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SEWAGE WORKS JOURNAL

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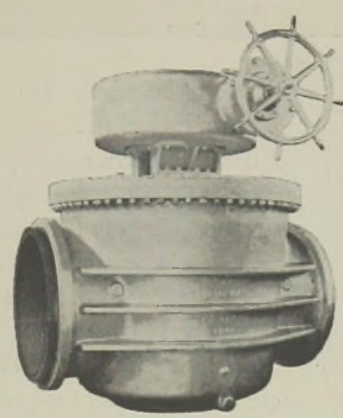

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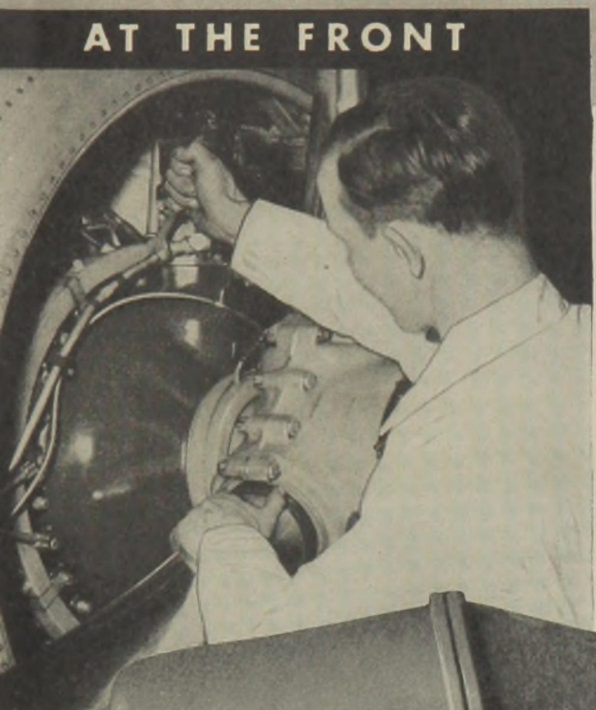

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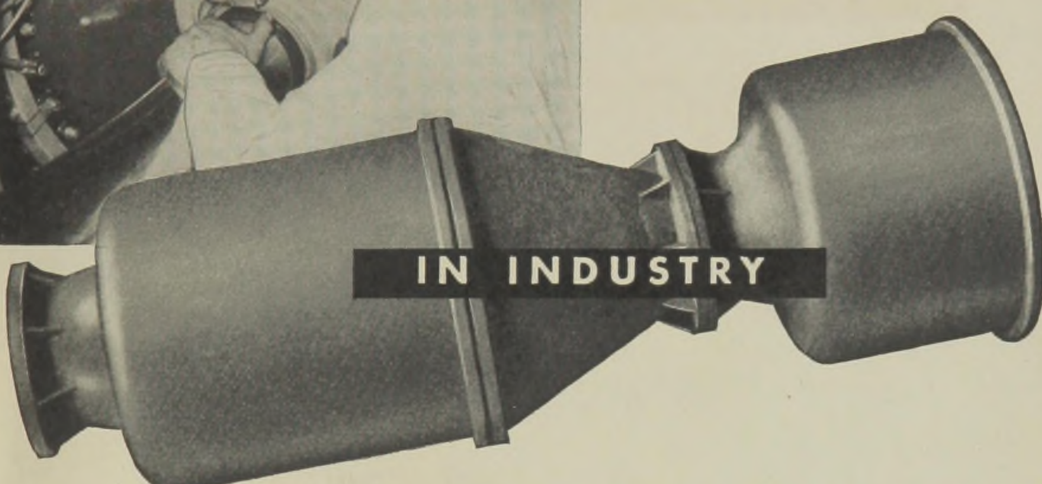

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Plant Operation

SEWAGE TREATMENT AT ARMY POSTS*

By Lewis H. Kessler and John T. Norgaard

Chief and Associate Chief, Respectively, for the Sanitary Engineering, Water, Sewer and Services Unit, Repairs and Utilities Branch, Construction Division, Office Chief of Engineers.

In October, 1940, the War Department undertook what is believed to be the greatest construction program ever attempted in so short a time. This task was brought about by the passage of the Selective Service Act of 1940 with the accompanying need for immediate construction of Cantonments, Posts for Armored Divisions, General Hospitals, Air Fields and Munitions Depots. Architect-Engineers in private practice were retained by the Construction Division, then under the Quartermaster General, not only to design but to supervise the building of these military establishments.

Obviously, the utilities, water, sewerage, garbage removal and incineration, presented design and operation problems. Relative to sewage treatment, the subject of this paper, the engineering firms of Metcalf and Eddy, Boston, and Greeley and Hansen, Chicago, were selected to make a study of about 50 defense projects, to advise with respect to sewage treatment. Data for bases of design were meager and in some cases construction had already started before the firms could visit sites. Nevertheless, the decision to appoint such a board of engineers and those chosen was a happy one. The general design policies adopted by the engineers resulted not only in modern sewage treatment for our Army but also in the saving of large sums of money.

The instructions given to the reporting firms we have chosen to call the "Engineering Board" were to:

(*a*) Advise and report as to the simplest sewage treatment plant at each project suitable and adequate to meet the minimum requirements under local conditions, and

(*b*) Secure modification of plans already prepared where, in the interest of economy, such modification was necessary in their judgment, taking into account, however, the exigencies of the situation.

A booklet prior to the appointment of the Engineering Board, entitled "Instructions and Information for Architect-Engineers," dated October, 1940, by the Engineering Branch, Construction Division, O. Q. M. G., included this statement:

* Presented by Mr. Kessler at the Fourteenth Annual Spring Conference of the California Sewage Works Association, Bakersfield, California, April 27, 1942. Released by courtesy of the War Department.

In the design of sewage treatment works, simplicity and economy are essential. Only the minimum requirements of the State Board of Health should be met, as the plants are in general expected to be in use for only a limited period. Primary treatment with chlorination will in many cases be adequate. Complicated, unproved or patented processes should be avoided.

The Engineering Board states it was guided by the following general factors:

"*a.* The character and use of the receiving water course.
b. The environment of both treatment plant and camp.
c. The degree of permanence required.
d. The need for utmost speed in design and construction.
e. The need for safeguarding the health of both troops and neighboring civilians.
f. The need for reasonable economy of construction allowing for the fact that operating costs would not be as important a factor as in more permanent plants for municipal service.
g. The relation of all projects to the National Defense Program making them of equal interest to all citizens."

The board transmitted its report in December, 1940. The recommendations appeared as a part of Technical Bulletin, "Sewerage and Incineration," Engineering Branch, Construction Division, O. Q. M. G., War Department, dated April 23, 1941, primarily arranged as a guide only to Architect-Engineers engaged under Cost-Plus-A-Fixed-Fee contract.

Recommendations embodying improvements due to increase in capacity at permanent posts did not prove to be troublesome. Most of the posts were new and classed as temporary, presumably to be used for the duration only. No operating experience for guidance was available and design bases had to be developed rapidly, hence it is not surprising that in the light of experience, the War Department has recommended recently some modifications in design units.

To provide for the maintenance, repair and operations of utilities, in March, 1941, a new section was organized in the Construction Division, O. Q. M. G., known as the Repairs and Utilities Section. This has since been expanded into a Branch consisting of six sections, namely;

1. Control and Records.
2. Defense Housing.
3. Fire Prevention.
4. Fuel and Service.
5. Equipment.
6. Maintenance and Repairs

The Sections are headed by army officers or civilians whose civil experience particularly qualifies them for these responsible posts. The Branch, known as R. and U., began to function effectively in July, 1941, in the Nine Zones. These Zones corresponded in number and geographical boundaries to the Corps Areas. The Zone C. Q. M. reported directly to the Corps Area Commander and assistants were appointed to handle repairs and utilities work through the Post Utilities Officer at all posts. The Post Utilities Officer is on the staff of each Post Commander and reports directly to him.

On December 16, 1941, by an Act of Congress, the office of the Chief of Engineers took over the construction division of the office of the Quartermaster General. There has been no great change in method or channel of operation. The Zones were abolished and in their stead the Division and District Offices of the U. S. Engineers took over the tasks.

In most cases only a few changes in personnel occurred. The Maintenance District Engineer, an assistant to the District Engineer, has charge of R. and U. work throughout the Corps Area. The original 59 District Offices are not disturbed and they continue to function as offices for new construction of army posts and at existing posts within their areas. The former post C. Q. M. is now an Area Engineer. New construction is classified in general as any project materially altering the post and utilities or the purpose for which construction was intended. Such projects usually start at $50,000. Maintenance and Repairs projects $5,000 or less are approved at the Maintenance District Engineer Office. This office makes recommendations on projects greater than this amount but these must come to the Office of the Chief of Engineers for final approval and recommendations as to allotment of funds.

One of the first acts of R. and U. was to urge reconsideration of some of the design units to avoid continuance of errors and to request manufacturers of sewage treatment plant equipment to criticize the Sewerage and Incineration Technical Bulletin. The response is a thick document that represents as of January, 1942, the culmination of what is known and recommended by manufacturers to date on sewage treatment so far as design units are concerned. The reports were carefully and faithfully prepared after representatives of manufactures had visited many of the sewage plants.

In August, 1941, the Water, Sewer and Services Unit prepared monthly operating report forms, that were sent to all posts having treatment plants.

The best information the office could get from state sanitary engineers and municipalities was used in compiling the report forms. The completed reports, which include daily test results, are studied in the district Office and in Washington. As the district staffs become complete, only quarterly reports will come to Washington. The reports and plant visitations have been used as a basis for the operating data shown in this paper, and also as a guide for revision of design units described in this paper and in detail in Chapter VII, Engineering Manual, March, 1942, Office of Chief of Engineers, "Design of Sanitary Sewers, Sewage Pumping Stations and Sewage Treatment Plants."

Since June, 1941, publication in loose leaf form of the Repairs and Utilities Manual has been in progress. The small papers therein deal with utility plant operation from the operator's standpoint. Funds are being provided to start plant libraries and in the manual, references are made to these books. The manual is taking hold because as soon as an operator fails to receive a new chapter, the Washington or District Office soon hears about it. If the manual were written under the name of any man, it would be called, in spots, plain plagiarism. The plan has been to offer to the operators useful and proven information from the most reliable sources and a debt is owing to the sanitary engineers, the faithful plant operators, the technical press and others for the help they have been providing, perhaps unknowingly, by disclosing operating and maintenance helps that have come about the hard way. There is one thing certain, that in the case of future national emergencies, all that has been learned in sewage treatment at army posts in this war will not be lost.

Design Factors and Units

Table I shows most of the flow factors and design units now used as a guide to Architect-Engineers and the District Offices. One of the departures from the first basic units is the capacity factor. This has been brought about due to study of all data that R. and U. could collect from the field prior to March, 1942; the trend to enlarge posts beyond the original specified population; the uncertainty as to civilian population; the flow due to post laundries that never appeared in 1918 data; and more than usual infiltration due to hurried construction of sewers.

By the water waste survey now under way using technically trained men, the installation of urinal flush valves, and the reduction in use of water in the kitchens, the most recent data indicate the units shown should be reasonable. Based on more recent results, the B.O.D. removal expected may be a little low in the case of single-stage high capacity filters and a little high in contact aeration. Forty per cent removal in primary sedimentation does not take into account the return of strong supernatant liquor from the digester and we believe a value between 30 and 35 per cent will more likely be obtained. An argument is advanced that with the loading of B.O.D. as shown for the high-capacity filters (including the capacity (flow) factor), the filters become too large or are overdesigned. This appears correct on the basis of one single-stage filter plant that is operating very well.

On the other hand, its flow diagram with dual recirculation is almost identical with a two-stage plant, except that the settling tanks are smaller. Further study might very well be given the single-stage filter, during its original design, to accomplish dual recirculation by discharge of filter effluent to the primary clarifier influent and from final clarifier effluent to filter influent. In effect, the suspended matter in the filter effluent then receives only one period of sedimentation. Indications are that clarifier capacity may be cut about 30 per cent. (See Plant XIV, Table V.)

The increase in per capita B.O.D. of 0.03 pound is warranted over the normal 0.17 due to the fact that army sewage approaches institutional sewage where adult populations only are encountered. Fats and greases are predominant in army menus. Each kitchen has a fat frier.

TABLE I.—*Sewage Treatment Design Factors as Revised March 20, 1942*

Flow Factors—Gallons per Capita per Day

Designed Post Population			10,000	20,000	30,000	40,000	50,000
Capacity Factor		Basic Flow	2.00	1.50	1.25	1.10	1.00
	24 hr. Average Rate of Flow	70	140	105	87.5	77	70
Camps	16 hr. Average Rate of Flow	87.5	175	131	109	96.5	87.5
and	4 hr. Maximum Rate of Flow	122.5	245	183	153	135	122.5
Cantonments	Extreme Peak Flow	210	420	315	262	231	210
	4 hr. Minimum Rate of Flow	28	56	42	35	31	28
	24 hr. Average Rate of Flow	100	200	150	125	110	100
Airfields,	16 hr. Average Rate of Flow	125	250	212.5	156	137.5	125
Permanent Posts	4 hr. Maximum Rate of Flow	175	350	262	219	193	175
and Hospitals	Extreme Peak Flow	300	600	450	375	330	300
	4 hr. Minimum Rate of Flow	40	80	60	50	44	40

Design Units

Type of Plant	B.O.D. Removal, Per Cent	Detention Period, Hrs. 16 Hr. Average Flow		Applied B.O.D. Loading per Day	Sludge Digestion Capacity* Cu. Ft./Capita	
		Primary	Secondary		Heated	Unheated
Standard Trickling Filters	85–95	2.0	2.0	600 lb./acre ft.	3.0	4.5
High Capacity Filters						
Single Stage	60–80	2.0	2.0	3000 lb./acre ft.	3.0	4.5
Two Stage	85–95	2.0	2.0	3000 lb./acre ft.	3.0	4.5
Activated Sludge						
Compressed Air	85–95	1.2	2.0	8 hr. aeration	4.0	6.0
Mechanical Aeration	85–95	1.2	2.0	12 hr. aeration	4.0	6.0
Contact Aeration	85–95	2.0	2.0	156 sq. ft./lb. B.O.D., $1\frac{1}{2}''$ plate spacing 1.5 cu. ft. air	3.0	4.5
Plain Sedimentation	40	2.0	—		2.0	3.0
Imhoff Tank Only	40	2.0	—		—	4.5
Maximum Overflow Rate (Gals./sq. ft./day)	– – – –	– – – –	800			

* Multiply by capacity factor shown above.

Sewage Characteristics—Pounds per Capita per Day	
B.O.D.—5-Day	0.20
Suspended Solids	0.27
Other Soluble	0.29

The high grease concentration has affected plant operation, caused a new grease trap rehabilitation program to be set up to eliminate clogging of sewers and piping in the plants and to effect reduction in scum difficulties and partial clogging of filters.

Previous design standards for digester capacities showed a range of values. This has been eliminated. The lowest figure was often used by designers to cut initial costs to a minimum. This placed more liberal designs at a disadvantage when the type of plant was selected and caused operating difficulties when installed.

Operating Personnel

The most important cogs in successful plant performance are the plant operators. About 25 per cent of the time of the engineers in the Water and Sewer Unit during the early months was placed on personnel problems trying to assist the District Offices and Civil Service to obtain qualified men. The assistance of members of your association and engineers and universities was solicited and the results have been gratifying, with a small turnover in operators. The instructions in Table II are not mandatory but merely a guide to post utility officers. In substance it was first approved by the O. Q. M. G. in October, 1941. All water and sewer utilities have been placed in one of four classifications relative to population bracket and type of plant. Obviously additional helpers are needed when two plants exist at a post. The Office of the Chief of Engineers is encouraging a personnel set-up at each post whereby a substantial nucleus of men will always be available for water distribution and sewerage collection system maintenance and the sanitary engineer in charge will not have to go about the post corraling men from the plumbing section and the like in order to render prompt repair service.

The wisdom of the plan of heading up the water and sewer utilities by sanitary engineers is being revealed more and more as monthly operating reports come in and reports from the Sanitary Corps officers indicate better plant operation and fewer complaints or recommendations of the inspecting officers. It is believed these high-grade men, skilled somewhat in administration as well as in operation, are in general of the type that can obtain co-operation with the Medical Corps and Sanitary Corps officers and can also assist in explaining the limitations of each plant and how it should function best. The Office of the Chief of Engineers welcomes all inspections and tests on results of plant operation by proper military authority in accordance with army regulations but it insists on full control of plant operation and other agencies shall not dictate plant control procedure.

The salary scale of operators and helpers in general compares favorably with that of municipal plants, but in many cases the living conditions have not been particularly inviting. Difficulties were met in attracting qualified men due to more attractive pay in war projects and industries, but so far at least 80 per cent of the civilian workers have remained at their tasks or have been promoted or transferred to other posts. The office is continually trying to reward excellent operators by transfer with promotion when more important plants are completed. Since the declaration of war and the second draft, applications for plant operators have increased and it is believed key personnel will be rather easily obtained for the plants now under construction.

TABLE II.—*Table of Allowance—Civilian Personnel for Sewerage and Sewage Disposal at Army Posts*

Section	Designation	Class	Base Pay	38,000 and over		12,000 to 38,000		6,000 to 12,000		1,500 to 6,000	
				No.	Annual Cost	No.	Annual Cost	No.	Annual Cost	No.	Annual Cost
Sewerage and Water Supv.	Sanitary Engineer	P-4	$3,800	1	$3,800						
	Assoc. Sanitary Engineer	P-3	3,200			1	$3,200				
	Asst. Sanitary Engineer	P-2	2,600					1	$2,600	1	$2,600
	Class "A"										
Sewage Pumping and Treatment Plants	Asst. San. Engr.	P-2	2,600	1	2,600	1	2,600				
	or Chief Oper. Engr.	Uncl.	2,600								
	Jr. Chemist	P-1	2,000	1	2,000	1	2,000				
	Oper. Engrs.	Uncl.	1,680	4	6,720	4	6,720				
	Class "B"										
	Asst. San. Engr.	P-2	2,600	1	2,600	1	2,600	1	2,600		
	or Chief Oper. Engr.	Uncl.	2,600								
	Oper. Engrs.	Uncl.	1,680	4	6,720	4	6,720	4	6,720		
	Class "C"										
	Principal Oper. Engr.	Uncl.	2,000					1	2,000	1	2,000
	or Jr. San. Engr.	P-1	2,000								
	Jr. Oper. Engr.	Uncl.	1,500					4	6,000	4	6,000
	Class "D"										
	Oper. Engr.	Uncl.	1,680					1	1,680	1	1,680
	Sewage Disp. Plant Worker	Uncl.	1,320					1	1,320	1	1,320
Sewers and Water Distr. System	Inspector	Sp-6	2,000	2 *a	4,000	1 *b	2,000				
	Sr. Foreman of Const. and Maint.	Uncl.	2,000	1 *a	2,000						
	Foreman of Const. and Maint.	Uncl.	1,860					1	1,860		
	Jr. Foreman of Const. and Maint.	Uncl.	1,680	1 *a	1,680	1 *b	1,680			1	1,680
	Classified Labor	Uncl.	1,320	3 *a	3,960	2 *b	2,640	2	2,640	1	1,320
				(*a 24,000 or over)		(*b 12,000 to 24,000)					

Classification of Sewage Treatment Plants

Sewage Treatment Plant Types	Classification			
Post or Contributory Population	38,000 and over	12,000 to 38,000	6,000 to 12,000	1,500 to 6,000
Complete Treatment with Separate Sludge Digesters	A	A	B	C
Primary Tanks and Separate Digesters—Primary Treatment Only	A	B	C	C
Doten or Imhoff Tanks with Trickling Filter	B	B	C	D
Doten or Imhoff Tanks Only or Sand Filters Only	—	—	D	D

Some of the operators have been attending the state-sponsored short courses and post commanders in general encourage this training. The monthly reports indicate that a need exists, particularly among men skilled in some trade who are now operators, for some short-course work in at least six of the Corps Areas. These courses will be directed by the Office of Chief of Engineers, in co-operation with sanitary engineering departments of universities and state boards of health. Plans for three courses are just getting under way. The special "Defense Courses" offered by a number of universities are proving of value to the work of the utilities. The special manner in which the qualifications of each man attending these courses are neatly and clearly presented has been a great help to Post Utility officers in selecting operators. With the exception of about twelve widely distributed plants either under-designed or improperly operated, criticism of plant performance has ceased as soon as capable operators were employed or inexperienced men became familiar with their duties.

Description of Portions of a Few Plants—Some Operating Problems

Grit.—Figure 1 shows one type of grit chamber used with a proportional weir. Other measuring and control devices are used, such as

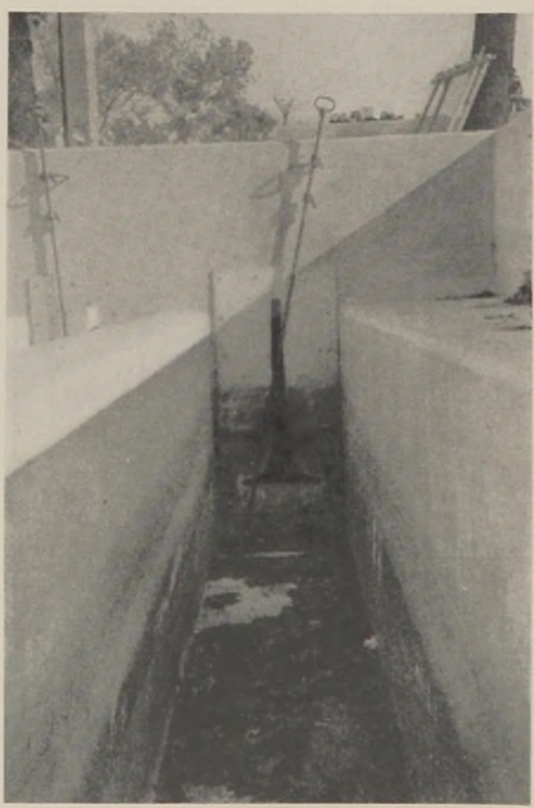

Fig. 1.

the rectangular flume (Palmer-Bowlus), Parshall Flume and venturi meter. The plants located in sandy terrain are having considerable grit trouble and the ashes getting into the floor drains of kitchens are causing increased grit. With more continued use of the sewerage system some of the early troubles immediately encountered after acceptance of the system are disappearing. The remarks of operators disclose particular trouble with accumulated grit in digestion tanks.

Sedimentation.—Figure 2 shows a new design of primary tank effluent launder that is operating very well. This design comprises

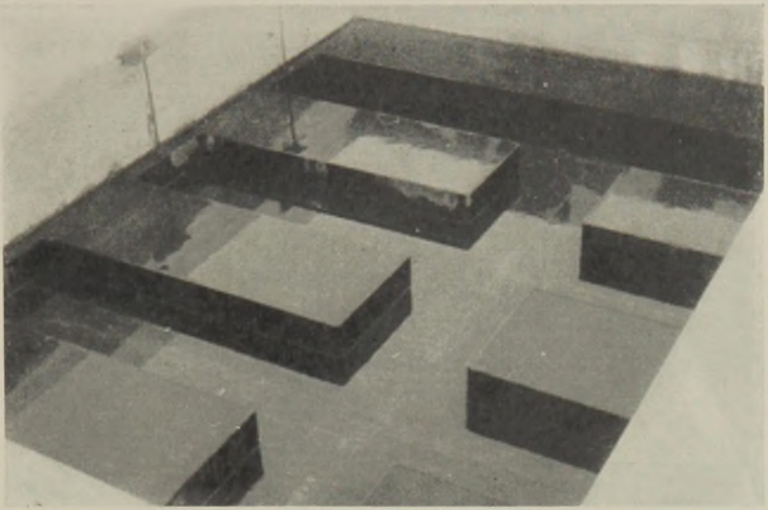

Fig. 2.

horizontal orifices or short tubes welded to a plate under pressure at the effluent end of a secondary tank. The sludge concentrating mechanism is deflected below the plate but the bottom of the tank is properly squeegeed. So far no scum difficulties have occurred on the underside of the plate. Note the total available weir length.

Figure 3 is a sludge mechanism installed at both primary and secondary tanks of a southern post. The mechanism spans two parallel tanks. Considerable operating trouble has been encountered with this mechanism and its efficiency of sludge concentration for final tanks is questionable in our opinion. It is believed it is more applicable to primary tanks. Consulting engineers recommended recently that it be given six weeks more trial. Apparatus has been out of operation nine times in the last six months.

Filters.—At several enlarged permanent posts engineers have designed standard rate filters to fit within walls or tanks of existing structures, as shown at a southern post in Fig. 4. Provision has been made to add distributor arms to handle increased flow rate.

Figure 5 shows a flocculation tank, clarifiers and filters at the Army's largest single-stage high rate filter plant. Considerable operating trouble has resulted by failure to provide piping for pumping sludge from the final clarifier directly to the digester. No chemicals have been used prior to flocculation, although feeding equipment has been provided. Figure 6 shows grease accumulation on the flocculation tank surface and Fig. 7 shows much grease in the scum on the clarifier following

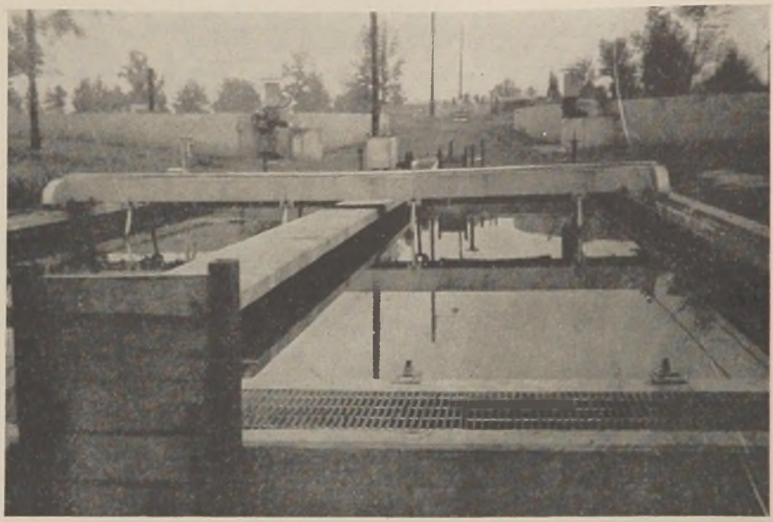

Fig. 3.

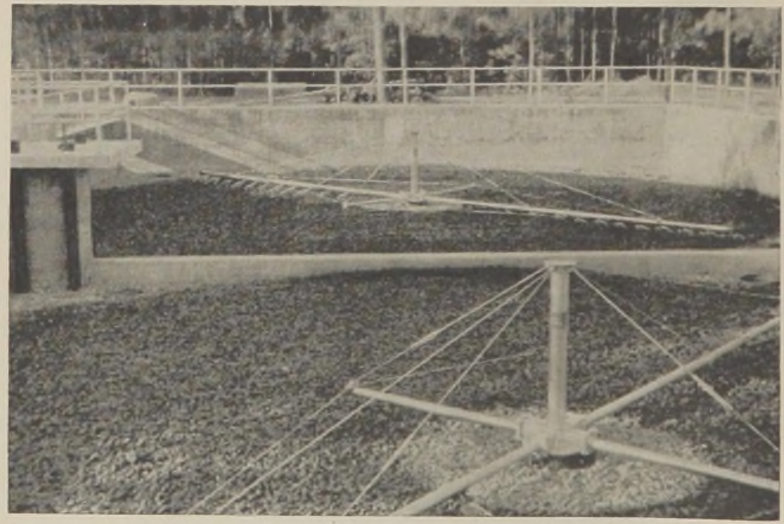

Fig. 4.

the flocculation tank. In Fig. 8, the filter following the clarifier had about 25 per cent of the area of the filter clogged. It is not concluded that this was caused entirely by grease, but grease did play a part. These observations, together with operating reports from western plants, were the reasons that R. and U. began a research project followed by a grease trap rehabilitation program for all mess halls of the 700 series buildings. This research is described briefly elsewhere.

Aerators and tanks have not proven to be successful grease removers. That a grease problem would exist was recognized, but collecting and removing it at the source appears to be the only positive solution.

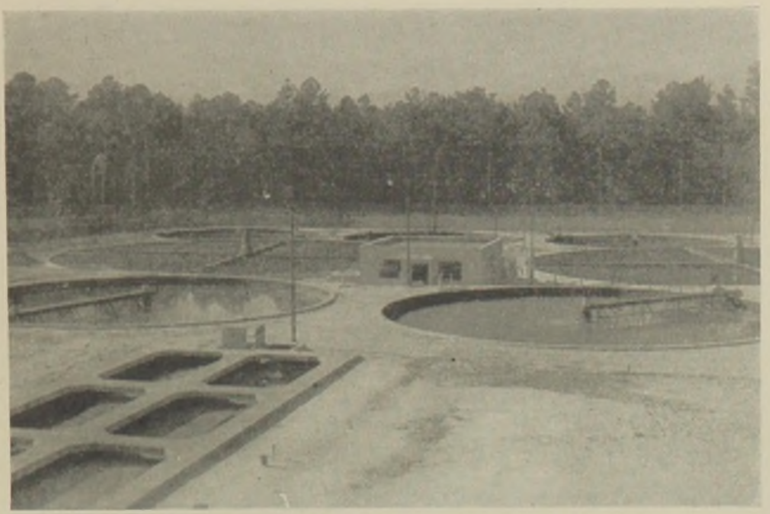

Fig. 5.

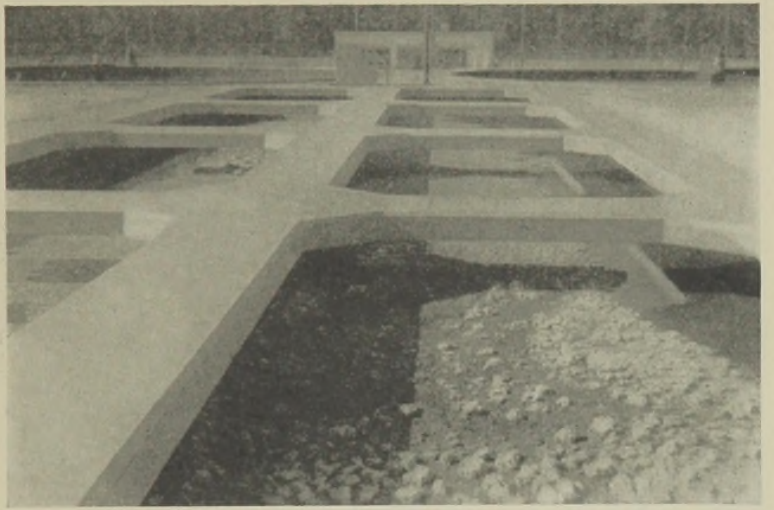

Fig. 6.

Activated Sludge.—Figure 9 is a view of aeration tanks and control house at the Army's largest activated sludge plant, overloaded since it first began operation but doing a fairly creditable job as shown by the results for Plant XXIV, Table VII. The plant uses carbon air diffusers arranged for tapered aeration.

In the largest mechanical aeration plant, the early results were promising but the plant is now overloaded and some betterments will be accomplished. A roughing filter ahead of the aeration units has been proposed but has not met with our favor.

Sludge Digestion.—The Doten tank, long a favorite with the Army,

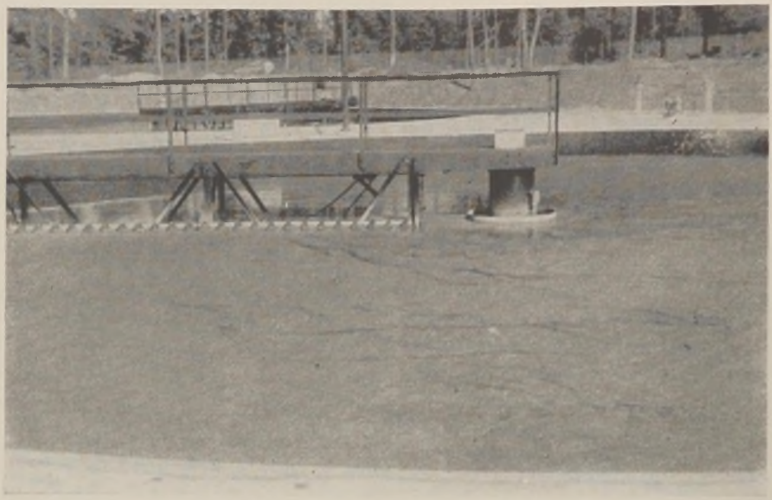

Fig. 7.

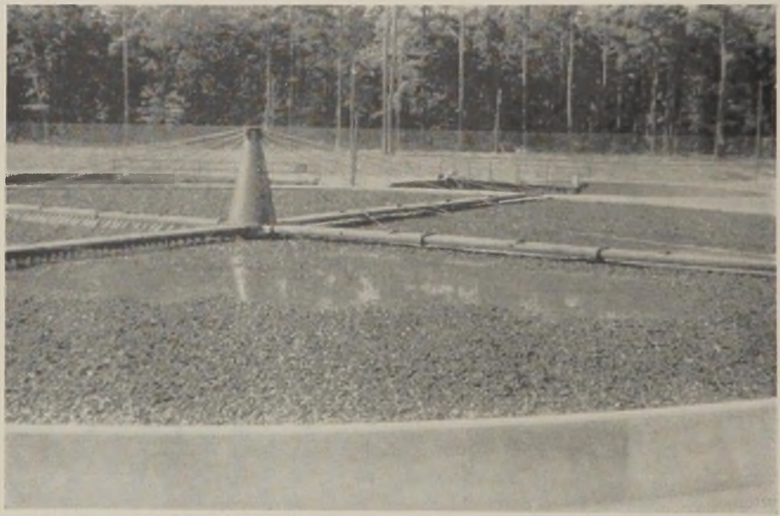

Fig. 8.

is still in use at a few posts. At only two posts is it giving satisfactory performance. In some posts, as shown in Fig. 10, it has been made into a digestion tank. Operators have found fairly good results by forcing supernatant liquid to break up the sludge and scum daily. The use of clear water at fairly low temperature has given poor results. The Doten tank seems to work in reverse. Little or no solids are found on the bottom. They are all on the top. In one post the top sludge and scum is transported in wheelbarrows to drying beds.

