, a tendency to purchase under a lower priority rating than that allowable. I have always believed that plants should purchase parts and supplies on the highest rating available. The vendor can re-order and keep up his stock, the manufacturer can get allotments of raw materials for making the goods required by those using the high priority rating. In other words, use the highest rating, as that is what was intended or such rating would not have been granted.

The slowness of deliveries must be recognized and the orders for expendible articles such as packings, wear rings, pump impellers, leather and rubber gaskets and seals must be placed earlier than in normal times. A good rule for some things such as sludge pump packings is to re-order at the time a new set is installed. This cannot be called hoarding; it is certainly allowable under government rules and is consistent with the government's desire to keep sewage plants operating.

I presume that most of you, as it is with me, are flooded with the paper wasting flow of miscellaneous advertising, advice, and good wishes of manufacturing concerns, many of whom have nothing to offer at this time. However, some very good articles are published by those making sewage plant equipment. An equipment maintenance and operation file with a folder for each piece of machinery is invaluable and is a handy place to keep such instruction sheets and information leaflets.

The latest current articles on detailed maintenance of equipment are being published in *Sewage Works Engineering*. One installment has been appearing each month since October, 1943. The articles "Equipment Maintenance in Time of War" are compiled by Morris M. Cohn, Editor of the magazine. It is promised that these articles will be republished in the form of a manual and, if so, it will be a very valuable reference book.

No doubt most of you subscribe to *Sewage Works Engineering*, but should you not, I can strongly recommend this magazine along with *Sewage Works Journal* as a "must" for sewage plant operators.

Probably no one item of maintenance is more vital and common than that of painting. Due to the nature of the materials handled, sewage plants always need paint. Buildings, pipe lines, motors, gratings, valve stands, machinery, etc., require particular attention. All kinds of paint seem to be available in any needed quantity; even aluminum paint is to be had. The manpower may be scarce but usually no great skill is required to paint around the plant so that whatever help is available can paint. Certainly it is a poor policy to get into the habit of not spending money for painting, war or no war.

As to kinds of paint to use, I will not say. I am still looking for a good paint to use on outdoor equipment such as rotary distributors. No priorities are required to purchase paint and the O.P.A. has just recently promised relief from the outlandish rise in the prices of paint brushes. Good paint brush maintenance can do wonders in making a brush last. A good chemical soaking and a hot water washing can often revive an old stiff brush. We have all thrown away better brushes than can now be purchased.

Electric motors usually need very little care but the inconvenience of losing the use of a motor makes it especially important to give all motors exceptional care. Check your motors every time they are used by using your nose, your hands and your ears. A motor too warm will smell of hot grease. Heat and vibration can be felt with your hands. Your ears will tell of loose, slapping chains and belts. Listen to a motor start—it should come up to full speed quickly.

The only good method of motor lubrication is to use a good oil or grease systematically according to a schedule and to keep a written record of what and when. All motor manufacturers furnish instructions for motor care. It is always a safe and good practice to follow their recommendations. Good greases and oils are cheap—only poor ones are expensive. Remember that ball bearings can be overgreased.

Power transmission chains and belts need rather close attention. The wear on loose chains is much greater than the wear on chains just tight enough. Chains and belts that are too tight put much strain on the shafts and bearings. V-belts get their grip from the sides of the belt and do not need to to be very tight.

The electric welder is a great boon to the plant operator. The speed and ease with which repairs, reinforcements, additions and even entirely new equipment can be built is something to look into if you do not already have a welder. Welders are available to sewage plants. If women war workers can weld, the men who make sewage plants go can do it just as well. Many time and labor saving implements and gadgets can be made with a small welding outfit. If you can not get your own welder, the next best solution is to call the local garage man to do your welding.

I have tried to generalize somewhat on plant maintenance and have mentioned painting, motor care, chains and belts, and electric arc welding. No doubt the discussion to follow will get into the details and subjects in which you are most interested.

Discussion

Notes by L. O. Stewart

Secretary, Iowa Wastes Disposal Association, Ames, Iowa

There seems to be no paint that will stand up completely. A good grade of aluminum paint is very satisfactory and zinc chromate primer covered by bituminous base aluminum has been found satisfactory.

It has been difficult to maintain floating digester covers because of the difficulty in getting at the sides. One member suggested consideration of cathodic protection. It was suggested that some material other than steel might be used in some places. For example, floating covers might be made of wood, using modern methods of construction.

In connection with the shortage of repair parts, one operator reported that he had been able to have many parts made at a local machine shop. There was some discussion of wear at under-water bearings because of grit action. The suggested remedy was to furnish grease lubrication to such bearings. One plant operator reported a substantial saving of money where it seemed necessary to replace a large chain by building up the teeth of the sprockets by welding.

It was suggested that a combination of flocculation and grit basins would give more effective grit removal and thus aid in alleviating some of the problems caused by the presence of grit. This would give us something in the nature of an assembly line procedure. One difficulty seems to lie with patents.

There was discussion of rotary distributors in small towns. They often go out of service in the winter, which is a very critical period for streams which are frozen over and in poor condition to receive the treatment effluent. It was suggested that it might be desirable to build covers over the filter beds which would involve an additional cost equal to approximately ten per cent of the original cost. In some places this condition can be alleviated by recirculating the sewage to eliminate rest periods. The use of snow fences may help. The addition of a cover would bring other maintenance problems, such as the upkeep of roof and side walls.

TIPS AND QUIPS

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Our apologies to Superintendent N. Herda of the sewage treatment works at the Willow Run Bomber Plant of the Ford Motor Company of Ypsilanti, Mich. Mr. Herda was one of the busy men who contributed a most complete questionnaire return to the "Summary of Experience in Mechanical Aeration Activated Sludge Plant Operation," published in the January *Journal* (**17**, 1, 101 (1945)). Due to an oversight, credit for the contribution was accorded to R. W. Dulmage instead of to Mr. Herda, an error which we regret exceedingly. Mr. Dulmage is superintendent of the Power Department at Willow Run and is not in charge of sewage treatment.

We shall see that it doesn't happen again!

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Superintendent J. H. Spaeth of Salina, Kansas, in a letter ordering additional copies of the Federation's new safety manual, advises that he expects to use them for acquainting members of the City Council with some of his problems. He deplores the common inclination of municipal officials to place the requirements of the sewage works at the bottom of the list when it comes to purchasing needed equipment and supplies.

You have something there, Mr. Spaeth, but you have also struck upon the solution. If the City Dads do not appreciate the requirements of the sewage works, it is because they lack understanding and must be educated. Seeing that they become informed is just another of the many inherent responsibilities of the superintendent!

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Distribution of the safety manual prompted another interesting communication from Martin C. Klann, formerly city sanitary engineer at Bay City, Michigan. The list of sewage works accidents in the appendix of the report reminded Mr. Klann of some personal experiences, which he relates as follows:

"I have been connected with a 'series' of sewer explosions. The first one occurred in the extreme south end of Bay City when the plumbing inspector and myself were called out to investigate gasoline odors in some homes and a school. We opened several manhole covers to check for gasoline odors. One appeared suspicious and, as we were both kneeling and looking into it, a lighted cigarette fell into the sewer—and nothing happened. A moment later, the plumbing inspector dropped a lighted match and as it struck the bottom a ball of flame struck me squarely in the face! I was set aflame, of course, but my companion soon put out the fire. It left me with a badly burned face and almost no hair on my head. This was about March, 1941. [This method of detecting explosive gases is *not* recommended. See pp. 30–31 of the safety manual.—Ed.]

"The same year, a large 48-inch and 60-inch storm sewer, which was under construction, exploded and blew off manholes for several blocks in all directions from the point of ignition. The blast was caused by the presence of natural gas which had escaped from a leaking main and was set off by open flame type miner's lamps worn by men in inspecting the job. Several men working on the sewer were injured by this explosion. [See page 36 of the safety manual for recommended lighting equipment in explosive atmospheres.—Ed.]

"Another explosion in 1942 was caused by escaping natural gas, evidently ignited by a spark at the street surface. A manhole cover was blown 50 feet in the air, damaging a nearby tree, and burst a fire hydrant and water main."

There must be others who have had similar experiences, previously unreported. Let us hear about them—each carries a lesson which may prevent a like accident somewhere else.

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At this point, it is pertinent to inquire if you have all of the copies of Manual of Practice No. 1 that you need. (Subtle, isn't it?) Foremen, chief shift operators, city officials and others can use them to good advantage:

The demand has been heavy and it appears that a second printing will be necessary. Extra copies are 25¢ each to members and 50¢ each to non-members.

Place your order now for prompt delivery!

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Notes from New York City, where the New York State Sewage Works Association barely beat the gun on the ODT ruling by staging its Seventeenth Annual Meeting on January 19, 1945 . . . actual registration figures are not at hand but the attendance was obviously better than average . . . presentation of two Kenneth Allen Awards, the N.Y.S.S.W.A. Kenneth Allen plaque jointly to Lloyd R. Setter and Gail P. Edwards and the Federation award of the same name for service to Member Associations to Charles A. Holmquist . . . special significance in the fact that Mr. Holmquist succeeded the late Kenneth Allen when he became the second president of the N.Y.S.S.W.A. in 1929 . . . a technical program of unusually high caliber including at least four papers certain to receive consideration in the deliberations of the 1946 Awards Committee . . . a most interesting historical paper by Charles A. Emerson, in which he reviewed 35 years of progress in sewage treatment . . . a sequel to Mr. Emerson's remarks by William R. Copeland, a member of the original technical staff of the Lawrence (Mass.) Experiment Station . . . an unprogrammed talk by Major Andy Fuller, now of the Sanitary Corps, U. S. Army, and formerly of the New York State Department of Health, who related his experiences and observations on sanitation in the China-Burma-India theater of war, in which he has served for 2½ years . . . a most satisfying personal thrill in the resolution adopted by the Association in commendation of "The Operator's Corner", for which collaborators Van Kleeck, Sperry and Dreier may take well-earned bows . . . followed by a determination that "The Corner" will receive every opportunity for further improvement as compensation to such appreciative readers . . . a conviction, while homeward bound, that meetings such as this are of unquestionable value . . . and a feeling of regret that there would be few, if any, of them held during the remainder of the year . . . .

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M. B. Sullivan has recently been appointed as Chief of the Sewerage, Sanitation and Highway Branch of the Government Division of the War Production Board, replacing Henry M. Evans, who has been assigned to another post.

Any inquiries on sewage works priorities should be directed to Mr. Sullivan's personal attention.

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Statistics on labor and materials used in sewage works construction, released by the Associated General Contractors of America, show that this type of work will go far toward providing postwar employment. Data compiled by the U. S. Bureau of Labor statistics indicate that for every million dollars of such construction (at 1940 levels), "a total of 330,000 man-hours of labor would be provided on the site, and 430,000 hours off site—in mines, forests, factories, transportation and administration—and about 50 different kinds of materials and equipment would be used."