There are many multi-stage digestion tanks at Army plants. The fixed and gas holder type as well as the floating cover type has been widely used. A real unsolved problem, at least from the operator's

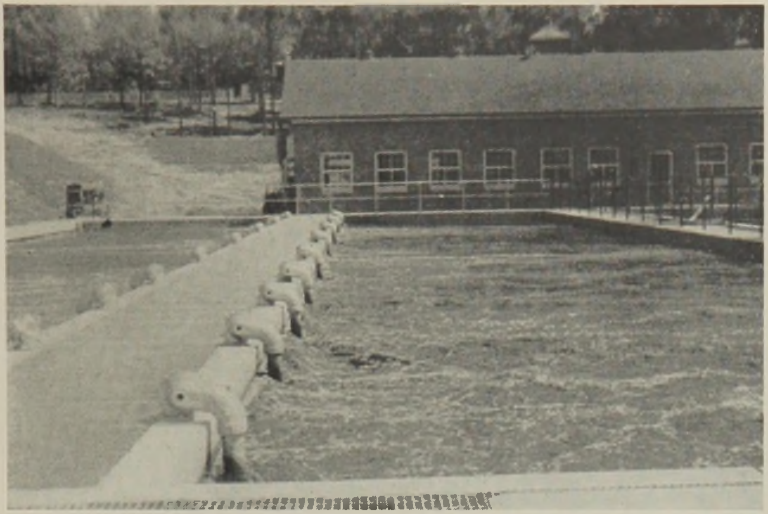

Fig. 9.

Fig. 10.

viewpoint, is the best method of treating the supernatant liquor. Experiments are under way in Mississippi aerating the liquor with a new device, and test results to date indicate that the capacity of existing digesters may be increased and a liquor of lower oxygen requirements can be returned to the primary tank. The new technical bulletin insists that a connection be made also between digester supernatant takeoff and sludge drying beds. In the southern plants the major problem has been sludge drying, with lack of sludge capacity second. Obviously a sandy country brings up other operating problems, with much sand found in the settling tanks.

FIG. 11.

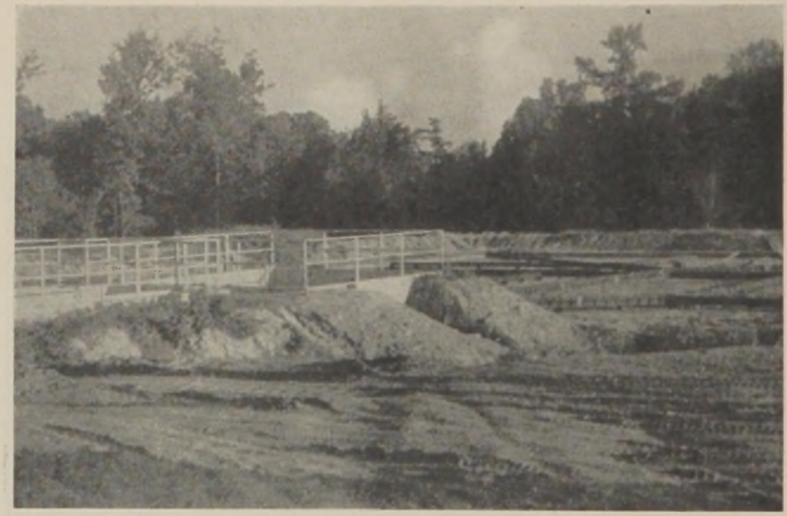

FIG. 12.

Figure 11 shows the three stages in sludge drying by uncovered beds at a southern post. It also shows difficulties encountered with soil erosion, filling up of the dry run with ultimate clogging of the underdrains of the filter where these have been built too low. One post is using a "lemonade" wagon to spread wet digested sludge on the ground at various points in the reservation, and report of medical officers is awaited to learn whether this practice will be continued.

Figure 12 is a small Imhoff tank—sand filter plant at an airfield. This type has been giving good results. The picture illustrates also one of the headaches encountered by Post Utilities officers when plants were built under the cost-plus-fixed-fee contract and contractor was ordered off the job suddenly. The dike in the foreground could have been completed in about one-half day. A rise of water in the bayou due to sudden rainfall washed part of the sand filter away and caused damage and operating delays easily avoided if a thorough check had been made prior to terminating the contract.

Fig. 13.

Figure 13 illustrates the type of buildings constructed to house laboratory and control rooms at some of the more important airfield plants. While laboratories and equipment are by no means complete at many posts, in a very few weeks most of the plants will be running the tests specified by the O. C. E.

Plant Operating Results

We are pleased to disclose some operating results at twenty plants, without mentioning posts by name. The data selected are from plants where we have every reason to believe the operators are qualified and the results of their testing can be considered reliable. Tables III to VII inclusive have been organized by type of plant, with the design capacity obtained from the best sources possible, using the flow rate of 70 gallons per capita per day as set up by the first O. Q. M. G. Technical Bulletin. These data merit some study, but time will permit of only a brief discussion and a few comments as follows:

Primary Treatment—Table III.—In Post II the flow is normal, average B.O.D. in raw sewage is low and the average B.O.D. removal is 28 per cent. In Post XVIII the flow is normal but higher than in II. The B.O.D. strength and pounds of B.O.D. per capita are almost double

Table III.—*Operating Results*

Primary Treatment

Post and Designed Capacity	Month 1941–42	Contributory Pop.	Aver. M.G.D. Flow	Flow—Gal./Cap./Day	Aver. B.O.D.		Aver. Susp. Sol.		Per Cent Reduction	
					Raw	Effl.	Raw	Effl.	B.O.D.	Susp. Sol.
	Aug.	12,138	1.49	123			216	60		72
	Sept.	13,232	0.98	74	96	69	132	59	28	55
II	Oct.	50,533	3.59	71	100	78	155	76	22	51
3.5 M.G.D.	Nov.	11,530	0.74	64	81	53	126	51	35	59
50,000 pop.	Dec.	44,700	3.31	74	136	100	180	91	26	49
	Jan.	46,024	3.60	78	127	93	173	91	27	47
	Feb.	37,699	3.15	84	139	97	202	76	30	62
	July	16,439	1.43	87	265	195	159	69	26	56
	Aug.	19,045	1.52	80	224	163	182	112	27	38
	Sept.	19,113	1.48	77	192	140	197	112	27	43
XVIII	Oct.		1.55		216	151	217	82	30	62
2.0 M.G.D.	Nov.	21,000	1.68	80	246	157	203	85	36	58
	Dec.	18,921	1.61	85	240	164	186	93	32	50
	Jan.	17,887	1.65	92	215	158	176	85	26	52
	Feb.	20,196	1.66	82	237	175	163	90	26	45

that of Post II. The average per cent removal of B.O.D. is 29 per cent. One would expect increased per cent B.O.D. removal. Both of the above plants have unheated digesters. Foaming is expected in XVIII this spring.

Standard Filters—Table IV.—In Post XX there is a progressive decline in operating efficiency. Filters are clogging and the main sludge line clogs with grease. No raw sludge was pumped for eight days in

Table IV.—*Operating Results*

Standard Filters

Post and Designed Capacity	Month 1941–42	Contributory Pop.	Aver. M.G.D. Flow	Flow—Gal./Cap./Day	Aver. B.O.D.		Aver. Susp. Sol.		Per Cent Reduction	
					Raw	Effl.	Raw	Effl.	B.O.D.	Susp. Sol.
	Sept.	17,736	1.29	96	346	44	195	20	77	90
	Oct.	31,073	1.91	61	332	38	240	34	89	86
	Nov.	31,096	2.30	74	288	55	254	34	81	86.5
XX	Dec.	32,000	2.58	81	306	65	230	70	79	70
3.0 M.G.D.	Jan.	43,000	2.81	65	152	38	178	75	75	69
	Feb.	37,150	3.21		234	57	153	55	76	64
	Mar.	36,709	2.99	89	268	73	156	70	73	53
	Sept.		1.26		164		296	24	88	92
XXIII	Oct.		1.2		143	9	196	12	94	94
	Nov.		1.07		183	12			94	
	Feb.	14,274	1.172	82	204	12	90	14	94	85

March. In Post XXIII there is consistently high removal of both B.O.D. and suspended solids.

Single-Stage High Capacity Filters—Table V.—In Post VII the biofilter unit apparently is affected adversely by the Imhoff primary treatment. This is in a northern climate. In Post XXII 25 per cent of the primary capacity was out of service the entire month for equipment repairs. Post VIII plant will be altered and extended to better treatment with ultimate disposal in a dry run. This plant is not claimed by any manufacturer and is one of the reasons for the adoption of the following recommendation to Architect-Engineers: "Where it is determined that the use of high capacity filters will result in economies, it is suggested that the design data set forth in this communication be strictly followed and that the manufacturers' recommendations on the required equipment and processes be followed. This will make it possible to fix responsibilities and require guarantees covered by performance bonds."

Post XIV plant has dual recirculation (*a*) from filter effluent to primary influent, (*b*) from final clarifier to filter influent. It shows the best results of any single-stage plant and better results than several two-stage filter plants. Plant III has exceptionally high flow rate and high pounds of B.O.D. per capita, with 0.276 pound for January. Plant I is to be enlarged along with a program for expansion of the post. Broad irrigation of the effluent is contemplated on recommendation of the State Board of Health.

Two-Stage Biofilters—Table VI.—Post XII is chlorinating heavily to control filter flies. Representative sludge analyses are:

Raw	6.2 per cent solids with 75 per cent volatile
Digested	7.6 " " " " 40 " " "
Gas production	1.24 cu. ft. per capita

At Post XXI the population shown is much lower than usual. Per capita flows have been high due to excessive infiltration. The effluent characteristics are excellent.

In Plant XVI excessive per capita flow rates for September and October are due to 15 and 11.5 inches of rainfall respectively. The operator tried various primary recirculation ratios at one-week intervals, as follows: 0.5, 1.0, 2.0, 3 and 4, 4 and 5 and back to 1.0. Very little differences in effluent were noted, although raw sewage strength increased during some periods. The length of test period is considered too short. It does indicate some of our operators are doing some constructive thinking.

At Post XIX the decrease in efficiencies is due to excessive sludge pumping. Strong supernatant is returned to primary, grease content of sewage is high and laundry wastes are definitely interfering. At Plant XV there is a high recirculation ratio in both primary and secondary filters with excellent overall reduction. The accuracy of the low per capita flow figures is questioned. At Plant IX the effluent is used for irrigation. Excellent removals of suspended solids are obtained

TABLE V.—*Operating Results*

Single-Stage High Capacity Filters

Post and Designed Capacity	Month 1941–42	Contributory Pop.	Aver. M.G.D. Flow	Recirculation Ratio	Flow—Gal./Cap./Day	Aver. B.O.D.		Aver. Susp. Sol.		Per Cent Reduction	
						Raw	Effl.	Raw	Effl.	B.O.D.	Susp. Sol.
	July	25,692	2.371	1.47	92	250	108	138	46	57	67
VII	Aug.	15,592	1.88	2.96	121	225	70	116	38	70	67
2.1 M.G.D.	Sept.	14,190	1.604	3.78	113	187	54	108	37	70	63
30,000 pop.	Dec.	14,700	1.090	4.88	74	317	107	308	152	66	50
Bio-filter	Jan.	19,970	1.189	4.56	60	400	118	221	84	70	62
Imhoff Primary	Feb.	18,113	1.109	5.16	61	394	111	238	97	72	59
XXII											
4.62 M.G.D.	Jan.	62,410	3.85	2.6	62	360	43	245	42	88	83
65,000 pop.											
Bio-filter											
	June		2.47			251	109	240	59	56	75
	July	24,000	2.85			214	58	192	53	77	77
VIII	Aug.		1.36			256	20	218	12	94	93
2.0 M.G.D.	Sept.		0.53			185	13	159	2	93	99
28,500 pop.	Oct.		1.73			216	47	199	22	75	90
Aero-filter	Nov.		1.97			212	53	207	24	75	88
	Dec.		1.87			197	65	174	58	67	67
	Jan.		1.86	0.55		193	51	173	37	69	64
	Feb.		2.46	0.26		190	48	118	47	84	60
	Aug.	17,120	1.215	2.08	71	185	11	339	5	94	98.5
XIV	Sept.	17,668	1.339	2.13	76	177	18	495	5	90	99
1.4 M.G.D.	Oct.	14,861	1.292	2.00	87	185	12	200	4	94	98
20,000 pop.	Nov.	13,700	1.222	2.15	89	271	9	391	24	97	98
Bio-filter	Dec.	12,500	1.108	2.88	89			346	9		
	Jan.	15,552	1.312		84			339	9		97
	Feb.	21,662	1.58	1.63	73			323	16		95
	July	23,926	2.40		100						
	Aug.	8,367	1.78		212						
III	Sept.	6,400	1.35		211			93	11		89
2.1 M.G.D.	Oct.	25,252	4.6		183	220	51	179	27	77	85
30,000 pop.	Nov.	25,272	3.14		124	242	60	157	29	75	82
Aero-filter	Dec.		3.11			162	39	171	27	76	85
	Jan.	18,500	2.96		160	207	43	131	27	79	79
	Feb.		2.93			207	39	141	35	81	75
	Oct.	10,670	0.977		92	201	75	195	32	63	84
I	Nov.	13,703	1.385		101	210	92	186	30	57	84
1.4 M.G.D.	Dec.	16,312	1.603		98	181	92	200	46	49	77
20,000 pop.	Jan.	12,577	1.492		109	210	105	180	40	52	77
Aero-filter	Feb.	17,620	1.520		86	215	108	212	58	50	73

TABLE VI.—*Operating Results*

Two-Stage High Capacity Filters

Post and Designed Capacity	Month 1941–42	Contributory Pop.	Aver. M.G.D. Flow	Recirculation Ratio		Flow—Gal./Cap./Day	Aver. B.O.D.		Aver. Susp. Sol.		Per Cent Reduction	
				1st Stage	2nd Stage		Raw	Effl.	Raw	Effl.	B.O.D.	Susp. Sol.
XII 2.24 M.G.D. 32,000 pop. Bio-filter	July	29,551					226	40	224	25	81	88
	Aug.	16,070					220	20	226	19	91	91.5
	Sept.						144	7.4	159	25	95	84
	Oct.	28,428	2.18	1.21	1.39	77	193	26	217	24	86	89
	Jan.	27,011	1.96	1.28	1.32	73	223	34	223	31	85	86
	Feb.	30,681	1.65	1.65	1.88	54	261	39	311	37	85	88
XXI 2.0 M.G.D. 28,600 pop. Bio-filter	July		1.09				96	28	120	32	71	74
	Aug.		1.15						71	17		76
	Sept.		0.88						69	15		77
	Nov.	3,631	0.789	2.52	2.52			5	40	3		92
	Dec.		1.41	1.42	1.42		97	14	51	4	86	92
	Jan.		1.44	1.39	1.39		111	17	63	6	89	97
	Feb.	6,360	1.19	1.68	1.68	187	135	16	48	5	89	90
XVI 1.05 M.G.D. 15,000 pop. Bio-filter	Aug.	7,920	0.77	0.96	1.38	97	230	48	147	27	79	86
	Sept.	7,656	0.95	0.83	1.10	124	166	19	208	19	88	91
	Oct.	7,730	0.88	0.89	1.21	114	149	12	228	18	92	92
	Nov.	9,650	0.88	0.77	1.21	91	223	25	236	36	89	85
	Dec.	10,353	0.68	1.01	2.98	65	288	38	322	51	86	84
	Jan.	8,446	0.43	2.58	3.20	51	339	43	410	58	87	86
	Feb.	11,072	0.66	0.76	2.50	60	302	59	414	43	81	85
XIX 1.26 M.G.D. 18,000 pop. Bio-filter	Sept.	17,472	1.44	1.18	1.18	82	264	54	165	34	85	87
	Oct.	17,456	1.38	1.12	1.12	79	240	44	196	26	81	87
	Nov.	18,929	1.35	1.63	1.19	71	292	75	171	37	74	78
	Dec.	19,425	1.36	1.15	0.90	70	312	90	193	52	71	73
	Jan.	17,495	1.46	1.23	1.23	83	326	90	188	44	72	76
	Feb.	19,811	1.49	1.11	1.01	75	275	82	173	51	70	73
XV 2.1 M.G.D. 30,000 pop. Bio-filter	Aug.	26,000	1.82	2.04	3.32	70	380	50	307	15	87	95
	Sept.	25,550	1.27	4.42	4.42	50	292	18	278	21	94	92
	Oct.	22,000	1.11	5.06	5.06	50	330	31	275	16	91	94
	Nov.	26,000	1.17	4.80	4.80	45	314	35	255	10	89	96
	Dec.	20,528	0.70	6.61	7.00	34	236	20	275	17	91	94
	Jan.	23,120	0.781	5.85	5.85	34	240	22	291	29	91	90
	Feb.	27,402	0.81	6.94	6.94	30	286	33	305	42	88	86
IX 0.84 M.G.D. 12,000 pop. Bio-filter	Sept.	6,658	0.631	0.33	0.25	95						
	Oct.	7,503	0.681	0.32	0.24	91						
	Nov.	8,144	0.724	0.16	0.14	83			250	55		78
	Dec.	5,300	0.73	0.70	0.63	138			207	17		92
	Jan.	6,188	0.99	0.55	0.31	160			197	22		88
	Feb.	9,628	0.78	0.71	0.67	81			122	10		92

with low recirculation ratios. No equipment is ready for B.O.D. determinations.

Note.—All types of high capacity filters have shown filter fly breeding. Flooding and chlorination has been practiced extensively as a plant control measure.

Activated Sludge—Table VII.—In Plant V there is a lack of aeration capacity. Plant XXIV has been overloaded consistently on a flow basis,

TABLE VII.—*Operating Results*

Activated Sludge Plants

Post and Designed Capacity	Month 1941–42	Contributory Pop.	Aver. M.G.D. Flow	Flow—Gal. Cap./Day	Aver. B.O.D.		Aver. Susp. Sol.		Per Cent Reduction		Mixed Liquor P.P.M.	Sludge Index	Cu. Ft. Air/Gallon
					Raw	Effl.	Raw	Effl.	B.O.D.	Susp. Sol.			
V 1.96 M.G.D. 28,000 Mechanical	Oct.	24,220	1.58	65	374	15	326	17	93	95	676	426	
	Nov.	21,733	1.42	65	373	42	348	37	39	89	364	1,431	
	Dec.	17,307	1.31	76	351	37	285	39	89	86	260	1,043	
	Jan.	15,971	1.35	85	405	37	261	41	91	84	393	598	
	Feb.	21,208	1.67	79	352	59	257	67	83	74	444	661	
XXIV 4.2 M.G.D. Diffused Air	Nov.		5.48		187	28	269	58	85	78	1,642	430	1.22
	Dec.	41,792	5.33	127	167	11	161	40	93	75	1,155	421	1.26
	Jan.		4.5		145	14	199	16	90	91	1,133	285	1.26
	Feb.	43,000	4.16	97	219	48	204	23	78	88	907	474	1.17
XIII 0.70 M.G.D. Diffused Air	Oct.	13,500	0.86	64	265	51	219	56	81	74	285	337	
	Nov.		0.74		203	46	250	64	77	82	400	1,020	
	Dec.	11,080	0.84	76	227	44	232	80	81	65	666	734	1.6
	Feb.	16,301	0.81	50	313	22	373	47	93	87	1,675	223	2.4
XXV Mech. Aerator	Jan.	1,111	0.095	86	137	20	172	9	85	92	430	1,080	
	Feb.	2,091	0.16	77	150	17	189	34	89	82	516	826	

with some daily flows twice the designed capacity. Local clay has been used successfully to control bulking. During the last month, aeration units were totally out of operation one-third of the time because of plugged diffusers. At Post XIII special attention is called to the increased removal in February when mixed liquor concentration and sludge index were at more normal conditions. Chlorine has been applied to the final clarifier influent with satisfactory results. Plant XXV is a small mechanical aeration plant serving an airfield.

Discussion of Operating Results

Bearing in mind the original instructions to Architect-Engineers and considering the varied problems encountered by operators, the variety and sizes of plants, the large number of different engineers employed on their design, the fact that most of the designs did not permit any factor for growth, and that the plants were loaded largely the first day they were operated, the general outlook for successful sewage treatment at Army posts is good. A reasonable expenditure in a few plants will make them adequate.

It is believed the knowledge gained from plant operation and behavior eventually will be of value to our municipalities. The success of plants in some locations, particularly in the South, has created a new consciousness of the problem of stream pollution facing some cities and has caused one legislature to take steps to compel cities to adopt some method of sewage treatment. This is an important step whose social impact may not be fully felt for some time. At least the Army plants have hastened a desirable objective for municipal and industrial waste treatment.

Operating Costs and Estimates

The Water and Sewer Unit of R. and U. is charged with preparation of budget estimates for all maintenance, repair and plant operation, so it is only fitting that Table VII, while brief, should be included in a paper

Table VIII.—*Unit Costs and Budget Estimates*

	Maintenance *					
	Sewers per Mile		Pumping Plants		Treatment Plants	
			Per M.G.D. Installed Capacity		Per M.G.D. Installed Capacity	
	Normal Maintenance	Alterations and Additions	Normal Maintenance	Alterations and Additions	Normal Maintenance	Alterations and Additions
Average Municipal Cost	$ 75	$ —	$ —	$ —	$1297	$ —
Preliminary Estimate	100	100	300	300	1930	1930
Cost from Survey of 20 Army Posts	148	45	520	475	1450	1730
Final Budget Estimate	100	100	500	500	1600	1600
Total Estimate	$200		$1000		$3200	
Labor	$ 80	$ —	$278	$ —	$ 647	$ —
Material	68	—	242	—	803	—
Total Maintenance	148	45	520	475	1450	1730
Total Units Reported in Survey	1023 mi.		42.47 M.G.D. Cap.		26.58 M.G.D. Cap.	
	Operating Supplies *					
Average from Survey of 20 Posts	—	—	$47.00		$1153	
Budget Estimate	—	—	50.00		1150	

Sewerage Service Contracts

Average Cost Per Capita per Year	$ 0.53
Average Cost at 70 Gal./Cap./Day	12.00 per M.G.
Individual Contract, Maximum	40.00 per M.G.
Individual Contract, Minimum	3.30 per M.G.

Garbage Disposal Service

Average Cost Per Capita Served per Year	$0.30
Cost per Ton at 1.4 Lbs. Per Capita per Day	1.18

* Figures do not include operating labor nor power costs.

of this kind. To arrive at some figures for the first budget, questionnaires were sent to 75 representative cities of sizes comparable to army posts. The response was most gratifying in spite of the different accounting systems encountered. The analysis of costs transmitted provided the only basis we had for estimating budget requirements. The funds provided proved to be adequate.

In February, 1942, 20 posts were selected and requested to report maintenance, repair and operating costs. The analysis is found in the table, and also the estimate for the 1943 fiscal year. Until one is faced with the problem of finding good operating costs with a good breakdown, he will not realize how little data are available. About 50 per cent of one engineer's time is spent on budgetary matters and as greater familiarity with the field problems materializes, better estimates can be made and costs reduced by some extent.

Research Projects

The senior author having been a teacher for part of each year of 19 years, during which he had charge of many research projects, naturally would observe the need for setting up some experimental investigations to help solve current problems. The projects attempted so far have been:

1. Water hammer relief in sewage pumping mains.
2. Adequate grease trap design and selection.
3. Pretreatment of laundry wastes.
4. Partial treatment of supernatant liquors.
5. Sterilization of dishes in Army kitchens and production of adequate hot water.

(1) Figure 14 is a view of a typical sewage lift station with motor and gasoline driven pumps discharging into a header and force main.

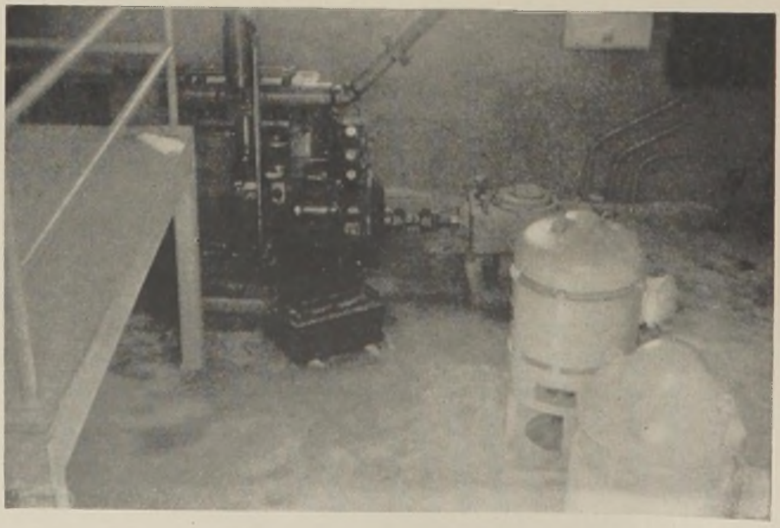

Fig. 14.

Transite pressure pipes had undergone 16 breaks. A cast iron replacement section had fractured. Pressure-time recordings by indicator chart, and analyses showed that large air chambers with air replenished by small motor-driven air compressors should afford necessary relief from water hammer. In one case a saving was made of a planned expenditure of $150,000 for three pump discharge lines by two days of field work and an installation cost of about $400. It merely demonstrated that technology has a denite place in War Department utility work.

(2) It was found by test that grease traps outside the mess halls designed by the Engineering Branch and R. and U. were not satisfactory to either branch, that they were not cleaned properly and were, in general, insanitary. The cast-iron traps in kitchen sinks were very inadequate and flows from kitchen sinks often ejected the collected grease and discharged it as a slug into the sewer. Tests conducted on the standard Army sinks on single and simultaneous discharge disclosed high peak flow rates heretofore unrecognized. No reasonable

Fig. 15.

size of kitchen trap had any possibility of successfully collecting and retaining the grease. One cast-iron clean-out flow control type tee at the end of the drain pipe proved to be the answer, to iron out flow fluctuations and reduce discharge rates and still give reasonable times of discharge. This fitting and the recommended cast iron trap of 25 gallon per minute flow rate—50 pounds of grease retention capacity at 90 per cent efficiency, is the installation now being made at all posts. The University of Iowa Hydraulic Institute provides official test certificates

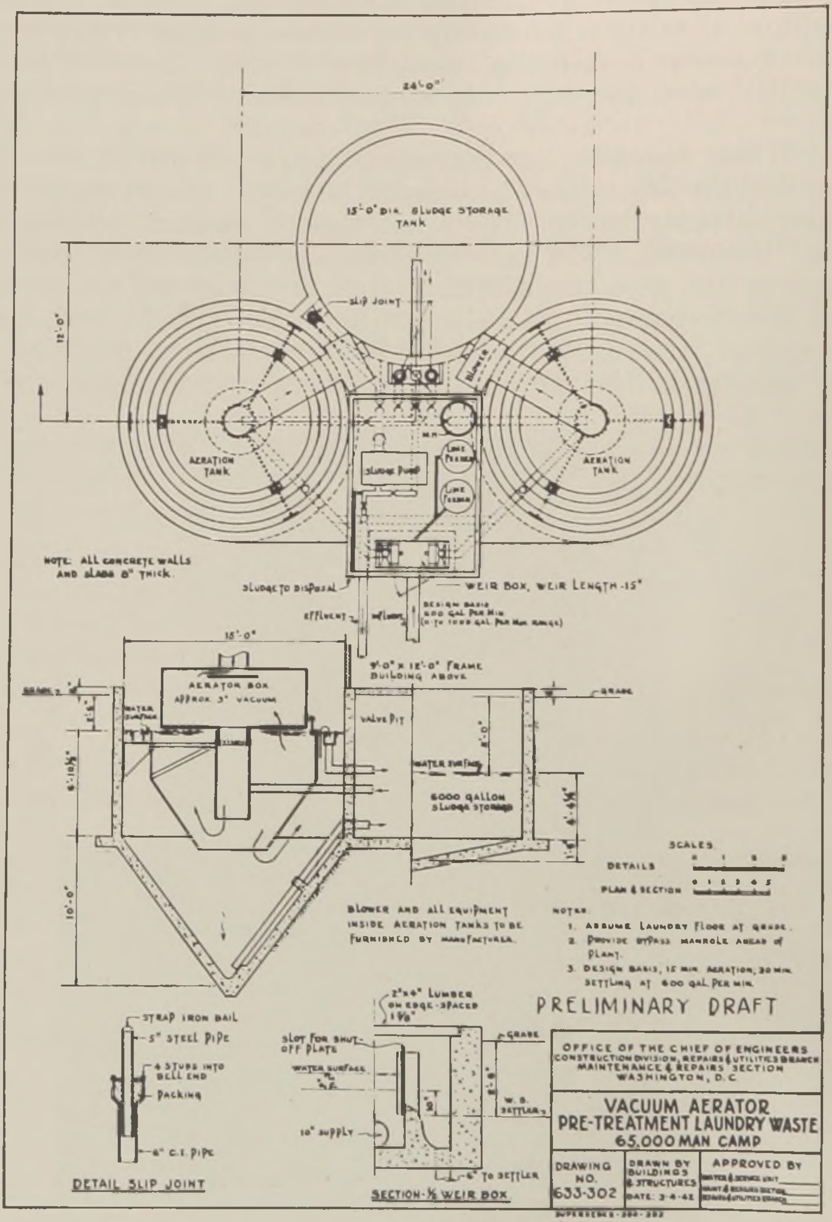

Fig. 16.

on each manufacturer's trap before the O. C. E. purchases any unit. Since April 1, the new traps are ceramic in order to conserve critical materials, but they have hydraulic and sanitary characteristics similar to metallic units.

(3) Figure 15 shows an ordinary septic tank with sour laundry waste scum accumulating on the top and no solids in the bottom. This waste is the only one that can be called industrial in Army Post sewage. There is evidence that at some plants the laundry waste must have pre-

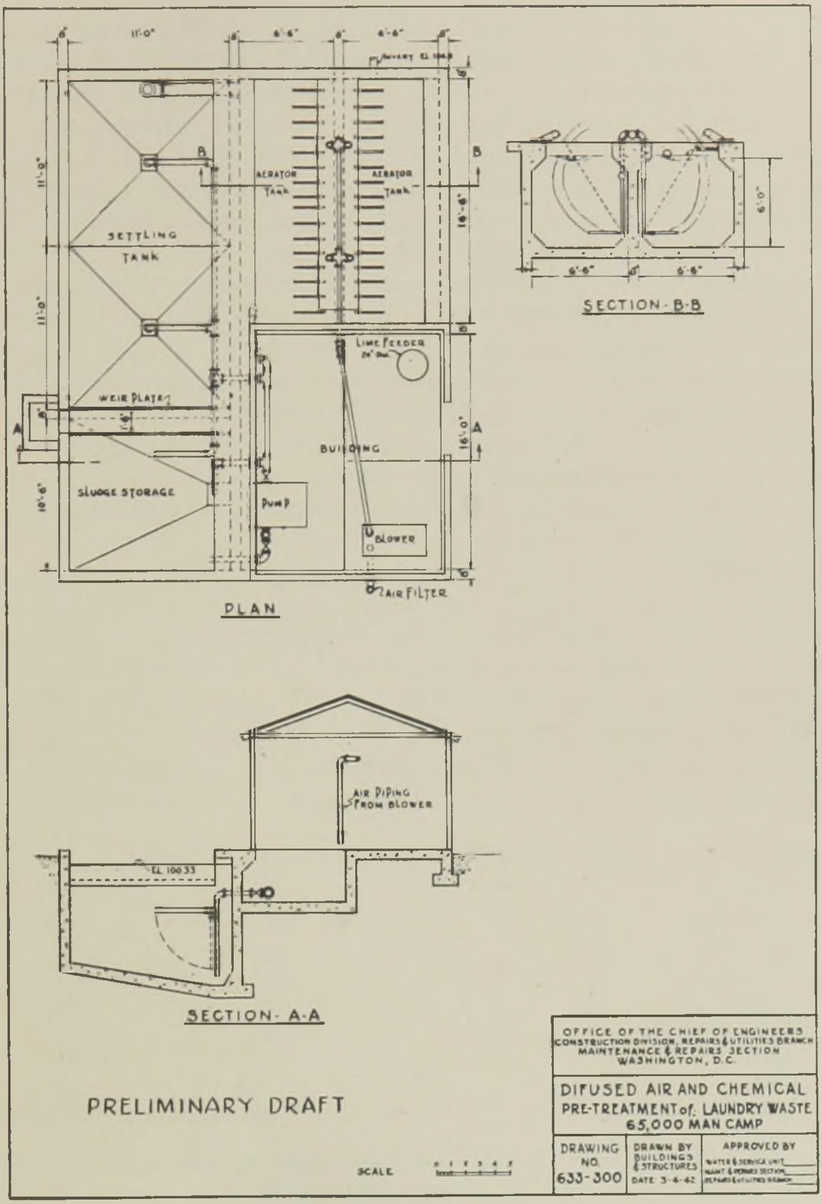

Fig. 17.

treatment of some sort. A five months study on pilot and full scale plants disclosed that 25 grains per gallon of lime and 15 minutes of aeration, followed by 30 minutes of settling, will produce a fairly stable sludge suitable for digestion in the sewage plant tanks or perhaps drying on sand beds. The effluent is reduced about 35 per cent in B.O.D. and a like amount in grease. The treatment in no way affects the low amino acids present in the liquid. The effluent is still turbid but is believed to be suitable for washing of vehicles. One plant will be built soon and given a fair try.