A breakdown of expenditures for labor and materials per $1,000,000 of contracts awarded for water and sewerage projects follows:

Labor at site		$ 318,000	31.8%
Materials:			
Iron and steel products	$236,200		
Stone, clay and glass products	122,500		
Machinery	57,100		
Forest products	42,800		
Non-ferrous metals	9,900		
Chemicals	6,400		
Other materials	17,100		
		492,000	49.2%
Other expenses and profit		190,000	19.0%
Totals		$1,000,000	100.0%

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New gas engine designs announced recently by the Worthington Machinery Corp. and the Cooper-Bessemer Corp. will make this equipment even more popular in modern sewage treatment works than it has been in the past. Both manufacturers are introducing engines capable of operating on gas or liquid fuel, which can be converted from one fuel to another while operating under load and which will yield much higher efficiencies when operating on gas fuel.

The new engines will also be advantageous from a safety standpoint, since electric spark ignition is not used.

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Superintendent C. D. Decker of Bryan, Ohio, offers a simple but effective tip on the prevention of electrolytic corrosion at the dispersing cones of Chicago mechanical aerators. There being no metallic connection between the motorcone-impeller assembly and the cylindrical draft tube which comprises this equipment, Mr. Decker ascribed a severe pitting near the bottom of the aluminum cone to electrolytic action, the mixed liquor serving as the electrolyte in conducting the current from the cone to the grounded draft tube. Some of the pitting in the lower part of the cone developed into holes through the metal.

Mr. Decker's analysis was confirmed by his solution of the problem. He tells about it:

"Being unable to get replacement cones without undue delay, we provided a copper wire to carry any electrical currents from the upper cone assembly directly to the draft tube. This wire was fastened to the shaft collar above the cone, out over the edge of the cone and the lower end connected to the draft tube below the mixed liquor surface, making sure that a good contact between the wire and metal was made at both ends.

"We then patched the pitted part of the cone and filled the holes with a paste made of litharge and glycerin and gave the entire surface of the aluminum cone a coat of Inertol under-water paint.

"Upon examination of these cones after fifteen months of additional service, the pitting appears to have stopped, although the paint on some of the cones has scaled off in places. We believe this is because the surface of the metal may not have been entirely clean before the paint was applied.

"From our experience, we feel that we can recommend this solution for this type of problem to those who operate the same equipment. We are glad to pass it along for whatever it may be worth."

We too, Mr. Decker, are glad to have you pass it along! Many thanks!

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Editorial

STATE POLLUTION CONTROL AGENCIES IN ACTION

Across the nation, state departments of health, sanitary water boards and water control agencies are working vigorously to make sure that stream pollution abatement receives proper consideration in the postwar planning picture. Municipal sewage treatment projects are not spontaneously initiated and developed, even in the most far-sighted of city councils, and it is gratifying that the various state pollution control agencies are directing attention, where necessary, to problems requiring early solution.

The Pennsylvania Sanitary Water Board is now in the midst of one of the most comprehensive and well timed programs in the nation. Ten regional hearings were held in the summer of 1944 at which municipal and industrial officials were acquainted with the policies of the Board. Basic requirements as to degree of treatment are simple and logical; except where streams are so polluted by acid mine waters as to make sewage treatment unreasonable at this time, all sewage is to receive a minimum of primary treatment and, where the character and usage of the stream dictates, complete treatment must be provided. Industrial pollution abatement is requested on an equivalent basis. At this writing, the Board has issued orders to about 200 municipalities, giving specific notice of the degree of treatment required and setting a definite date by which plans must be submitted. A few other state pollution control agencies are proceeding along similar lines but on a smaller scale than in Pennsylvania, as in Illinois, for example, where about 80 cases of long standing are being pressed against municipalities. The plan is sound and well advised.

In Michigan, the State Department of Health and State Stream Control Commission are working closely with the State Postwar Planning Commission to assure inclusion of necessary pollution abatement works in the broad program. New York is proceeding likewise, with excellent results, to set a pattern for other states in which planning funds are appropriated from the state treasury.

Many states are handicapped in that there is no agency empowered adequately to control stream pollution but several of them are considering legislation which would create such bodies. In Tennessee, a committee of the legislature has completed a lengthy study and report on the pollution problem in that state, and recommends legislation creating a Stream Pollution Control Board. The proposed legislation is much the same as that which has been administered successfully for some years in Pennsylvania and Illinois. Colorado, where water conservation is of paramount importance, is also considering more specific pollution control laws, as are the states of Virginia, Maryland and others. Even where the enforcement authority is limited, however, most state health departments are exercising their advisory powers to the greatest possible extent by directing the attention of municipal officials to needed sewage treatment works.

In Indiana, a well conceived publicity campaign is keeping the state's stream pollution problem in the foreground. Each issue of *The Monthly Bulletin,* published and distributed statewide by the State Board of Health, contains a non-technical article by a member of the State Stream Pollution Control Board or of its technical staff. The same publication carries a series of discussions, by principal watersheds, of the present situation in each region of the state, so that local newspapers are supplied with "ammunition." In cooperation with the Bureau of Government Research of Indiana University, the Board of Health has published an extremely useful planning manual for the assistance and guidance of municipal officials in developing sewage and water works projects. A few other states have distributed similar literature and have achieved good results.

Recognizing the need for scientific progress in meeting difficult industrial waste pollution problems, many state pollution control agencies are sponsoring or conducting valuable joint research studies. Typical of these are the Upper Mississippi Board of Engineers (comprising Minnesota, Wisconsin, Iowa, Illinois and Indiana) and the Interstate Commission on the Potomac River Basin (comprising Maryland, Virginia, West Virginia and the District of Columbia). Research in more localized problems is being fostered in a number of individual states, such as on mine drainage in Pennsylvania, citrus fruit processing wastes in Florida, textile and metal wastes in Connecticut and pulp and paper wastes in Washington. Great advances in the art may be anticipated from these and like activities in other states.

When it is noted that the technical staffs of all state agencies are reduced to very limited numbers of trained men at this time, because of contributions to the armed services, the present accomplishments of these bodies are even more commendable. Several offices, depleted to the most meager of staffs, have found it necessary to eliminate many routine functions in order to make sure that needed pollution abatement works are "blueprinted now." Such a policy is justified by the permanence of the dividends accruing from the effort invested, and denotes vision and foresight. These state engineers have not forgotten the lesson learned in regard to hasty planning in the mad scramble of P.W.A. days.

The "National Inventory of Needs for Sanitation Facilities," as compiled by the U.S.P.H.S. in 1944, estimates that 10,522 municipalities will require new or improved sewage treatment works. This surprising total offers a formidable challenge to the postwar planners and, when the results are tabulated, a full share of credit must go to the state pollution control agencies which are performing such sterling service today.

W. H. W.

Proceedings of Member Associations

IOWA WASTES DISPOSAL ASSOCIATION

Twenty-fifth Annual Meeting

Ames, Iowa, September 15, 1944

A meeting of the Iowa Wastes Disposal Association was held at the Iowa State College, Ames, on September 15, 1944, with 53 members and guests attending.

Of special interest on the program was the paper, "Maintenance Problems in Wartime," which was presented by Paul Winfrey of the Des Moines sewage works, and discussed by Leo Holtcamp of Webster City and H. J. Spragg of the Iowa Great Lakes sewage works.

Another highlight of the meeting was a paper by Charles Alexander, Superintendent of the water works at Ames, outlining the steps which should be followed in putting into effect a program on "Retirement and Pension Plans for Municipal Employees."

W. H. Wisely, Executive Secretary of the Federation, was present at the meeting and explained the objectives and progress of that organization.

"Some Thoughts on Unification of Water Works and Sewage Organizations in Iowa" was presented by Earle Waterman, Professor, State University of Iowa, and discussed by H. V. Pederson, Marshalltown, and C. T. Wilson, Waterloo.

Officers elected to serve during the ensuing year are as follows:

President—T. R. Lovell, Marshalltown
Vice-President—Paul Winfrey, Des Moines
Director—R. G. Miller, Vinton
Director—C. G. Spragg, Arnolds Park
Director, Federation Board of Control—John Pray, Fort Dodge
Secretary-Treasurer—L. O. Stewart, Ames

L. O. Stewart, *Secretary-Treasurer*

OHIO CONFERENCE ON SEWAGE TREATMENT

Executive Committee Meeting

Mansfield, Ohio, February 26, 1945

An Executive Committee meeting of the Ohio Conference was held at the Mansfield sewage treatment works on February 20 with J. R. Turner presiding. Present were Chairman Turner, C. D. McGuire, J. H. Wenger, R. L. Snyder, L. C. Huffman, L. B. Barnes and Ben H. Barton, acting for C. D. Decker.

A motion was made and seconded that the 1945 Annual Meeting of the Ohio Conference be cancelled if a permit is not issued by the O.D.T.

Nominees for the 1945 Kenneth Allen Award, the recipient to be selected by letter ballot of the membership, are F. D. Stewart, F. H. Waring and C. D. McGuire.

Committee appointments by Chairman Turner, approved by the Committee, were as follows:

Membership: J. H. Wenger, *Chairman,* V. R. Shick, H. Bloem, Franklin Ruck.
Nominating: R. L. Snyder, *Chairman,* A. H. Niles, B. H. Barton.
Legislation: A. H. Niles, *Chairman,* C. D. McGuire, Floyd Browne.
Education: T. C. Schaetzle, *Chairman,* G. E. Flower.
Research: B. H. Barton, *Chairman,* E. F. Whittmer, C. D. Decker.
Program: D. D. Heffelfinger, *Chairman,* with two additional members of his choice.

The report of the Secretary-Treasurer showed a total membership of 82, which included 7 new members.

There being no further business, Chairman Turner adjourned the meeting.

L. B. Barnes, *Secretary-Treasurer*

TEXAS WATER WORKS AND SEWERAGE SHORT SCHOOL AND TEXAS SEWAGE WORKS SECTION

Twenty-Seventh Annual Meeting

College Station, Texas, February 5–7, 1945

The twenty-seventh Annual Meeting of the Texas Water Works and Sewerage Short School was held at College Station, Texas, during the period of February 5, 6 and 7, 1945, in co-operation with the State Board of Health, State Board for Vocational Education, and Texas A. & M. College.

During the week preceding the regular Short School, a special laboratory training course was conducted. Each of the twenty-nine regional water works and sewerage associations in the state were invited to have one representative attend this course, which included instruction and demonstration on procedures employed in water works and sewage works laboratories. Twelve persons attended this course and received certificates upon completion.

In order to expedite registration, a majority of the attendants registered for the Short School on Sunday, February 4th. On Sunday evening as well as each morning during the Short School, Messrs. W. A. Bandy and W. E. Cuzick, itinerant instructors, conducted coaching sessions for the men desiring to take examinations for either Water Works or Sewage Plant Operators Licenses. Examinations for all grades of licenses were held each afternoon during the Short School, supervised by the members of the Licensing Committees. Approximately 50 men took examinations.

A very excellent program on subjects of interest to both the water works and sewage plant operators and engineers was arranged. During the first day of the Short School, subjects of a general nature of interest to both groups were presented and the groups met jointly. The remainder of the program was divided into water works sessions and sewage works sessions. Prominent out-of-state speakers who participated in the program included Col. W. A. Hardenbergh, Sanitary Corps, U. S. Army, Washington, D. C.; Prof. Don E. Bloodgood, Purdue University, Lafayette, Indiana; Dr. H. T. Dean, U. S. Public Health Service, Washington, D. C.; Y. C. Mar, Sanitary Engineer, National Health Administration, China, who has been visiting in the state for several weeks, observing methods and procedures in the field of sanitary engineering; and H. E. Hargis, Sanitary Engineer of the Pan American Sanitary Bureau, now stationed in Mexico. Five sanitary engineers from the Department of Public Health of Mexico City attended the Short School. The remainder of the speakers participating in the program were also outstanding authorities in their various fields.

Of particular interest to those attending the Short School this year were the subjects concerning pending legislation, the material that is being compiled for the publication of a Manual for Sewage Plant Operators, and a review of the status and activities of the Texas Water and Sanitation Research Foundation which was created last year.

On Tuesday evening the annual banquet for the group was held, at which Dr. George W. Cox, State Health Officer, was the principal speaker. Dr. Cox gave a review of the progress in the water and sewage works fields in Texas during 1944 and announced the Honor Roll for the State Department of Health for the year as follows:

WATER SUPPLY SYSTEMS:

- Highest percentage of population connected to the public water supply system. MISSION
- Municipality having the best bacteriological analysis record .... JACKSBORO
- For maintaining the best laboratory for control .... JACKSONVILLE
- City completing the greatest improvements to its water treatment plant .... EL PASO
- City maintaining the most attractive water plant (West Texas Utilities Company). SAN ANGELO

SEWER SYSTEMS:

- For having the highest percentage of its population connected to the water flush system .... BRADY
- Maintaining the sewage treatment plant presenting the most attractive appearance. CAMP SWIFT
- Most advantageous use of the effluent from the sewage plant
  - For industrial purposes .... BIG SPRING
  - For irrigation .... UVALDE
  - Best method of sludge disposal .... LUBBOCK

For maintaining the best laboratory for sewage treatment plant control. NORTH AMERICAN AVIATION CORPORATION
For maintaining the sewage treatment plant which during 1944 had the best average effluent .... ALOE ARMY AIR FIELD
Greatest improvement to the sewage treatment plant .... BIG SPRING
Greatest ratio of sewer connection completed during 1944 .... WEST COLUMBIA

Special awards in the form of loving cups and plaques were presented by Dr. Cox to representatives of Aloe Army Air Field, Big Spring, West Columbia, West Texas Utilities Company of San Angelo, and El Paso.

Other speakers at the banquet included Col. J. W. McNew who has recently returned from the China-Burma-India area and gave a most interesting account of conditions in that area and of experiences of our troops. Senator A. M. Aikin, Jr., of Paris and Roger Q. Evans, member of the House of Representatives, from Denison, both complimented the organization for the work that it is carrying on and pledged their support of legislation affecting the group. C. N. Avery of Austin, who served this organization as its President in 1925, made a short, interesting and humorous talk to the group.

Uel Stephens of Fort Worth, Chairman of the Committee on Awards, made the following presentations:

Honorary Membership Awards—J. L. Horner, Henderson and Major Lewis Dodson, Eighth Service Command, Dallas
For faithful and meritorious service—W. S. Mahlie, Fort Worth

Attendance Award—Panhandle Water and Sewerage Association for having the greatest number of members who had travelled the most number of miles to attend the Short School. This is the third successive year that this Association has won this award and it thereby becomes the permanent possessors of the plaque.

There was a change in the usual procedure of the Short School this year and Wednesday afternoon was set aside for the regular business session. At this session reports of the standing and special committees were presented. Copies of these reports will be included in the printed Proceedings of the Short School with the abstracts of papers which were presented at the meeting.

Officers elected to serve the Texas Water Works and Sewerage Short School for the ensuing year included:

President—W. N. Joiner, San Marcos
First Vice-President—Joe B. Winston, Galveston
Second Vice-President—S. L. Allison, Corpus Christi
Third Vice-President—N. E. Trostle, Temple
Fourth Vice-President—E. J. Umbenhauer, El Paso
Secretary—V. M. Ehlers, Austin
Asst. Secy.-Treas.—Mrs. Earl H. Goodwin, Austin

On Tuesday afternoon there was a special business session of the Texas Sewage Section. Mr. E. J. M. Berg, Chairman of the Section, presided at the meeting. The report of the Committee on Resolutions was adopted and copy of this report will be included in the Proceedings. The primary activity of the Sewage Works Section at their meeting this year was the review of the manuscript for the Manual for Sewage Plant Operators which is proposed to be published this year. Mr. W. S. Mahlie of Fort Worth is Chairman of the Committee preparing the data for the proposed Manual. Officers elected to serve the Sewage Section during the ensuing year were:

Chairman—Major R. M. Dixon, Dallas
Vice-Chairman—L. C. Billings, Dallas
Secretary—V. M. Ehlers, Austin

V. M. Ehlers, *Secretary-Treasurer*
Mrs. E. H. Goodwin, *Asst. Secretary-Treasurer*

Reviews and Abstracts*

Conducted by

Gladys Swope

Mellon Institute of Industrial Research,
Pittsburgh 13, Pennsylvania

PUBLIC HEALTH (DRAINAGE OF TRADE PREMISES) ACT, 1937, FAULTS AND ANOMALIES; DESIRABLE AMENDMENTS

By W. Porthouse

Institute of Sewage Purification (Dec. 6 and 7, 1944)

Five years of war have hindered the local authorities in administering the Act, which came into force on July 1, 1938. Under the Act, the trader can turn effluent into public sewers, on terms determined by local authority, with right of appeal to Minister of Health. The local authorities may charge for the service but only under certain conditions.

The unsatisfactory administrative features of the Act are as follows:

1. Creation of prescriptive right.
2. Unsatisfactory basis for the determination of prescriptive right.
3. Undesirability of administration by a code of by-laws.
4. Restriction of control of discharges, unless by-laws are codified.
5. Guidance lacking where sewers have insufficient capacity to receive trade effluent discharges.
6. Exemption of liquids "produced solely in the course of laundering articles."
7. Imperfect definition of "trade premises."
8. Guidance lacking as to whether trader or local authority shall pay for measuring or recording apparatus.

The greatest fault of the Act is its unfortunate recognition of a prescriptive right to discharge trade effluents into sewers. This creates an unfair discrimination between old and new industry. The author believes payment should be compulsory in all cases.

In the adoption of by-laws, authority should be granted to control the temperature and reaction of trade effluents.

Further, the Minister of Health should not have the power to override the local authority on making by-laws.

The Act is vague as to the necessity of the municipality to furnish adequate sewers or build new ones, where none exist.

The exemption of laundry wastes is unfair. Further, the Act fails to define what is meant by "any liquid produced solely in the course of laundering articles."

The author believes it is unfair to a trader with a prescriptive right to lose that right if he moves. Apparently the prescriptive right vests in the premises.

The cost of meters and inspection chambers should rest on the trader. On this the Act is not clear.

Langdon Pearse

MELBOURNE AND METROPOLITAN BOARD OF WORKS

Annual Report for Year Ending June 30, 1944

In the year ending June 30, 1944, there was a record demand for water, with increases in the domestic and manufacturing use. On two days the daily consumption exceeded 197 million Imp. Gal. (236.4 million U. S. Gal.) for approximately 1,144,000 people. The annual daily average rose from 77 million Imp. Gal. in 1938 to 96 million Imp. Gal. in 1944.

* It will be appreciated if Miss Swope is placed on the mailing lists for all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in this *Journal*. Publications of health departments, stream pollution control agencies, research organizations and educational institutions are particularly desired.

In the sewerage system an important problem, resulting from the generation of hydrogen sulfide, is under investigation. The sewage farm is largely used for raising and fattening cattle. During the year, 5,288 cattle were bought for fattening and an additional 2,000 bred. Sales numbered 6,549. Owing to the destruction by fire of the grass on large areas of land in Victoria, the Board accepted free of charge 11,648 sheep for temporary care. The farm income for the year was £59,904 (of which £52,589 was profit on cattle and sheep); the expense (including interest) £137,581, making a net cost for sewage purification of £77,677, or one shilling four pence (approximately 27 cents) per capita. The total acreage of the farm is 23,793, including 1,125 acres recently purchased for £34,000 (approximately $121.00 per acre).

The accounts show a substantial increase in revenue in the sale of water. In the last four years 12,000 new houses have been erected. Postwar works are being considered for a 5-year period, scheduling approximately £10,000,000, mostly new work. The staff (1,659 employees) is about half its pre-war size.

LANGDON PEARSE

MEMO ON THE AGRICULTURAL USE OF SEWAGE SLUDGE AND STRAW SLUDGE COMPOSTS

British Agricultural Research Council (1944)

Since 1940, over 80 field experiments have been conducted in England to test the manurial value of sewage sludge, and determine its short-term (one-year) and long-term (repeated additions for several years) value, as well as the value of the principal kinds of sludge and the conditions under which they can best be used.

It is estimated that of the nitrogen and phosphorus originally in the sewage, from one-half to two-thirds is lost in the sewage works effluent, as well as most of the potash.

Raw sewage sludges are generally wet and offensive, drying slowly. If lagooned, digestion occurs.

Digested sludges dry more readily, producing an almost inoffensive product. In a few works, partially dried sludge from the drying beds is stacked under cover in open sheds. The material heats up rapidly, often to 60° C., and dries down below 20 per cent moisture. At this stage disintegration will produce a fine powder, easy to handle, and higher in available nitrogen than ordinary sludge.

A moisture content of 55 per cent appears to be a critical point, above which sludge appears wet and is handled in lumps with a fork, and below which sludge is friable and appears dry.

It is unlikely that sewage sludge exerts the same physical action on soil as farmyard manure, as sludge lacks fibrous material such as straw. However, at some sewage works farms heavy dressings of sludge have improved the physical condition of the soil.

The chemical composition of sewage sludges may average as follows:

	Dry Matter	Organic Matter	Ash	Total Nitrogen	Inorganic Nitrogen	P_2O_5
Per cent of fresh material:						
Raw sludge	40	20	20	0.9	0.05	0.5
Digested sludge	52	23	29	1.4	0.06	1.1
Digested shed-dried	80	32	48	2.0	0.26	2.1
Farmyard manure	26	16	10	0.6	0.06	0.4
Per cent of dry matter:						
Raw sludge	100	51	49	2.4	0.13	1.3
Digested sludge	100	44	56	2.6	0.12	2.2
Digested shed-dried	100	39	61	2.4	0.33	2.6
Farmyard manure	100	64	36	2.2	0.22	1.6

Sewage sludges are primarily nitrogenous manures, in which a considerable proportion of organic nitrogen becomes slowly available. Some digested sludges, however, may contain more active nitrogen compounds than raw sludge.

Activated sludge has a very high content of nitrogen, with an availability approaching that of concentrated organic manures and fertilizers.

The phosphoric acid in normal sludge is about as effective as half of its weight of phosphoric acid in the form of superphosphate.

Sewage sludges are very deficient in potash, as compared with farmyard manure.

Sewage sludge may contain weed seeds and eelworms. No case is known where the use of sewage sludge as fertilizer of crops for human consumption has caused either typhoid or dysentery. However, wet sewage sludge should not be used for salad or other crops to be eaten raw. If dried sludge is used for those crops, it should be applied several months before sowing.

In the field experiments, potatoes were used mostly. Where no potassium was added, sewage sludge gave much lower yields and poorer quality than farm manure.