Figures 16 and 17 disclose designs by R. and U. of two different plants, for a 65,000 man camp, based on flow recordings at three posts and the experimental test results. One plant uses a vacuum-type aerator with the waste sucked up through 2-inch tuyeres and thence discharged into a settling compartment. The other plant uses wing-type air diffusers. It is believed all manufacturers' representatives who co-operated in these tests are also agreed that no beneficial results can be obtained without the addition of lime. There are other critical chemicals that will do a better job, and some others produce only a light floc. Pre-treatment of the waste will remove the most troublesome solid material when the waste is the strongest.

Approximate figures on quantities of laundry waste indicate 4.7 to 5.0 gallons per pound of clothes, with the amount of clothing and bedding being washed daily ranging from about 1.2 pounds per capita in summer to 0.6 pound per capita in winter.

Approximate quantities of laundry waste for three camps have been measured as follows:

Camp	Number of Troops	Rate of Flow, Approx. Average g.p.m.	G.P.M.* Peak
A	15,000	130	300
B	14,000	100	320
C	56,000	433	1060

* Laundry operating 2 shifts—8 A.M. to Midnight.

Some characteristics of laundry waste are as follows:

Determination	Parts per Million Average	Maximum
B.O.D. (5-Day)	530	2500
Total Solids	1100	5800
Volatile Solids	750	3800
Grease Content	280	1250
Alkalinity	100	100
pH	8.7	9.25
Temperature Range	90 Deg. F.	130 Deg. F.

It should be recalled that the laundry waste problem did not present itself during World War I at Army cantonments.

(4) Partial treatment of supernatant digester liquor by vacuum aeration at 20 gallons per minute flow appears to be a definite success at one large post, according to reports from the engineers of the Atlanta District office. The unit can be purchased for about $2,000 and R. and U. proposes to allot funds to give this plant a trial. Success will mean

a large increase in sludge digestion capacity, the sludge beds will be more adequate and the B.O.D. of the primary effluent will be less. To date, tests show the lower the per cent solids in the supernatant, the less the degree of treatment.

(5) While sterilization of dishes may not appear to be a sewage treatment task, tests so far show that with improved hot water heating and dishwashing facilities in kitchens, installation of about $250 worth of equipment may pay for itself in one year in the saving of hot water alone. This saving results by wasting less coal, heating and pumping less water, chlorinating less water and treating less waste at the sewage plant. No one dreamed that this research study during the past eight weeks would reveal such an important fact and at the same time provide a method for meeting Army Regulations in the sterilization of dishes and reducing the incidence of respiratory disease and trench mouth. The problem really came about because the R. and U. Branch is charged with seeing that the proper authorities provide all chlorine. Calcium hypochlorite became so critical that the situation precluded its use in sterilizing the rinse water. Ozonation is also being tried. The answer so far appears to be adequate hot water with 180 degree F. rinse.

Many interesting water supply, pumping and treatment problems, as well as garbage and incineration problems, come to the office almost daily. The solution of most of the problems seems to fall back to proper operating personnel—to those men who are most loyal and take the keenest interest in their daily tasks and always try to do the job that particular day the best they can and not worry about what is going to happen 30 or 60 days hence. We want them to take their jobs seriously but not themselves too seriously. It is believed continual improvement in the utilities is being observed and we have utmost confidence that when the final chapter is written on this war effort, we will be proud to have had a small part in its guidance.

VARIED PROBLEMS IN DESIGN AND CONSTRUCTION OF SEWERS AT LOCKPORT, N. Y.*

By Walter R. Drury

Shoecraft, Drury and McNamee, Consulting Engineers, Ann Arbor, Michigan

In carrying out a major sewerage and sewage disposal construction program in the City of Lockport many unusual problems were encountered.

This paper describes some of the more important and unusual problems which were met and solved and the text rambles a good deal from problems of sewerage and drainage through a discussion of intercepting sewer design and construction, sewer materials, sewer appurtenances and principles of design for sewage treatment. Several exhibits have been prepared which will be referred to throughout the paper.

When the engineers were asked by the city to make a study of the city's sewerage there was found an industrial city of some 24,000 population situated for the most part on the upper level of the Niagara escarpment, but with some development at the foot of the escarpment and practically the whole city area underlain with rock which in some localities lies at the surface. While the city has a large and varied assortment of industrial development, there are several very large and important industries upon which the city largely depends for its industrial activity and general economy. These large industries comprise the Harrison Radiator Division of General Motors Corporation, manufacturing radiators for General Motors cars and also equipment for refrigeration; the Flint Kote Company, manufacturing fiber board, roofing and similar materials; the United Paper Company, manufacturing paper; Simonds Steel Company, manufacturing high-grade steel; the Upson Fiber Products Company, manufacturing fiber board and the Lockport Cotton Batting Company which processes cotton and produces a high-grade cotton batting.

Like many cities, Lockport had outgrown its existing sewer system and was badly in need of relief sewers and storm sewers to carry off storm water runoff and in addition needed certain trunk sewers to serve districts which were growing and demanding sewer services but which could not be supplied by the present sewer system or extensions thereto. Flooding of basements was the rule after heavy rain and it was not an uncommon sight to see manhole covers lifted off due to the surcharge of water which filled the sewer at times of heavy runoff.

The city's sewage disposal problem was one toward which nothing had ever been done in the way of solution. The existing sewers had been built with outlets into Eighteen-Mile Creek, a small stream with a drainage area of about only 15,000 acres above the city, and with other

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outlets into the State Barge Canal, which bisects the city running northeast and southwest through the heart of the business district. With sewage treatment plants under way or completed in Buffalo and Niagara Falls and with plants contemplated at Tonawanda and North Tonawanda, this left Lockport as the only city of importance in Niagara County without sewage disposal facilities. The State Health Department had urged Lockport to provide sewage disposal and city officials realizing the necessity were ready to plan and carry out a sewage disposal program.

By far the greatest need of the city and the thing which was of most interest and upon completion would be of most benefit to the residents of Lockport was the construction of relief sewers for handling storm water. Before these sewers could be intelligently planned, however, it was necessary to make a complete survey of existing sewers and a general sewerage plan for the entire city.

General Sewerage Plan

The purpose of a general sewerage plan as was made at Lockport is to obtain by actual field surveys a complete inventory and evaluation of the existing sewers and with this information available, to design new sewers where necessary, to the end that full use can be made of existing sewers and new ones can be built to supplement them where necessary. This inventory of existing sewers and general plans for the new ones was made and recorded on suitable maps and plans with the information in such form that it can be used year after year in any sewer building program. In this way nothing of value in the existing sewer system is thrown away and whenever sewers are built they can be built with the assurance that they will fit into the ultimate picture and make a complete and satisfactory sewer system for the city.

In order to carry out such a program, a W.P.A. crew was organized to work under the direction of two competent engineers employed by the city. This crew went into the field and located every sewer manhole, inspected the sewers coming into the manhole and obtained their size and elevation. This information was brought into the office where another engineering staff, furnished by the city's consulting engineers, which likewise was assisted by some N.Y.A. help, plotted it and recorded it on suitable maps and drawings and then followed with detailed computations of sewage flow and storm water runoff which were used in laying out and designing new sewers where they were needed.

The finished general plan comprises an atlas of drawings which shows the entire system of present and proposed sewers on small scale maps, together with larger scale maps showing the topography of the city, the size, location and elevation of existing sewers and the size, location and grade of all proposed new sewers. This sort of a plan is one which is placed on file in the city engineer's office and can be used for many years in the layout of and design of new sewers that may be petitioned for or otherwise required.

Intercepting Sewers

One of the important problems encountered in the sewage collection and disposal program had to do with the layout of the necessary intercepting sewers to collect the sewage from the several outlets and carry it to a sewage treatment plant site. Figure 1 is a general map of the city. There were ten existing sewers which discharged directly into the canal. Seven of these came into the canal on the southeast side and three others from the northwest side. In addition to these there were some fifteen outlets directly into Eighteen Mile Creek. With such a layout of outlets it would normally be necessary in a city to provide an intercepting sewer on either side of the canal and on either side of Eighteen Mile Creek, all coming together at some common point, then leading to a sewage treatment plant. In this particular case, however, the construction of two lines of intercepting sewers in any available streets would have resulted in tearing up streets through thickly congested areas and in addition the problem of crossing the deep channel of the canal would have meant some special type of inverted siphon or pumping station.

With the city located on the escarpment, it was found in the study that there were some 200 ft. difference in elevation between the most of the city area and the ground to the north of the city on which the sewage treatment plant could be built. This meant that with sewers of normal depth a good many feet of head would be thrown away or lost. Another fact which was soon developed was that there existed a large residential area in the southeast part of town which lies in another natural drainage area to the south which had no sewer service. Service could be provided for either by building a deep sewer outlet to the north through town or building a number of sewers all leading to a pumping station and pumping the sewage into some existing city sewer.

After careful consideration of all of these problems and the existing conditions at Lockport, it was decided to build intercepting sewers largely in tunnel at such an elevation that they could cross underneath the barge canal without the necessity of using any inverted siphon or special construction to get past this barrier and they could be extended to serve all city areas by gravity flow. This resulted in the design of these sewers, to be built at depths of 75 or 80 ft. below the surface, but still high enough so that they could be carried to the sewage treatment plant site and through the plant by gravity flow without the necessity of pumping sewage.

Tunnel Sewer Design

The size of these tunnel sewers was determined not on the basis of the required capacity to carry the sewage flow but rather on the basis of the minimum size of tunnel that could be built by modern tunnel methods. The main intercepting sewer below the tunnel work, a sewer built in open cut, to carry the entire flow of sewage from most of the city on the grades available, varies in size from 24 to 48 inches. In

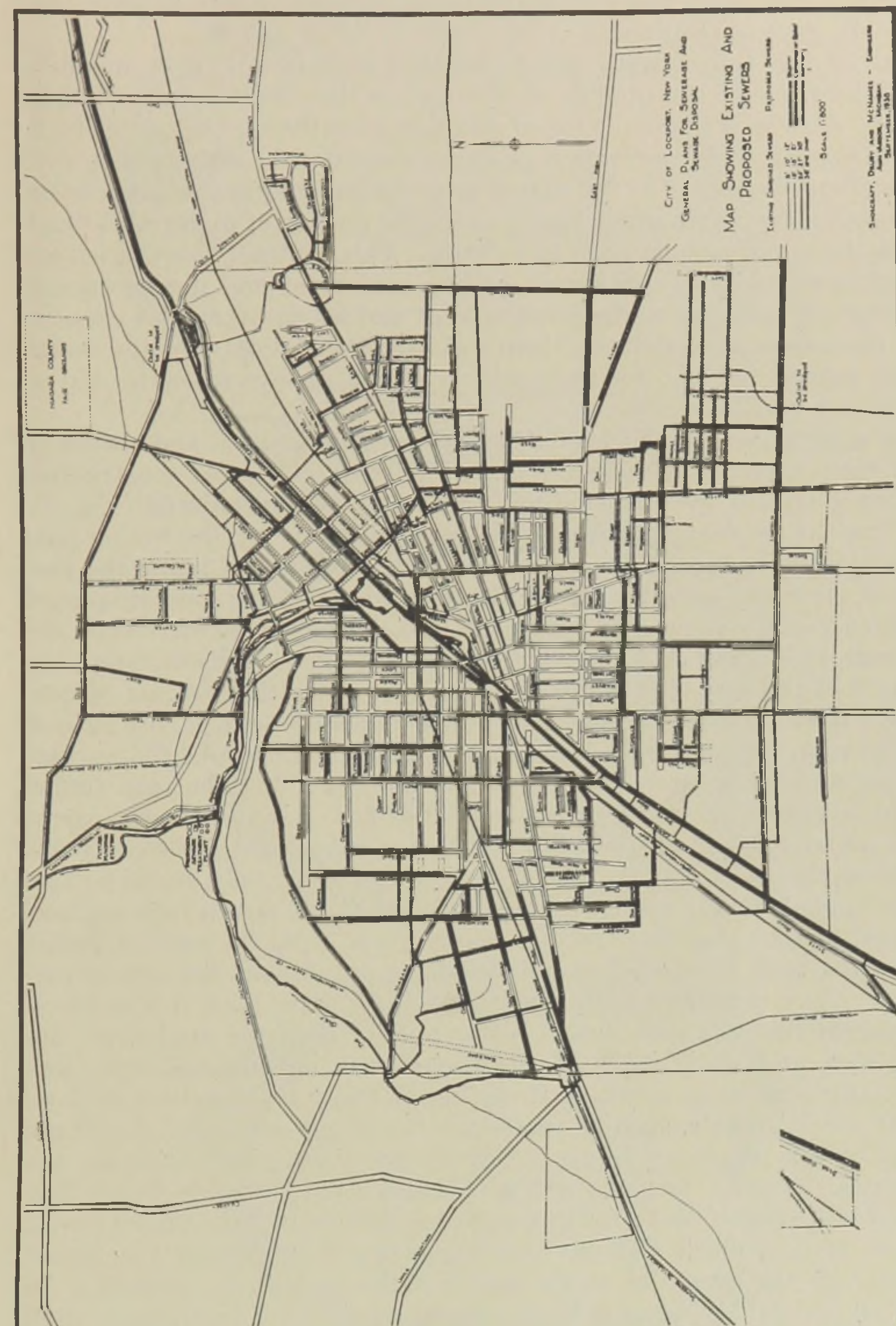

City of Lockport, New York
General Plans for Sewerage and Sewage Disposal
Map Showing Existing and Proposed Sewers

Fig. 1.

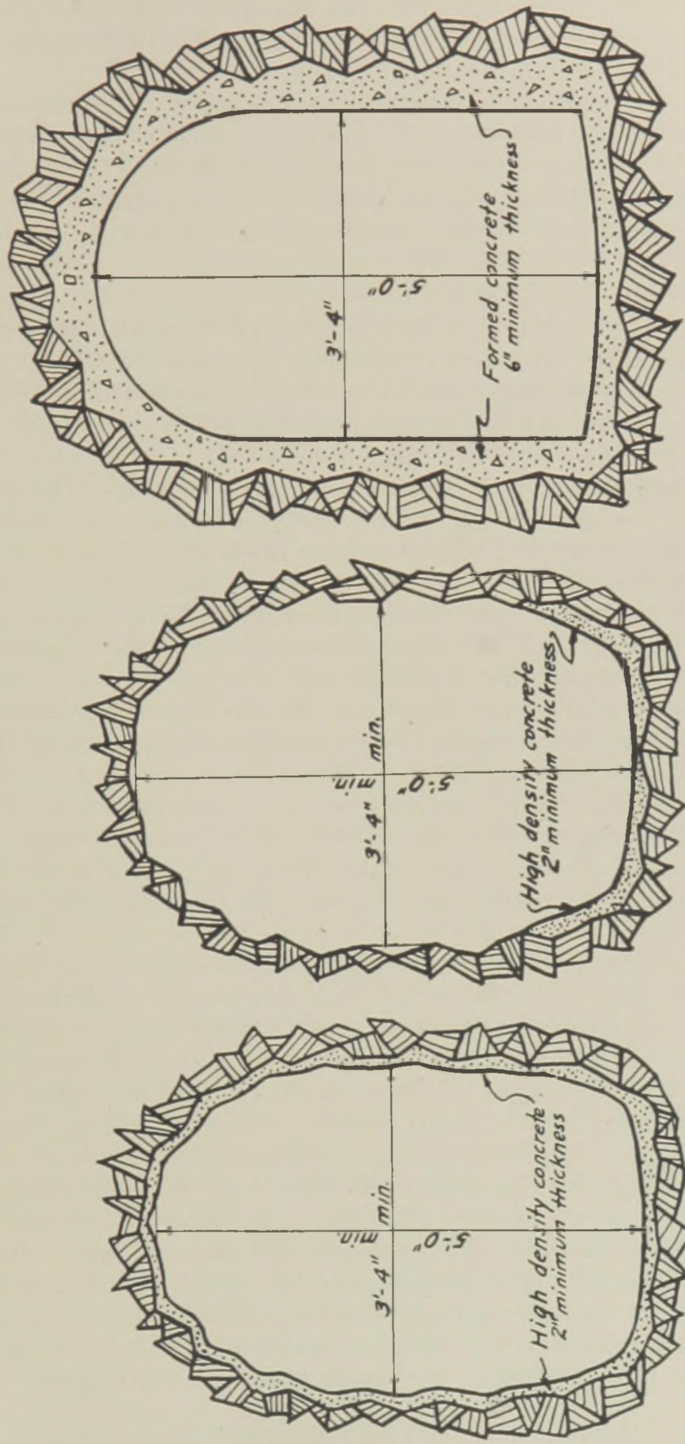
tunnel construction, however, sizes of this kind are too small to permit modern construction methods and a tunnel some 4 or 5 ft. in width and 6 to 7 ft. high is required.

All of this tunnel work was to be built in limestone rock and little was known about the quality of the rock at the depth at which these sewers were to be built. One of the early contracts, therefore, to be undertaken in the construction program consisted in making core drill holes along the routes of the tunnel intercepting sewers to depths below the sewer elevation in order to determine the quality of material through which the tunnels would have to be built. This contract was carried out expeditiously by an experienced drilling contractor and the samples of the rock encountered were carefully kept and set up in exhibit cases so that the information given by them was available not only for the design of the tunnels but also for the guidance of contractors who later bid on the tunnel construction work.

Several types of tunnel construction were worked out and shown on construction plans, it being the aim to provide a type of construction for every kind of rock or condition that might be encountered (Fig. 2). The type of construction which was decided upon for the major part of the job before construction work started consisted of lining the surface of the rock tunnel with a thin layer of high density concrete placed by the use of a cement gun. This was the cheapest type offered by the contractors bidding on the work and seemed to be entirely satisfactory, in spite of the fact that the interior surface under this method of construction would be left somewhat rougher than would be the case if poured concrete and forms were used. This roughness of the surface was of no consequence, however, in view of the fact that the tunnel would be greatly oversize for the amount of flow it would have to carry.

Another type of construction which was considered for some parts of the work consisted in the use of the concrete lining only on the bottom of the tunnel leaving the upper part unlined with a rough rock surface. It was thought that this type of construction could be used at points where the rock was solid enough to stand up without the use of any lining. As a matter of fact, when the tunnels were built it was found in general that the rock was a better quality than the engineers contemplated and much more of the tunnel was left unlined than was originally estimated, resulting in saving of many thousands of dollars.

At special points, such as where the tunnel passed under the Barge Canal, it was necessary to use a full concrete lining built with the use of forms, in order to make a tunnel which would exclude water that tended to leak from the canal through rock fissures into the tunnel below. At two points, much difficulty was encountered in driving the tunnel underneath the canal due to the fact that the rock above seemed to be fissured and full of water. It was necessary in these locations to drill holes diagonally off from the side of the tunnel and force in concrete grout mixed with bran or cornmeal, which served to fill and seal up the fissures in the rock and shut off the water to such an extent that the concrete lining could safely be placed. Even after the tunnel was



Unlined rock tunnel.

Lined rock tunnel, pneumatically placed concrete.

Lined rock tunnel, form placed concrete.

Fig. 2.

finished these two places showed a considerable amount of leakage but this leakage soon disappeared, due no doubt to the silting up of the rock fissures above with silt from the canal.

These tunnels were built at a contract construction cost of $24.90 per lineal foot for the completely lined tunnel and $21.80 per lineal foot for the tunnel lined only on the bottom. A saving of $3.10 per foot was effected therefore by omitting the complete lining wherever the work proved to be sound and stable against spalling and disintegration.

Tunnel Construction Methods

In building the tunnels the contractor worked on a 24-hour per day schedule, using three shifts of men. The procedure was first to sink a shaft on the line of the tunnel then start tunnel headings in both directions from this shaft. Each shift would drill a heading, load the holes, and shoot them and after the smoke was cleared away by the ventilating system provided, muck out the broken rock. This process was repeated; it was possible for one shift to complete the mining of some 6 to 10 ft. of length of tunnel in each heading.

Concrete lining was not placed in the tunnel until after the mining operation was complete. The lining was applied by the use of cement guns, with drill holes from the surface through which the concrete hose could be placed with the gun equipment on the surface of the ground. It was necessary to dam off the water which seeped into the tunnel where the lining operation was in progress. The result was a hard lining across the bottom of the tunnel for its entire length and at the sides and roof of the tunnel at points where loose rock was encountered which required concrete lining to keep it in place. The formed concrete lining was placed over movable wooden forms which were set up in the tunnel. This was used at only a few points where the tunnel passed under or closely adjacent to the canal.

This method of construction saved a great deal of money for the city and it was expected that in the unlined portion of the tunnel there might be some spalling and disintegration of the rock from the surface of the tunnel which might cause difficulty by dropping down and obstructing the flow of sewage through the finished tunnel sewer. After the tunnel was completed and put in service, however, a careful check was made from time to time to see how much, if any, rock spalled off in this way. The results were most gratifying. After a year's use it was found that the amount of rock which thus fell from the walls of the tunnel was negligible and could be removed at small cost. It is expected that this spalling of rock will grow less and less and even though it should continue, the city can well afford to clean it out once a year for many years at a much smaller cost than would have been entailed had a concrete lining been placed for the entire length of the tunnel.

Corrugated Metal Pipe for Sewers

One of the unusual problems of intercepting sewer design was the design of an intercepting sewer down the valley of Eighteen Mile Creek where it came off the escarpment from the higher level of town to the lower level. This creek valley is steep and precipitous, very rough and rugged with rock outcropping nearly its whole length and with many abandoned foundations, dams and other structures which made the location of a sewer most difficult. In fact it seemed almost impossible to find a route where a sewer could be built at a reasonable cost and in such a position that its integrity could be assured over the years to come. Another valley in the west end of the city called the Gulf presented a similar problem, this being a very deep narrow gorge with rock outcropping in the bottom and the sides. A sewer was necessary in this so-called Gulf in order to serve the west end of the city and particularly to provide an outlet for a large new plant for the Harrison Radiator Company. Likewise, the main intercepting sewer in some way had to be built down the Eighteen Mile Creek Valley.

Much thought was given to the selection of a suitable type of material and a suitable method of construction for sewers to be built in these locations. Consideration was given to the use of vitrified sewer pipe, concrete sewer pipe, cast iron pipe, and various kinds of steel pipe. The material finally selected was asbestos bonded corrugated metal pipe. This pipe was made by a company specializing in the construction of the common corrugated metal culvert pipe and is made of pure "Armco" iron galvanized, then coated inside and out with a layer of asbestos paper bonded with the galvanizing and the whole then covered with a heavy coat of asphaltic varnish. In addition to this the bottom portion of the inside of the pipe is filled with asphalt so that a smooth flow surface is presented to the sewage carried by the pipe. This pipe came in 20-ft lengths and was joined together by special bolted sleeves so as to form a watertight sewer.

The usefulness of this type of material over the usual construction materials for sewers such as vitrified clay or concrete is that it is very easy to lay in difficult, congested locations and being a resilient and inherently strong material it does not have to be covered and protected with earth, as would more brittle materials, to guard against breakage after it is in place. Its cost was considerably less than cast iron pipe or ordinary steel pipe. As finally built this corrugated metal pipe sewer in Eighteen Mile Creek Valley at some points is under considerable fill and at others is completely exposed on trestles for some distance. The sewer in the Gulf, likewise was carried in a very shallow trench, in some cases with only a very small amount of earth cover. By building a sewer at a shallower depth above the rock surface a good deal of money was saved in construction costs and yet the sewer is amply deep to serve all tributary area.

Where these two sewers come down the valleys and approach the area in which the sewage treatment plant is located, they were built as pressure sewers in order that they might be kept under cover of the ground and still make it possible to have all of the sewage from the city carried into and through the sewage treatment plant, without the necessity of pumping. These two sewers join a larger sewer near the sewage treatment plant and carry the sewage to the plant under a head of approximately 10 feet.

For these pressure sewers rather rigid specifications were drawn for a pressure test to determine their watertightness under pressure. These specifications called for a minimum test pressure of 11 lb. per sq. in., under which leakage should not exceed 0.10 gallon per joint per hour for 15-inch and 0.20 gallon per joint per hour for 24-inch. pipe. When the first line was put under test, some difficulty was encountered in getting satisfactory water-tightness due principally to the fact that the joint sleeves which joined one pipe with another were too light to withstand the test pressure that was required. In addition to this, some of the pipe in fabrication proved to be rather lightly riveted and some leaks developed, which made it necessary to replace a considerable length of pipe with new, better fabricated material. With the full co-operation of the contractor and the pipe manufacturer, these pressure lines were finally installed and tested satisfactorily and have given good service since they have been in operation.

Exposed House Connections

Along through the business section of town the stores and business buildings on one side of the street are built at the top of a steep rocky bluff. The easiest way to dispose of the sewage from these building has been to run house connections out of the back side of the building at the edge of this bluff and let the sewage drop into a headrace which existed at the foot of the bluff. How to pick up the sewage from these buildings was a problem. Construction of a sewer in the main business street in front of these buildings would have been very costly due to the very deep rock construction that would be required, also it would be necessary for every building to have the plumbing changed so as to bring the sewage out of the front side of the building instead of out of the back side.

It was understood that this headrace, which serves a small power develoment, was of little value and might eventually be abandoned. The city thereupon negotiated with the power company owning this headrace and as a result finally acquired it so that it could be used as a route for an intercepting sewer. In this way a sewer was provided at the back of these downtown buildings, and at an elevation below the elevation of their basements. The only problem remaining after this sewer was built was the connection of the various building sewer outlets with the new intercepting sewer. Some of these outlets were 40 and 50 ft. above the intercepting sewer and a very steep rock cliff intervened between the outlets and the sewer. The method finally developed for making these connections consisted in using the same asbestos bonded and coated corrugated metal pipe as was used on the intercepting sewers. Such a pipe was connected to each building sewer, then carried down into the intercepting sewer in the headrace, which was laid with a small amount of earth cover. This method of making sewer connections can scarcely be called an orthodox method but was about the only method that could be devised for such an unusual condition as this.

The only difficulty that has thus far been experienced with this type of sewer connection is the tendency to freeze in extremely cold weather. This is probably caused by leaky plumbing which allows a small amount of water to drip down continuously and freeze against the side of the pipe on the way down, gradually filling the pipe with ice. Residents were notified of this danger by the city and the suggestion was made that all plumbing be checked and kept tight, particularly during winter months.

Sewage Diversion and Overflow Chambers

In order to pick up the dry-weather flow of sewage from the city's combined sewer system it was necessary to design and build a great many diversion chambers. These structures are scattered throughout the city and are located in general at the point of outlet of each sewer system so that all the dry-weather flow can be diverted while the storm water flow can go out of the outlet into the canal or Eighteen Mile Creek.

A very simple design of diversion chamber was used which consisted essentially of a concrete structure housing a low diversion and overflow dam which diverts the dry weather flow of sewage into the intercepting sewer. For these chambers, several orifice plates were furnished of different sizes to meet actual variations in sewage flow which occur. The purpose of the orifice is to restrict the amount of storm water flow that goes into the intercepting sewer, limiting the total to the amount of dry flow plus a considerable amount of storm water. This restriction is sufficient during storm flows to cause backing up of the combined sewer to the extent that excess flows pass over the diversion dam into the storm water outlet. This type of diversion chamber avoids any mechanical devices with movable parts which are so often used in larger cities and for larger flows.

The dry-weather flow after passing through the orifice is carried down a drill hole through the rock into the tunnel intercepting sewer. These drill holes are 12, 16 or 18-inch, depending on the amount of sewage to be carried, and are cased at the top where necessary with steel casing. At the bottom each drill hole terminates in a small chamber at the side of the tunnel intercepting sewer which acts as a tumble bay or receiving chamber and avoids the dropping of sewage directly into the tunnel. Where a diversion chamber occurs near a tunnel shaft the sewage is carried down a cast iron pipe placed in the shaft.

In addition to the provision for spilling storm water at the diversion chamber, an overflow chamber was also provided at a point in the main intercepting sewer just below the end of the tunnel construction. The purpose of this overflow chamber was to provide a sort of safety valve so that the relatively large amount of flow which might come down the tunnel intercepting sewers at times of storm could be spilled out before it entered the Eighteen Mile Creek intercepting sewer, which was much smaller than the tunnel intercepting sewers. In addition to this overflow two overflow chambers were provided, one in the Eighteen Mile Creek intercepting sewer and one in the Gulf sewer at the upper end of each section of pressure sewer. In this way excess flows that may at times come into the intercepting sewer system are provided for, without making it necessary to carry all of these large flows to the sewage treatment plant.

Construction Problems

A construction program as large as this one for a city the size of Lockport becomes a major operation and many interesting experiences have been recorded during the construction program. The fact that practically all of the sewers had to be built in rock made it necessary to use explosives in all excavation and residents of the city soon became accustomed to being shaken up by explosions both day and night. While there were some objections to this work at first, people soon became accustomed to the program and the public sentiment on the whole was very good. Some accidents occurred, such as some broken windows and possible damage to parked automobiles along the street but all construction contractors were under bond and required to carry insurance, which gave the public full protection in such cases.

During the construction of one of the large relief sewers the contractor had proceeded to a point about opposite one of the city's hotels with a rock trench some 20 ft. deep and 8 to 10 ft. wide. The type of equipment used was such that this trench extended up the street and ended with no equipment or machinery at the end to block off the trench from the street. It was necessary, therefore, to carefully barricade the end of the trench. One afternoon, upon completion of the day's work, the contractor had erected the barricade and placed the necessary lights for protection during the coming night. During the night or the small hours of the morning a couple of men driving an old touring car came down the street and being either sleepy or under the influence of too much liquid refreshment, failed to see the barricade, broke through it and dropped right side up into the trench. Neither was seriously hurt and the car, somewhat the worse for its experience, was lifted out of the trench the next morning by use of the contractor's crane. One of the local papers showed a photograph of this car in the trench with the caption "Method of Backfilling Sewer Trenches in Lockport."

Degree of Sewage Treatment Required

The natural outlet for treated sewage for the city of Lockport is Eighteen Mile Creek, which flows northerly from the city into Lake Ontario. For a city the size of Lockport, with an outlet consisting of a creek with only about 15,000 acres of drainage area above the city, a complete treatment plant would normally be required. This problem of sewage treatment was solved, however, by providing for diversion of water from the State Barge Canal into the Creek, and installing a primary treatment plant with chlorination.

Ever since 1825, with the development of the New York State Canal system, it has been the practice to divert the water from the Niagara River into the Barge Canal. This water has been used for operation of the Canal, and for certain power development at various points. Much of this water finally arrives at Lake Ontario through diversion at Lockport into Eighteen Mile Creek. In addition to the water which is devoted primarily to the Canal, an amount of 275 cu. ft. per second was authorized by the Federal Power Commission to be diverted and discharged down the valley of Eighteen Mile Creek solely for the purpose of developing power. At the present time, however, the former power plants along Eighteen Mile Creek and immediately below the Barge Canal within the city of Lockport have been abandoned and the only use now put to the water of the creek is for industrial purposes in some of the city's industrial plants.

The diversion of this water, however, has been continued to a certain extent since these power plants have been abandoned and this diversion of water it was realized would have a very decided effect upon the type of sewage disposal works. It was estimated that, with a diversion on the average of 100 cu. ft. per second for the year with an average rate of diversion up to about 125 c.f.s. in the summer time, primary treatment of the city's sewage followed by chlorination would give adequate protection to Eighteen Mile Creek and the riparian owners below Lockport. The following computation of diversion requirements for sewage disposal were made on the basis of reasonable assumptions as to the amount and character of sewage from the city.

The water to be diverted from the canal must serve two purposes: first and chiefly, it must furnish a supply of oxygen and a means of oxidation for the readily oxidizable organic matter remaining in the sewage when it reaches the creek; and second, it must prevent the formation of secondary deposits of sewage materials in the bed of the stream, by increasing the rate of flow sufficiently to maintain a self-cleansing velocity.

For accomplishment of the first purpose, it was assumed that the water diverted from the canal, after passing down the steep, rocky course of Eighteen Mile Creek, would be practically saturated with dissolved oxygen when it reached the site of the sewage treatment plant. The amount of oxygen thus carried should range from about 9 p.p.m. in summer to about 13 p.p.m. in winter. It appears reasonable to figure that an amount ranging from 5 parts per million in summer to 9 parts per million in winter, equivalent to 42 pounds and 75 pounds per million gallons, respectively, could be used to balance the 5-day B.O.D. of the effluent sewage.

For the purposes of the calculations it was assumed that the oxygen requirements of Lockport's sewage would be at least the average year-round rate of .18 pound per day per capita of contributing population, including in the population count the "equivalent population" represented by industrial wastes. This figure was estimated as the composite 5-day B.O.D. of the raw sewage as it will reach the sewage treatment plant and was based on analyses of sewage from Lockport and many other comparable cities. Wide observation of sewage treatment plants indicates that seasonal variations in the B.O.D. of the sewage are usually negligible except such as may be caused by seasonal fluctuations in the operation of important industries, but that the normal hourly variations throughout the day must be taken into account. Ordinarily at least 60 per cent of this daily oxygen demand, or .108 pound per capita, will reach the plant during eight hours of the day, and the other 40 per cent, or .072 pound per capita, will arrive during the remaining sixteen hours.

In the summer months, the sedimentation and chlorination of the sewage during the 8-hour period of strong sewage will reduce this .108 pound per capita by fully 40 per cent, leaving .065 pound per capita of oxygen demand to be taken care of by the diluting water. During the remaining 16 hours, of weaker sewage, the removal of about one-third may be assumed, leaving .048 pound per capita to be taken care of by the diluting water. In the winter months, the purification process, assumed for design to be without the aid of chlorination, will reduce the oxygen demand of the strong daytime sewage by about one-third and that of the weaker night-time sewage by about 30 per cent.

The present population of Lockport is about 24,000, but inasmuch as a reasonable allowance should be made for future growth of the city in both population and industry, the following calculations were based on a total contributing population of 30,000, including the "population equivalent" of industrial waste.

Summer Requirements

8-hour Period

30,000 × .065 = 1,950 lb. oxygen demand in 8 hrs.
1,950 ÷ 42 = 46.5 m.g. of diluting water required in 8 hrs.
= a rate of 215 c.f.s. for the 8-hr. period.