When adequate potash was added, in 1942 and 1943 (26 tests), the results were:

Yield of Potatoes

	Tons per Acre
No organic manure	7.5
Sewage sludge	8.5
Farmyard manure	9.5

In these tests 7.5 tons of dry sludge per acre (at least 15 tons fresh sludge (wet) were used, and about 12 tons of farmyard manure per acre (fresh weight).

Further tests with sulfate of ammonia gave the following results:

Yield of Potatoes

	No sulfate of Ammonia	Sulfate of Ammonia 300 lb. per acre
No organic manure	6.6	7.7
Sewage sludge	8.3	8.6
Farmyard manure	8.7	9.5

On sugar beet, vegetable, and green fodder crops, the sewage sludge worked better than on potatoes. On swedes, either superphosphate, sewage sludge, or farmyard manure ensured a good crop.

The general conclusions given were as follows:

1. Sewage sludge is a material of moderate but definite agricultural value as a source of slowly available nitrogen and phosphate. In general its crop producing power is less than that of an equal weight of good farmyard manure.
2. It is markedly deficient in potash and is therefore markedly inferior to farmyard manure for potatoes and other crops needing much potash.
3. It may have beneficial physical effects on the land but these are of a different nature from those produced by farmyard manure.
4. Only sludges in a comparatively dry state (less than 50 per cent moisture) are likely to be generally useful owing to the cost of transport. Partially dried sludges need to be used at heavy rates per acre, and the material is therefore likely to be economical only within a few miles of the works.
5. Digestion improves the physical condition of sludge.
6. The most valuable form at present available is the digested, shed-dried and pulverized sludge from works using the activated sludge process.
7. Certain industrial sludges contain metallic and other wastes which may render their phosphate unavailable or be harmful to crops in heavy dressings.
8. Satisfactory rotting of straw takes place in compost heaps with about one-and-a-half parts of sludge dry matter to one part of long straw, provided the heap is satisfactorily wetted and aerated. It is not, however, possible as yet to state whether they have any appreciable manurial value.

LANGDON PEARSE

OPERATION OF AN ENCLOSED AERATED FILTER AT DALMARNOCK SEWAGE WORKS

By A. Hunter and T. Cockburn

Institute of Sewage Purification (Dec. 6–7, 1944)

For test purposes an enclosed filter was built with 9-inch reinforced walls, 52 ft. internal diam., containing 18 ft. of filtering material resting on 12-inch semi-circular aerating tiles. The filtering material was whinstone, originally—

Layer	Thickness Feet	Grade Inches
Top	1.5	$2\frac{1}{2}$
Middle	15.5	$\frac{3}{4}$
Bottom	1.0	3

Tank effluent was pumped into a rotary distributor with four arms, each $4\frac{3}{8}$-in. internal diameter. Air was taken in at the top by a 25-in. diameter fan, 3,000 cu. ft. per min. capacity and vented to the atmosphere through 104 3-inch exhaust posts.

The crude sewage was chemically precipitated with lime and albumina sulfate. The sewage flow was 24 m.g.d. (U. S.) containing a variety of industrial waste. For the year ended May 31, 1938, the composition was:

Determination	Parts per Million Crude Sewage	Tank Effluent
Free Ammonia	23.1	22.6
Alb. Ammonia	6.84	3.55
Oxygen Absorbed N/80 Permang. in 4 hr. at 27°C.	102.1	76.8
Chloride as Cl	118.3	123.9
5-day B.O.D.	189.7	137.2
Suspended Solids	210	25

The strength of the sewage varies widely.

The area of open filters in use was 4.75 acres, with material as follows:

Layer	Thickness, Feet	Grade, Inches
Top	1.5	$1\frac{1}{2}$
Middle	3	$2\frac{1}{2}$
Bottom	3	4

It is dosed by 16 rectangular water driven distributors, receiving 8.41 m.g.d. (U. S.) of tank effluent, or 156.1 (U. S.) gal. per cu. yd.

The enclosed filter went into service on May 30, 1938. The filter was matured with recirculation of effluent, starting with 660,500 (U. S.) gal. per day of tank effluent and increasing the amount of tank effluent by 18,013 to 24,018 gal. daily, while reducing the volume of recirculated liquid, so that by July 23 (7 weeks' period) the filter was receiving and treating tank effluent of 660,500 (U. S.) gal. per day.

Ponding occurred by September 23, so the flow was reduced for two weeks to 240,200 gal. per day, and again to a rate of 120,100 gal. per day, with recirculation at the rate of 540,400 gal. per day. Gradually the amount of tank liquor was built up and circulating liquor decreased until on November 21 the guaranteed volume of 660,500 (U. S.) gal. per day was handled. Clogging built up the pressure to 2 inches by the end of December. For five months various rates and procedures were tried. A larger fan was installed in May to deliver 5,000 c.f.m. against 2.5 inch water pressure. In August, coarser whinstone was installed:

Layer	Thickness, Feet	Grade, Inches
Top	1	3 to 4
Second	2	2 to $2\frac{1}{2}$
Third	14	$1\frac{1}{2}$ to 2
Bottom	1	2 to $2\frac{1}{2}$

This was washed in place for four hours at a rate of 859 (U. S.) gal. per day per cu. yd.; then dosed at the rate of 240,190 (U. S.) gal. per 24 hr. for 4 weeks and increased by 60,050 (U. S.) gal. per day for two weeks; and then built up to an application of 360,280 (U. S.) gal. per day for eighteen hours, and a rest period of six hours.

TABLE I.—*Dalmarnock Sewage Works*

Results of Operation of Enclosed and Open Filters

Period	Enclosed Filter					Open Filter				
	Gal. per Cu. Yd.	5-day B.O.D.			Nitrates P.p.m. Eff.	Gal. per Cu. Yd.	5-day B.O.D.			Nitrates P.p.m. Eff.
		P.p.m.		Per Cent Red.			P.p.m.		Per Cent Red.	
		Inf.	Eff.				Inf.	Eff.		
1940										
January	253	154.4	53.0	65.7	Trace	161	154.4	68.1	55.9	8.0
February–May	169	119.1	33.2	72.0	0.72	156	121.6	41.9	65.3	9.2
June–July	233	141.3	25.1	82.5	11.0	152	141.3	40.3	71.3	6.3
August–September	395	119.7	26.7	77.7	7.75	156	120.1	33.8	71.6	9.6
September–November	440	104.4	27.7	73.2	2.90	155	104.4	33.7	66.9	10.2
December	423	116.9	40.1	65.7	0.20	137	116.9	40.8	65.1	8.9
1941										
January–August	423	123.2	39.9	67.4	1.66	124	125.3	46.6	61.8	4.90
September–December	255	115.1	29.3	74.1	2.05	124	119.6	42.2	64.1	4.75
1942										
January–April	255	195.4	57.0	70.5	0.25	118	201.7	101.2	50.1	2.8
May–December	296	174.8	28.2	83.3	2.0	149	176.3	56.6	68.5	2.8
1943										
January–February	302	131.3	19.6	85.2	3.25	158	131.3	51.7	61.0	3.75
March–December	338	136.4	25.1	80.7	1.12	152	136.4	32.2	75.2	3.95

When the fan was shut down for three weeks the effluent deteriorated. The air pressure was low in the winter, rising during the summer and autumn, and falling towards the end of the year. Ponding was most pronounced in the late fall. As the pressure built up from 0 to 1.6 inches, the air flow was reduced from 5,000 cu. ft. per min. to 500.

On an average of four years (1940–1943) the enclosed filter treated twice as much volume of tank liquor per cu. yd. as the open filter. No odors were noted with either filter. Recirculation was beneficial during periods of excessive growth.

Operating results are given for four years (1940–1943), by months (Table I).

The cost of the enclosed filter was £6,250 ($25,000).

LANGDON PEARSE

SOME RISKS OF TRANSMISSION OF DISEASE DURING THE TREATMENT, DISPOSAL, AND UTILIZATION OF SEWAGE, SEWAGE EFFLUENT AND SEWAGE SLUDGE

By H. Wilson

South African Branch, Inst. Sewage Purification (1944)

In this paper Wilson reviews the subject during the past 100 years. After pointing out the general good health in and around sewage farms or works, he discusses the specific supposed hazards, such as—

Parisitic Entozoa or Helmintha. Of this Bilharzia has been confined to tropical or sub-tropical climate. The embryo, when released from the eggs, dies in 24 hours unless it reaches its immediate host, the fresh water snail. The cercariae is developed in 14 days, and released, to die in 48 hours unless it has access to the human host or other animal. The cercarie of *Bilharzia Mansoni* are killed by 3.5 to 7 p.p.m. of free chlorine in 10 min. (Hamburg tests).

Tapeworm eggs may survive for a long time in sewage or sludge. At the Melbourne (Australia) sewage farm, 40 per cent of the cattle on the farm for six months were infested with the cysts but many become immune after 2½ to 3 years. The sale of cattle from the farm for human consumption is still banned.

Hookworm is a danger in tropical, sub-tropical, and warm-damp climates. In the soil larvae may persist over two years. At Singapore, hookworm eggs survived in Imhoff tank sludge, but in the United States prolonged digestion destroys them. At Colombo, Ceylon, covered and heated drying beds were recommended.

For the parasitic *helminth,* reference is made to Wright, Cram, and Nolan (*Sew. Wks. J.,* 14: 1274 (Nov., 1942).

Among the diseases due to Protozoa, amoebic dysentery is widespread. In 1938 Craig (*J. Am. Pub. Health Assn.,* 28: 187 (1938)) estimated 10 per cent of the U. S. population harbored *Entamoeba Histolytica.* Fair and Chang (*J. Am. Water Wks. Assn.,* 33: 1705 (1941)) reported cysts transmitted by sewage and a survival of 90 days at 10° C.; 30 days at 20° C.; 10 days at 30° C. Bolduc (*Can. Pub. Health J.* 26: 215 (1935)) reports cysts live in water for months but are killed in 5 minutes at 65° C., or by desiccation at room temperature for 10 min. Fair and Chang state in water of low pH 3 p.p.m. Cl_2 killed in 30 min.; 2 p.p.m., 60 min.; 1 p.p.m., 120 min. The work of Wright et al., and Cram is cited (*Sew. Wks. J.,* 14: 1274 (1942) and 15: 1119 (1943)). Their conclusion was that *E. Histolytica* cysts probably do not withstand sludge digestion and are destroyed by heating to 103° C. for three minutes. The disease is likely to be spread by eating uncooked and poorly washed vegetables irrigated with fresh sewage or top dressed with undried sewage sludge.

Among the diseases due to Bacteria are *Cholera* (no record of properly authenticated outbreaks attributable to properly managed sewage treatment works, although the disease is usually transmitted by polluted water).

Typhoid (can survive in sewage). Cites McConkey (2nd Rep., Royal Com. on Sewage Disposal, 1902); Shaw (Public Health Report) on outbreak at Malton, Yorkshire, 1932; Ministry of Health No. 69, 1933; Houston (25th, 26th, and 27th Reports, Met. Water Board, 1930, 1931, and 1932).

Paratyphoid has been found in sewage. Cites epidemic at Epping in 1931 due to sewage polluted water supply (Houston); North Battleford, Saskatchewan (Davidson, Canadian P.H.D., 33, 305 (1942)).

Anthrax is an example of organism forming very resistant spores. Cites investigation at Yeovil, England (Houston, 2nd Rep. Royal Com. Sewage Disposal, 1902). The sewage of towns with large tanning industries may be dangerous.

Poliomyelitis is a virus disease. Cites work on polio in sewage in the United States. Also notes only one case recorded of isolation of polio in drinking water from infected well (Kling, Internat. *Bull.* A40).

B. Pyocyaneus persists for 10 days in sewage (Houston, 4th Report Royal Com. Sewage Disposal, 3: 79).

Bacteriophages are poorly defined and with little definite information. Various phages are said to be found in sewage (Hadley, *J. Infectious Diseases,* 40: 1 (1927)). The development of phages may furnish a control for pollution in time of epidemics.

The evidence indicates that "Although the eggs or larvae of disease-causing parasites and many pathogenic micro-organisms can survive in sewage, sewage sludge, or sewage effluents for a time, they do not reproduce under the unfavorable conditions of a sewage plant."

"Taking *B. Coli* as an index, the reduction in numbers is of the same order as the reduction in bacteria of all forms." "On the other hand, bacteria of all kinds, as well as some pathogens and eggs or ova of parasites, become concentrated (for a time at least) in the sludge settled out at various points in the treatment plant."

Wilson believes that the use of sewage, sewage sludge, or effluents may be regulated—

1. Unrestricted use; suitable only in a few localities with an entirely clean bill of health.
2. Restricted use permitted.
   (*a*) Only on crops to be cooked before eating.
   (*b*) On crops or orchards where grains, berries, or fruit cannot become wetted with sewage or fouled with sludge.
   (*c*) On crops grown for animal food.
   (*d*) On crops not grown for food of either man or animals.
   The degree of such restricted use is subject to the Health Official.
3. Total restrictions on any use for any crop. Such total restriction is rarely justified unless as a temporary measure during an epidemic.

The use of raw sewage for irrigation is rare. Irrigation with settled sewage still affords dangers. Further treatment by biological or other methods may be desirable, although chlorination does not seem necessary, except in an emergency. A drinking water standard is not required.

On the use of sewage sludge as fertilizer, Wilson cites Firth and Horrocks (*Brit. Med. J.*, **II**: 936 (1902)), on the viability of *B. Typhosus* in soil, on cloth, and in sunshine. Ruchhoft (*Sew. Wks. J.*, **6**: 1054 (1934)) and Tanner (*Sew. Wks. J.*, **7**: 611 (1935)). According to Tanner, *B. Typhosus* may be viable in wet sludge for two months, and in soil for three to four months. *B. Anthracis* and *B. Tetanus* may persist for a longer time.

Wilson concludes that further study is necessary to confirm the value of desiccation of sludge at ordinary temperatures as a means of eliminating dangerous bacteria or parasite ova and that "the risks presented in the use of sewage sludge as fertilizer are similar to those presented by untreated sewage itself when used to irrigate crops." Especially at the time of an epidemic the growing of salad crops should be forbidden and only those crops permitted which are cooked before eating or unlikely to be contaminated.

Composting to a temperature over 160° F. is required for several hours, or heat-drying. Artificially heated compost heaps may be desirable.

Air-born infection from sewers or sewage treatment plants is discussed in the light of old data (Frankland, 1877; Carnelly and Haldane, 1887; Parry, Daws, and Andrews, 1892–1894; Horrocks, 1907; Alesei, 1895; Delepine, 1909). Wilson concludes that odors like hydrogen sulfide may come from sewer manholes but dangerous infection of sewer air is unlikely, depending on the cleanliness or turbulence in the sewer and the number of pathogenic bacteria in the sewage.

Grazing of cattle on sewage farms is apparently not affected. A British case is cited to show that sewage poisoning of cattle does not exist. The quality of milk is not affected. Cleanliness of animals prior to milking is essential.

Even where dilution is available, Wilson urges a considerable degree of treatment and sterilization of the effluent where bathing beaches are affected. On the danger to shell fish from sewage discharge, he cites Dodgson (Conway Shellfish Research Station, Ministry of Agriculture and Fisheries, Fisheries Investigation Series II, Vol. 10, No. 1 (1928)).

Wilson suggests that the Health Officer temper his regulations to the habits of his people in washing vegetables.

His conclusions are:

1. That there is a mass of evidence from work extending back over 70 years which shows that in some circumstances real danger of spreading infections may arise in the course of sewage treatment and disposal, or the use of sewage, sewage effluent, or sewage sludge as fertilizer for raising vegetable crops.
2. That where a town has long enjoyed a clean bill of health in respect of possible water-borne diseases or infections, there is little danger in unrestricted use of sewage or its products.
3. That in these towns or localities where a large percentage of the population suffers from chronic infestation or where there is outbreak of epidemic disease or where there has been an epidemic a few years previously, the use of sewage, sewage effluent or sewage sludge as fertilizer should be restricted, and in these localities salad crops should not be grown on sewage farms or fertilized with sewage sludge.
4. That there is grave doubt whether desiccation of sewage sludge at ordinary temperatures will render infected sewage sludge harmless.
5. That drying or treatment at elevated temperatures is called for or composting with special provision to secure sufficient heating.
6. That in general sewer air carries no more bacteria than town air, but where there is considerable turbulence in sewers or where there is septic action due to stagnation, infected droplets may be carried in sewer ventilation air.
7. That sewage poisoning as a specific disease in cattle does not exist, though cattle may become infected by specific disease, *e.g.*, anthrax or tapeworm in those localities where there are very large numbers of the causative organisms in the sewage.
8. An experimental study in the washing of vegetables is given, and it is recommended that all salad vegetables to be eaten raw should be soaked after washing in some solution to kill off possible dangerous infection.

An appendix follows by Miss E. S. Hogg on "The Washing of Watercress Grown in Sewage Effluent" from the Cydna Sewage Works at Johannesburg. The use of salt and N/80 potassium permanganate were unsatisfactory. For household purposes, soaking is recommended for ten minutes in 0.25 per cent bleaching powder solution or two teaspoonsful to a quart of water. Three successive washings in sterile water were unsatisfactory.

Langdon Pearse

EFFECT OF NITRATES ON THE RISING OF SLUDGE IN SEDIMENTATION TANKS

By T. W. Brandon and J. Grindley

The Surveyor, 104, 7–9 (January 5, 1945)

The difficulties experienced at some sewage disposal works by "rising" of the sludge in final settling tanks in the activated sludge process is discussed. Rising sludge usually occurs as a result of liberation of gaseous nitrogen and it is usually associated with a high degree of nitrification in the effluent.

The work done by Wooldridge and Corbet is referred to which showed that rising of activated sludge could be induced or aggravated by the addition of nitrite or nitrate and that it could be inhibited by addition of assimilable carbonaceous matter, such as glucose or soluble starch. These workers suggested that the rising depended on the formation of nitrite in a liquid containing some organic matter, since it appeared that liberation of nitrogen occurred principally during utilization of nitrite for synthesis of protein.

It is generally agreed that denitrification resulting in liberation of gaseous nitrogen is brought about by bacterial activity. The action is usually an aerobic one.

Two instances are cited of the rising of sludge in primary sedimentation tanks. At the sewage disposal works at Bushey and Norton Green, the sewage contains high concentrations of ammonium nitrate from shell filling factories. The other instance was a water treatment plant in which the raw water was polluted by an effluent containing nitric acid.

Experiments were conducted at the Bushey sewage works to determine the effect of ammonium nitrate upon the rising proclivities of the sludge. 90 liter samples of the sewage were used to which were added various amounts of ammonium nitrate and the sewage allowed to stand for 24 hours, after which period of sedimentation observations were made of the quantity of floating sludge. Concentrations of added nitrate varied from 40 to 200 parts per million. The results indicated that rising sludge occurred when ammonium nitrate was added in concentrations above 50 or 60 parts per million.

At the Norton Green sewage disposal works the sewage treatment consists of two stage sedimentation. The sedimentation tanks are emptied each week and the settled sludge is removed. Experiments were undertaken with 90 liter volumes of sewage as at Bushey. Rising of large amounts of sludge occurred when ammonium nitrate was added in concentration of 60 to 70 parts per million. On two occasions rising of sludge from the sewage when it contained 70 p.p.m. of ammonium nitrate appeared to be inhibited. On the first occasion the sewage was septic; on the second occasion the sewage contained oil and there was a smell of creosote. Apparently bacterial activity was repressed by the presence of hydrogen sulfide or creosote in the sewage.

Plant scale experiments were conducted by adding concentrated solutions of ammonium nitrate to the sewage feeding the two primary sedimentation tanks. Observations were made on the effect of adding ammonium nitrate in concentrations varying between 40 and 70 parts per million. With 40 p.p.m. discharge there was very slight rising of sludge in one tank and none in the other tank after 21 hours. After 52½ hours there was still very little sludge on the surface in one tank and about 10 per cent of the surface of the second tank was covered with thin sludge. No further rising occurred after 60 hours.

With a concentration of 50 p.p.m. in one tank there was slight rising of sludge after 23 hours with no increase in the quantity of sludge after 34½ hours.

With ammonium nitrate added at the rate of 60 p.p.m., sludge rose in both tanks after 2 hours. After 9 hrs. about 25 per cent of the surface was covered with sludge. After 23 hrs. the surface of one tank was completely covered with sludge and the surface of the other tank about 60 per cent. Both tanks were then emptied, cleaned and refilled, with an ammonium nitrate concentration in the sewage of 70 parts per million. After 3½ hours sludge appeared slightly at the surface of both tanks, increasing after 6½ hours. After a total period of 8 hours the surfaces of both tanks were heavy with sludge.

In the example cited of rising sludge at a water treatment plant, the concentration of nitrate was equivalent to between 20 and 30 p.p.m. nitrogen. The water contained high permanent hardness and algae. At times during the warmer months when algae were plentiful, sludge formed on the surface of the sedimentation tanks in a layer 6 ins. thick. A sample of gas evolved from the sludge contained about 92 per cent by volume of nitrogen.

Rising of sludge did not occur in water from a neighboring source containing an abundance of algae and similar in composition as to hardness, but which contained only one p.p.m. nitrogen. Gas was not evolved from the sludge when washed with this water. Addition of 30 p.p.m. of nitrogen to the sludge caused gas evolution. Similarly, gas was evolved when sludge was washed with tap water to which had been added 30 p.p.m. of nitrogen; likewise, gas was evolved from the chemical sludge of the unpolluted water when 30 p.p.m. of nitrogen were added to it.

The experiments showed that evolution of gas which caused rising of sludge in the sedimentation tanks at the water treatment plant was due to the presence of an abnormally high concentration of nitrate in the raw water from contamination of the supply by waste waters from the shell filling plant.

Small scale experiments indicated that additions of one p.p.m. of copper sulfate, or 10 parts of hydrated lime or 5 p.p.m. of chlorine, or 10 p.p.m. of activated carbon did not prevent sludge from rising after two days sedimentation. Rising was prevented by additions of 20 p.p.m. of chlorine.