16-hour Period

30,000 × .048 = 1,440 lb. oxygen demand in 16 hrs.
1,440 ÷ 42 = 34.3 m.g. of diluting water required in 16 hrs.
= an average rate of 79 c.f.s. for the 16-hr. period.

Entire 24 Hours

46.5 + 34.3 = 80.8 m.g. of diluting water required in 24 hrs.
= an average rate of 124 c.f.s. for the entire day.

Winter Requirements

8-hour Period

30,000 × .072 = 2,160 lb. oxygen requirement in 8 hrs.
2,160 ÷ 75 = 28.8 m.g. of diluting water required in 8 hrs.
= a rate of 133 c.f.s. for the 8-hr. period.

16-hour Period

30,000 × .051 = 1,530 lb. oxygen requirement in 16 hrs.
1,530 ÷ 75 = 20.4 m.g. of diluting water required in 16 hrs.
= an average rate of 47 c.f.s. for the 16-hr. period.

Entire 24 Hours

28.8 + 20.4 = 49.2 m.g. of diluting water required in 24 hrs.
= and average rate of 75 c.f.s. for the entire day.

Total Dilution Requirements for a Year

The requirements as above calculated make up a yearly total about as follows:

6 winter months, at av. rate of 75 c.f.s.	450
6 summer months, at av. rate of 125 c.f.s.	750
1,200 ÷ 12 = 100 c.f.s. av. for the year	1,200

For the accomplishment of the second purpose, the prevention of the formation of secondary deposits of sewage material in the bed of the stream, it appeared desirable to maintain a combined flow of dilution water and natural creek water of at least 75 c.f.s. from the head of the upper Newfane Pool down to Lake Ontario. Since the east branch of Eighteen Mile Creek and some other watercourses are tributary to Eighteen Mile Creek above this pool, the amount of flow in the creek will be greater than the normal flow of the creek at Lockport, together with the water diverted from the canal. It would appear that the amount of water required for supplying dissolved oxygen would be sufficient to maintain self-cleansing velocity in the stream and serve the second of the purposes herein discussed.

On the basis of these computations arrangements were made with the State Department of Public Works for diversion of water in sufficient quantity from the barge canal, and a diversion weir with a recording gage was installed in order to obtain a continuous record. The sewage plant was designed and built as a primary treatment plant, with chlorination, and the diversion of water became a part of the sewage disposal system. While the State makes a nominal charge to the city for the water diverted, the city saves a good deal in first cost of plant which would have been required without this diversion and also saves in the cost of operation.

Sewage Treatment Plant

The sewage treatment plant provides for grit removal, screening, primary settling and chlorination with separate sludge digestion, sludge filtration and also sludge drying on open beds. The plant is designed for a nominal average flow of 8 m.g.d., an unusually large flow for a city the size of Lockport. Water consumption of the city is high, however, and there is a considerable amount of infiltration into the old city sewers. Large amounts of industrial wastes bring the total flow up to 5 to 6 m.g.d. Sewage is very weak and has shown the effects of the industrial waste in the large quantities of oil that came down until this material was recovered by the industry at its source.

While the plant is of more or less standard modern design there are certain features that warrant further comment.

Two 100-ft. diameter, radial-flow primary settling tanks provide a total volume of 3 hours flow at average design capacity of 4 m.g.d. each.

Two sludge digestion tanks, each 55 ft. diameter and 21 ft. deep, provide a volume of 100,000 cubic feet. They are built half in the ground and half above ground with brick veneer walls above ground. Between the brick veneer and the concrete tank wall 2 in. of mineral wool insulation are provided. Above the roof of the tank a cinder fill covered with a 2-in. concrete surface gives insulating value.

Since the sewage flows by gravity to and through the plant, no sewage pumps are provided and the only provision for the use of digestion tank gas is for heating tanks and buildings.

Provision is made for chlorination of both the raw and the settled sewage using solution-feed machines and 2000 lb. chlorine drums handled by means of an overhead trolley and hoist.

A fully equipped office and laboratory provide facilities for proper analytical work and plant control.

The construction program in Lockport, completed in 1940, as a P.W.A. project, provides relief sewers for practically all parts of the city and a complete sewage collection and disposal system. The cost of the project was $1,270,000 in round figures. With the many unusual problems of design and construction presented, the program made an interesting experience for the engineers and city officials in charge.

Sewage Research

GREASE IN SEWAGE, SLUDGE, AND SCUM *

III. THE SEPARATION OF GREASE FROM SEWAGE BY MECHANICAL AND CHEMICAL METHODS

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Lipoidal matter is one of the most important of the groups of substances present in sewage. It is found mainly in the form of fatty acids and their salts, mineral oils, vegetable oils and animal fats. On quiescent settling of sewage, some of the grease settles out as part of the settleable solids and generally a portion floats to the surface as part of the scum. A large portion of the grease does not separate out but remains dispersed in the form of an emulsion.

It was the purpose of this experimental work to follow the separation of the grease through some of the methods of sewage treatment in order that an evaluation of the methods for removing grease might be made.

Experimental

1. *Removal of Grease by Settling.*—The fact that much grease is removed by settling is evidenced by the fact that fresh solids contains from 20 to 50 per cent grease (1, 2). Heukelekian (3) studied grease removal by settling in Imhoff tanks and found that a substantial portion of the grease present in sewage was removed by them as evidenced by the fact that the sludge contained 30 per cent or more of grease.

In the first series of experiments, 27 different samples of sewage were collected from various sewage treatment plants. Total grease and suspended solids were determined on the raw sewages and on samples of supernatant siphoned from 5-gallon cans of sewage after two hours of quiescent settling in the laboratory. The determination of grease used was that described in the second paper of this series (4).

The results of these analyses are presented in Table I, including the calculated removal of grease and suspended solids, and the average of all samples. Plotting the p.p.m. total suspended solids in the raw sewage against the p.p.m. suspended solids removed by settling, and the p.p.m. total grease against the p.p.m. grease removed by settling, in the form of scatter diagrams, produced trend lines of similar slope (Fig. 1). The suspended solids line illustrates the well known fact that in

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TABLE I.—*The Separation of Grease from Sewage on Settling*

Sample	Total Susp. Solids			Total Grease		
	Raw Sewage	Settled Sewage	Removal	Raw Sewage	Settled Effluent	Removed
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.
South River	454	128	316	120	64	56
South River	388	128	260	154	81	73
South River	386	132	254	128	55	73
South River	294	136	158	56	33	23
South River	294	120	174	76	36	40
South River	322	104	218	80	32	48
South River	278	126	152	80	38	42
South River	252	110	142	62	32	30
South River	164	101	63	84	50	34
South River	292	90	202	116	38	78
Sayreville	306	104	202	60	18	42
Sayreville	192	80	112	37	18	19
Sayreville	142	82	60	55	33	22
Elizabeth	206	134	72	72	65	7
Elizabeth	454	155	299	94	53	41
Bernardsville	212	78	134	81	33	48
Bernardsville	734	156	578	248	104	144
Plainfield	364	105	259	139	47	92
Plainfield	426	153	273	74	46	28
Rahway	259	90	169	98	43	55
Rahway	298	102	196	116	55	61
Freehold	366	170	196	139	70	69
Freehold	326	150	176	69	40	29
Woodbridge	174	97	77	63	49	14
Morristown	568	177	391	94	66	28
Hillsdale	258	122	136	169	77	92
Rahway	164	52	112	65	35	30
Ave.	314	119	195	93	49	44
Ave. % removal			62			47

general the higher the suspended solids concentration the greater the removal by settling.

The similarity in slope of the grease removal line with that of the suspended solids shows that the same general principle holds for the removal of grease by settling. The data also show that grease does not separate from sewage on settling so completely as other suspended material. The averages of data presented in Table I prove this point. The grease content of the sewage was 29.6 per cent, of the settled solids 22.6 per cent and the non-settled solids 41.2 per cent.

Similar work was done with 15 min. catch samples of sewage collected at the South River, N. J., plant and composited over an eight-hour (8 A.M. to 4 P.M.) period of time each day for six different days of the week. The data collected from this run are presented in Table II.

The concentrations of solids and grease were found to be higher during the early part of the week. This was as expected, since most of the laundry work is done during Monday and Tuesday. The amount of grease removed by settling decreased, as well as the total suspended solids removal, as the week progressed.

Included in this work was also an experiment which consisted of following the separation of grease on long periods of sedimentation at

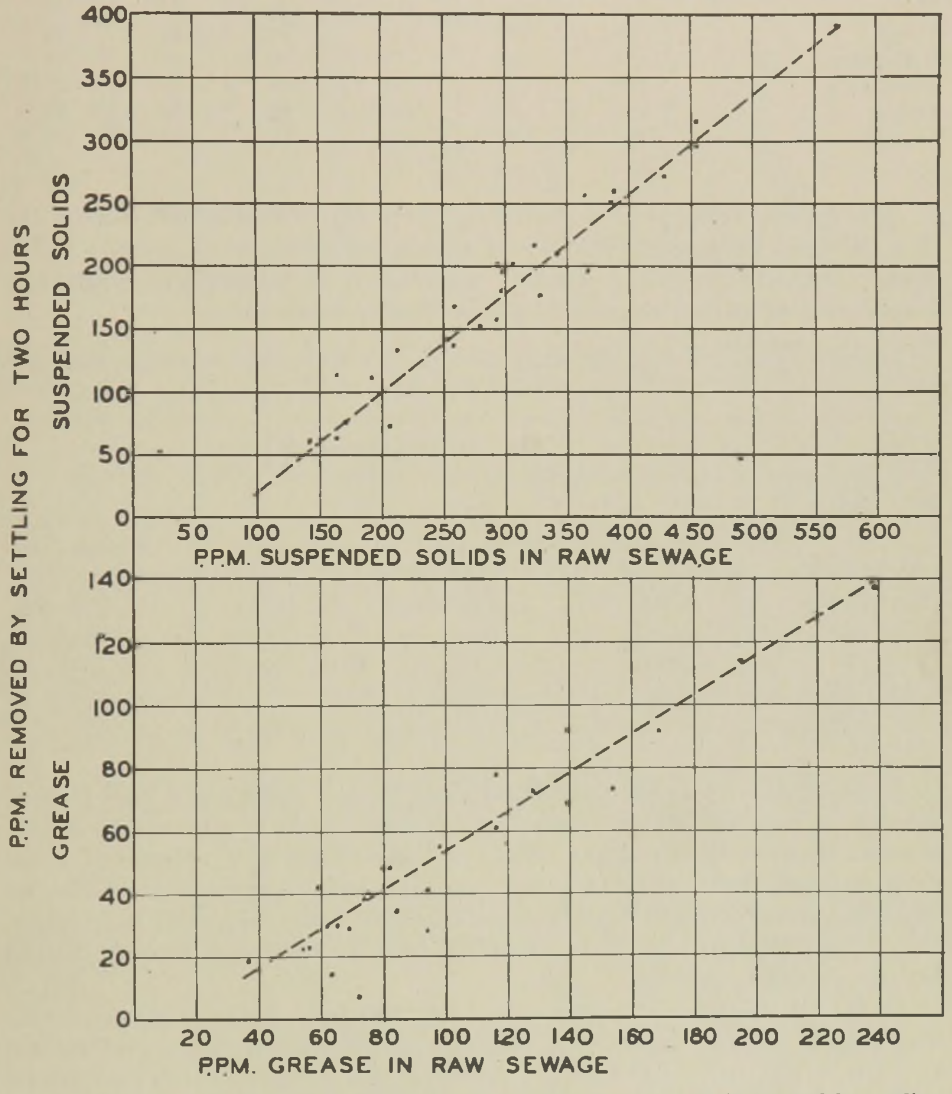

FIG. 1.—The effect of suspended solids and grease concentrations on their removal by settling.

20° C. and 7° C. Samples of raw sewage were collected in two 5-gallon containers. One was placed in an incubator maintained at 20° C. and the other in a refrigerator kept at 7° C. Samples of the supernatant of each can were withdrawn after 2, 24, 48, 72 and 96 hours and analyzed for suspended solids and grease.

TABLE II.—*The Removal of Grease from Sewage by Settling for Different Days of the Week*

South River Sewage	Suspended Solids			Grease		
	P.p.m. Raw Sewage	P.p.m. Settled Sewage	P.p.m. Removed by Settling	P.p.m. Raw Sewage	P.p.m. Settled Sewage	P.p.m. Removed by Settling
Monday	454	138	316	120	64	56
Tuesday	343	123	220	91	52	39
Wednesday	294	120	174	76	36	40
Thursday	277	119	158	78	41	37
Friday	252	110	142	62	32	30
Saturday	294	136	158	56	33	23

The figures obtained, as shown in Table III, indicate that during the first 24 hours suspended solids and grease removals were greater at the lower temperature but a greater separation of suspended solids and grease was obtained eventually at the higher temperature.

TABLE III.—*Removal of Suspended Solids and Grease by Long Periods of Settling at Low and Normal Temperatures*

Settling Time, Hours	Material Remaining at:			
	7° C.		20° C.	
	Susp. Solids	Grease	Solids	Grease
	P.p.m.	P.p.m.	P.p.m.	P.p.m.
2	218	94	218	94
24	116	67	132	80
48	106	65	104	70
72	102	69	80	50
96	118	60	91	42

2. *Removal of Grease by Aeration.*—It is a recognized fact that if sewage is aerated, prior to settling, grease removal appears to be increased because of the appearance on the surface of a volume of scum greater than that collected if no aeration were applied. A series of experiments was made to determine whether actual removal took place, or whether part of the grease, which normally settles, is merely floated by the aeration process.

A 9-liter sample of sewage was divided into three portions. One was settled for two hours, the second aerated for one hour and settled two hours and the third aerated for three hours and settled two hours. The supernatant was siphoned off below the surface and analyzed for suspended solids and grease. This experiment was repeated with eight different samples of sewage.

In Table IV the results of this experiment are presented together with the calculated averages and removal of suspended solids and grease. The results show that the additional solids separated on settling, due to pre-aeration, consisted of about two-thirds of grease. The

TABLE IV.—*Separation of Grease by Aeration and Settling*

Sewage Sample	Suspended Solids, P.p.m.			Grease, P.p.m.		
	Settled Sewage	Aerated 1 Hour, Settled	Aerated 3 Hours, Settled	Settled Sewage	Aerated 1 Hour, Settled	Aerated 3 Hours, Settled
South River	138	106	95	64	46	31
South River	136	139	110	33	21	14
South River	110	90	70	32	15	8
South River	120	91	68	36	24	22
Woodbridge	97	73	57	49	31	17
Bernardsville	78	61	54	33	34	10
Freehold	150	130	128	40	35	30
Plainfield	153	124	113	46	41	40
Average	120	102	87	42	31	22
Ave. removed by aeration	—	18	33	—	11	20

removal of grease by this procedure is an actual separation and not merely the formation of a scum from some of the grease which would normally settle.

3. *Separation of Grease by Mechanical Flocculation.*—Experiments identical with the previous set were made, except that mechanical flocculation was substituted for aeration. A paddle speed of 16 r.p.m. was maintained. Nine different sewage samples were employed.

The analytical data obtained together with average and removal calculations are presented in Table V. Preflocculation and settling produced a separation of grease greater than settling alone. The additional solids separated consisted of about one-third grease.

The total removal of suspended solids by mechanical flocculation appeared to be of the same order as that produced by pre-aeration.

TABLE V.—*Separation of Grease by Mechanical Flocculation and Settling*

Sewage Sample	Suspended Solids, P.p.m.			Grease, P.p.m.		
	Settled Sewage	Flocculated 1 Hour, Settled	Flocculated 3 Hours, Settled	Settled Sewage	Flocculated 1 Hour, Settled	Flocculated 3 Hours, Settled
South River	128	110	90	81	73	64
South River	132	116	104	55	45	41
South River	126	82	84	38	34	29
South River	104	74	52	32	22	19
Freehold	170	140	122	70	58	50
Rahway	102	65	59	55	48	43
Plainfield	105	84	81	47	28	20
Sayreville	104	64	62	18	11	10
Sayreville	80	64	51	18	9	7
Average	117	89	78	46	36	31
Ave. removal	—	28	39	—	10	15

4. *Separation of Grease from Sewage by Chemical Treatment.*—The fact that complete coagulation with ferric chloride or alum will separate the grease from sewage practically completely has been made the basis for several methods for the determination of grease in sewage. The grease is present almost entirely in the suspended solids and if they are removed completely, little grease remains in the liquor. Chemical treatment is an excellent method of removing grease; this is demonstrated by the figures presented in Table VI, which show the grease content of seven chemical treatment plant effluents. The amount of grease remaining in the effluent from a chemical treatment plant appears to be more or less in proportion to the suspended solids content of the effluent.

TABLE VI.—*Removal of Grease by Chemical Treatment*

Chemical Effluent	P.p.m. Suspended Solids	P.p.m. Grease
New Brunswick	31	8
South River	26	9
Sayreville	43	11
Somerville	29	7
Raritan	38	10
Middlesex	40	6
Bound Brook	37	9
Average	35	9

Experiments were made in the laboratory to determine the effect of rather small dosages of copperas on grease removal by aeration and settling. A sample of sewage was analyzed for suspended solids and grease. Four 2-liter aliquots were then measured out. One was allowed to settle for two hours, the second treated with 5 p.p.m. of iron in the form of copperas, aerated 30 minutes and settled two hours. The third and fourth aliquots were treated likewise, except that 10 and 15 p.p.m. of iron, respectively, were added. The supernatant was then siphoned off each of the treated samples and analyzed for suspended

TABLE VII

Sewage	Anal.	Raw Sewage	P.p.m. Iron (Copperas)			
			0	5	10	15
South River 9/8/41	S.S. Grease	444 —	126 50	178 59	172 52	122 12
South River 9/9/41	S.S. Grease	348 —	120 20	96 21	68 6	50 6
South River 9/11/41	S.S. Grease	284 —	86 29	116 13	92 12	68 5
Average	S.S. Grease	269 —	111 33	130 31	111 23	77 8

solids and grease. This procedure was repeated with three different sewage samples.

Table VII shows the data collected. It is evident that the suspended solids concentration in the settled copperas-treated sewage may increase over that of the untreated. This effect is undoubtedly due to unsettleable iron hydroxide. Despite this increase in solids the grease in the supernatants decreased as the copperas dosage increased. At the higher dosage of copperas (15 p.p.m. of iron) the suspended solids decreased to a point below the control but not in proportion to the high removal of grease obtained. It appears, therefore, that high removals of grease can be obtained with low dosages of copperas despite the fact that apparent clarification or suspended solids removal is low.

5. *Removal of Grease by Aeration as Compared to Aero-chlorination.*—Plant-scale experiments were made of grease removal by aeration as compared with aero-chlorination. The plant selected for this work was the South River, New Jersey, Treatment Works. The plant is equipped with an aeration tank providing a detention period of about 30 minutes. A skimming chamber is provided at the end through which the sewage must pass before it is discharged into the clarifiers. A sketch, showing sections of this layout, is presented in Fig. 2.

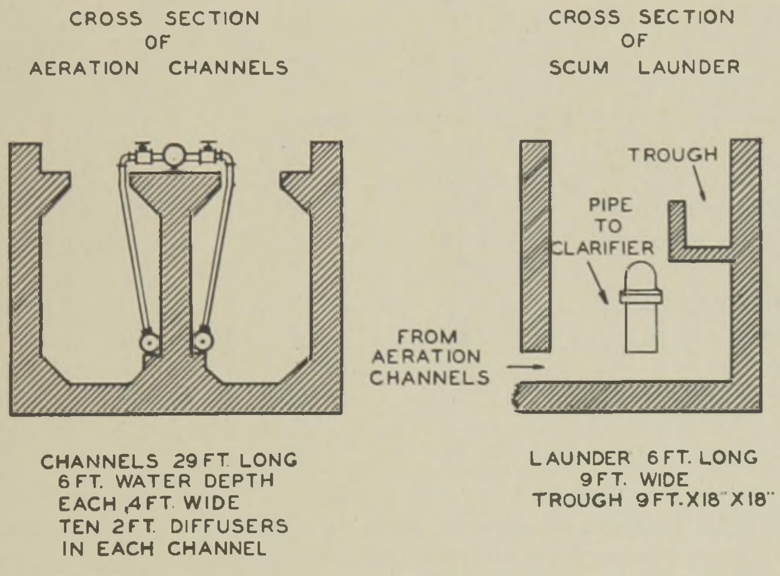

FIG. 2.—Sections of aeration tanks at the South River Sewage Disposal Plant.

The experiments were conducted over 8-hour periods, during which high flows of strong sewage passed through the plant. Since the work was done during dry weather, the flow was very constant and averaged 217,000 gal. for the 8-hour periods. The quantity of air used was 0.02 cu. ft. per gal. of sewage and the chlorine used amounted to 8.0 p.p.m. Chlorine was introduced into the air line by a gas fed chlorinator. The skimmings were removed from the skimming box and aeration channels before the test period started. After four hours the scum was collected and again after eight hours. The 8-hour collection was put in a tared steel drum and weighed. After thorough mixing with a paddle a quart sample was removed in a wide mouth jar and brought to the laboratory for solids and grease analyses. Grease was determined by the method presented in the first paper of this series (2).

The aeration tests ran thirty days and the aero-chlorination tests forty days.

The weight of dry grease collected for each 8-hour period is presented by days in Table VIII, in pounds per million gallons of sewage

TABLE VIII.—*Grease Removal by Aeration and Aero-Chlorination; Expressed in Pounds of Grease Removed in Scum per Million Gallons Sewage Treated. Chlorine Used, 8 p.p.m.*

	Mon.	Tues.	Wed.	Thurs.	Fri.	Ave.
Plain Aeration (30 days)						
	51	39	26	29	21	33
	57	37	29	25	55	41
	85	21	32	18	36	38
	57	42	39	30	37	41
	64	43	41	35	43	45
	60	29	32	27	37	37
Ave.	62	35	33	27	38	39
Aero-Chlorination (40 days)						
	60	56	52	21	30	42
	60	37	57	19	27	40
	66	43	33	49	35	45
	59	18	44	50	97	54
	92	37	37	31	62	52
	57	90	39	92	79	71
	58	68	60	67	71	65
	82	85	75	59	45	69
Ave.	67	54	50	49	56	55

treated. An average removal of 39 lb. of grease per million gallons of sewage treated was collected for plain aeration and 55 lb. for aero-chlorination. This represents an increase of 16 lb. of grease per mil. gal. or 41 per cent increase in grease removal for the aero-chlorination.

Discussion

Quiescent settling of twenty-seven samples of sewage yielded under laboratory conditions an average removal of 62 per cent of suspended solids and 47 per cent removal of grease. In accordance with experience, the removal of suspended solids was found to increase with the concentration of suspended solids in the raw sewage. It is shown that the grease removal is proportional to the suspended solids removal.

The data obtained indicate that the bulk of the grease is present as an integral part of the settleable suspended solids and not as separate particles. In general, for every 3 to 4 p.p.m. of suspended solids removed, one p.p.m. of grease was obtained. These removals check with the grease content of the fresh solids removed from these sewages, varying from 20 to 30 per cent of the dry weight.

That the grease is closely associated with the settleable solids is also brought out by the results showing suspended solids and grease removal obtained on samples collected on different days of the week. As the week progressed both the suspended solids and grease concentrations in the raw sewage and the removals obtained by settling decreased.

The close association of the grease with the settleable solids is probably due to several factors. First, the solids themselves have a natural grease content. Second, in removing dirt, soaps form an inclusion with it which remains intact. Thirdly, solids probably become coated with grease and soaps, or emulsified particles become attached to them. In normal domestic sewage, particularly Monday sewage, the greater part of the grease is in the form of soaps. The simultaneous removal of grease with other suspended solids is logical.

Even at lowered temperatures, grease separation is attended by the separation of incorporated solids. It might be presumed that some of the grease present in liquid emulsified form might congeal and either settle or rise as a scum. The long-time settling tests conducted at 20° and 7° demonstrate that this is not the case. At both temperatures grease and suspended solids removals accompanied one another in relative proportion, but at the lower temperature grease and solids separation were both slower than at the higher temperature.

It is well known that pre-aeration and pre-flocculation increase the separation of suspended solids by sedimentation. Some of the solids settle and others float after such pretreatment; this is also the case to a lesser extent when plain settling is practiced. No attempt was made in our experiments to determine the percentage separating in each manner. It is evident from visual observation, however, that aeration causes more separation by flotation than does pre-flocculation. This is also borne out by the fact that relatively less grease was separated in proportion to the suspended solids by the mechanical method. The increased removals of suspended solids over plain settling obtained by the two methods were about the same. It should be kept in mind that the sewages used for each set of experiments were not the same. Both methods of grease separation increased the removals as the time of pre-treatment was increased. It is interesting to note that the grease content of the additional weight of solids removed by the flocculation process was not much higher than the grease content of the non-settleable solids fraction, running about 36 per cent after 1 hour treatment and 39 per cent after three hours treatment. Aeration, however, removed solids containing 61 per cent of grease after both periods of pretreatment. The grease content of these solids check that of scums collected from aeration tanks which have been found to contain from 50 to 70 per cent grease (2).

It has been pointed out in a previous paper (4) that almost all the grease present in sewage is in a suspended form. Therefore, if all the suspended solids are removed the grease is likewise completely removed. This is illustrated by results of analysis of seven effluents from chemical treatment plants where both suspended solids and grease were found to be low.

Chemical treatment of sewage with copperas shows that low dosages of copperas will often increase the suspended solids present in the supernatant after settling, due to hydrolyzed iron salt in dispersed form. Nevertheless, these low dosages of copperas precipitated some of the grease, despite the fact that iron sols remained dispersed. While an average of 77 p.p.m. of suspended solids was found in effluent samples of sewage treated with 15 p.p.m. of iron, only 8 p.p.m. of these was grease. This grease concentration was lower than that of the chemical treatment plants effluents, despite the fact that the solids concentration was about double. It appears then that small dosages of copperas can effect a substantial reduction in grease despite the poor clarification obtained. The copperas evidently coagulates the grease in suspension, although it does not precipitate in settleable form itself.

Plant-scale tests confirmed previous findings at other plants that additional grease can be removed by aeration if chlorine gas is bled into the air line (5, 6, 7). In the experiments presented here only the grease removed in the form of scum was measured. It is claimed that this treatment also increases the amount removed by settling, but such a comparison could not be made part of the experiments reported in this paper because plant details would not permit.

The increase of grease removal obtained by the application of chlorine with air was 16 lb. per m.g. or 41 per cent. While the percentage increase was high the actual amount was not. Perhaps of more value than the analytical results were the visual observations made during the several weeks of experimentation.

It was noticed by the plant operators that while aero-chlorination was practiced the clarifiers required much less frequent skimming. While it was necessary to skim the clarifiers three times per day with plain aeration, one skimming per day sufficed to keep them in good shape when chlorine was used in conjunction with air. Improvement of the general appearance of the clarifiers was noted. In general, the chlorine aided in removing the grease which would have floated out progressively through the plant. It does not require much grease to form an unsightly scum and the additional 16 lb. per m.g. was undoubtedly most of the offending fraction of the total grease present.

The use of chlorine for the purpose of appearance alone is not easily justified. However, in many plants it is necessary to prechlorinate for odor control, as was the case in the plant employed for these experiments. Where this is the case and aeration channels are provided, the combination of the two offers a distinct advantage in operating ease.

The mechanism of the action of the chlorine is believed by Faber (5) to be the reaction of the chlorine with proteins associated closely with the grease, coagulating them, thus breaking the emulsion and allowing the grease to separate. There remains little doubt from the data presented in the paper that other materials, some undoubtedly proteins, are closely related to the grease suspended in sewage. Faber's explanation may be correct since many emulsions consist of such combinations and the removal or change of one of the components will break the emulsion. Nevertheless, the complete mixing of the chlorine and the sewage obtained by this method of application is to a great extent responsible for the results obtained. Proper dispersion of chlorine on application to sewage often has been neglected and additional plant-scale work on the many phases of this problem might be fruitful.

Summary and Conclusions

Laboratory and plant experiments were conducted to determine the effect of settling, temperature, mechanical mixing, aeration and aerochlorination on the removal of grease from sewage. From the studies the following conclusions are drawn:

(1) Sedimentation removes a large percentage of grease from sewage. The removal is not as high as for total suspended substances. The grease content of the non-settleable solids was found to be higher than of the settleable solids.

(2) Grease removal by settling closely follows total suspended solids removal; separation of both increases in proportion to the original concentration, the higher the original concentration the greater the removal observed.

(3) The grease content of domestic sewage is high on Mondays and decreases as the week progresses. A close association of grease exists with other substances, particularly with dispersed solids.

(4) The grease content of sewage as well as the total suspended solids content decreases on long periods of quiescent standing. The removal proceeds faster at 20° C. than at 7° C. It is probable that bacterial action is involved.

(5) Increased removals of suspended solids on settling are obtained with either pre-aeration or pre-flocculation. With both methods the suspended solids removals were of the same order, but the grease content of the additional solids removed by aeration was higher than that of the solids obtained by mechanical flocculation.

(6) Grease in sewage is practically all in a state of suspension and nearly all can be removed by proper chemical treatment.

(7) Treatment with low dosages of copperas can remove most of the grease from sewage despite the fact that general clarification is poor. The apparent lack of clarification is due to dispersed iron hydroxides.

(8) Plant-scale experiments conducted over a period of 70 days showed an average grease removal in the scum of 55 lb. per m.g. for aero-chlorination as compared to 39 lb. per m.g. for plain aeration, or an increase of 41 per cent. It is possible that a still greater removal takes place, as additional grease may be broken from the emulsion form and settle with the solids.

Acknowlegement

Sincere thanks are due the officials of the Borough of South River, New Jersey, for permission to make these tests. Mr. Kermit Devoe, Plant Superintendent, and staff are to a large degree responsible for the successful completion of the aero-chlorination experiments because of their co-operation throughout the work. The Wallace and Tiernan Company made these experiments possible by generously supplying all special equipment and offering technical advice on certain problems involved.

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RIBOFLAVIN IN SEWAGE SLUDGE

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The market value of sewage sludge as a fertilizer has generally been based on its nitrogen and available phosphorus content. In some instances the humus in the sludge has been cited as a beneficial soil conditioning material and the market value of the fertilizer was considerably enhanced because of this factor. However, the quantities of fertilizers sold at a price above the market value of the nitrogen and phosphorus they contain has been relatively small. The great bulk of fertilizer sold as activated sludge have been sold on the basis of its nitrogen and phosphorus content.

In recent years Rudolfs, Heinemann and Ingols have pointed out that sewage sludges contain growth promoting substances other than nitrogen and phosphorus and have emphasized the possible importance of these substances in the stimulation of plant growth and seed germination (1). Their work includes studies of the presence of ascorbic acid, carotene, tryptophane, tyrosine, phenyl compounds, naphthyl compounds, indole and skatole in sewage effluents and sewage sludges.

In this work an effort has been made to study the growth promoting substance present in sewage with properties very similar to those of riboflavin, a growth promoting vitamin. The compound has not been isolated from sewage sludge and identified as riboflavin, however its properties are sufficiently like those of riboflavin to be referred to as riboflavin in this paper.

The purpose of this paper is to summarize some of the results obtained in this study, and to stimulate further studies, particularly those on the effect of riboflavin and pantothenic acid on plant growth and seed germination using wide varieties of plants and seeds.

Properties of Riboflavin

Riboflavin is the chemical name of the compound formerly known as vitamin G and at present known as vitamin B_2. It is a yellow crystalline solid soluble in water to the extent of about 120 p.p.m. at 25° C. An aqueous solution is of a greenish yellow color and exhibits fluorescence over a relatively wide range of pH.

It is relatively stable in solutions of mineral acids but tends to decompose in strongly alkaline solution. It is a photosensitive compound, decomposing rapidly when in solution if exposed to ultra-violet or visible light. The rate of decomposition due to light irradiation is greatly accelerated if the solution is strongly alkaline.

It is quite heat stable, little decomposition taking place by heating the compound at 100° C. When solutions of riboflavin are subjected to heat, the losses in acid solution are much less than in alkaline solution. The rate of loss, of course, increases as the temperature increases, complete decomposition occurring at the melting point, which is 275° C.

Riboflavin is one of the growth-promoting vitamins. It is essential to the growth of certain bacteria and over specific ranges of concentrations the growth is directly proportional to the concentration. This is particularly true of *Lactobacillus casei* and this principle is the basis of a method for determining riboflavin concentration (2, 3).

It has been demonstrated that small animals such as rats, chickens and pigs respond to the growth stimulation produced by riboflavin (4, 5, 6).

Little work has been done on the growth stimulation of plants. Dennison reports that the rate of growth of egg-plant is accelerated by the addition of synthetic riboflavin to nutrient solutions used in his experiments (7).

Riboflavin in proper concentrations in chicken feed increases the hatchability of eggs (8). Large quantities of riboflavin concentrates purchased by the feed mixers are used in chicken feeds.

Riboflavin has been observed to increase the germination of pollen grains. Two articles report the highly effective germination of cariaca papaya pollen brought about by solutions containing riboflavin (9, 10).

Riboflavin is thought to be necessary to the well being of man and many small animals. Deficiency of this vitamin may cause a decrease in rate of growth and reproduction, and diseases of the eye, the skin and nervous system.

Analytical Procedure

The analytical procedure used in this study is that proposed by L. M. Pruess in an unpublished work. The method is a modification of the microbiological procedure proposed by E. E. Snell and F. M. Strong in *Industrial and Engineering Chemistry,* Anal. Ed., **11**: 346–350.

A riboflavin-free broth containing yeast extract, inorganic salts, peptone and dextrose is prepared and separated into a number of equal portions in flasks. To six of the flasks is added known amounts of synthetic riboflavin. To the others the unknown samples to be assayed are added in varying amounts. All flasks are sterilized.

Cultures of *Lactobacillus casei* are prepared in broth and a small quantity used to inoculate the sterilized flasks containing the known and unknown quantities of riboflavin.