K. V. Hill

THE PHENOMENON OF RISING SLUDGE IN RELATION TO THE ACTIVATED SLUDGE PROCESS

By Wm. T. Lockett

The Surveyor, 104, 37–39 (Jan. 19, 1945)

The author refers to his observations in 1914–15 in his experiments at Manchester with the activated sludge process, which indicated that when activated sludge was allowed to remain in contact for several hours with purified sewage containing nitrate, gas formed in the sludge mass and caused it to float to the surface. This behavior of the sludge was considered to be due to denitrification resulting in the production of nitrogen gas. The quantity of nitrate remaining in the liquid after the sludge had risen was less than that present when the sludge was settling.

The Manchester experiments were on the "fill-and-draw" method of operation and the purification process was carried to an advanced stage of nitrification. The raw sewage contained 34.6 p.p.m. of free and saline ammonia. After 4 hours' aeration with 25 to 33⅓ per cent activated sludge, the effluent contained 2.1 p.p.m. of free and saline ammonia and 0.7 and 16.0 p.p.m. of nitrite and nitrate, respectively.

Experiments on the "continuous flow" activated sludge process indicated the importance of adopting effective measures to prevent short-circuiting in order to produce a highly oxidized sludge, as imperfectly activated particles, due to short-circuiting, is one of the causes of rising sludge.

Experiment showed that the sludge must be removed from the settling tanks as quickly as possible to maintain its activity and to prevent sludge rising.

The author points out that to produce a good quality sludge and a highly purified effluent, air must be applied at the rate of 7 to 12 cubic feet per hour per square foot of tank surface. When the objective of the treatment process is nitrification, it would appear best to apply sufficient air for a long enough detention period to produce from 8 to 20 p.p.m. of nitrate nitrogen.

At the Mogden works in the West Middlesex Drainage District treatment provided is of the "continuous flow" activated sludge type. Sewage passed to the aeration tanks had the following characteristics in 1939:

Ammonia Nitrogen	39.3 p.p.m.
Albuminoid Nitrogen	5.3 p.p.m.
B.O.D. (5-Day at 18.3°C.)	201.0 p.p.m.
Suspended Solids	75.0 p.p.m.

The aeration tanks are 400 ft. long, 15 ft. wide, and 12 ft. deep at the water line. At 100 ft. intervals there is a transverse baffle with air diffusers underneath to prevent short-circuiting.

Provision is made for sludge withdrawal from the final settling tank at rates up to 50 per cent of the dry weather sewage flow. Normally at Mogden, the volume of sludge, in the mixed liquor, after one hour's settling, is 15 per cent. In these circumstances and in order to reduce to a minimum the period of non-aeration of the sludge, it has been the practice since 1936 to withdraw the maximum volume of sludge from the settling tanks (average water content 99.3 per cent).

Air has been applied at rates of 10 to 12 cu. ft. per hr. per sq. ft. for a period of 8.2 hr. on the mixed liquor. The quantity of air was 1.27 cu. ft. per gallon.

The effluent had the following characteristics during 1939:

Ammonia Nitrogen	13.2 p.p.m.
Albuminoid Nitrogen	0.95 p.p.m.
Nitrous Nitrogen	4.6 p.p.m.
Nitric Nitrogen	11.4 p.p.m.
B.O.D. (5-Day at 18.3°C.)	6.3 p.p.m.
Suspended Solids	7.0 p.p.m.

Periods of rising sludge have been rare and have been attributed to an unusually high proportion of sludge to sewage in the mixed liquor, a sudden influx of storm water to the aeration tanks, and consequent temporary build up of sludge in the final settling tank, and insufficient sludge withdrawal from a settling tank.

Samples of the averaged mixed liquor in the aeration units are taken daily and settled for one hour. Rising of sludge within this period is rarely observed. The author points out that this is a very severe test as settled sludge obtained from samples taken in the early stages of the aeration period is always likely to rise sooner than samples of fully activated sludge such as are taken from the mixed liquor passing to the final settling tanks.

The author concludes that under certain conditions, notably when both activated sludge and sewage are brought by aeration to a well oxidized state, the period of time necessary to clarify the mixed liquor will not produce rising of the sludge.

He concludes further that rising sludge can be prevented by the adoption of effective measures to (1) prevent short-circuiting of sewage and sludge in the aeration tanks; (2) prompt removal of sludge from the final settling tanks and return of the same to the aeration tanks; (3) application of air at sufficiently high rates to ensure thorough but steady mixing of the sludge and sewage; and (4) a sewage detention period sufficiently long to ensure an average amount of 8 to 12 p.p.m. of nitric nitrogen in the effluent.

K. V. Hill

THE O.M.S. SYSTEM FOR SEWAGE TREATMENT

By C. F. Venzano Botet

Publication No. 836 of *La Ingeniera,* Official Organ of the Centro Argentino de Ingenieros

Otto Mohr's two-story tank provides, according to the inventor, more digestion space, larger surface area, better separation of sewage from settling sludge, prevents scum troubles and keeps the sewage fresh. The city of San José Das Campos, Brazil, has built a plant according to the "Mohr system." This "System" is a modification of an Imhoff tank, resulting in a submerged sedimentation unit, having slots at the bottom and also slots at the top to permit floating scum to pass out of the chamber. Because of the submerged compartment construction the whole area of the tank is utilized for collection of scum and release of gases. The slopes of the false bottom are steeper than in the usual Imhoff tank. The round tank with a diameter of 27 meters (88.6 ft.) provides a detention time of 1½ hours and has a floating dome shaped cover.

W. Rudolfs

CONTRIBUTION TO THE BIOLOGY OF TRICKLING FILTERS

By H. Bethge

Kleine Mitteilungen für Wasser, Boden und Lufthygiene, 17, 35 (1941)

Samples of sewage and effluent from different types of high rate trickling filters were examined for algae, fungi and insects. The number of species was low and about the same (13–16) for all three types of filters. The quantity of organisms present differed somewhat. The number of samples taken was limited.

Willem Rudolfs

THE CHEMICAL INVESTIGATION OF SEWAGE WITH REFERENCE TO SLUDGE ANALYSES AND STREAM POLLUTION STUDIES

By G. Jordan, M. Manthey-Horn, F. Meinck, P. Sander, and R. Schmidt

Kleine Mitteilungen für Wasser, Boden und Lufthygiene, 17, 191 pages (1941)

The compilation of methods is organized into two parts: sewage and water; and sludges. Description and discussion of sampling; physical, chemical and biological methods of analyses. Apparatus and glassware used in sampling and analyses are described and illustrated. Sample calculations of results are given. The specific purpose for the analyses are indicated, while attention is called to interfering substances. A series of micro-analyses, particularly for nitrogen compounds, are included. Among the many standard analyses a simple method to determine the "oxygen utilization" in streams is presented. The method consists of filling two bottles with stream water (filtered through cotton as much clay as present) and one sample fixed at the spot with sodium hydroxide and manganous chloride for dissolved oxygen determination; the other bottle is closed and incubated at 22° C. for 48 hours and D.O. remaining determined. The difference between the two is the oxygen utilization. A special method for grease in sewage is given. Determinations of substances in industrial wastes include nickel, zinc, chromium, arsenic, cyanides, benzenes, organic acids, sugars, starches, pyridin, terpenes, total, volatile and non-volatile phenols, etc. The section on sludges deals with sampling and determinations of quantities of solids, extent of sludge bank formation in streams, sludge sampling, and physical and chemical analyses.

Willem Rudolfs

WAR-TIME DISPOSAL OF WASTE PICKLE LIQUORS

By Wallace G. Imhoff

Wire and Wire Products, 18, 389–92 (July, 1942)

A plant for waste pickle liquor treatment is described which comprises preliminary settling, neutralization, aeration, and final sand filtration. The plant has been operating for 25 years and treats an average of about 13,000 gallons of combined sulfuric and hydrochloric acid waste liquor per day.

The waste pickle liquors, as well as waters containing oils from the machine shops, are collected in a sewer system which discharges into an acid-proof brick lined tank 10 feet deep by 12 ft. in diameter, which serves as a grease trap. The wastes flow from this tank to a similar one adjacent to it from which they are pumped to the preliminary sedimentation tank consisting of two units, each $40 \times 7 \times 8$ ft. deep, which are filled alternately. The sludge which collects in these tanks is discharged as occasion demands into a sludge tank 40 × 35 × 6 ft. deep containing a two-foot layer of crushed traprock covered with a layer of sand.

The settled liquor discharges into an acid-proof concrete tank with a capacity of 1,500 gallons where it is treated with lime to precipitate the iron. The treated liquor flows to an aeration tank 60 × 40 × 8 ft. deep in which it is sprayed from a series of nozzles over a six foot depth of crushed traprock. The aerator operates automatically on a 15 minute cycle. From the aerator the liquor flows to a secondary settling tank 20 × 15 × 6 ft. deep. The sludge collected in this tank is discharged to the sludge tank. Finally the liquor flows to a pair of sand filters, 100 × 40 × 3 ft. deep, used alternately. The filtering medium is a one-foot layer of crushed traprock covered with two feet of sand. The filtered water collects in a sump, equipped with a fine screen, from which it is discharged to a stream.

It is reported that the plant produces a clear, iron-free effluent. No analytical data or operating costs are given. The plant cost $10,000 originally, and it is estimated that it could be duplicated for about $25,000 at the present time.

R. D. HOAK

CLEAN STREAMS IN PENNSYLVANIA

BY H. E. MOSES

Pennsylvania's Health, 5, Nos. 5, 6, 7, 15 (July–September, 1944)

The 100,000 miles of streams in the commonwealth are a most important natural resource. When the Purity of Waters Act was passed in 1905, and the Department of Health established with jurisdiction over the discharge of sewage, few communities were equipped with sewerage. Today, however, there is scarcely a town of 2,500 population without sewers, and many smaller places have public systems. In 1905 there were only 15 sewage treatment works in the State; today there are more than 300.

Despite the great improvement in sanitation, millions of gallons of untreated sewage are discharged daily into streams, many of which are heavily polluted. In addition a serious burden is imposed by the discharge of a variety of industrial wastes. While many industries treat their wastes much work remains to be done in that field as well as in the treatment of sewage.

The Sanitary Water Board, organized in 1923 with authority over stream pollution, has striven earnestly to improve the condition of the streams of the State. The Board believes that the present is an opportune time to attack the problem of waste treatment on a State-wide basis because not only will accomplishments in this field have a bearing on the health and welfare of the public, they will provide postwar employment for returning service men and for war workers awaiting the conversion of industry to a peacetime economy.

The Board proposes that sewage shall receive a minimum of primary treatment, consisting of quiescent sedimentation or its equivalent, whereby about 35 per cent of the polluting matter will be removed. Where the need is indicated, complete treatment, corresponding to about 85 per cent purification, will be required. Exception will be made in the case of streams carrying such a large burden of acid mine drainage that treatment would result in no public benefit. Treatment of industrial wastes, including coal mine silt but excluding acid mine water, will be required to an equivalent degree.

Public hearings were held by the Board in eight cities of the Commonwealth, including as many main river systems, to provide all interested persons with an opportunity to appear before the Board and give their views on the proposed program. Following these hearings the Board intends issuing orders to those responsible for waste treatment, informing them of the degree of treatment necessary, and requiring the preparation and submission of plans covering such treatment.

R. D. HOAK

THE EFFECT OF TREATMENT IN PERCOLATING FILTERS ON BACTERIAL COUNTS

By L. A. Allen, T. G. Tomlinson, and Irene L. Norton

Civil Engineering (London), 40, 20 (January, 1945)

Chemical and bacteriological studies were made on settled sewage and trickling filter effluents at the experimental plant at Minworth, Birmingham. Settled sewage was applied to two filters, one of which was a single filter operated at a rate of 60 gal. per cu. yd. per day. The other was an alternating double filtration unit operated at a rate of 240 gal. per cu. yd. per day. The order of the filters was changed daily. The following table shows results for two periods of operation.

Sample	Plate Count (per ml.) at 30°C.	Coliform Bacteria Count (Presumptive), Number per ml.	B.O.D., P.p.m.	Oxygen Absorbed 4 hr., P.p.m.
Period Nov. 12, 1943 to Feb. 29, 1944				
Settled sewage	2,350,000	4,000	215	132
Primary filter effluent	2,470,000	4,000	56	30.5
Secondary filter effluent	1,050,000	500	17.5	18.5
Effluent from single filter	335,000	300	17.5	17.5
Period March 7, 1944 to May 23, 1944				
Settled sewage	5,250,000	35,500	215	115
Primary filter effluent	3,500,000	18,400	62	41.5
Secondary filter effluent	1,310,000	2,250	31.5	22.5
Effluent from single filter	291,000	425	27.5	16.5

Samples were collected at various depths of the single stage filter to determine what the reduction in count was at various levels. Samples were taken at one, two and four foot depths in addition to the feed and from the bottom of the filter (6½ ft.) The effect of the first two feet was quite variable, with frequent increases in the count. Between two and four feet there was a more consistent reduction. It appears that a consistent reduction is not obtained until the full depth of the filter is reached. Most of the reduction in oxygen demand and oxygen absorbed occurred during the passage through the first two feet of the filter.

During passage through the double filtration unit the oxygen demand and oxygen absorbed values were reduced appreciably in the primary unit and were reduced to satisfactory levels in the second filter. The bacterial count was high in the primary effluent and in the secondary effluent it was higher than the count found in the effluent of the single stage filter.

T. L. Herrick

NEW SEWAGE TREATMENT PLANT FOR THE CITY OF LETHBRIDGE

By E. M. Proctor

Water and Sewage, 82, 22 (August, 1944)

In 1912 an Imhoff tank-trickling filter plant was built for the city of Lethbridge, Alberta, but has not been operated for some time. The present city population of 13,000 plus a prisoners-of-war camp of approximately the same population provide a sewage flow of 2 to 3 m.g.d. As the old plant was designed for a flow of one m.g.d., and since the equipment and concrete structures are in a bad state of repair, it was concluded that it would be unwise to use funds for reconditioning existing facilities. A new plant is to be constructed adjacent to the old, with provision for using the old Imhoff tank as a sludge storage tank.

The new plant was designed for a normal flow of 2.4 m.g.d. (Imp.) and provides the following facilities; coarse screens, sedimentation tanks, sludge digesters, and sludge drying beds. There are two settling tanks, each 50 ft. diameter with a side wall depth of 9 ft. Provision will be made for chlorinating the effluent.

The digestion tanks, two in number and operated in parallel, are each 40 ft. in diameter and 20 ft. deep at the side wall. Digester gas will be utilized for heating the tanks. Sludge will be dried on open beds with an area of approximately 14,400 sq. ft.

T. L. Herrick

SEWAGE TREATMENT AT PORT HOPE

By G. Graham Reid

Water and Sewage, 82, 22–23 (Sept., 1944)

Extensions to, and improvement of, the sewer system, and a new sewage treatment plant are planned for Port Hope, Ontario. Plans are being made to have the project ready for construction as soon as possible after the war. The present sewers were built as required over the past 50 years. They were apparently designed as a separate system, but were used as storm sewers as streets were improved. Some storm sewers were built, and lateral sewers carrying sanitary sewage have been connected to them. Thus it is impractical to separate the storm and sanitary systems.

Necessary extensions are to be provided to serve areas not now sewered. New intercepting sewers are planned to have a capacity of not less than twice the dry weather flow from all existing sewers.

The treatment plant as now planned will include two combined grit removal and screening units, a pumping station for sludge and low level sewage, a 50 ft. dia. sedimentation tank, a chlorine house and contact tank, and a sludge digestion tank. The layout is such that secondary treatment may be provided at a later date.

The estimated cost of the entire project is $170,326.

T. L. Herrick

TORONTO'S SEWAGE TREATMENT PLANT

By W. E. Micklethwaite

Water and Sewage, 82, 15 (Dec., 1944)

The first part of Toronto's new sewage treatment system is now under construction. This work includes six primary settling tanks, each 66½ ft. wide and 200 ft. long with an average water depth of 14 ft. 8 in. They are designed for an average flow of 84 m.g.d. (Imp.) with a detention period of about 2 hours. The hydraulic capacity is about 210 m.g.d. to take care of peak storm flows. Each tank will have four main sludge collectors, one cross sludge collector and one cross scum collector. The tanks will be covered.

T. L. Herrick

ANNUAL REPORT OF THE INTERSTATE SANITATION COMMISSION—NEW YORK, NEW JERSEY, CONNECTICUT

Annual Report, 79 pp. (1944)

The report contains data covering 1943 and 1944. The policy of the Commission has been one of co-operation with the municipalities within its jurisdiction and the response has been one of conformance insofar as conditions permitted, on the part of the municipalities to the objective of pollution abatement. In fact, during its entire existence the Commission has not been required to resort to court action to obtain compliance in a single instance. Among the special problems were the oil pipelines under Arthur Kill and Kill Van Kull and chlorine contact. In the latter uranine yellow was applied with the chlorine to determine the time of passage in the outlet pipe. The time varied from 2 min. to 75 min. according to the location.

Pollution abatement has been achieved by the construction of sewage disposal plants (in the past) and checking up on the performance of existing plants. In the past year the activity of the Commission, in addition to checking up of the performance of plants, has consisted in many cases of furthering the program to prepare detailed plans for the construction of plants as soon as conditions permit. On the basis of plant investigations, ratings were given to the performance of the various plants in comparison with certain standards of treatment set by the Commission. A rating of I is given to plants complying with the standards in regard to removal of suspended solids and coliform organisms. Plants which fail by a small margin or where minor additions or changes may enable the plant to meet the requirements are given a rating of II. Plants requiring major additions or modifications before satisfactory treatment can be obtained are given a rating of III. In 1943 forty-five per cent of the 67 plants fell in merit rating I group, 10 per cent in group II, and 23 per cent in group III. In 1944, seventy-one per cent of the total were in group I, 7 per cent in group II, and the balance in group III. The analyses are based on results from composite samples taken over an eight-hour period generally during peak flows. A study of the large number of data obtained from plants employing primary sedimentation and post chlorination revealed that maintenance of 0.6 p.p.m. residual chlorine is adequate to secure a maximum count of 30 coliform organisms for 100 ml. which is within the compact requirement.

The most advanced use of the waters under the jurisdiction of the Commission is for shell-fish culture and bathing. Such areas are classified as "Class A." Lesser degree of treatment is required for Class B areas which are primarily industrial areas. The total volume of sewage treated within the area under the jurisdiction of the Commission was about 200 m.g.d. in 1937 when the Commission started and it increased to 520 m.g.d. in 1944. During this same period the volume of sewage failing to meet the compact requirements showed a decrease. Ten million nine-hundred thousand people live in the area draining directly to the Interstate Sanitation district. Approximately half of this population is served by sewage treatment works. The quantity of sludge formed in the settling tanks amounts to 850,000 pounds a day. The B.O.D. of all the sewage is 2,370,000 pounds a day which is reduced by 620,000 pounds a day before entering the waters of the district. Despite the progress in pollution abatement there is still 720,000,000 gallons of sewage a day being discharged without treatment. The estimated cost of the projects contemplated and required to correct this condition is in excess of 120 million dollars.

H. Heukelekian

THE LAW RELATING TO THE POLLUTION OF RIVERS AND STREAMS

By G. E. Walker

J. Inst. Sanitary Engineers, No. 7, pp. 329–354 (July, 1944)

This is a concise summary of the *British* law relating to the pollution of rivers and streams, at common law and by statute.

At common law, a riparian owner (in the absence of a prescriptive right to the contrary) is entitled to receive the flow of water in the stream in its natural state as to quality and quantity. In the case of a polluted stream, the aforesaid right gives rise to a cause of action against the person responsible, unless such person has acquired a prescriptive right by long continued use. A riparian owner has a right of action provided he has suffered damage in *law*. However, he must prove some actual pollution, though he need not have suffered actual damage.

Under the Prescription Act (1832), after twenty years' use, a person acquired a prescriptive right to pollute, which became absolute in forty years. However, no such right exists where an Act of Parliament forbids pollution of a particular watercourse. Since August 15, 1876, no prescriptive right can be acquired on streams to which the Rivers Pollution Prevention Act (1876) applies. Nor can the right to pollute a stream be acquired if such pollution would result in injury to public health.

Of the Statutes of Parliament prohibiting pollution, the most important are the Rivers Pollution Prevention Acts, 1876, 1893, and the Public Health Act, 1936. Under Section 14 of the Local Government Act, 1888, the powers of Sanitary Authorities were conferred on County Councils. The Minister of Health could also constitute a joint committee representing all administrative counties on a watershed or part thereof, such as the Joint Committees for the West Riding of Yorkshire (now West Riding of Yorkshire Rivers Board), the Rivers Mersey and Irwell, River Bibble (now the Lancashire Rivers Board), and River Dee. Under the salmon and Fresh Water Fisheries Act, 1923, fishery boards can regulate pollution.

Under the Defence (General) Regulations, 1939, certain relaxations of orders are permitted to essential undertakings.

There are also private or local acts, such as the Lee Conservancy Act, 1868 (River Lee supplies about one-third of the London water supply); West Riding of Yorkshire Rivers Act, 1894; Port of London (Consolidation) Act, 1920 (relates largely to tidal portion of River Thames); and the Thames Conservancy Act, 1932 (with jurisdiction over 3,812 sq. mi., supplying about two-thirds of the London water supply), extending into fourteen counties. The conservators of the River Thames have control of the non-tidal river, with extensive police powers to regulate and prevent pollution, and pass on plans for sewers, drains, and treatment. The Thames Conservancy Act does not prescribe any standard of purity for effluents, although as a rule an effluent infringes if the albuminoid ammonia exceeds 2 p.p.m.; the suspended matter 30 p.p.m; and the dissolved oxygen absorbed in five days exceeds 20 p.p.m. In two cases Parliament did insert a standard (susp. solids 30 p.p.m.; D.O. 20 p.p.m. in five days at 65° F.).

Walker believes the prevention of pollution is a problem of administration rather than of statute.

LANGDON PEARSE

POSTWAR POSSIBILITIES IN SEWAGE WORKS DESIGN

BY J. HURLEY

J. Institute of Sanitary Engineerss, No. 7, pp. 354–376 (July, 1944)

This is a general discussion of technical developments from the British standpoint. Where trade wastes are present the policy should be decided concerning pre-treatment.

On screening and grit removal, the preference is for screens ahead of the detritus chambers. The popularity of fine screening is declining and interest increasing in the comminution of screenings. In some of the larger works screening has been practically abolished. Screening to protect sewage pumps or sludge pumps should be considered. The production of clean grit is important, either by special design of the grit chamber or cleaning the detritus. In storm water tanks, 10 to 12 hr. d.w.f. capacity is now found instead of the older basis of 6 hr. d.w.f. For even feed to biological filters, balancing tanks may be desirable.