After 48 hours incubation the quantity of lactic acid produced is determined by titration of an aliquot from each flask with standard sodium hydroxide solution. A graph of the relationship between the known riboflavin concentrations and the quantity of standard sodium hydroxide is prepared and the quantity of riboflavin in an unknown sample is determined by reading the quantity of riboflavin corresponding to the titration obtained for that sample. Riboflavin is usually reported in micrograms per gram.

Riboflavin Studies

These studies were started with the object of determining the effect of the methane fermenters in the sewage sludge digestion on riboflavin in an industrial waste. It is well known that certain bacteria and yeasts produce riboflavin from media containing but little of this compound. An industrial waste containing riboflavin was subjected to anaerobic fermentation and riboflavin was determined on the material before and after digestion. In addition the determination was made on other sewage sludges in the treatment works. A number of interesting and noteworthy results were obtained. Samples of various sewage sludges of different origins were obtained and analyses made for their riboflavin content. The properties of the growth promoting substance in sewage sludges were studied.

Table I.—*Riboflavin Content of Sewage Sludges*

Sample		Per Cent H_2O	Per Cent Volatile Dry Basis	Per Cent Total Nitrogen	Riboflavin Micrograms per Gram
Activated Sludges					
Peoria	Laboratory Dried	0.0	76.5	5.84	47
Milwaukee	Plant Product	4.2	73.3	5.47	35
Chicago-Southwest	Plant Product	4.9	63.0	4.42	29
Chicago-Calumet	Plant Product	2.7	54.3	3.77	21
Primary Tank Sludges					
Minneapolis	Plant Product	3.0	70.0	2.40	20
Buffalo	Plant Product	2.2	41.8	1.63	9
Aurora	Laboratory Dried	1.3	77.2	2.67	34
Digested Sludges					
Dayton-Primary and Filter Sludge	Plant Product	2.6	52.1	2.27	11
Buffalo-Primary Sludge	Plant Product	2.9	52.8	1.36	6
Peoria-Primary and Activated Sludge	Laboratory Dried	0.0	53.9	2.93	20
Peoria-Primary and Activated Sludge	Plant Product	54.4	50.5	2.83*	12*
Trickling Filter Sludge					
Aurora	Laboratory Dried	1.6	67.6	3.33	42

* Dry basis.

Riboflavin Content of Sewage Sludges.—Table I indicates concentrations of riboflavin found in various sewage sludges. Some of the samples are laboratory prepared while others are samples of sludge obtained from a few plants in various parts of the country. While the data are not of sufficient weight to warrant specific generalizations, it appears that sludges from secondary treatment have higher riboflavin contents than primary sludges. It is also apparent that in each group the trend of riboflavin concentration follows in some degree the variation in volatile matter and organic nitrogen. Noteworthy also is the reduction in riboflavin content in the Peoria digested sludges due to drying on sludge drying beds. The effect of light over the three week to one month drying period is sufficient to materially destroy the riboflavin. Sludge taken from the surface of the stock pile has been found to contain no riboflavin.

Effect of Digestion.—The effect of digestion on the riboflavin content of sewage sludge and an industrial waste was estimated. The data reported is the average of nine determinations made on several liquid composited samples. The riboflavin concentrations reported in micrograms per gram are computed to a dry solids basis.

Industrial Waste

Riboflavin Content

Before Digestion 60 Micrograms per Gram

After Digestion 48 Micrograms per Gram

Reduction in Total Solids 60%

Riboflavin Content if no decomposition of riboflavin took place

$$\frac{60}{0.40} = 150 \text{ micrograms per gram}$$

% Reduction in riboflavin due to digestion

$$\frac{150 - 48}{150} = 68\%$$

Sewage Sludge

Riboflavin Content

Before Digestion 47 Micrograms per Gram

After Digestion 20 Micrograms per Gram

Reduction in Total Solids 35%

Riboflavin Content of sewage sludge if no decomposition took place

$$\frac{47}{0.65} = 72 \text{ micrograms per gram}$$

% Reduction in riboflavin due to digestion

$$\frac{72 - 20}{72} = 72\%$$

Effect of Heat.—As noted previously riboflavin is a relatively heat stable vitamin. Due to this property very little is destroyed by the commonly used sludge drying process; however where recovery is important drying should be carried out at as low a temperature for as short a time as possible. Experiments with drying activated sludge indicate that drying activated sludge at 103° C. for 24 hours reduces riboflavin content 21.6 per cent.

Heating dried activated sludge for one hour at various temperatures results in decomposing riboflavin as follows:

Temperature ° C.	Loss of Riboflavin: Micrograms per Gram	Loss of Riboflavin: Per Cent
140	1	2.4
160	5	12.2
180	19	46.3
200	31	75.7
220	37	90.2
240	39	95.0

Thus it may be seen that heating above 160° C. results in considerable losses. In addition practically complete decomposition takes place at temperatures in the order of 220° C. and 240° C. The effect of temperature on riboflavin in digested sludge follows a similar curve to that of activated sludge.

Repeated tests indicate that heating for one hour at 240° C. decomposes practically all of the riboflavin present.

Effect of Light.—When activated sludge suspensions are made strongly alkaline (1 gm. sodium hydroxide per 100 ml.) and exposed to the irradiation of a 100-watt lamp at a distance of 10 inches for four hours, complete destruction of riboflavin takes place. When the pH of the irradiated activated sludge is 4.0 but 20 per cent of the riboflavin is destroyed in four hours and when the pH is 8.0 but 47 per cent of the riboflavin is decomposed. Thus it is noteworthy that the growth promoting substance in activated sludge is decomposed by light in strong alkaline solution and that the rate of decomposition is decreased as the solution becomes more acid.

Strongly alkaline controls not exposed to light show that none of the riboflavin decomposes in the four hour period.

Effect of Filtration.—Since riboflavin is slightly soluble in water it is important to know the effect of filtration on the riboflavin content of sludge cake. Investigation reveals that activated sludge containing 45 micrograms per gram when treated with ferric chloride and filtered results in a concentration of 43 micrograms per gram of riboflavin in the activated sludge cake and none of the vitamin in the filtrate.

It is possible that the vitamin is contained in the bacteria of the sludge and it is not released until the bacterial cells are destroyed.

Extraction of Riboflavin.—When 10 grams of dried activated sludge is extracted with 100 ml. of 5 per cent hydrochloric acid solution for 40 minutes under a reflux condenser 76 per cent of the riboflavin may be recovered in the acid solution.

Riboflavin in Sewage.—Riboflavin is present in raw sewage in concentrations varying from 20 to 44 micrograms per liter. Activated sludge effluent was found to contain 4 to 5 micrograms per liter. Settling has practically no effect on the riboflavin content of raw sewage.

Significance of Riboflavin in Sewage Sludges

It is impossible to forecast the importance of the knowledge of the presence of riboflavin in sewage sludge. There is a strong possibility that this knowledge may enhance the utility and value of sewage sludges in that research along the lines of the application of the vitamin to plant growth and seed germination may disclose hitherto not appreciated properties. It is worth recalling that fertilizer experts consider sewage sludge to be a low grade fertilizer on the basis of analyses. Plant growth tests, however, usually disclose better results than they anticipate. The presence of riboflavin in these sludges may account for this discrepancy.

Riboflavin in Fertilizers.—There are few published evidences of the benefits of riboflavin to plant growth, however it is very probable that extensive studies on the effect of riboflavin on plant growth will disclose that the rate of growth of many plants may be increased by its use, particularly in certain plants in which the production of the vitamin is low. In connection with studies on the effect of riboflavin on plant growth, experiments should be conducted with pantothenic acid as an accompanying vitamin since this compound is found to be present in sludges in concentrations in the order of 150 to 200 micrograms per gram. Pantothenic acid is also a growth promoting, water soluble, heat stable vitamin.

Riboflavin and Seed Germination.—The scanty articles appearing in the literature indicate that riboflavin may be useful in accelerating the rate of seed germination and more importantly of increasing the germination yield.

TABLE II.—*Average Riboflavin Content of Common Food Stuffs*

Material	Riboflavin Content Micrograms per Gram
BY Flavin Concentrate	60
Liver Meal, Argentine	41
Brewers' Dried Yeast	35
Dried Whey	26
Dried Skim Milk	21
Dried Butter Milk	20
Alfalfa—Leaf Meal Dry	18
White Fish Meal	10
Sardine Fish Meal	7
Wheat Germ	6
Wheat Bran	4
Wheat	1.0
Patent Flour	0.3

The importance of acceleration of seed germination and plant growth is obvious. Many crops are lost to the farmer because of their failure to reach maturity before fall frosts. Increasing the germination yield will result in an increase of crop yield per acre in many crops.

Riboflavin from Sludge as an Animal Feed Supplement.—It is possible to remove riboflavin from sewage sludges and to prepare riboflavin concentrates which could be used to supplement animal feeds. It is well established that riboflavin is an essential growth factor for small animals such as pigs and chickens and that it materially increases the hatchability of eggs. The removal of part of the riboflavin from sludges would not materially effect the nitrogen content of the sludge. At this time particularly this might be done because of the use of products, such as dried skimmed milk, which formerly were used as animal feed supplements, and are now being used for human consumption. Vast quantities of these riboflavin concentrates are being sent to England.

Summary

The growth-promoting substance in sewage sludge as measured by the growth stimulation of *Lactobacillus casei* is soluble in dilute acid solution as is riboflavin.

It is relatively temperature-stable at moderate temperature below 140° C. and decomposes rapidly at a temperature of 240° C. or above as does riboflavin.

Its solution decomposes when exposed to light radiation, the rate of decomposition increasing as the solution is made more alkaline as does riboflavin.

It responds to the analytical procedure used in the same manner as does riboflavin.

On these relatively few properties it is here presumed that this substance is riboflavin.

Riboflavin is present in high concentration in sludges from secondary sewage treatment, such as activated sludge and trickling filters.

Riboflavin is present in lesser amounts in primary tank sludges.

The riboflavin content of sewage sludges varies in the same direction as does the organic nitrogen and volatile matter of the sludge.

Riboflavin is decomposed by the methane fermenters of sludge digestion in the order of 70 per cent of that originally present.

Riboflavin is present in sewage and sewage effluents.

Studies should be made to determine the growth-promoting effect of riboflavin on plants.

Studies should be conducted on the effect of riboflavin on seed germination. All studies should be made in connection with pantothenic acid, since this vitamin is also present in sewage sludges in large amounts.

It is possible to prepare riboflavin concentrates from sewage sludges and use these as animal feed supplements.

Acknowledgment

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STUDIES ON THE TREATMENT OF SEWAGE AND TEXTILE WASTES BY RECIRCULATING FILTRATION. II. DOMESTIC SEWAGE ON A CONTINUOUS BASIS *

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Before investigations were made on the treatment of textile wastes by recirculating filtration, it was considered advisable to study the treatment of sewage alone. A previous study on the batch method of operation (1) has been reported. The present article reports the results of a study made on continuous operation. In it an effort has been made to investigate further the fundamental factors underlying recirculating filtration, to determine which factors have the greatest influence, and to see what conditions are most favorable for optimum purification. Future articles in this series will describe the treatment of textile wastes.

Description of the Experimental Plant

All of the studies on recirculating filtration reported in this and previous articles of this series were carried out in an experimental pilot plant and laboratory located on the property of the Proximity Print Works in Greensboro, N. C. The bio-filter plant consisted of two separate but identical systems which were operated independently.

As shown in Fig. 1, sewage was pumped first into a 250-gallon holding tank. One holding tank, in which sewage was maintained at all times, was used to supply both filter systems. By the use of a float switch, the tank was filled automatically whenever the sewage volume reached a certain low level. From the holding tank sewage was pumped by either of two 1½-in. centrifugal pumps (only one pump shown in Fig. 1) to the detention tank of each filter system.

The detention tanks used in these studies were the same 210 gal. tanks used previously when the plant was operated on a batch basis (1). The desired volume of waste in each detention tank was maintained constant by the use of a float-operated contact switch which controlled the pump supplying sewage to the detention tank. By means of this contact switch raw sewage was added to the detention tank at exactly the same rate at which the final effluent was discharged from the plant. Each detention tank had a slightly sloping bottom with a sump in the middle through which waste was withdrawn and recirculated by a 1½-in. centrifugal pump. No appreciable amount of solids settled out in the detention tanks.

* This research project was carried out under joint sponsorship of the University of North Carolina and The Textile Foundation.

The two bio-filters, described in a previous article (1), consisted of 2- to 3-in. broken stone to a depth of 4 ft. and were contained in a single sheet-iron cylinder having a diameter of 4 ft. 7 in. This cylinder rested upon a wooden grill contained in a shallow metal pan 5 ft. 7 in. in diameter which was mounted on top of another cylinder the same size as the first. Effluents from the filters were gathered in the metal pan. On top of the stone bed within the upper cylinder rested a shallow perforated pan, which was used for distributing the waste over the filter area. The waste was discharged onto this distributor pan in continuous streams from the recirculating pumps. A vertical

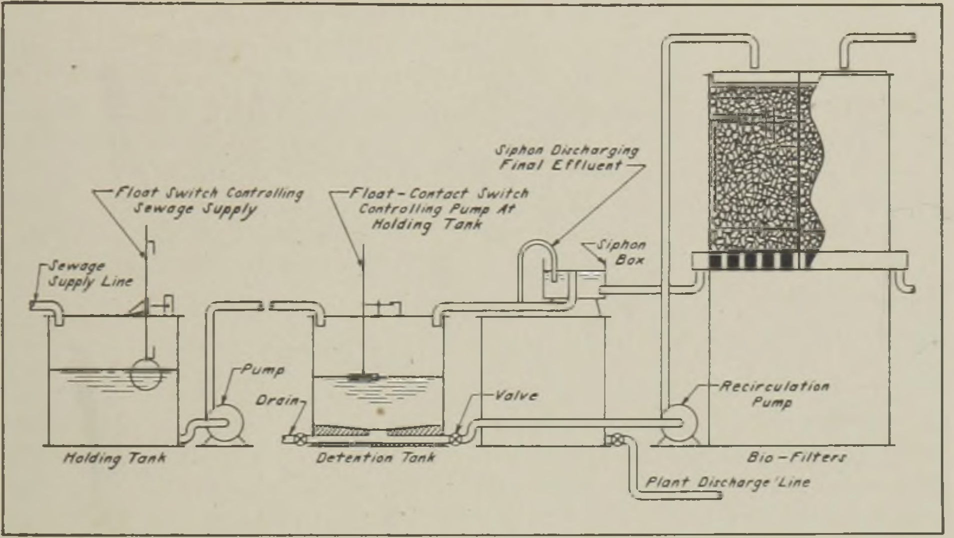

FIG. 1.—Diagrammatic sketch showing plant layout for studies on recirculating filtration on a continuous basis.

sheet-iron partition divided the distributor pan, stone bed, and effluent pan into two sections so that there were two complete and independent filters.

Several factors tending to increase the efficiency of the trickling filter were incorporated into the design of these filters. These factors, which were in accordance with the findings of several other investigators, have been discussed in a previous article of this series (1). Briefly, they were: continuous dosage, size of the aggregate, depth of the filter, and bottom ventilation.

The effluent from each filter, after being collected in the metal pan, flowed by gravity into a siphon box. From this box part of the flow from the filter was discharged by a fixed siphon as final effluent of the plant. The remainder of the flow was returned through an overflow pipe to the detention tank, where it was mixed with fresh sewage and recirculated. As pointed out above, fresh sewage was added to the detention tank at exactly the same rate at which the final effluent was discharged.

It was possible to vary both the rate of discharge of final effluent and the rate of recirculation over wide ranges. The rate of discharge was varied by changing the size of the discharge siphon. The rate of recirculation was measured by an orifice meter in the pressure line from the recirculation pump and was varied by means of a valve.

Fig. 2 shows part of the plant and one of the filter systems; the holding tank is not shown. The detention tank, with its contact float

FIG. 2.—View of filter system.

switch, is on the right; the filter unit and recirculation pump are in the center; and the siphon box, from which the final effluent is discharged, is on the left (only part of discharge siphon is shown).

Procedure and Technique

The sewage used in these experiments consisted of fresh domestic waste and was obtained from the outfall sewer on the north side of the city of Greensboro, N. C., by a centrifugal pump placed in a manhole near the plant. Sewage was pumped at intervals directly to the holding tank, as explained above.

The procedure for each run was to set up the filter at desired conditions of operation in respect to rates, time, and volume, and to let the filter become adjusted to these conditions before collecting samples. Samples were collected at half-hour intervals over a period of several hours. Samples were taken of the raw sewage as it was pumped from the holding tank into the detention tank and of the final effluent as discharged from the plant. All effluent samples were collected in ⅔ gal.

bottles and settled for one-half hour. At the completion of the run, all samples were composited and the composites used for analysis. Consequently, the results obtained represented average conditions over the entire duration of the run. All analyses were performed according to the procedures in *Standard Methods of Water and Sewage Analysis*.

In a study of recirculating filtration it is necessary to consider many variables, more or less mechanical in nature, which relate directly to the way the filter is operated. These are rate of treatment, rate of recirculation, number of recirculations, time of treatment, and volume in the detention tank. None of these variables is entirely independent, but all of them are interrelated in some manner to one or more others. Then, too, there are the factors of dissolved oxygen in the detention tank, initial load as measured by B.O.D. and temperatures of air and sewage, which affect the efficiency of the filter. These factors, some of which can be controlled more readily than others, vary in their influence upon filter operation.

In this study, series of runs were made, and in each series one controllable factor was varied while the other factors were kept as constant as possible. Because of the way in which certain factors are related to others, in some cases it was not possible to have just one varying factor. However, by making comparisons between different series, it has been possible for the most part to note the effect of each factor upon filter efficiency. One of the factors not considered as an independent variable was the volume in the detention tank. In the continuous filtration process, the volume maintained in the detention tank is fixed by the rate of treatment and the time of treatment. If these two variables are considered of primary importance, then the volume is of little or no significance.

For ease of interpretation, results of the various series have been grouped according to the variable factor. However, before considering the results, the following definitions are given.

Definition of Terms

Rate of Treatment is the rate of discharge of final effluent from the plant. This is also the rate at which raw sewage was added to the detention tank to be mixed with the recirculating material.

Rate of Recirculation is the rate at which material was withdrawn from the detention tank and applied to the filter. Hence, the recirculation rate is the actual rate at which sewage was passed through the filter bed.

Number of Recirculations is the theoretical number of times sewage was passed through the filter before being discharged. This is also equal to the ratio of recirculation rate to treatment rate. Also, number of recirculations indicates the per cent of the filter effluent that is recirculated. For example, if the number of recirculations is five, then 20 per cent of the effluent is discharged and 80 per cent is recirculated.

Treatment Time is the theoretical length of time sewage was recirculated before discharge.

Results

Rate of Treatment.—The effect of treatment rate upon filter operation was investigated in two series of runs. The results of one series are plotted in Fig. 3, and are also given in Table I. Because of the way

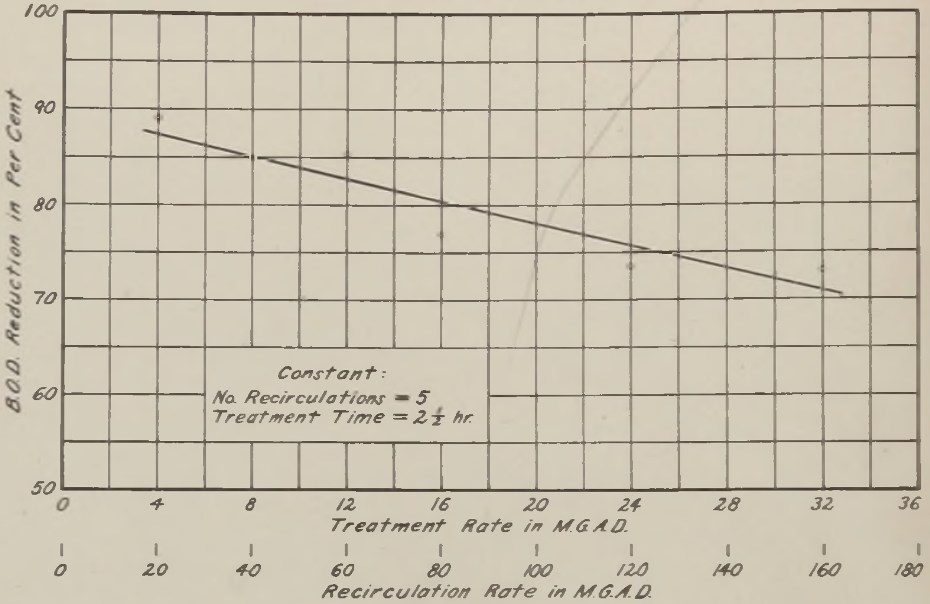

Fig. 3.—Per cent reduction in B.O.D. vs. treatment rate and recirculation rate.

in which different factors are interrelated, it was impossible to vary the treatment rate without varying at least one other factor. Consequently, in the first series, rate of recirculation varied with the rate of treatment. The results show that as the treatment rate or the load on the filter increased, the pounds removal of B.O.D. increased, and the per cent removal of B.O.D. decreased (Table I).

Table I.—*Results Obtained by Treating Sewage at Varying Rates*

Treatment Rate, M.G.A.D.	B.O.D.			
	Initial, P.P.M.	Final, P.P.M.	Removal	
			Per Cent	Pounds per Acre per Day
4	320	34	89.2	9,560
8	273	41	85.0	15,500
12	530	76	85.5	45,500
16	243	56	77.0	25,000
24	425	116	73.6	62,000
32	370	98	73.2	72,600

The results of the second series of runs are plotted in Fig. 4. Two curves are shown, but only the curve plotted from runs having dissolved oxygen in the detention tank can be used as an indication of the effect of varying rates, or as a basis for comparison with other data. In this series the recirculation rate was kept constant, but the number of recirculations was varied with the treatment rate. Figure 4 shows that purification decreased as the rate of treatment increased and as the number of recirculations decreased. By comparing Figs.

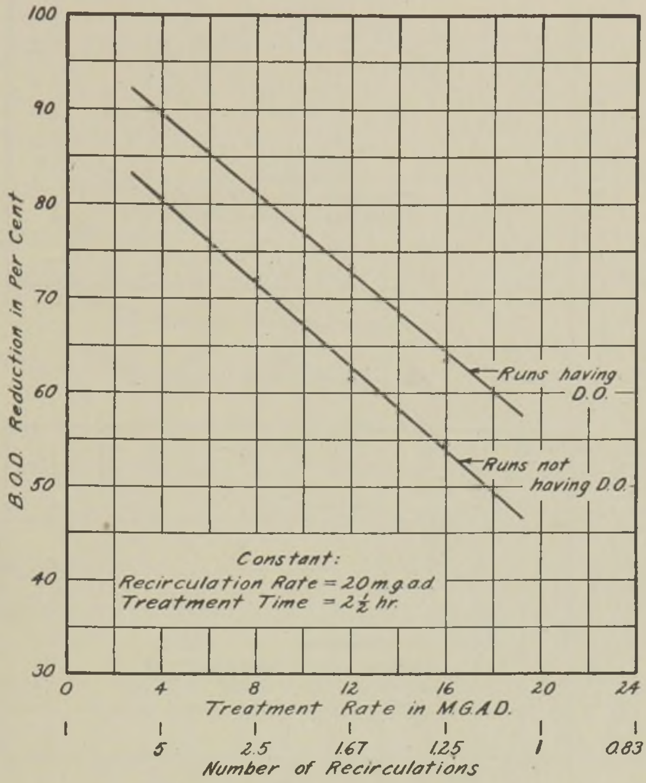

FIG. 4.—Per cent reduction in B.O.D. vs. treatment rate and number of recirculations.

3 and 4, and noting the variation in purification obtained over an equivalent range of treatment rates, it is seen that the curve in Fig. 4 has a much greater slope. This indicates that the number of recirculations has a greater effect on purification than does the rate of recirculation.

Rate of Recirculation.—In Fig. 5 are shown curves plotted from two series of runs in which recirculation rates and number of recirculations were varied. Throughout one series of runs the recirculation rate was three times that of the other. The treatment rate was kept constant throughout each series. Both curves have the same shape and show maximum purification at the same number of recirculations. Curve *A* in Fig. 5, which was plotted from the series of runs having lower recirculation and treatment rates, shows a slightly greater per cent reduction in B.O.D. at each number of recirculations. The results plotted in Curve *A* were obtained during cold weather operation (average temperature of sewage was about 18° C.), whereas those plotted in Curve *B* were obtained during warm weather operation (average temperature of sewage was about 26° C.). Because of the fact that biological filters remove large amounts of B.O.D. at higher temperatures,

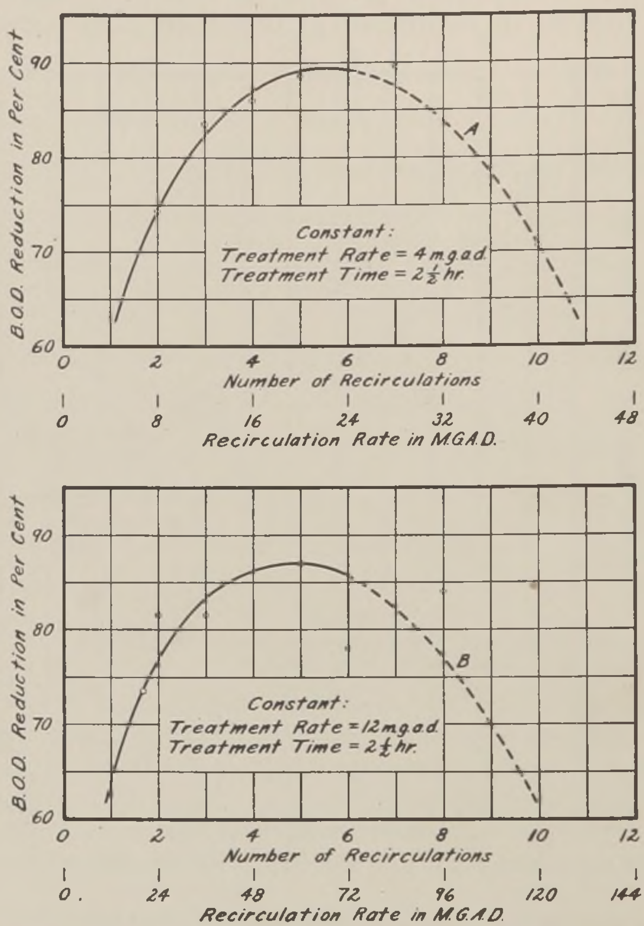

FIG. 5.—Per cent reduction in B.O.D. vs. number of recirculations and recirculation rate.

the runs in Series B should have given better purification than those in Series A, if other factors had not affected purification. Since the runs in Series A gave better purification, it is obvious that the treatment rate and recirculation rate affected the results, and that the lower rates offset the disadvantage of lower temperatures and gave better results. This agrees with the results shown above in Fig. 3.

Rate of recirculation is the actual rate at which sewage is applied to the filter. The effect upon purification caused by variations in the rate of application can be noted in Fig. 6. In this figure the results from a number of runs in which recirculation was not employed have been plotted. The per cent of B.O.D. removal curve shows that the faster sewage is put through the filter the less the purification. Even though the actual per cent reductions would, no doubt, have been different if the filter effluent had been recirculated, it seems that the trend towards decreased purification with increased rates of application is established. The other results shown in Fig. 6 are interesting from the standpoint of ordinary trickling filter operation and will be mentioned later.

Number of Recirculations.—As already pointed out, the results of the study on number of recirculations are plotted in Fig. 5. Even

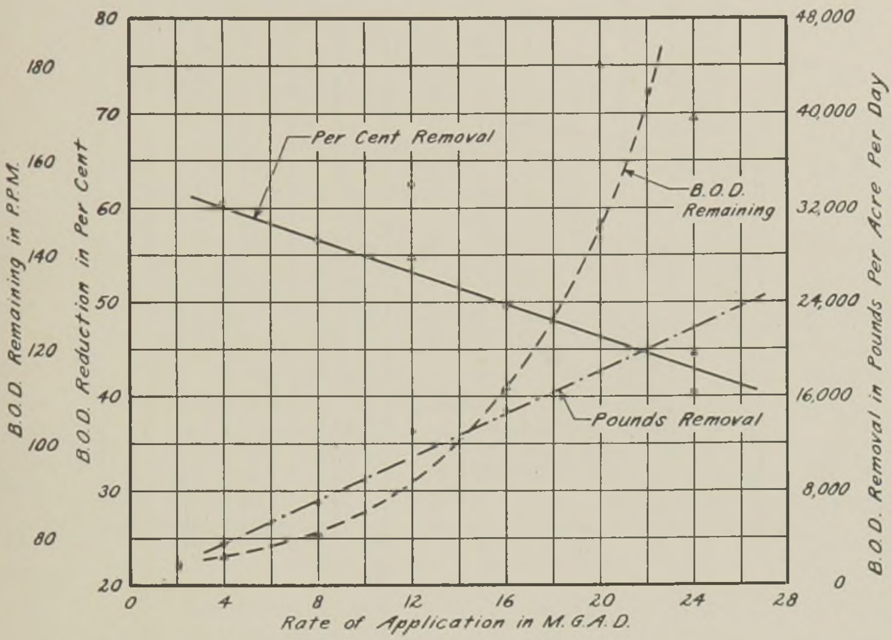

FIG. 6.—Results from the treatment of sewage at different rates of application without recirculation of the filter effluent.

though recirculation rates varied and treatment rates were different in each of the two series, the curves show the same trends. Purification increased as the number of recirculations increased until five recirculations were reached. As the number of recirculations was increased further, the rate of purification leveled off and dropped. It seems, then, that the number of recirculations is of vital importance, and that it has a greater effect upon filter operation than either treatment rate or recirculation rate. Also, it is apparent that optimum purification for this particular waste occurs when the waste is recirculated five times. The decrease in purification that results when the number of recirculations is reduced below five has also been shown previously in Fig. 4.

Treatment Time.—A series of runs was made in which all factors except the total time of treatment were kept constant. The results have been plotted in Fig. 7. Because of great variations in the initial B.O.D. values of the sewage, the curve in Fig. 7 is at best only an approximation of the amounts of purification which would have been obtained if the initial strengths had been the same. It seems, though, that as the treatment time was increased up to one to two hours the amount of purification increased rapidly, and that beyond two hours purification advanced only slightly. For treatment times of one to two hours the average reduction in B.O.D. was about 80 to 82 per cent and for six hours treatment the reduction was around 87 per cent.

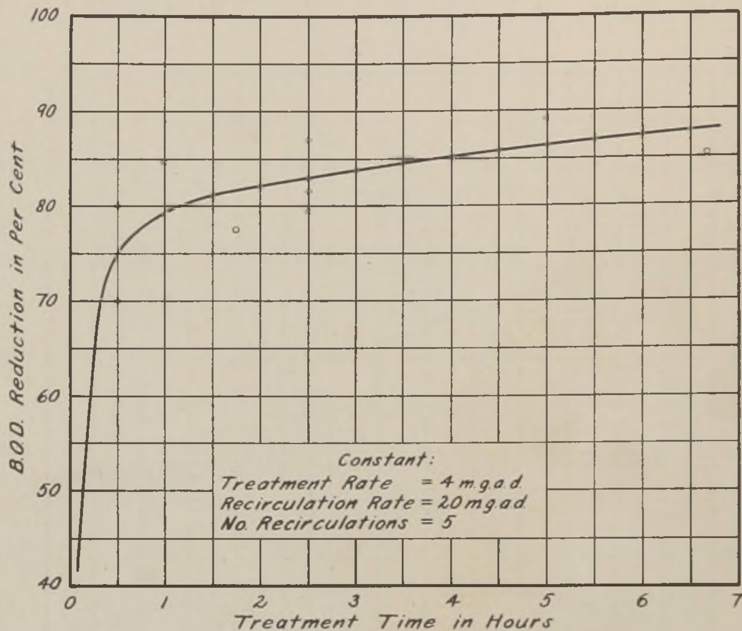

FIG. 7.—Per cent reduction in B.O.D. vs. treatment time.

Dissolved Oxygen.—Early in this study it was found that maintenance of dissolved oxygen in the recirculating material was of fundamental importance. Results of runs made under identical conditions could not be duplicated unless dissolved oxygen was maintained during both.

Throughout this work all other comparisons and curves have been made from runs in which dissolved oxygen was present in the detention tank. In some runs it was necessary to pump small quantities of air through the material in the detention tank in order to maintain dissolved oxygen.

The effect of dissolved oxygen upon purification is shown in Fig. 4, in which the results of two series of runs have been plotted. In each run of one series, dissolved oxygen was present in the detention tank, while in each run of the other series, dissolved oxygen was not present. Except for dissolved oxygen, all other factors in comparable runs of each series were kept as constant as possible. It is evident, then, that an absence of dissolved oxygen causes a decrease in purification.

The detrimental effect that lack of dissolved oxygen has on purification is shown also in Table II. The table presents the results of six groups of runs. The runs in each group were made under as nearly identical conditions as possible except for the factor of dissolved oxygen concentration.

TABLE II.—*Effect of Dissolved Oxygen upon B.O.D. Reduction*

Group Number	Per Cent Reduction in B.O.D. — D.O. Not Present	D.O. Present
1	61.5	73.6
2	72.0	81.5
3	56.0	81.2
4	54.8	75.0
5	44.8	63.4
6	76.4	85.0

Filter Run on a Continuous, Non-Recirculating Basis.—As already mentioned, one series of runs was made in which the filter was operated as a continuous trickling filter without recirculation of the filter effluent. Rates were varied from 4 to 24 m.g.a.d., and the results have been plotted in Fig. 6. The results show that a reduction in B.O.D. of 60 per cent was obtained at a rate of 4 m.g.a.d., and that the per cent reduction decreased as the rate of treatment increased. The results also show that the pounds of B.O.D. removed increased, but that the B.O.D. of the effluent became progressively worse as the treatment rate, or load applied to the filter, increased.