Flocculation is sometimes attempted, either by adding chemicals or by gentle mechanical agitation (about 30 min. period) or a combination of both ahead of sedimentation. The period of detention in settling tanks is longer (10 to 15 times d.w.f.) in Great Britain than in the United States (around two hours). The longer period may be reduced with mechanically desludged tanks. Mechanical devices are more suited to primary sedimentation than for secondary works. The author likes circular tanks for the smaller plants.

Recent developments in percolating filters are classified under (1) high-rate single filtration, with coarse media, at rates up to 1,000 Imp. (1,200 U. S.) gal. per cu. yd. per day, useful for partial treatment; (2) recirculation is used more frequently in the United States and may be advantageous on stronger sewage in Great Britain; (3) enclosed aerated filters, with artificial aeration, with rates of 1,000 Imp. gal. per cu. yd. per day for partial treatment and 200 Imp. (240 U. S.) gal. per cu. yd. per day for full treatment; (4) alternating double filtration with two-stage filters at rates of 150 to 200 Imp. gal. per cu. yd. per day.

Tapered aeration is receiving some attention in activated sludge plants. On contact aerators cost data are required, as well as elimination of operational headaches. The respective merits and economics of filters and activated sludge are better defined. There is a tendency to use the two procedures in tandem, as at Birmingham with the activated sludge preceding the filter, or in the opposite order, on very strong sewage. The two processes may be mutually helpful. Such procedure is more suitable for large works.

For final sedimentation, the old-fashioned manually desludged tanks are on the wane. The relative direction of flow of effluent and sludge is being studied, as well as the location of effluent weirs.

Sludge drying beds are increasing in Great Britain; sludge pressing declining. Covered beds may prove attractive. The utilization of sludge for agriculture directly or by composting is receiving more attention where such material is needed. The provision of 100 acres of farm land was suggested for disposal of liquid sludge from one million Imp. (1.2 million U. S.) gal. per day.

In concluding, emphasis is placed on the importance of designing works for convenient operation.

Langdon Pearse

TENTH BIENNIAL REPORT OF THE STATE WATER COMMISSION FOR THE YEARS 1942–1944

State of Connecticut, Public Document No. 78 (1944)

This 48-page report reviews the conservation of water resources and the broadening of Commission activities to include stream gagings and ground water surveys, Interstate Sanitation Commission, flood control and water policy Commission and supervision of dams. Since 1925, the new or rebuilt sewage treatment plants serve 900,000 people and remove 90 tons daily of dry solids. All State institutions except one are treating their sewage.

Seven pages are devoted to a Review of Research by G. A. Hill and M. G. Bwiford, covering textile, fermentation, paper, metallurgical, and miscellaneous wastes. Various types of filters, centrifuging, and aeration have been explored. A study of paper deinking wastes showed that dilution with an equal volume of water and successive treatment with lime and alum led to a 96 per cent reduction in suspended solids and 94 per cent in oxygen consumed.

B. F. Dodge reviews investigations of treatment of kier liquor and metallurgical wastes. Kier liquor from textile mills is carbonated with flue gases and treated with a controlled amount of the original liquor, thus converting all the caustic alkali to carbonate. Calcium chloride is added, and the liquid settled. The process was covered by U. S. Patent No. 1,802,806 (April 28, 1931), issued to H. A. Curtis and R. L. Copson, assigned to the State of Connecticut. Pickling wastes result from industries making steel or brass products. In some steel mills, the spent-liquor is treated to produce copperas. The rinse water should be kept separate from the spent liquor. The problem varies according to their relative volumes. The study on steel mill wastes covered dilution with sea water; treatment with alkaline reagents (which produces a sludge disposal problem); manufacture of ammonium sulfate and iron oxide (applicable to strong liquors but not economically attractive); manufacture of copperas (which has a limited use). An investigation of pickling methods is required. The difficulty of disposing of copperas leads to a study of possible ways of converting it to more useful products. No satisfactory solution was found generally applicable to all plants.

In the brass mill waste the goal sought is to produce materials of value in the mill itself. Three processes are briefly described:

(1) Treating the liquor by passing it through beds of scrap brass, precipitation by lime, recovery of sludge, roasting and separating of sodium chromate and zinc sulfate. A high-copper scrap also results.

(2) Regeneration of spent chromate pickling liquor or the treatment of wash water concentrate, or a combination of the two. The first step in concentration by precipitation with lime, followed by settling, thickening, and filtration. The filter cake is dissolved in sulfuric acid, mixed with any spent pickling liquor; then filtered; reacted with brass scrap to reduce chromium and plate out copper; treated with zinc dust; and electrolysis of the solution to produce zinc and regenerated chromic acid-sulfuric acid solution.

(3) This procedure resembles (2) except that the oxidation of the chromium is accomplished at high temperature in the air instead of electrolytically.

The best solution for the brass pickling waste seems to be to separate the two classes of waste; concentrate the dilute waste by precipitation with lime followed by settling and filtration; then treat this concentrate combined with strong spent pickling liquor by either of the last two processes above described. The same general procedure of concentration and processing can be applied to a mixture of the wastes.

Further investigations are recommended, with a survey at important plants.

LANGDON PEARSE

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"Monograph for Solving Manning's Formula." Paul McH. Albert, pp. 330–331.

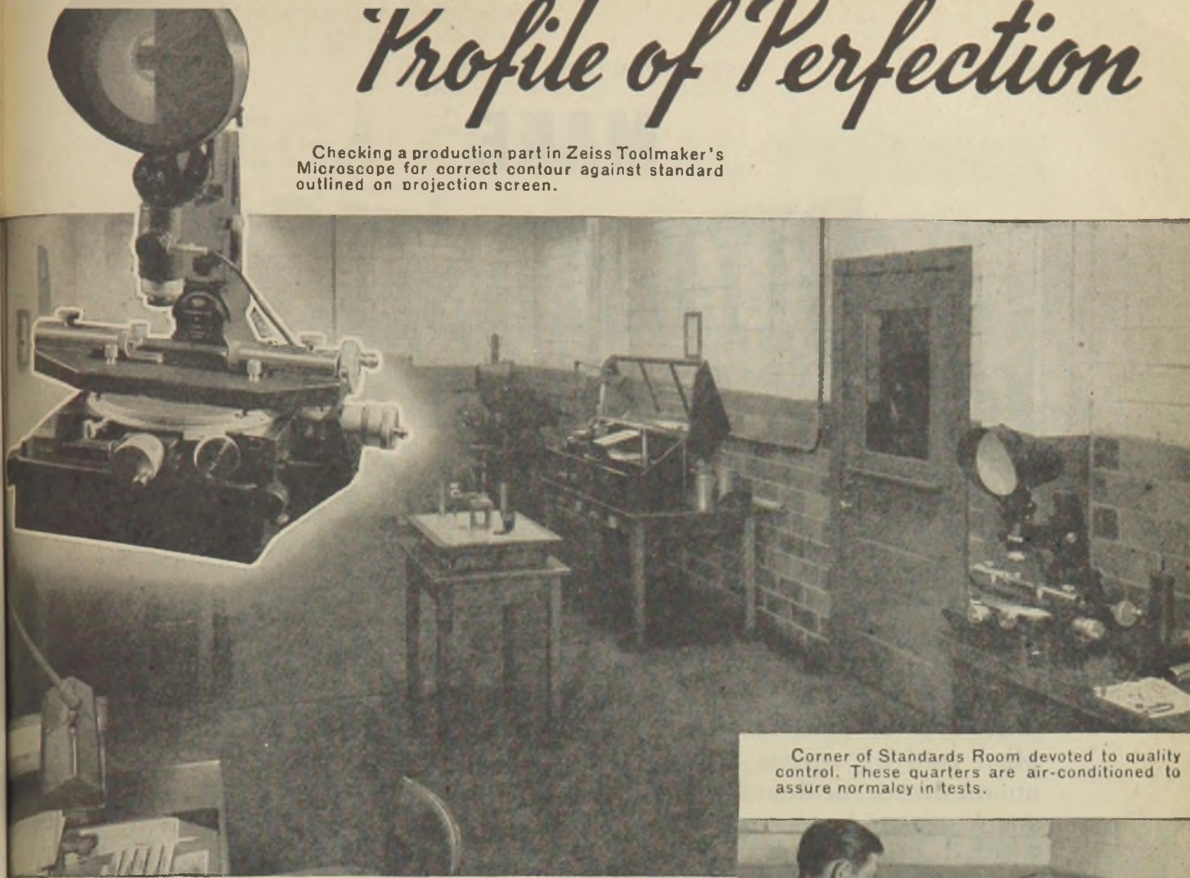
October, 1944 (No. 10).
"Gas Engine Performance at Marion, Indiana." David Backmeyer, pp. 335–339.
"Solving a Sewage Pumping Problem." W. W. Glover, pp. 367–369.

November, 1944 (No. 11).
"Municipalities Can Finance Improvements if They Make the Effort." W. F. Tempest, pp. 383–387.
"Importance of Sewage Plant Operating Records." H. T. Rudgal, pp. 393–398.
"Build Your Own! Lime Solution Controller." A. A. Bailey, p. 400.
"A Temporary Hypo-Chlorinator for Five Dollars." J. R. Snell, pp. 404–405.

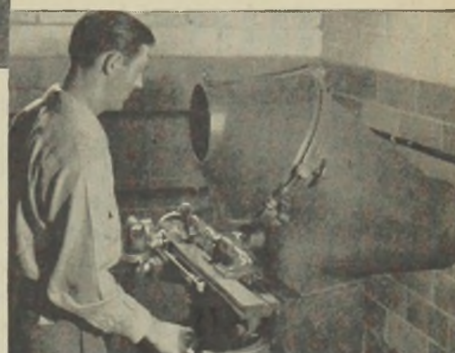
December, 1944 (No. 12).
"The Sanitary Engineering Division of the U.S.P.H.S." Pp. 436–437.

Profile of Perfection

Checking a production part in Zeiss Toolmaker's Microscope for correct contour against standard outlined on projection screen.



Corner of Standards Room devoted to quality control. These quarters are air-conditioned to assure normalcy in tests.



Jones and Lamson Pedestal Comparator used to check tools for wear after service.

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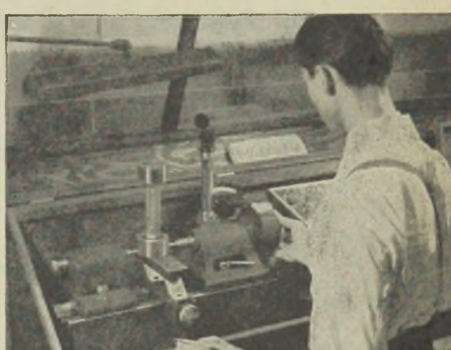
With the aid of our Standards Department we can deal in probabilities too. We can pre-evaluate the performance of a product and, through controlled manufacturing procedure, know with reasonable assurance that any one of its thousands of counterparts will duplicate this performance in the field.



Pratt and Whitney Measuring Machine reads directly to 1/100,000 of an inch.

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