Discussion

The action of a biological filter is explainable from a consideration of underlying principles. According to Metcalf and Eddy (2), filter purification is a "contact phenomenon," and is accomplished by changes in the film concentration of the sewage, adsorption, and the activity of organisms and their enzymes. It is evident, then, that the degree of purification obtained is largely dependent upon the time of contact between the sewage and the gelatinous film found in the filter bed. In a recirculating filtration process, the factors which affect the contact time and, therefore, the amount of purification, are the total number of times the sewage is recirculated, and the rate at which the sewage is put through the filter.

Some purification is accomplished in a recirculating filtration process by the action of the filter as a flocculator or colloider, and by seeding, which probably occurs along with other contact changes. Flocculent solids, which are washed from the filter bed, are returned continuously to the detention tank. In the method of recirculation employed in this work, these solids were not settled out but were recirculated. The recirculation of these solids together with the seeded sewage, then, resembled in some respects the action of the activated sludge process.

That purification is produced by seeding and recirculation of the flocculent solids discharged from the filter was demonstrated previously in the batch studies made on the treatment of sewage (1). In those studies it was shown that after sewage had been passed through the filter bed once, purification continued when the sewage was recirculated through piping which by-passed the filter.

Of basic importance in the operation of any biological process is the load applied to that process, which is measured by the initial strength of the waste. It was the aim in this work to eliminate the consideration of initial strength of waste as far as possible in order that the study of other variables might be facilitated. All runs in the same series were made on consecutive days or within as short a time interval as was feasible. Seasonal and even weekly and daily variations in the strength of sewage are encountered, and consequently, treatment results are affected. The B.O.D. of the sewage used in these experiments varied from 130 to 600 p.p.m., with an average around 200 p.p.m. In most runs the initial B.O.D. remained close to the average range, but in a few it varied considerably. Because of these variations in initial strengths of the sewage, the exactness with which interpretations may be made is limited. However, the trends and general effects of the different factors affecting recirculating filtration can be determined.

In Figs. 3 and 6 it is seen that a decrease in the per cent removal of B.O.D. is obtained when the rate at which the sewage is applied to the filter is increased. This is readily explainable by a consideration of contact time. It is obvious that as the rate is increased, the contact time is decreased, and, consequently, a decrease in purification is to be expected. In Fig. 3 both the treatment rate and the recirculation rate vary. However, by definition, recirculation rate is equal to the treatment rate multiplied by the number of recirculations. Since the number of recirculations was maintained constantly at five throughout all the runs plotted in Fig. 3, the recirculation rate is equal to a constant times the treatment rate, or, in other words, is merely a multiple of the treatment rate. Therefore, in Fig. 3, the variations in purification are due to changes in the rate of application, which may be expressed by either or both the treatment rate and the recirculation rate. A straight line has been drawn in Fig. 3 with the sole aim of indicating the trend, and with no attempt to maintain that the relation shown is a straight-line function.

Even though the per cent of B.O.D. removal decreased with increasing rates of treatment, the pounds of B.O.D. removal increased. If a waste of constant strength is treated, the rate of treatment is a measure of the load applied to the filter. The operation of ordinary trickling filters, as reported by other investigators (3, 4, 5), has shown that, in general, the removal of B.O.D. in pounds increases with increasing loads. The trend towards increased removal of B.O.D. in pounds with increased treatment rates is well established by the data in Table I and Fig. 6.

It is evident from Fig. 5 that maximum purification of the sewge used in this investigation was obtained at about five recirculations. Apparently the number of times the sewage is in contact with the filter media is of greater importance than the actual contact time. This is clearly demonstrated in Fig. 5. In both curves in Fig. 5, the recirculation rate varied in the same ratio as did the number of recirculations; for example, if the number of recirculations was doubled, the recirculation rate was also doubled. Since this was the case, the total amount of contact time was the same, regardless of the number of recirculations. However, there was definite improvement in purification as the number of recirculations was increased to five. Figure 4 also shows the decided increase in purification that resulted when the number of recirculations was increased to five.

It appears that biological purification in a filter is approximately unimolecular; that is, each time the sewage is passed through the filter bed the decrease in B.O.D. is proportional to the amount of removable material present. As the number of recirculations is increased, although the amount of material removed with each additional passage through the filter decreases, the overall or cumulative removal increases. This means that if there were no limiting factors, the ultimate B.O.D. removal would approach 100 per cent if the number of recirculations was increased sufficiently. The factor which limits filter efficiency appears to be the thickness of sewage film passing over the surfaces of the stones in the filter bed and its effect upon adsorptive and other phenomena at the contact surfaces. Obviously, the faster the rate at which sewage is applied to the filter, the thicker the film is, and the less efficiently contact changes can be accomplished. From this it can be seen that there are two opposing tendencies.

The results of these studies show that for this particular sewage the tendency toward increased removal is the greater up to about five recirculations. At this point the two tendencies are balanced and maximum purification is obtained. Beyond five recirculations the tendency toward decreased removal is the greater and there is a falling off in purification. Even though this trend is indicated by the results plotted in Fig. 5, the conclusion cannot be established with absolute certainty until further investigations have been made.

That five recirculations is about the optimum for the treatment of domestic sewage was also found by Jenks (6). Jenks stated further that maximum purification would probably be obtained at six to eight recirculations, and that beyond this maximum value biologic efficiency might be impaired because of the excessive rate of passage of the liquid through the biofilter bed.

In the treatment of industrial wastes having high B.O.D. values, the number of recirculations probably will have to be greater than for sewage alone. Because of the greater load, a larger number of contacts with the filter bed will be required for adequate purification. Another consideration is that of dilution of the material in the detention tank by return of the filter effluent. As the number of recirculations is increased the amount of effluent returned for recirculation is also increased, and therefore greater dilution is afforded for the raw, incoming waste. In the treatment of wastes which are toxic, or which have pH values or other characteristics detrimental to biological action, increased dilution will lessen the effects of these characteristics. Therefore, in such cases purification will be augmented by an increased number of recirculations.

Eldridge, in his studies on the treatment of milk wastes by recirculating filtration (7), obtained better purification with 8.3 recirculations than with 6.0 and 4.0. He also concluded that the number of times the waste was recirculated seemed to have a greater effect on the efficiency of the filter than did the loading, which he considered as a combination of the initial strength and rate of treatment. It appears that the results of his work bear out the conclusion that number of recirculations is most important. In Fig. 5 it has already been shown that the degree of purification was dependent upon the number of recirculations even though the actual contact time remained the same. Also, it has been pointed out in a comparison of Figs. 3 and 4 that changes in purification which are due to variations in the number of recirculations are greater than those which are due to variations in the treatment rate or the recirculation rate.

The number of recirculations required for maximum biological purification is not necessarily equal to the number at which it is most economical to operate. As the number of recirculations is increased pumping costs are also increased. Consequently, a point is reached beyond which any increase in purification due to increased recirculation is unwarranted by the additional cost of pumping. This is demonstrated in Fig. 5, which shows that near the top of the curves a considerable increase in recirculation produces only a relatively slight increase in purification. The economic limit of recirculation should always be the deciding factor in filter operation.

The total time of treatment is highly important in filter operation. As has been pointed out, the results of this study show that the amount of purification increases rapidly as the time of treatment is increased to one or two hours, and that beyond two hours the increase in purification is only gradual with increases in time. Jenks (6) found that most rapid increases in purification occurred within the initial one to two hours, but concluded that for complete treatment a period of recirculation from 4 to 6 hours would be required. Campbell (8) found that the maximum amount of purification occurred within the first two hours of treatment, and concluded that it would probably not be economical to recirculate sewage longer than this. In a previous study (1) on the treatment of sewage by the batch method, it was found that optimum purification was obtained with about 2½ hours treatment. It appears, then, that in the treatment of domestic sewage the economical time for recirculation is around 2 or 2½ hours. When industrial wastes are treated, treatment times may have to be higher than for sewage alone.

The maintenance of dissolved oxygen is essential for the operation of any aerobic biological process. The detrimental effect that absence of dissolved oxygen has on purification results has been demonstrated in Fig. 4 and Table II. Maintenance of dissolved oxygen in the recirculating liquor is affected by several factors and may be facilitated by control of some of these factors. One factor which greatly affects the dissolved oxygen content is that of temperature. Throughout these experiments, the maintenance of dissolved oxygen was a considerable problem during the summer months but offered practically no difficulties during the winter months. Obviously, the reasons for this are that water dissolves less oxygen at higher temperatures, and that oxygen is used at a faster rate in warm weather because of increased biological activity.

It does not appear that the difference between temperatures of air and sewage has any great effect on the dissolved oxygen content. Halvorson (9) noted that a temperature difference of 4° C. was necessary to cause an air current of 1 cu. ft. per sq. ft. per min., and suggested the use of artificial aeration when temperatures of air and sewage were approximately the same. However, in this work, temperatures of air and sewage were recorded every half hour, and it was found that differences in the two had little or no effect on the dissolved oxygen content of the liquor.

Dissolved oxygen is affected by the strength and oxidizability of the applied load. As the waste becomes stronger or more readily oxidizable, more oxygen is required and a residual oxygen content is more difficult to maintain.

It would seem that maintenance of dissolved oxygen might be facilitated, particularly in warm weather, by increasing the number of recirculations and thus increasing the amount of aeration. But it has already been shown that in the treatment of domestic sewage, optimum purification is obtained with about five recirculations. However, this optimum was determined from runs in which dissolved oxygen was present. Since dissolved oxygen is of such vital importance, it would seem that, when operating under conditions in which it is not present, the best procedure would be to increase the number of recirculations to the minimum points at which dissolved oxygen is present.

As stated above, a few runs were made during this work in which the filter was used as a high rate trickling filter without recirculation of the filter effluent. The filter was operated in this manner during fall weather; and the results are in close agreement with the following conclusions which Keefer and Kratz drew from their experiments with high-rate trickling filters at Baltimore (10):

1. There is no reason to believe that ponding will occur at any rate of flow from 6.5 to 30 m.g.a.d.

2. As the rate of flow increases, a gradual increase in the B.O.D. of the effluent and a decrease in nitrification can be expected.

3. Even at high rates of application (26 m.g.a.d.) a reduction of approximately 50 per cent of the B.O.D. of the influent to the filter can be expected in winter and 70 per cent or more in summer.

The highest rate at which sewage was treated when recirculation was not employed was 24 m.g.a.d. In the recirculation studies, sewage was applied to the filter at rates as high as 160 m.g.a.d., and even at such rates no difficulties with ponding were encountered. In Fig. 6 it is seen that with the non-recirculating filter a reduction in B.O.D. of about 45 per cent was obtained at a rate of 24 m.g.a.d. and that about 60 per cent reduction was obtained at 4 m.g.a.d. Also, it is apparent that the B.O.D. of the effluent increased as the rate of treatment increased.

Because of the effects of many variables, a comparison between the non-recirculating and recirculating filters is difficult. In one case in which the treatment rate was 4 m.g.a.d. and the filter effluent was recirculated twice, about 75 per cent reduction in B.O.D. was obtained. In another case in which the rate of treatment was 4 m.g.a.d. and the effluent was recirculated 5 times, about 90 per cent reduction in B.O.D. was obtained. Throughout the entire work, regardless of number of recirculations, treatment rate, time of treatment, and other factors, results obtained by the non-recirculating filter were never as good as those obtained when recirculation was employed.

From this and past studies on recirculating filtration, it appears that both the continuous and batch methods of operation are practicable for the treatment of sewage. However, the batch method is undoubtedly limited to small installations. Operation is necessarily more complex in the fill-and-draw process and a much larger holding tank capacity is required, involving the difficulty of keeping the sewage fresh. Still further, if the batch method is used, the filter receives a waste which is strong at the beginning of operation and which gets progressively weaker as operation is continued. On the other hand, the continuous process should be more efficient from a biological standpoint, because the filter receives a more nearly uniform waste throughout operation.

Summary and Conclusions

The treatment of domestic sewage on a continuous basis by the recirculating filtration process was investigated for the purpose of studying some of the fundamental factors underlying filter operation. The factors investigated were treatment rate, recirculation rate, number of recirculations, total time of treatment, and dissolved oxygen content of the recirculating material.

It was found that purification, as measured by per cent reduction in B.O.D., decreases as the treatment rate is increased, but that the pounds of B.O.D. removal increases.

Increasing recirculation rates decrease the time of contact between the sewage and the gelatinous film in the filter bed, and consequently, decrease the amount of purification.

The factor appearing to have the greatest influence on filter operation is that of number of recirculations. Maximum purification for this particular sewage was obtained at about five recirculations. When dissolved oxygen is absent from the recirculating material, it appears logical to augment aeration by increasing the number of recirculations to the minimum point at which dissolved oxygen can be maintained, or to supply oxygen by diffused air.

Total time of treatment is of vital importance in any biological process. The greatest rate of purification was obtained within the first one to two hours, and it appears that this is about the economical time limit for the treatment of domestic sewage.

Maintenance of dissolved oxygen is essential in the operation of a bio-filter. The dissolved oxygen content is affected by temperature of the air and sewage, strength of the applied load, and the number of recirculations, which is a means of aeration.

The results obtained by operating the filter as a high-rate trickling filter without recirculation of the filter effluent were never as good as those obtained by the recirculating filter.

Finally, it appears that both the continuous and batch methods of recirculating filtration are practical means for sewage treatment. The continuous method should prove to be more efficient biologically because it affords treatment of a waste more nearly uniform in strength.

Acknowledgment

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Stream Pollution

ACCELERATED REAERATION *

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The treatment of sulfite waste liquor by biochemical means presents a problem that can be comprehended more clearly by comparing the liquor to ordinary domestic sewage. It contains from 9 to 15 per cent of solids in solution and has a B.O.D. of 15,000 to 55,000 p.p.m. Average domestic sewage, on the other hand, contains less than 0.1 per cent total solids, 0.05 per cent of solids in solution, and has a B.O.D. of 150 to 250 p.p.m. A comparison of the B.O.D.'s gives the best idea of relative strengths and difficulty of treatment.

Another characteristic of sulfite waste liquor which makes it difficult to treat is its acidity. The pH of the concentrated liquor varies from 1.4 to 2.5 depending primarily on the cooking process. Ten to fifteen tons of hydrated lime per day would be required to neutralize the liquor (having a pH of 1.4) produced by a 100-ton pulp plant. This is equivalent to from fifty to seventy-five tons of lime per million gallons of concentrated liquor. Since it is necessary to neutralize the liquor before subjecting it to biochemical treatment, even this preliminary step in the process is seen to be a formidable one.

It should be obvious from the above that present methods of sewage disposal would prove excessively costly if pulp and paper plants were required to treat their wastes by these methods. A small plant would have to build and operate a disposal plant large enough for a sizeable city.

Because of the size and difficulty of the problem of treating this waste, another possible approach was investigated. All of the commonly accepted methods of disposal attempt to remove or reduce the oxygen demand of the waste liquor so as to make a corresponding reduction in the oxygen depletion of the receiving waters. An opposite approach would be to permit this depletion to occur through the natural biochemical process taking place in the receiving waters and then bring the dissolved oxygen content of the water up to any desired requirement by artificial aeration. Since this would be merely accelerating the natural process of reaeration which is taking place in the stream, the writer will call this artificial aeration of the stream "accelerated reaeration."

This aeration of the stream or other receiving waters should preferably be done at a point sufficiently removed in time of flow below the

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sewer outlet so that oxygen depletion has had time to approach critical values. Aeration at this point will have its maximum effectiveness and enough air could be added to insure an oxygen content sufficient to complete the oxidation of the waste or sewage to the required degree. Obviously this method of aeration would not be applicable to, or necessary for, short coastal streams except where tidal build-up of oxygen demand occurs.

The problem would thus involve the relative cost and effectiveness of adding a pound of dissolved oxygen as against that of removing a pound of B.O.D. Mechanical devices such as blowers and motors might be expected to have a higher efficiency than disposal plants. Blower equipment, also, is subject to more accurate control than are waste disposal processes, and is not subject to the varied and frequently obscure interferences so common at sewage disposal plants. A further advantage of letting the stream digest the sewage is that the requisite flora are always present, being replenished continuously by the washings from the soil.

Experiments were conducted to determine the amount of air required for replenishing the dissolved oxygen of sewage- and waste-polluted waters. The various formulas currently used for purposes of determining air absorption for various conditions were also consulted. Some of these are not in readily useable form for computing stream aeration problems. Experiments were run on water deoxygenated by passing it through iron filings, on water and sewage mixtures and on water and sulfite waste mixtures. While different results were obtained for different waters, absorptions as great as 40 to 50 per cent of the air used in 16 ft. depths at laboratory temperatures were obtained. Data available as to air absorption at activated sludge plants made these figures appear excessive. However, it should be kept in mind that methods of aerating sewage at such plants are not designed to give maximum oxygen absorption. The need for agitation and the production of currents as in spiral-flow tanks demands an air supply rate greatly in excess of that best adapted to efficient oxygen absorption. Dr. Sierp states that Dr. Imhoff has obtained 30 per cent absorption at Berlin by retaining the air in the sewage for a longer time by rotating paddle wheels in a direction against the rising bubbles. From 10 to 17 per cent absorption has been obtained at various places in this country. The present paper does not stress the quantitative values of air absorption given herein, except as indicating possibilities that may be attainable. Further experiments may indicate the presence of certain factors peculiar to these tests that may have been responsible for the high values obtained. However, most present data apply to oxygen absorption in relatively pure water. The accompanying figure gives the results of several test series. The deoxygenated water was aerated in a column 4 ft. in depth. The temperature was 21° C. As water contains 8.99 p.p.m. dissolved oxygen at this temperature, the air absorption can be easily computed from the curves in the figure.

Experimenters are not sure that oxygen added through aeration will result in equivalent reductions in B.O.D., though present evidence favors this assumption. The amount of air to be added, if this assumption is true, would be that required to balance the B.O.D. Assuming, for example, that a city of 10,000 population produces 1 m.g.d. of domestic sewage having a B.O.D. of 250 p.p.m.; 8300 lb. of oxygen must be furnished per day, assuming 25 per cent absorption. Air contains about 21 per cent of oxygen, so this would require 39,400 lb. of air per day, which, at 13.1 cu. ft. air per pound, would be 516,000 cu. ft. of air daily. This amounts to 0.5 cu. ft. of air per gallon of sewage. Comparing this with the 1.0 to 2.0 cu. ft. of air per gallon used at activated sludge plants, it appears that the air consumption for accelerated reaeration would be less than that for activation. It is unnecessary, perhaps, to state that the former is not a method of oxidation but that the air replaces that used up from the stream by the natural oxidation processes of the latter. However, comparisons of air requirements will give some idea of relative costs, especially as the necessary construction would probably be simpler and less expensive.

The above quantity of air would require 358 cu. ft. per min., which, at usual efficiencies, would require about 12 to 15 horsepower to furnish. Absorption efficiencies as low as 6 to 12 per cent would give air consumption equal to that used in activated sludge practice.

Increased efficiency of air absorption can be obtained by decreasing the bubble size. There would be no objection to decreasing the size of bubble below the critical diameter and thus greatly extending the time of contact and the absorption efficiency, except where it was proposed to use diffuser plates along the sides of a stream and to produce spiral flow in the stream, thus aerating the entire water volume without obstructing the channel with structures. Here bubble velocities equal to those in aeration tanks would be required. Where diffusers could be located across channels, the smallness of bubble would be limited principally by considerations of efficient use of power. Since the pressure loss, and therefore the power requirement, for supplying a given quantity of air through diffusers, varies inversely with the permeability, there is a practical limit to the reduction in size of voids and therefore of bubbles. Nordell secured high oxygen absorption with bass-wood block diffusers in 1916, but practical difficulties prevented the use of wood for diffuser plates. Very little data are available on minimum limits to bubble size, since low pressure loss through diffusers is desirable in aeration tanks as currently designed, and it has not been advantageous to develop diffusers having very small voids. The possibility of using finer grained and thinner plates for stream aeration might be explored with profit.

Accelerated reaeration is not proposed as a panacea for all stream pollution problems, but it appears to be one other method to be considered in cases where conditions make it appear feasible. Primary settling is necessary, of course, in any case where it is desired to prevent the formation of sludge banks with their accompanying high oxygen demand. Chlorination is likewise required where sterilization is desired. Accelerated reaeration might be considered as a method of secondary treatment where the stream is the last unit of the disposal plant and aeration is used as a last step for adjusting the oxygen content of the stream to satisfactory values. It should be particularly applicable to those cases where the primary objection to a low oxygen content arises from its detrimental effect on fish life or the production of nuisances. In the Pacific Northwest, this is an important factor, as is also the case in many other parts of the country.

Discussion of this proposal should be especially opportune during the present emergency when such vast and sudden increases in B.O.D. loadings are occurring with the influx of defense workers or industrial plants into various defense areas. Primary treatment, chlorination and accelerated reaeration offer a possible solution to some of these problems, which would prevent investment of unnecessarily large federal and local funds in disposal plant capacities that will not be needed after the emergency has passed. Such a plant could be easily expanded by adding more diffusers so that installations need not be built for larger than present requirements, thus obviating the necessity for large present expenditures for hypothetical future requirements. Recent census figures only too clearly indicate the advantage of plant types that can be built for present needs because of ease of making future expansions. Population trends have changed abruptly in many areas. Those engineers responsible for the design of sanitary facilities predict future populations less confidently now than they did a few years ago. Assuming an installation consisting of the required number of rows of diffuser plates along each side of a stream with units located at any desired intervals along the stream, it should be a comparatively simple matter to extend the diffusers and add blowers when and if desired.

The engineering and practical construction problems incident to installing stream aeration plants might become a limiting factor in some cases. Methods of aerating navigable streams and channels would have to conform to restrictive regulations of the War Department which would limit the application of the process. The ingenuity of engineers to meet such situations may be confidently trusted if further experiments check the speaker's findings with reasonable closeness and indicate the feasibility of the method.

Those agencies responsible for safeguarding the purity of streams and other waters will naturally prefer methods which keep polluting materials out of streams as against those which counteract the influence of those materials after they have been discharged into the stream. But there are many streams which are already badly polluted where accelerated reaertion would be a possible means of returning them to useful purposes. There are many cases also, where the primary objection to a low oxygen content consists in its detrimental effect on fish life or because of the nuisance produced. Research into the possibility of treating such cases by the proposed method would undoubtedly receive the approval of federal and state officials.

In 1933 I inspected two large reservoirs which Dr. Imhoff had constructed on the Ruhr River, Germany, to furnish additional time of flow and area of water surface for increasing the natural reaeration of the river, thus obviating much needed expansions in existing disposal plant facilities serving the numerous industrial areas along the Ruhr. The U. S. Public Health Service and various others have carried out experiments for determining the amount of oxygen absorbed by water surfaces under varying conditions met with in practice; but apparently little work has been done on the amount of oxygen that can be supplied by bubble aeration. One purpose of presenting this preliminary discussion of accelerated reaeration is to invite the publication of any available data not heretofore published. Imhoff and Fair call attention to the possibility of aerating the sewage and/or the water in a stream at the sewer outlet, if the dissolved oxygen is low. This would aid in some cases, but would be inadequate in those cases where the pollutional load was large with respect to the stream flow, as the amount of oxygen which the water could carry, even at saturation, would be inadequate to care for more than a part of the B.O.D. Aeration downstream, after oxygen depletion has occurred, and at several points if necessary, offers greater possibilities for handling large pollutional loads. The stream is part of the disposal plant or plants located along its course and is a very effective part. With the meager data available, it would doubtless be more economical and equally effective to add oxygen to the stream than to remove oxygen demand in the polluting materials being discharged therein.

RARITAN RIVER POLLUTION STUDIES *

COMPARISON OF RESULTS OBTAINED IN 1927–28, 1937–38, 1940–41

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The lower Raritan River has been subject to investigations regarding the type and degree of pollution over a period of years. Studies made in 1927–28 (3) indicated the condition of the river when, with two exceptions, no sewage or industrial waste treatment existed. The results obtained during 1937–38 (4) showed the condition of the river after practically all the domestic sewage and some industrial wastes discharged in the municipal sewer systems reached the river after treatment. The studies made during 1940–41 were designed to show the effect of treatment of wastes discharged by a number of the larger industries on the general character of the stream and its main tributaries.

Stream pollution studies are frequently made before pollution abatement, but are rarely continued after remedial measures have been taken. On account of the density of population and complexity of the problem, the measures taken in the lower Raritan River basin have been gradual. Perhaps the most difficult part of the problem has been, and in part still is, for the various industries to adopt treatment processes for their specific wastes. A number of the larger industries involved, discharging many millions of gallons of wastes daily, have spent considerable sums of money in the development of treatment processes. In several industries entirely new methods have been or are being developed to treat adequately the complex wastes. Inasmuch as scientific results on general pollution abatement of a whole stream, polluted by a number of municipalities and various large industries, and where the abatement has progressed in a series of steps, have not been available, a comparison of the principal results obtained appears to be of general as well as state or local interest.

Raritan River and Its Main Tributaries

The Raritan River system is the largest in New Jersey, except that of the interstate Delaware, with a drainage area of 1,105 square miles. The tributaries of the Raritan do not combine until they reach points within about seven miles from tide water or in the tide water basin itself. The river is tidal to a point about two miles above the city of New Brunswick and is navigable to that city.

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The upper part of the river drainage system lies in the hills and the physiography of the territory changes until the lower part of the river runs through low and marsh land into Raritan Bay.

The South Branch is 42 miles long and drains 277 square miles. The North Branch has a drainage area of 192 square miles. The Raritan River proper is formed by the union of the North and South Branches near the town of Raritan. At Manville the drainage area is 490 square miles. The Millstone River flows into the Raritan below Manville; it is 35 miles long and has a drainage area of about 300 square miles. Green Brook has a drainage area of 49 square miles and receives the effluent from the Plainfield Joint Meeting Sewage Treatment Plant. Lawrence Brook has a drainage area of 45 square miles; the water is impounded for the water supply of New Brunswick. South River drains an area of about 95 square miles at Old Bridge, entering the Raritan River section subject to tide.

The waters of the Raritan River and tributaries are soft, having a low mineral content, are normally clear, except during and after rains, when considerable quantities of fine shale, silt and clay are carried.

The population of the entire Raritan River watershed is about 325,000, according to the 1940 U. S. Census. The lower section of the Raritan River Valley has a large urban population, while the upper section of the drainage area is mostly rural. The population of the lower Raritan drainage area is about 255,000. Growth in population in the entire watershed was very rapid during the period 1900–1930, amounting to 20.9 per cent between 1900–1910, 29.4 per cent between 1910–1920 and 29.1 per cent between 1920–1930, but comparatively slow between 1930–1940, amounting to less than 5 per cent. In the lower section growth of population was rapid during the period 1900–1930, but very slow during the period 1930–1940. The combined population of the highly industrialized communities contributing sewage and wastes to the lower sections of the river remained nearly stationary during the latter period. The population of 15 municipalities in the lower section was 154,184 in 1940. On account of the greatly increased industrial activity since 1939 the population in many of the communities has again increased rapidly.

Stream Flows

The volume of water in the Raritan proper and its tributaries varies greatly.* The daily mean discharges of the Raritan and Millstone Rivers for the different months of the surveys in 1927–28, 1937–38 and 1940–41 are shown in Table I. The periods May–October are considered "summer," while the periods November–April are designated as "winter." These periods are designated on the basis of water temperatures and stream conditions rather than upon the calendar. The

* Through the courtesy of Mr. O. W. Hartwell, District Engineer, U. S. Geological Survey, Trenton, N. J., the original data on stream flows of the North Branch, South Branch, Raritan River at Manville, Millstone, Green Brook and South River were secured for the period of sampling during the different years.

Table I.—*Daily Mean Discharge in Cu. Ft. Per Second of Raritan River (Above Manville) and Millstone River, 1927–28, 1937–38 and 1940–41, During the Months of the Surveys*

1927–28

Month	Raritan	Millstone	Total
March	748	317	1065
April	456	237	693
May	624	185	809
June	345	185	530
July	410	355	765
Aug.	1210	634	1844
Sept.	554	229	783
Oct.	554	146	700
Nov.	1370	550	1920
Dec.	989	550	1539
Jan.	1130	502	1632
Feb.	1190	643	1833

1937–38

Month	Raritan	Millstone	Total
May	711	281	992
June	323	212	535
July	287	118	405
Aug.	512	228	740
Sept.	205	127	332
Oct.	365	226	591
Nov.	1036	507	1543
Dec.	672	333	1005
Jan.	1094	514	1608
Feb.	962	544	1506
March	859	434	1293
April	690	323	1013

1940–41

Month	Raritan	Millstone	Total
Nov.	967	507	1474
Dec.	1141	548	1689
Jan.	845	532	1377
Feb.	1146	568	1714
March	1140	646	1786
April	850	426	1276
May	219	161	380
June	215	203	418
July	288	563	851
Aug.	183	121	304
Sept.	51.2	43.8	95
Oct.	64.8	43.9	108.9
Nov.	157	133	290
Dec.	472	289	761

total daily mean discharge during the 1927–28 period varied from 337 to 1,223 m.g.d., in the survey 1937–38 from 212 to 1,070 m.g.d. and during 1940–41 from 60.5 to 1,143 m.g.d. The daily mean and winter and summer average discharges for the three surveys, together with the percentages of the total discharged during winter and summer, are given in Table II.

Table II.—*Daily Mean Discharges for Sampling Periods and Summer and Winter Discharges of the Raritan and Millstone Rivers*

Period	1927–28		1937–38		1940–41	
	C.F.S.	M.G.D.	C.F.S.	M.G.D.	C.F.S.	M.G.D.
Average for period	1176	759	959	620	895	579
Average winter	1420	917	1391	900	1296	839
Average summer	905	586	599	386	359	232
Minimum flow	195	126	161	104	57	36.7
% winter of total	61.5		65.9		81.2	
% summer of total	38.5		34.1		18.8	

It is evident from the figures that the average stream flow was about 18 per cent lower during the period 1937–38 as compared with 1927–28 and more than 23 per cent lower during the survey of 1940–41. The summer flows in 1937–38 period were 34 per cent less and in 1940–41 period, 60 per cent less, than in the summer of 1927–28. During the survey of 1940–41 the average summer flow was about 40 per cent less than during the survey of 1937–38. The lowest flow on a single day on record since 1923 of the combined Raritan and Millstone flows occurred during the 1940–41 survey. During the same period other tributaries showed also very low flows. The low flow period extended over a considerable time during the months of September–October, 1941. For comparison the monthly average daily mean flows, the cumulative average daily discharges during summer and winter and the cumulative average daily discharges for the three different surveys are graphically shown in Fig. 1. It is of interest that the cumulative dis-

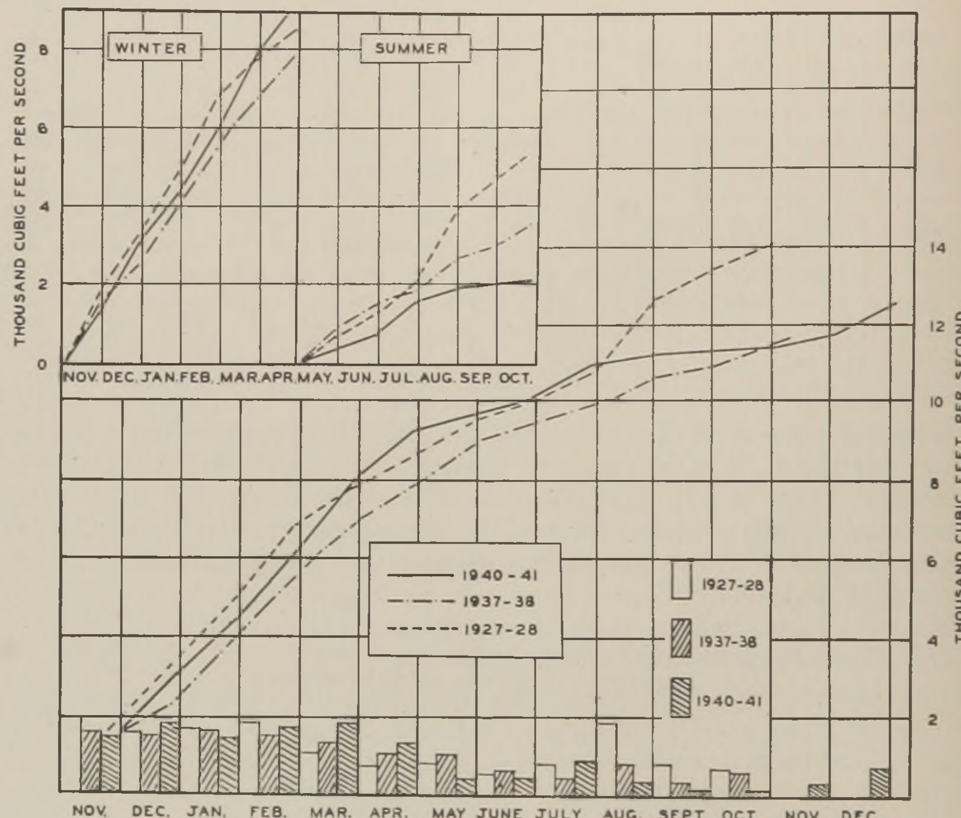

FIG. 1.—Comparison of the monthly average daily mean flows and cumulative average daily discharges and the cumulative summer and winter discharges for the three survey periods.

charges during the three surveys do not greatly differ. The cumulative mean winter discharge in the 1940–41 survey falls between the 1937–38 and 1927–28 values. However, there is a pronounced difference between the cumulative daily mean summer discharges in the three surveys. It would appear, therefore, that any material subject to settling present in the river would not be greatly influenced during the winter periods, but the settling may be pronounced during the different summer sampling periods.

Sampling Stations

The various sampling stations used during the three surveys had originally been located, as far as practicable, in such a way that larger sewer outfalls and tributaries had a minimum disturbing effect on the water samples to be taken. The distances below the larger sewer outfalls were sufficient to allow considerable mixing with the river water or close enough to permit taking samples before the influence of the

TABLE III.—*Location of Sampling Stations Along River and Tributaries*

No.	Place	Location	Tributaries	Aver. Depth of Sample Taken, Feet	Velocity of Flow, Channel, etc.
1	South Branch	Bridge at village of South Branch		2	Medium swift flow, channel shallow
2	North Branch	Steel bridge over North Branch about 5 miles above town of Raritan		2	Medium swift flow, channel shallow
3	Manville	Bridge across Raritan on state highway between Finderne and Manville		2	Ordinarily swift flow, shallow channel
4	Millstone River	Bridge above dam at Weston	Millstone River	3	Slow flow, shallow channel
5	Green Brook	State highway from Plainfield to Easton over Green Brook at Bound Brook	Green Brook	2	Medium swift flow, shallow stream receives effluent from Plainfield sewage disposal plant
6	Bound Brook Bridge	Bridge over Raritan between Bound Brook and South Bound Brook		3	Fairly swift flow, shallow channel
7	Raritan Landing	Bridge across Raritan		3	Fairly swift flow, shallow channel, about 2½ miles below Five-Mile Dam, subject to tide
8	New Brunswick	About ½ mile below entrance of Delaware and Raritan Canal on south side of river		6	Swift flow, deep channel, subject to tide
9	Sayreville	Raritan River opposite Raritan Arsenal south side of river	¼ mile below South River entering	6	Swift flow, deep channel, subject to tide
10	Perth Amboy	Raritan River Victory Bridge		18	Deep channel, subject to tide
11	Old Bridge	Bridge across South River about ¼ mile below village of Old Bridge	South River	4	Slow flow, shallow channel
12	South River	Bridge across South River on highway leading from South River to Matawan	South River	11	Near mouth of South River, sluggish flow, deep channel

sewage discharged would be significant. The locations of the sampling stations are indicated by arabic numbers on the map (Fig. 2). A condensed description of the locations of the sampling stations is shown in Table III.

Since the first survey, a number of sewage treatment plants have been built and are in operation. The treatment plants along the Rari-

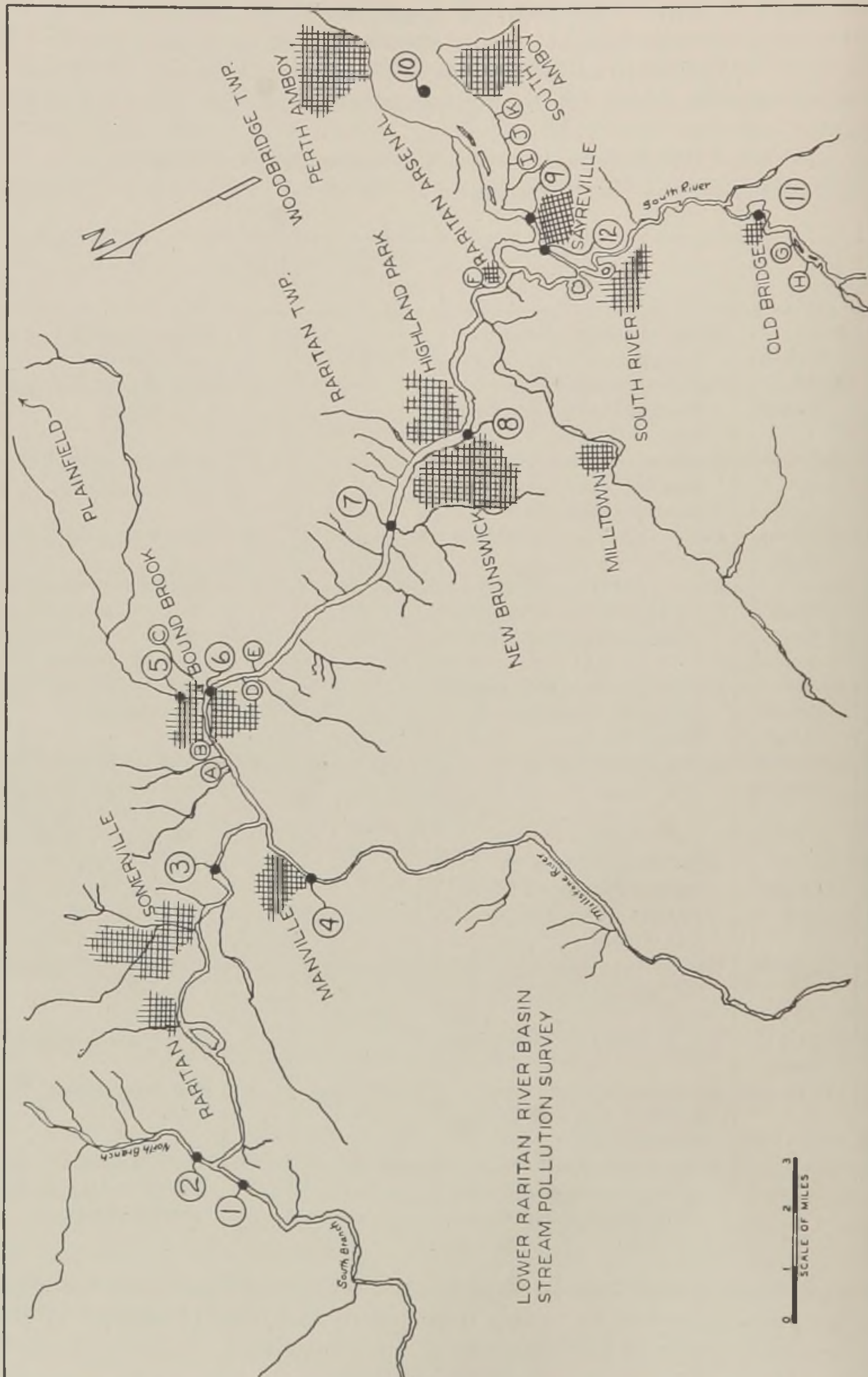

FIG. 2.—Map of lower Raritan River, indicating location of sampling points, treatment plants and major industries.

tan, together with brief statements regarding the treatment processes employed, are described in Table IV. The locations of the treatment plants are indicated by Roman numerals on the map. All these sewage treatment plants, with the exception of the Joint Plainfield plant, have been built since the first survey, while nearly all were in operation during the second survey. The Joint Plainfield plant, although not on the

TABLE IV.—*Sewage Treatment Plants Along the Raritan River*

No.	Municipalities	Treatment Processes
I	Raritan	Scr., floc., chem. tr., settl., straining, chlor., sl. dewater., incineration
II	Somerville	Scr., floc., chem. tr., settl., straining, chlor., dewatering
III	Manville	Settl., trick. filt., sec. settl., chlor., sl. drying
IV	Bound Brook	Scr., floc., chem. tr., settl., chlor., digest., sl. drying
V	Middlesex Borough	Scr., floc., chem. tr., settl., chlor., digest., sl. drying
VI	New Brunswick	Scr., floc., chem. tr., settl., chlor., digest., sl. dewatering
VII	Highland Park	Scr., settl., chlor., digest., sl. drying
VIII	Raritan Township	Scr., settl., chlor., digest., sl. drying
IX	Raritan Arsenal	Sed. and chlor.
X	South River	Scr., grit remov., floc., chem. tr., settl., straining, chlor., sl. dewatering
XI	Sayreville	Scr., grit. remov., floc., chem. tr., settl., straining, chlor., sl. dewatering
XII	Woodbridge	Sed., settl., straining, chlor., digest., sl. drying
XIII	Perth Amboy	Scr., floc., chem. tr., settl., straining, chlor., sl. dewatering
XIV	Plainfield	Scr., settl., trick. filtr., sec. settl., chlor., digest., sl. drying

main stream, has been included because the plant treats a relatively large volume of sewage from four municipalities and the effluent reaches the Raritan within a comparatively short time. Several other treatment plants located on tributaries to the Raritan proper have been constructed or improved since the first survey but are not indicated on the map or mentioned in the table.

The major industries discharging wastes directly into the Raritan and South Rivers are given in Table V. They are given in the order of location along the streams. The locations of the industries are in-

TABLE V.—*Major Industries Discharging Wastes Directly into the Raritan River*

No.	Industry	Waste	Treatment
A	Calco Chemical Co.	Chem.	Sed., chem. tr., lagoons
B	Sherman Williams	Chem.	Sed. in lagoons
C	Bakelite Corp.	Chem.	No treatment (experimenting)
D	Rubberoid	Chem.	No treatment
E	Pathe Lab., Inc.	Chem.	Chlorination and lime
F	Nixon Nitration Works	Chem.	Sed. and land treatment
G	Schweitzer	Paper	No treatment (experimenting)
H	Anheuser Busch	Yeast	Pilot plant (experimenting)
I	Hercules Powder Co.	Chem.	No treatment (experimenting)
J	Dupont Parlin Pl.	Chem.	No treatment (experimenting)
K	Titanium Pigment Corp.	Chem.	No treatment

dicated on the map by letters. The table shows the type of treatment, if any, by which the wastes are treated.

As indicated previously, the Raritan is subject to tide water to a point between sampling Stations 6 and 7. However, the river at Stations 7 and 8 is subject only to fresh water backing up, while the river at Stations 9 and 10 is subject to salt water encroachment. Depending upon the stage of the tide, the chloride content of the river water at Stations 9 and 10 varies between 200 and 14,000 p.p.m., as compared with the normal 6 to 10 p.p.m. chloride in the river water at Station 3.

The lower section of the South River (Station 12) is also subject to tide, while the upper section (Station 11) occasionally shows some salt penetration.

Sampling and Methods of Analyses

Water samples for chemical and bacteriological analyses were taken at intervals throughout the years when the surveys were conducted. Chemical analyses consisted principally of determinations of alkalinity, acidity, pH, ammonia, nitrites, nitrates, suspended solids, ash of suspended solids, dissolved oxygen and biochemical oxygen demand. The bacteriological determinations included total organisms, coliform organisms and confirmation of *E. Coli.* In addition, observations were made on the temperature of the water, color, floating solids, oils, grease, foam and other visible conditions of the streams.

Dissolved oxygen was determined at the sampling stations.

Samples were collected with a standard heavy brass apparatus, while the methods of analyses were in accordance with the "Standard Methods" of the A. P. H. A. For estimation of the probable number of *E. Coli* in a given sample McGrady's tables (2) were used.

Results 1940–41

The data presented in this paper are restricted to the yearly, winter and summer averages of chemical and bacteriological results obtained, while special emphasis is placed on the dissolved oxygen, B.O.D. and *E. Coli.*

The average yearly results are shown in Table VI. It will be noted that the average acidity in the river above tide water is low, gradually increasing downstream. The Millstone River has little effect, but the South River affects the acidity of the Raritan considerably in spite of the increased salt concentration. This is clearly indicated by the average pH values and total acidity in the South River at the confluence with the Raritan and at the Sayreville sampling station. Similar variations and effects are indicated by the average ammonia figures, while particular attention is called to the nitrates present in the river and tributaries. The rather high nitrate content of the Green Brook is caused by the oxidized sewage effluent from Plainfield, while the high nitrates in the lower part of the South River are caused by industrial wastes (nitric acid).

TABLE VI.—*Yearly Average Results of Chemical and Bacteriological Analyses of Raritan River and Tributaries, 1940–41*

Location	Temperature	pH	Suspended Solids	Acidity [1]	Alkalinity [1]	Chlorides	Ammonia Nitrogen	Nitrite Nitrogen	Nitrate Nitrogen	Dissolved Oxygen	Dissolved Oxygen Saturation	B.O.D.	Total Bacteria [2]	Coliform Organisms: Presumptive	Coliform Organisms: Confirmed
	°C.		P.P.M.	P.P.M.	P.P.M.	P.P.M.	P.P.M.	P.P.M.	P.P.M.	P.P.M.	%	P.P.M.	Per c.c.	Per c.c.	Per c.c.
1. South Branch	14.3	7.5	15.8	2.2	50.5	19.7	0.11	0.011	0.51	9.6	88.7	1.5	4.7	14.0	7.8
2. North Branch	13.4	7.6	8.1	1.9	50.1	6.9	0.09	0.007	0.33	9.7	88.0	1.5	2.5	9.5	5.0
3. Manville	14.4	7.5	12.6	2.6	44.6	8.0	0.26	0.020	0.49	8.9	80.7	2.0	8.5	116.1	102.0
4. Millstone River	14.3	7.4	13.4	3.2	29.7	8.0	0.17	0.017	0.63	9.0	83.9	1.6	2.7	36.8	28.0
5. Green Brook	14.2	7.2	9.2	7.4	67.2	27.8	1.97	0.167	2.20	6.9	64.1	5.8	26.9	2026	1904.0
6. Bound Brook	14.7	7.0	15.0	8.3	43.9	57.7	1.45	0.045	0.69	6.4	55.6	14.6	30.9	859	98.0
7. Raritan Landing	14.9	7.0	13.2	7.3	43.5	46.0	1.36	0.063	0.64	5.9	47.8	13.2	73.5	2028	1062.0
8. New Brunswick	16.1	7.0	17.0	8.4	37.2	558	1.79	0.072	1.10	5.5	47.5	9.2	94.1	3780	904.0
9. Sayreville	15.7	6.2	25.7	16.0	21.3	5280	1.07	0.075	3.70	6.0	57.9	4.0	6.1	81.7	33.1
10. Perth Amboy	16.1	6.6	23.2	11.9	53.9	10450	0.68	0.060	1.40	7.0	75.0	2.6	3.5	31.7	15.2
11. South River at Old Bridge	17.5	6.5	21.4	16.9	14.5	487	1.57	0.029	1.50	6.5	63.3	13.9	43.7	2285	2035.0
12. South River before confluence with Raritan	17.8	3.9	23.8	52.1	4.4	4245	1.31	0.073	7.30	4.6	43.6	4.1	4.6	133.0	12.4

[1] As $CaCO_3$.
[2] 5-day nutrient agar counts in thousands per c.c.

B.O.D.—The yearly average B.O.D. of 1.5 p.p.m. for the North and South Branches of the river may be considered normal for this river. The same holds for the Millstone. The yearly average B.O.D. of Green Brook, which receives a considerable volume of treated sewage effluent, is several times higher than that of the Millstone, while the upper portion of the South River had a yearly average B.O.D. value very much higher than that of the other tributaries mentioned.

Near the mouth of the South River, after the wastes of a number of factories and the effluents from the South River and Sayreville sewage treatment plants are discharged, the average p.p.m. B.O.D. was less than one-third of that at Old Bridge. This apparent reduction is due to the dilution received and the effect of tide water.

The yearly average B.O.D. results of the Raritan proper at Manville, below the towns of Raritan and Somerville, was only slightly higher than of the North and South Branch. The increase in B.O.D. can be considered as the total effect of the sewage plant effluents discharged by the towns of Raritan and Somerville.

Progressing downstream for about four miles, the B.O.D. of the river increased rapidly from a yearly average of 2 p.p.m. at Manville to 14.6 p.p.m. at Bound Brook. This section of the river receives the effluent of industrial waste treatment plants. After the Green Brook enters the Raritan, the sewage plant effluents from Bound Brook, South Bound Brook and Middlesex Borough and the untreated wastes of some industries, the river passes over a dam about 6 feet high, which provides for considerable reaeration of the stream. The dam is located about 2 miles above the sampling station at Landing Bridge. In spite of the discharge of various effluents, the yearly average B.O.D. at Landing Bridge was somewhat less than at the Bound Brook sampling station, probably due to the reaeration during about 4 miles flow and the dam. All individual samples taken show lower results at the Landing Bridge no matter the stage of tide in the river.

The dilution factor becomes increasingly greater farther downstream, either by backing up of fresh water or dilution with salt water. Consequently, the B.O.D., expressed in p.p.m. reduces rapidly.

Dissolved Oxygen.—The yearly average dissolved oxygen saturation in the North and South Branches was 88 and 88.7 per cent, while the Millstone River showed an average of about 84 per cent dissolved oxygen saturation, Green Brook about 64 per cent and about the same in the upper part of the South River. Near the confluence of the South River with the Raritan the average dissolved oxygen concentration was reduced to 43.6 per cent of saturation in spite of the greater dilution.

The percentage D.O. saturation in the Raritan proper at Manville was about 8 per cent less than in the North and South Branch, amounting to about 81 per cent. This was reduced rapidly in the river between Manville and Bound Brook to 55.6 per cent and decreased further to 47.8 per cent when the Landing Bridge station was reached. During the extreme low river flow in September, several days' samples were collected at the Bound Brook and Landing stations which contained zero dissolved oxygen, with only traces of oxygen found below New Brunswick. No further deterioration nor material improvement occurred in the section of the river where the sewage effluent from the New Brunswick plant is discharged, in spite of the effect of tide water. Farther downstream the dissolved oxygen saturation increased gradually to 75 per cent below Perth Amboy, where the effect of the salt water dilution is greatest and the river reaches the Raritan Bay.

Bacteria.—The total number of bacteria (plate counts) and *E. Coli* estimations at the North and South Branch sampling stations were consistently and relatively low during the year. The total numbers of bacteria averaged somewhat lower in the Millstone, whereas the average *E. Coli* numbers were higher than in the North and South Branch. The samples from Green Brook varied greatly in total numbers of bacteria and *E. Coli.* The latter varied in individual samples from 6 to 25,000 per c.c., the majority of the high numbers occurring during the winter period. High numbers of organisms occurred also in the samples obtained from the upper part of the South River, varying from an estimated number of 60 to a maximum of more than 11,000 per c.c. Here, the higher numbers occurred during the summer season. The average numbers of total organisms and *E. Coli* in the lower section of the South River was only a fraction of the number of organisms found in the upper section.

At the Manville station of the Raritan, fluctuations of numbers of *E. Coli* were greater and the counts materially higher than in the North and South Branch of the river, while the average numbers at the Bound Brook station were approximately the same as at Manville, but the fluctuations during the year were much less. No municipal sewage treatment plant is located between these sampling stations. Discharges from industrial waste treatment plants in this section have apparently no deleterious effect on the *E. Coli* numbers in the river, but probably prevent increases. The average *E. Coli* numbers at Landing Bridge sampling station indicate a rapid deterioration of the river. During most of the year the numbers were persistently high. The high numbers may be attributed to raw sewage, discharged by part of New Brunswick, the very incompletely treated sewage of a large industry, the relatively high bacteria numbers in Green Brook, and the effluents from two municipal sewage treatment plants. In spite of the increased dilution the average numbers of *E. Coli* below New Brunswick were but slightly lower than the average numbers above New Brunswick. With the increase in dilution the organisms per unit of water decreased rapidly, until below Perth Amboy the numbers were only slightly higher than in the North and South Branches of the river.

Comparison of Winter and Summer Results

Self-purification of a stream takes place throughout the year, but is considered to be greater during the summer. The period in which the 1940–41 survey was conducted was marked by a prolonged absence or low rainfall and subsequent low flow of the river and tributaries.

The low flow in the Raritan and main tributaries extended from May to November, but was particularly acute during September and October, 1941. The May–October period has been designated as "summer" and the November–April period as "winter." A comparison of the results obtained during these two periods should give an indication of the combined effects of higher water temperatures and lower flows observed during the summer. The average chemical and bacteriological results recorded during the summer and winter are presented in Table VII.

The average pH values of the river water and its tributaries were higher during the summer than in winter; the same held for the total alkalinity of the water in the upper section of the river, but varied in the lower section in relation to the amount of dilution caused by salt water. Of particular interest are the low pH values recorded during the winter and summer seasons in the South River. Large volumes of spent acids are discharged into the South River by industries.

With the exception of Green Brook and the upper part of the South River the average amount of nitrates found was greater during the winter than during the summer, indicating a lower degree of oxidation in summer. Since the temperature of the water is higher in summer it would be expected that the degree of stabilization of nitrogenous material would be higher. It is highly probable that the materially lower flow in summer, amounting to an average daily mean of 359 c.f.s. in the Raritan and Millstone, as compared with an average daily mean of 1,296 c.f.s. during the winter period, was responsible for these unusual results. In spite of the low flow, which usually tends to cause deposition, the suspended solids concentration in the river and tributaries was materially higher in summer, with the exception of that part of the river below New Brunswick subject to tide. However, although the concentration of suspended solids was greater, the total quantity was less than in the winter. The tidal effect is indicated by the higher chlorides present in the water.

For a comparison of B.O.D., D.O. and bacteria the summer and winter average results obtained at the various sampling stations in the Raritan proper have been plotted in Fig. 3. The average B.O.D. results obtained were similar during the two periods in respect to a rapid increase, followed by a decrease, downstream, but the peak load occurred at Bound Brook during the summer, whereas the highest average results were found at the next station downstream during the winter. Obviously the largest B.O.D. load on the river throughout the year was discharged between the sampling stations at Manville and Bound Brook. The shift downstream during the winter may be accounted for by the increased rate of flow, resulting in an increased velocity of the stream.

The rapid deterioration of the river during the summer is also brought out by the curves showing the dissolved oxygen results. In the winter period the average dissolved oxygen in the North and South Branch of the river was high, gradually decreasing as more pollutional

TABLE VII.—*Average Summer and Winter Results, Raritan River and Tributaries, 1940–41*

Station No.	Location	Season	Temperature	pH	Suspended Solids	Acidity [1]	Alkalinity [1]	Chlorides	Ammonia Nitrogen	Nitrite Nitrogen	Nitrate Nitrogen	Dissolved Oxygen	Dissolved Oxygen Saturation	B.O.D.	Total Bacteria [2]	Presumptive	*E. Coli* [3]
			°C.		P.P.M.	P.P.M.	P.P.M.	P.P.M.	P.P.M.	P.P.M.	P.P.M.	P.P.M.	%	P.P.M.	Per c.c.	Per c.c.	Per c.c.
1	South Branch	Winter	5.3	7.2	9.9	2.7	45.0	14.6	0.08	0.016	0.78	12.2	95.6	2.0	8.8	6.8	5.0
		Summer	22.3	7.7	20.4	1.7	65.5	24.3	0.13	0.006	0.25	7.3	82.4	1.0	0.9	20.6	10.3
2	North Branch	Winter	4.5	7.3	7.2	2.4	38.0	6.8	0.08	0.012	0.58	12.2	94.4	1.8	4.8	4.1	2.4
		Summer	21.4	7.9	8.8	1.5	59.9	7.0	0.10	0.020	0.10	7.4	82.0	1.1	0.6	14.4	8.1
3	Manville	Winter	5.3	7.3	8.1	2.6	40.9	7.3	0.22	0.013	0.69	11.7	91.1	2.3	6.1	18.5	18.6
		Summer	22.5	7.7	16.1	2.6	57.9	8.7	0.30	0.027	0.31	6.3	71.4	1.7	10.4	203.9	177.2
4	Millstone River	Winter	5.6	7.3	10.3	3.1	24.5	8.3	0.18	0.020	0.77	10.9	85.2	1.4	4.5	32.0	25.9
		Summer	22.1	7.5	15.8	3.4	34.4	7.7	0.16	0.014	0.50	7.3	82.7	1.7	1.0	41.1	29.8
5	Green Brook	Winter	6.6	7.1	8.8	7.1	56.8	24.7	1.90	0.096	1.70	9.3	75.7	6.9	40.0	3,930	3,899.0
		Summer	21.0	7.3	9.5	7.7	76.6	30.6	2.02	0.230	2.70	4.8	53.7	4.7	15.0	311.0	109.5
6	Bound Brook	Winter	5.7	6.8	12.7	9.0	31.3	42.9	1.23	0.036	0.80	10.2	79.4	12.4	10.6	84.0	75.8
		Summer	22.7	7.2	16.8	7.5	55.2	71.0	1.67	0.053	0.59	3.0	34.2	16.5	49.2	1,557.0	118.0
7	Raritan Landing	Winter	6.1	6.9	8.6	6.4	34.0	34.0	1.07	0.030	0.81	9.8	70.0	14.0	60.8	752.0	752.0
		Summer	22.7	7.1	17.0	8.1	52.0	56.7	1.62	0.093	0.50	2.4	27.7	12.5	85.1	3,175.0	1,340.0
8	New Brunswick	Winter	7.4	7.0	14.4	6.6	31.8	300	2.08	0.045	1.30	9.4	76.3	11.1	60.0	412.0	386.0
		Summer	24.0	7.0	18.9	10.0	42.1	790	1.52	0.097	0.90	1.9	21.6	7.6	121.2	6,810.0	1,370.0
9	Sayreville	Winter	6.9	6.2	29.0	14.1	27.9	4,000	0.91	0.072	3.30	9.0	75.7	5.5	7.8	42.0	23.4
		Summer	23.5	6.2	23.1	17.7	16.3	6,435	1.21	0.077	4.00	3.4	41.7	2.6	4.8	117.0	41.8
10	Perth Amboy	Winter	7.6	6.5	27.2	12.0	52.6	9,500	0.61	0.050	1.40	9.0	81.4	2.9	8.7	46.6	19.1
		Summer	22.8	6.7	20.4	11.8	54.9	11,135	0.73	0.069	1.40	5.4	69.9	2.4	1.2	19.8	12.1
11	South River	Winter	8.1	6.6	16.6	6.4	18.6	31	1.11	0.020	0.37	10.0	82.9	15.6	26.6	1,117.0	768.0
		Summer	23.2	6.5	23.8	23.1	12.1	760	1.85	0.033	2.16	4.4	51.4	12.9	55.1	2,986.0	2,796.0
12	South River	Winter	8.1	3.8	21.9	46.0	3.3	3,535	1.29	0.106	7.70	8.2	68.0	5.4	0.7	21.7	7.9
		Summer	23.7	3.9	24.7	55.8	5.1	4,670	1.32	0.052	7.00	2.4	29.0	3.2	7.3	200.0	15.1

[1] As $CaCO_3$. [2] In thousands 5-day nutrient agar counts at 20°C. [3] Partially confirmed.

matter entered. Notwithstanding the effect of salt water dilution, the dissolved oxygen saturation below New Brunswick was low. In the summer period the dissolved oxygen was reduced rapidly and continuously from the Manville sampling station to below New Brunswick. From this point on the dilution factor increased in importance, but was insufficient to produce a dissolved oxygen saturation at Perth Amboy comparable to that found in the North and South Branch.

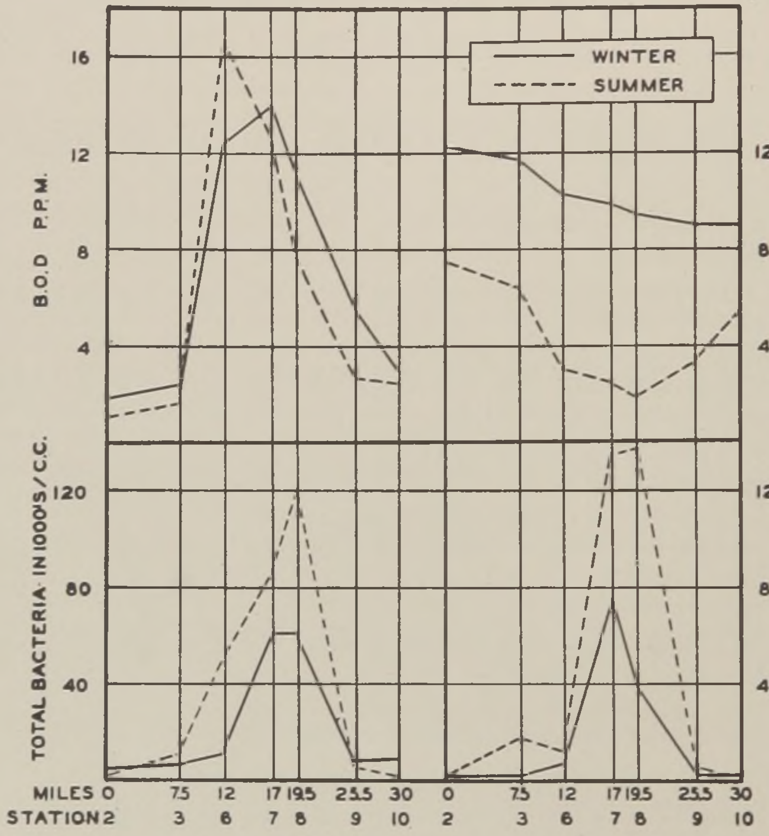

FIG. 3.—Comparison of average summer and winter values of B.O.D., D.O., total bacteria, and *E. Coli* at the different sampling stations in the Raritan River during the survey of 1940–41.

Perusal of the results raises several questions. The more important are: (1) What was the oxygen surplus and oxygen deficiency relationship in summer and winter? (2) Was the rapid deterioration during the summer caused by an increased pollution load or by the decreased flows? (3) What was the effect of sludge deposited during low flows? (4) To what extent does the pollution load interfere with the self-purification power of the stream? In an effort to find answers to these questions, the actual B.O.D. load, expressed as one-day B.O.D., occurring in the river at the prevailing temperature of the water and also expressed as 5-day B.O.D. at 20° C., as well as the dissolved oxygen surplus and deficiencies were calculated for the two periods.

The most important tributary to the upper Raritan is the Millstone River, with a daily mean discharge of 343 c.f.s. during the 1940–41 survey. The daily mean discharge during the summer period amounted to 189 c.f.s. and for the winter period to 457 c.f.s. In sampling, flood flows were avoided, so that the average flows on sampling days were less than the mean discharge on all days recorded by the U. S. Geological Survey. The flows and 5-day B.O.D. load during the sampling days were as follows:

	Flow, C.f.s.	B.O.D., P.p.m.	B.O.D., Lb.
Yearly Ave.	235	1.6	1,330
Winter Ave.	342	1.4	1,357
Summer Ave.	138.5	1.7	1,306

It is evident that the pounds of B.O.D. of the Millstone discharged into the Raritan was for practical purposes the same during the summer as during the winter period. A comparison of similar figures for the Raritan River at the Manville and Bound Brook sampling stations shows an entirely different picture.

	Manville		Bound Brook	
	Summer	Winter	Summer	Winter
Flow, c.f.s.	117	716	255	1,056
D.O., lb.	4,195	54,150	5,900	62,900
B.O.D. 1 day, lb.[1]	320	2,840	5,020	7,700
B.O.D. 5 days, lb.[2]	1,060	10,000	15,760	37,200

[1] Corrected for temperature existing in the river water.
[2] At 20°C.

At the Manville station the North and South Branches have been combined and the station is below two municipalities. At the Bound Brook station the Millstone has combined with the Raritan.

The average available dissolved oxygen during the summer increased between Manville and Bound Brook from about 4,200 lb. to 5,900 lb. This increase is due primarily to the Millstone River water. At Manville the available dissolved oxygen was about four times greater than the 5-day B.O.D., whereas at Bound Brook the available oxygen was scarcely sufficient to take care of one-third of the 5-day demand. Even the one-day B.O.D., corrected for the actual temperatures existing in the water, was over 80 per cent of the total available oxygen. The total B.O.D. at Manville (1,060 lb.) and the B.O.D. of the Millstone (1,300 lb.) together amounted to 2,360 lb. It appears, therefore, that the 5-day B.O.D. discharged into the Raritan between Manville and Bound Brook averaged 13,400 lb. per day for the summer period.

During the winter period the total dissolved oxygen available was more than ten times greater than during the summer, both at Manville and Bound Brook stations. The 5-day B.O.D. was also materially higher. The increase at Manville may be attributed to suspended and soluble solids carried down by washings from the drainage area, and particularly to sludge settled in the river during the low flows in summer. The fact that the winter average B.O.D. in the Millstone River was not materially different from the summer average would indicate that sludge deposits are of the greater importance at Manville. Assuming that the pollutional load of 13,400 lb. B.O.D. per day contributed to the river between Manville and Bound Brook during the summer remained the same in the winter period, the effect of the sludge deposited during low flows would amount to the following:

Station	Pounds
Manville	10,000
Millstone	1,360
Increase	13,400
	24,760
Bound Brook	37,200

or a difference of 12,440 lb. attributable to the sludge deposits. Efforts to determine the origin of these relatively large amounts of B.O.D. attributable to sludge, lead to considerable speculation, because there are several possible sources in the upper section of the river and no reliable data are available.

A comparison of the winter and summer conditions in this section of the river based upon surplus and deficiencies of oxygen is of particular interest (Table VIII). At the Manville and Bound Brook stations the daily average surplus of oxygen in the river based upon the 1-day B.O.D. was practically the same. This was the result of the dilution water entering from the Millstone. Based upon the 5-day B.O.D. the average daily oxygen surplus at Bound Brook was only half that present at Manville. The yearly average oxygen surplus was almost entirely due to the high winter surplus. During the summer the small average surplus at Manville was greatly reduced on the 1-day B.O.D. basis, while on a 5-day B.O.D. basis the small average oxygen surplus at Manville was changed to an average daily deficiency of over 10,000 lb. of oxygen at Bound Brook. The deficiencies occurred from the middle of May to the middle of December. This is more clearly shown

TABLE VIII.—*Average Daily Pounds of Oxygen Surplus and Deficiencies, Based Upon 5-day at 20° C. and 1-day B.O.D. Values Corrected for Temperature Prevailing in the River Water*

Season	Winter		Summer		Yearly	
Based on	1-day	5-day	1-day	5-day	1-day	5-day
Manville	52,000	46,700	3,830	2,990	26,600	24,500
Bound Brook	55,200	37,800	885	−10,850	26,300	12,000

− = deficiency.

in the plotted results in Fig. 4. Examination of the figures shows that even on the basis of 1-day B.O.D. the oxygen deficiency at Bound Brook occurred over a considerable period. The oxygen deficiencies coincided with the low river flows, which accentuated the effect of the pollution

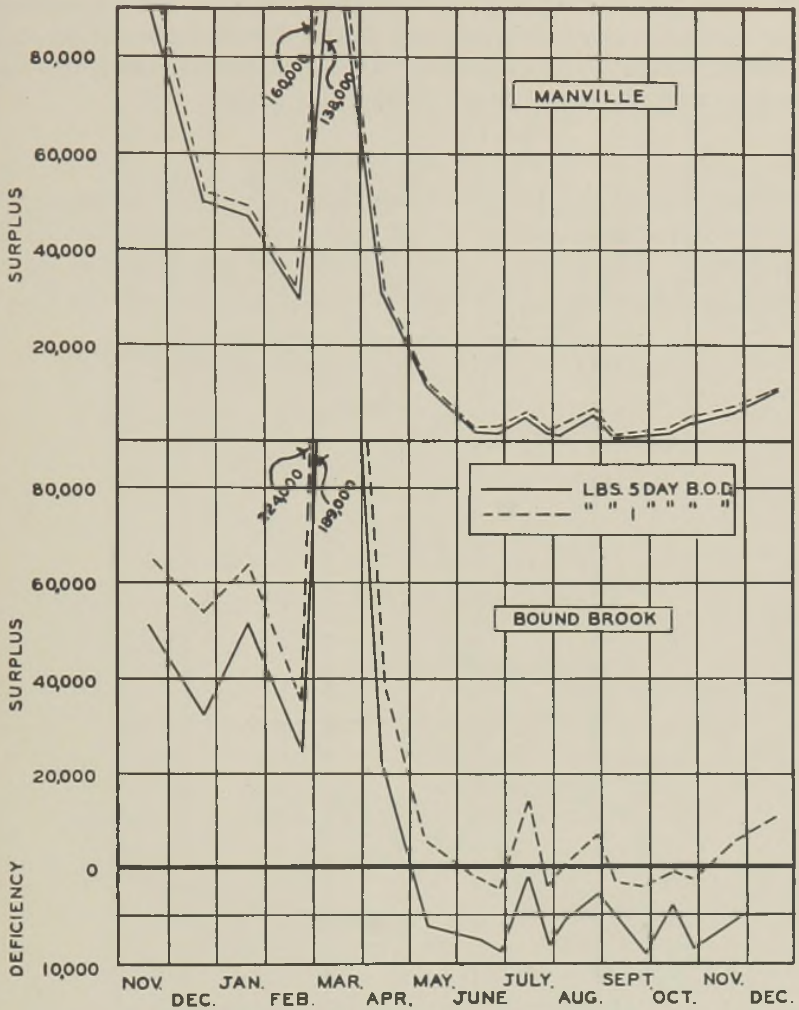

FIG. 4.—Average daily pounds of oxygen surplus and deficiencies at Manville and Bound Brook based upon the 5-day and 1-day B.O.D. values corrected for the temperature prevailing in the river water.

load entering the river between the Manville and Bound Brook sampling stations.

The difference between summer and winter conditions of the river in regard to bacterial content, illustrated graphically in Fig. 3, is rather pronounced. The numbers of bacteria during the summer continued to increase until they reached a peak below New Brunswick. The *E. Coli* numbers did not begin to increase until above New Brunswick, remaining high to below this city, where the dilution effect becomes important.

At the latter sampling place the numbers varied from 250 to 6,000 per c.c. during the period May to October, inclusive.

It is of interest that the total numbers of organisms and *E. Coli* per unit of water were about twice as high during the summer as during the winter period. Keeping in mind that the average flow during the summer was only about 28 per cent of the average winter flow, the results would indicate that the total bacterial pollution of the summer period was actually lower than during the winter.

Comparison of Three Surveys

The first survey made in 1927–28 was conducted primarily to determine the nature and extent of the pollution in the Raritan River and its tributaries. The second survey in 1937–38 was made to determine the effect of a number of sewage treatment plants built in the valley

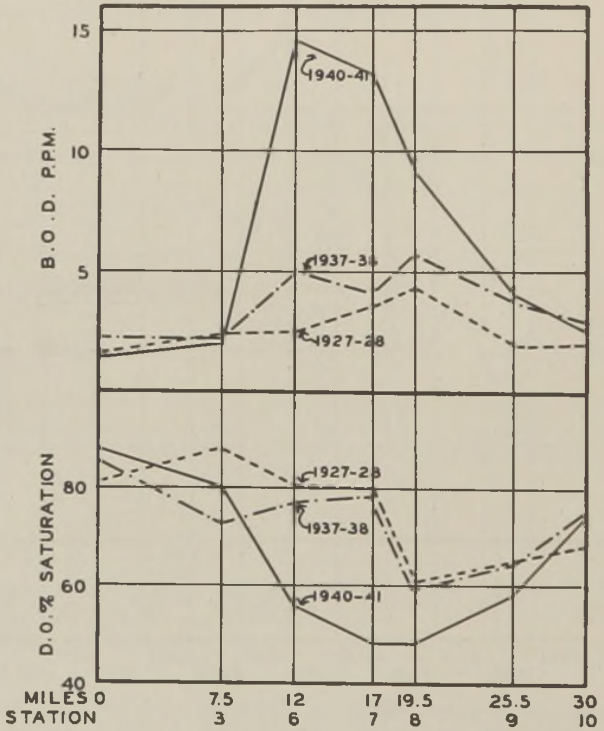

Fig. 5.—Comparison of the B.O.D. and dissolved oxygen saturation values of the Raritan River during the three surveys.

during the intervening years, while the third was made in an effort to determine the condition of the river after the sewage treatment plants had been in operation for some time and several industrial waste treatment plants had been installed. In addition, the various municipal sewage treatment plants receive a considerable volume of industrial and trade wastes.

For comparison of the general condition of the Raritan River during the three survey periods, the B.O.D., dissolved oxygen saturation, *E. Coli* and total bacteria are plotted in Figs. 5 and 6. The B.O.D., graphically shown in p.p.m., shows a relatively small but definite increase from 1927–28 to 1937–38 and a material deterioration of the river between 1937–38 and 1940–41. The percentage dissolved oxygen saturation shows the same general picture. The effect of the pollution load discharged has almost entirely disappeared at the Perth Amboy bridge station, on account of the large volume of salt water dilution. However,

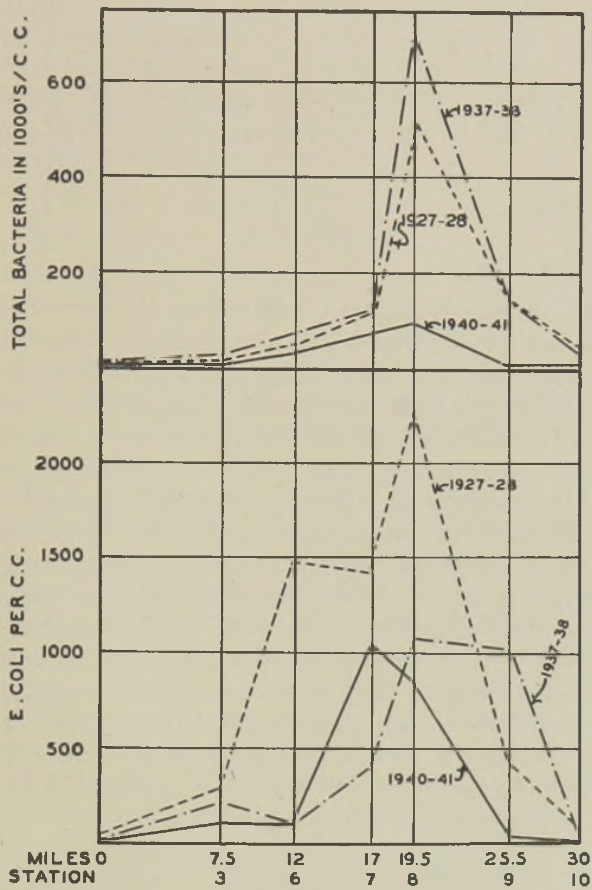

FIG. 6.—Comparison of the total bacteria and *E. Coli* in the Raritan River during the three surveys.

the deterioration of the river occurred in the greatest part of the lower Raritan.

Total bacteria, graphically shown in thousands per cc, showed a marked reduction in the entire lower river. In all three surveys the average maximum total bacteria were highest below New Brunswick. The *E. Coli* results show a material decrease between 1927–28 and 1937–38, but no corresponding decrease during the 1940–41 survey. It is evident that considerable sewage pollution occurred between Bound Brook and Landing Bridge just above New Brunswick. Undoubtedly, raw sewage discharged from a part of New Brunswick played a role.

This affected the bacteriological condition of the river for the next 10 miles.

The conditions in the tributaries to the Raritan have changed since the first survey in different directions, as indicated by the figures in Table IX. The Millstone River, entering the Raritan between Manville and Bound Brook, showed a gradual decrease in B.O.D. with a rather constant dissolved oxygen saturation. Green Brook, entering the river below the Bound Brook sampling station, deteriorated through the years both from the standpoint of organic and bacteriological pollution. The South River, entering the Raritan between the New Brunswick and Sayreville sampling stations, was in a materially poorer condition during the last survey as far as dissolved oxygen saturation and B.O.D. were concerned. Insufficient data obtained on the South River during 1937–38 prevent a fair comparison with the other years.

TABLE IX.—*Average D.O., B.O.D. and E. Coli in Tributaries*

Year	Millstone			Green Brook			South River *		
	D.O., % Sat.	B.O.D., P.P.M.	*E. Coli* per c.c.	D.O., % Sat.	B.O.D., P.P.M.	*E. Coli* per c.c.	D.O., % Sat.	B.O.D., P.P.M.	*E. Coli* per c.c.
1927–28	84	2.2	73	63.3	3.7	700	74.5	3.1	114
1937–38	87.5	1.9	11	52.6	4.4	864	—	—	—
1940–41	83.9	1.6	28	64.1	5.8	1904	43.6	4.1	12

* Near confluence with Raritan.

According to the 1940–41 survey, the greatest density of oxygen-demanding pollution in the river occurred between the Manville and Bound Brook sampling stations. It is of interest to analyze the conditions in this section of the river in more detail, particularly as far as B.O.D. load is concerned. Individual results obtained, together with the actual flows occurring on the sampling days, have been used for calculating the pounds of B.O.D. and percentages increase or decrease as compared with the results of the survey in 1927–28. The averages of the results and calculations are shown in Table X.

TABLE X.—*Average Yearly 5-day B.O.D., Based Upon Flows Occurring on Sampling Days*

	Raritan at Manville			Millstone			Raritan at Bound Brook		
	1927–28	1937–38	1940–41	1927–28	1937–38	1940–41	1927–28	1937–38	1940–41
Avg. B.O.D., p.p.m.	2.2	2.2	2.0	2.2	1.9	1.6	2.5	5.0	14.6
% increase or decrease*	—	0	−9.0	—	−13.5	−23.0	—	100.0	484.0
Avg. flow, M.G.D.	495	267	265	186	144	152	679	409	411
% decrease	—	46.0	46.5	—	22.6	18.2	—	40.0	39.6
B.O.D., lbs.	6,700	5,635	4,765	3,500	2,400	1,330	15,000	18,200	25,900
% increase or decrease*	—	−16.0	−29.0	—	−31.4	−62.0	—	21.3	72.5

* Increase or decrease over 1927–28; − indicates decrease.

The condition of the Raritan at Manville improved materially. In spite of a decrease in flow of 46 per cent between the survey years 1927–28 and 1937–38 the actual pounds of B.O.D. decreased by 16 per cent, while during the 1940–41 survey the pollutional load had decreased by 29 per cent. Improvement in the Millstone was considerably greater. With a decreased flow of 22.6 and 18.2 per cent as compared with 1927–28, the B.O.D. load was reduced 31 and 62 per cent, respectively, in 1937–38 and 1940–41. Some distance below the confluence of the two rivers and after large quantities of industrial effluents enter, the picture is entirely different. During the survey years of 1937–38 and 1940–41 the river flow on the sampling days was about 40 per cent less than during 1927–28, but the pollution load, as expressed by the 5-day B.O.D., increased by 21 and 72 per cent.

Discussion

Unusual drought conditions in the summer and culminating during September–October, 1941, affected the pollutional condition of the lower Raritan. Deterioration of the river in regard to lowering of dissolved oxygen and higher B.O.D. progressed in the populated and industralized area in spite of the fact that a number of sewage treatment plants were operating and some of the larger industries treated their wastes. Of particular interest is the fact that in the section of the river (Landing Bridge to below New Brunswick) where the first effects of tide water are felt, no improvement occurred. It appears that the oscillations of the tide water, which in this part of the river consists mainly of fresh water backing up, are of doubtful benefit. Only when larger volumes of salt water are mixed with the river water farther downstream does the apparent condition of the river improve.

The Millstone, used as a water supply and one of the main tributaries, was in good condition in spite of the low flows. On the other hand, the Green Brook and South River were in poor condition.

From the standpoint of bacterial pollution, the river and tributaries were in a fairly good condition, with the exception of a stretch of the river in the neighborhood of New Brunswick and Green Brook.

A comparison of winter and summer results indicates that the low flow intensified the bad conditions in summer. The low flows during the summer appeared to allow sludge to be deposited, which was stirred up during the winter.

When the first survey was made in 1927–28, only a small portion of the sewage discharged was treated. In 1937 a number of sewage treatment plants had been built. On the basis of surveys made, Forman and Johns (1) estimated that in October, 1939, as a result of sewage plant construction, the B.O.D. reduction amounted to 14,728 lb. or a reduction of 53.2 per cent, while the suspended solids reduction equalled a removal of 16,566 lb. or 71.1 per cent. Since then, raw sewage from two more municipalities has been subjected to treatment, reducing the domestic pollution load still further.

Forman and Johns (1) found that 37 industries were discharging an average of 38 m.g.d. of wastes, untreated, into the Raritan and its tributaries. At the time when the inspections were made the wastes had oxygen requirements amounting to 74,679 lb. per day, or on the basis of 0.17 lb. of oxygen requirement per capita per day for sanitary sewage, a population equivalent of 439,000. On January 1, 1940, they state that the status of waste treatment was as follows: Of the 37 industries 19 had either treatment plants installed or had removed their discharges entirely from the river, 4 were not considered polluting, 7 had treatment plants under construction, 4 were studying methods of treatment, 2 were under legal notice and 1 was constructing a new plant off the watershed. It may be assumed, therefore, that industrial pollution during 1940–41 would be materially reduced. The results secured substantiate this assumption.

Comparison of the three surveys indicates general bacterial improvement of the river, with the exception of a section around New Brunswick. In regard to B.O.D. reduction, the same appears to be the case, with the exception of a section of the river between the Manville and Bound Brook sampling stations. If the self-purification power of the river in this section is disregarded and the pounds of 5-day B.O.D. present in the river at the Manville station, as well as the B.O.D. contributed by the Millstone River, are subtracted from the pounds of B.O.D. found at the lower station at Bound Brook, we find that the B.O.D. loads contributed by this section were as follows:

Year	Lb., B.O.D.
1927–28	4,800
1937–38	10,165
1940–41	19,805

Assuming the oxygen requirement of sanitary sewage to be 0.17 lb. per capita a day the population equivalents in the river at Bound Brook as compared with the combined values for the river at Manville and the Millstone were about as follows:

Year	Population Equivalents		
	Manville and Millstone	Bound Brook	Difference
1927–28	60,000	88,200	28,200
1937–38	47,000	107,000	60,000
1940–41	35,200	171,200	136,000

Whereas the oxygen requirements, expressed in population equivalents, were reduced steadily in the upper section of the Raritan and Millstone, the oxygen requirements at Bound Brook doubled from 1927–28 to 1940–41. The difference, attributable to discharges in the section between Manville and Bound Brook, increased several times. These increases undoubtedly reflect to a considerable degree the increased industrial activities. Fortunately for the condition of the river, some of the large industries located in this section of the valley have treated their wastes to a considerable extent, especially in respect to neutralization, suspended solids removal and *E. Coli* reduction. The removal of acids has probably aided greatly in preventing destruction of the self-purification power of the stream. The removal of suspended and oily substances is important in connection with sludge deposits and unsightly conditions along the river banks.

Concurrent with changes in the condition of the lower section of the river, the appearance of the water has changed. Observations made during the surveys in regard to turbidity, color, oil, sleek, debris and odor show a general increase between 1937–38 and 1940–41 in part of the Raritan, Green Brook and upper South River. The percentage of time when noticeable color was present is summarized in Table XI.

TABLE XI.—*Percentage of Times When Noticeable Color was Present*

No.	Place	1937–38	1940–41
1	South Branch	0	0
2	North Branch	0	0
3	Manville	0	0
4	Millstone	2	2
5	Green Brook	33	58
6	Bound Brook	33	63
7	Raritan Landing	25	58
8	New Brunswick	17	37
9	Sayreville	0	26
10	Perth Amboy	0	21
11	South River (upper)	0	70
12	South River (mouth)	—	5

The color of the water in Green Brook was mostly black, while at Bound Brook and Raritan Landing there were various colors in the water. It will be noticed that during 1940–41 the noticeable color persisted in the river from Bound Brook to Perth Amboy, although the percentage of time color was observed decreased down the river. Color in the upper South River had most of the time disappeared by the time the water reached the Raritan. Noticeable froth or scum never present in the Raritan at Manville and in the Millstone was observed 40 per cent of the time at Bound Brook and 20 per cent of the time at Raritan Landing. Oil and sleek are mostly observed below New Brunswick (38 per cent of time) and occasionally farther downstream. Perceptible and distinct odors emanating from the river were recorded 25 per cent of the time at Bound Brook station and 10 per cent of the time at Landing Bridge. Faint odors were more frequently present from Bound Brook to well below New Brunswick. With the exception of Green Brook the color and odor in the Raritan and South Rivers were due to industrial discharges. Color due to run-off, which coincides with high turbidity, was not taken into consideration. It is evident that the

Raritan, Green Brook and upper South River were aesthetically in a poorer condition during 1940–41 than in previous years.

When all factors and results are considered, the conclusion is reached that during the period 1927–1940 the Millstone has improved gradually, both from a bacteriological and oxygen requirement standpoint. Green Brook has deteriorated generally, while the South River improved from a bacteriological standpoint, but was more polluted by oxygen-demanding material. The Raritan proper improved bacteriologically, although

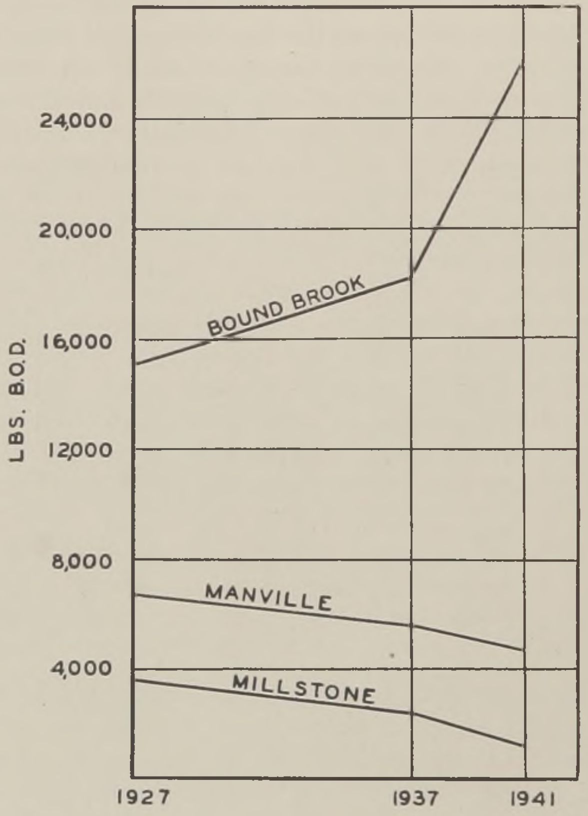

FIG. 7. Comparison of lb. 5-day B.O.D. at Millstone, Manville and Bound Brook during the three surveys.

a sore spot in the vicinity of New Brunswick was still prevalent. The gross pollutional load on the river, as indicated by B.O.D. and oxygen saturation, has increased greatly below the Manville sampling station. This is primarily caused by a heavy load placed into the river between Manville and Bound Brook. Whereas the load in the upper section of Raritan and Millstone decreased, the reverse was true in the next section of the river. The change in load is graphically shown in Fig. 7. Coincident with a greater oxygen demand, the river became colored more frequently and discharged distinct odors. It is difficult to visualize what the condition of the river would be if municipal sewage plants and several of the larger industrial treatment works had not been built and operated.

Great strides have been made in connection with sewage pollution (public health aspect) and localized bad conditions undoubtedly will be corrected. It is clear, however, that further improvement is necessary before the river can be restored to reasonable purity, to maintain fish and other aquatic life, allow unrestricted recreation (boating, bathing, fishing), is fit for economic and industrial uses and will not offend aesthetic feelings.

Summary

The results of three surveys of the Raritan River and tributaries conducted in 1927–28, 1937–38 and 1940–41 are assembled and discussed. The first survey covered a period when with few exceptions no sewage or industrial waste treatment existed. The survey of 1937–38 was made when practically all the domestic sewage reached the river after treatment. During the 1940–41 survey some of the larger industries had installed waste treatment facilities.

The stream flow was about 18 per cent lower during the period of 1937–38 and 23 per cent lower during the survey of 1940–41 as compared with 1927–28. The summer flows of 1937–38 were 34 per cent less, and in 1940–41, 60 per cent less, than in the summer of 1927–28.

During 1940–41 the average B.O.D. of the Raritan River increased from 2.0 p.p.m. at Manville to 14.6 p.p.m. at Bound Brook within a distance of about five miles. Below this point the B.O.D. gradually decreased, with increasing dilution and self-purification in the river. The dissolved oxygen during the year showed a progressive decrease from a value of about 81 per cent saturation at Manville to a low value of 47.5 per cent below New Brunswick and then increased to 75 per cent at Perth Amboy. The greatest percentage decrease was again between Manville and Bound Brook but the effect of the pollution on the dissolved oxygen was exerted down to New Brunswick in spite of the greater dilution.

The differences in the B.O.D. values between summer and winter were not great, except that the peak occurred at Bound Brook in summer and at a point below Bound Brook in winter. The dissolved oxygen saturation was decidedly lower in the summer than winter at all points, the lowest value being reached at New Brunswick. During the low flow in late summer on several occasions there was no dissolved oxygen present in the samples collected from Bound Brook and Landing Bridge, with only traces of oxygen below New Brunswick.

The total bacteria reached a maximum at New Brunswick and *E. Coli* at a point three miles above the town. Both the total bacteria and *E. Coli* were higher in the summer than in winter at all sampling points. The highest number of total bacteria was obtained at all points during the survey of 1937–38 and the lowest during 1940–41. This relationship was somewhat changed for *E. Coli,* which did not show a similar improvement in 1940–41.

Cancelling the effect of low flow, which undoubtedly aggravated the situation, the results expressed as pounds B.O.D. at the various flows

observed during the sampling days, showed an absolute increase of 19,820 lb. of B.O.D. between Manville and Bound Brook in 1940–41. Similar values for 1937–38 and 1927–28 were 10,165 and 4,500 lb., respectively. There was a calculated deficiency of 10,000 lb. of oxygen at this station during the summer period of 1940–41. Calculations show that the sludge deposits between Manville and Bound Brook exerted an oxygen demand equivalent to 12,440 lb. The color of the water at Bound Brook and stations below showed a decided increase in 1940–41 over the previous surveys; noticeable odor was present a considerable portion of the time. Sewage and industrial waste treatment has improved the river from a public health standpoint. Further improvement is necessary to restore the river to reasonable purity.

Addendum

After this paper was nearly ready for publication a paper by King, Bean and Lester * appeared which contains data on the Raritan River checking rather well with figures presented in this paper. Table VII of the article shows the monthly average oxygen consuming power of the river water above and 1,000 ft. below a dam. The first place is below the confluence of the Millstone and the second about 2 miles above the Bound Brook sampling station used in our work. The authors state that the 5-day B.O.D. is estimated to be about 62 per cent of the chemical oxygen consuming power. Calculations of the monthly average oxygen consuming power for the period 1940–41 (from Table VII) in pounds per day, show this to be 28,700 and 73,200 lb., respectively, for the two sampling places. However, according to the findings of the authors, only 62 per cent of these quantities should be expressed as 5-day B.O.D. A comparison on the latter basis shows the following in lb. of 5-day B.O.D. per day:

King, Bean and Lester		Rudolfs and Heukelekian	
Above dam	17,800	Manville and Millstone	6,095
Below dam	45,500	Bound Brook	25,900
Difference	27,700		19,800
Pop. Equiv.	163,000		136,000

It will be noticed that all our figures are lower, but in general correspond very well with those of King, Bean and Lester.

Results on dissolved oxygen saturation are also of particular interest. A comparison of the average oxygen saturation results again for identical months of the two surveys shows:

King, Bean and Lester	Per Cent	Rudolfs and Heukelekian	Per Cent
Above dam	81	Manville and Millstone	82
Below dam	76	Bound Brook	55

The oxygen saturation above the industrial discharges was practically the same, but a material difference was found between the oxygen

* *This Journal*, 14, 666 (1942).

content 1,000 ft. below the dam and some 2 miles farther downstream. It appears possible that the oxygen-consuming materials discharged had the effect of further depleting the oxygen available in the stream.

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THE OPERATOR'S CORNER

Conducted by W. H. WISELY, Executive Secretary*
Federation of Sewage Works Associations
Box 18 · · Urbana, Illinois

PRIORITIES

Insofar as currently limited resources will permit, the Federation is working with the War Production Board to retain priorities of favorable rank for the materials and supplies required to operate and maintain sewage works. Thus far, the field has not fared badly, although deliveries of some of the more critical materials have been unavoidably slow.

Contact with the Power Branch of W.P.B. was first made late last year, when estimates of the quantities of strategic materials required for sewage works construction (1940 level) were furnished. In May, 1942, at the invitation of Power Branch officials, your Secretary attended a conference in Washington in which general maintenance, repair and operation requirements were discussed. Furnishing of these data was made possible by the co-operation of manufacturers and plant superintendents who responded so promptly and completely to requests for detailed information.

In May, there was no indication that the priority ratings assigned sanitation services under P–46 (amended) were to be raised or lowered and it was assured that, even though the form of the current order were revised, adequate ratings would continue to be available in the future. There was no intention at that time to curtail any treatment processes which might be eliminated without undue hazard to the public health, such as by improvised methods of sludge disposal or by dependence upon high outlet stream dilutions to dissipate the effects of partially treated effluents. The situation as regards critical materials (steel plate, forgings and castings, chrome, nickel, copper, mercury, tin, zinc, rubber, chlorine, etc.) is "very tight"—and will become tighter as the war progresses.

Users of P–46 are urged to adhere strictly to the provisions of that order and to maintain, in a form which can be audited conveniently, the stores inventories mentioned therein. Asked to clarify the application of the A–2 and A–5 ratings of P–46 as amended, Power Branch officials advised that "the term 'production and pumping facilities' is intended to cover all facilities for which maintenance, repair and operation supplies required are proportional to the load being carried." In other words, the A–2 rating can be applied to treatment facilities as well as

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pumping plants and the A–5 rating is applicable to the sewage collection system.*

When the priority assignments afforded by P–46 are inadequate to obtain delivery of supplies involving critical materials, a PD–1–A application may be used, forms for which may be obtained from the Power Branch, War Production Board, Washington, D. C. PD–1–A applications will be expedited when accompanied by a clear and concise statement explaining the situation in detail and stating why a substitute material cannot be used.

There is a dearth of statistical data concerning the quantity of operation and maintenance materials required in sewage works and the Power Branch will appreciate such data from treatment works serving 50,000 population or more. Lists of the various materials used with quantities and costs of each (at the 1940 level) are particularly desired. General information including the type of treatment, population served and flow treated should accompany the lists. If detailed lists cannot be furnished, overall operation and maintenance costs such as are contained in many annual reports, will be of value.

The War Production Board is cognizant of the importance of this field and intends to give us all the assistance possible. We must not forget our own obligation to comply completely with the rules and to confine our requirements of the critical materials to a minimum by careful operation and by ingenuity in developing substitutes.

HOUSE LATERALS AND CONNECTIONS †

By Harold J. Huber

Supt. Public Works, Village of Lancaster, New York

The importance of properly installing house laterals and connections is frequently discounted by municipal authorities, who only too often spend thousands of dollars for the services of a consulting engineer in constructing a system of main sewers, and, by some strange quirk of human nature, later entrust to some unqualified political appointee the responsibility for enforcing inadequate local ordinances regulating the installation of house connections.

The disastrous results which follow the careless installation of laterals are known only too well to those in charge of treatment plants. Those of us who have seen a perfectly-operating plant blitzkrieged in a few short hours by a surcharge of storm water in the sanitary sewer system are competent witnesses of the results which follow the lenient enforcement of local sewer ordinances.

* Confirmed by letter from Power Branch dated July 10, 1942. Order P–46 has been extended as of June 23, 1942, to allow a preference rating of A–1–C for emergency repairs under certain limitations.

† Presented in connection with a course for Grade III Sewage Plant Operators in Buffalo, N. Y., on April 18th, 1941.

A chain is said to be as strong as its weakest link, and a main sewer system, no matter how well installed, is only as impervious to ground water as its house laterals. This may seem like a rather broad statement, but it is based on personal experience with a 35 year old sewer system which thus far has defied all efforts to make it water tight. To make a field inspection of a main sewer system and find the telltale "woodchuck holes" which indicate that surface water is finding its way into an open joint is a simple matter. But did you ever try to locate, under an eight inch concrete pavement, a spot where a storm sewer crosses a house lateral, and where half the water being carried in the storm sewer is spilling out through an open joint in the surface sewer into an open joint in a house lateral three feet below? If you ever have, you will join with me in a prayer for a State plumbing code which is mandatory and not optional.

The term "house lateral" or "house connection" as commonly used generally applies to a pipe used to carry sewage from a building to a public sewer (1). It is an intermediate link between the plumbing system in the building and the main sewer. Since a house lateral is usually installed at the expense of the property-owner, it is accessory to, but not, strictly speaking, a part of the public sewer system. And, since it is not part of the public sewer system, local authorities are often too little interested in seeing that the house lateral is installed with the same care and diligence as the main sewer to which it connects.

For ordinary purposes, a house sewer should not be less than 6 inches in diameter, of vitrified tile laid true to line and grade. We have, however, approved installations of 4 inch cast iron soil pipe in some instances, but only with certain mental reservations. Use of a pipe with a diameter of less than six inches usually results in trouble later, since house laterals do not run continuously and are therefore more subject to obstruction than the main sewers. A six inch house lateral to serve a modern Cape Cod cottage looks as big as the Holland Tunnel, yet modern living and modern laundry methods soon coat the inside of the tile with grease and fungus and soap curd which quickly reduces its capacity. It is very important, therefore, that the house lateral be laid true to grade, which in everyday practice is usually ¼ inch per foot.

To prevent the ingress of roots into the house lateral, the tile joints should be constructed with just as much care and with materials of a quality equal to those used in the construction of the main sewer. The use of cement mortar for lateral joints has been outlawed in many communities, and justly so. Mortar joints are always moist and wet from the sewage in the tile, and, during dry seasons, they attract the roots of neighboring trees. Now, a tree root apparently is a persistent and patient cuss, because, once having been attracted to the sewer by this moisture at the joints, it waits and waits and waits until the joint starts to disintegrate, when it makes its way without difficulty into the sewer and sets up housekeeping there.

While a cast iron pipe with caulked lead joints may be considered the ideal house lateral, nevertheless, a vitrified tile sewer with poured bituminous joints is a very satisfactory substitute. Bituminous joints of approved material and careful construction have given very good service under varying conditions. They are water tight, and since there is no moisture present at the joint, they do not so readily attract tree roots to the vicinity of the lateral. While this is also true of lead joints in laterals made of cast iron soil pipe, we have found from experience that cast iron laterals have certain other disadvantages, one of them being an affinity for soap and milk curds. Very recently we investigated a complaint at an ice cream manufacturing plant where trouble was being experienced with a cast iron lateral less than three years old. We found the inside of the pipe coated with an ivory-like deposit of casein and soap which reduced the diameter to the point where an inch and a half sewer rod could not be pushed through the six inch pipe. It was noted that where the cast iron lateral joined the main sewer, there was no deposit of curd on the vitrified tile.

The matter of traps in house laterals to exclude sewer gases from the building to which they connect has always been a debatable one. Some communities require the installation of a water-sealed trap in a house sewer between the house and the street sewer while some authorities argue that the use of these traps is a dangerous practice, since it may result in the building up of pressures which will force the water seals on fixtures connected to the plumbing system. While the ventilation of main sewers is usually accomplished by installing perforated manhole covers along the main sewer line, the house sewer cannot be so ventilated. Modern plumbing, however, which is usually connected to an untrapped cast iron soil or vent stack extending above the roof of the building, ordinarily provides all of the ventilation necessary to prevent the building up of pressures in the house sewer and the backing up of gases into the building. In most cases where traps are installed in house laterals today, they are of the type known as running traps, equipped with a clean-out hole which is extended to the ground surface with a smaller tile, and their express purpose is not so much that of ventilation, but of providing access to the house lateral to force out temporary obstructions. In this respect, they are a convenient accessory to the house sewer, although a tee or Y-connection extended to the ground surface from the sewer and provided with a gas-tight cap would provide the necessary access to the lateral without the danger of creating pressures in the plumbing.

In laying a main sewer, common practice is to install Y or T connections at regular intervals, or at least opposite each building lot or building location. These connections, if unused, are usually equipped with a vitrified tile cover sealed in place with the same jointing material which is used in installing the main sewer.

There are two schools of thought regarding the proper type of fitting to install in the main sewer for future house connections. The common practice for years has been to install Y connections, and proponents argue that this is the only practical connection since it provides a smooth junction of the streams in the two sewers. The other school insists that it is habit and habit only which dictates that sewer connections be made to Y branch fittings.

Inasmuch as the connection between the house lateral and the main sewer is usually made by a laborer, often in a tunnel under pavement to avoid the necessity of breaking up the road surface, it is important that the connection be made with as few fittings as possible. The use of a Y connection in the main sewer, especially if it is tipped up to form an angle with the vertical, requires the advice of a mathematician to secure a perfect joint if the angle of the curve or elbow used to connect to the Y does not correspond to the angle of the Y itself. Often a well-laid house lateral gives trouble because the laborer who made the connection to the main sewer while lying flat on his stomach with gravel dropping down his neck gave up in disgust his attempts to make the connection with one bend and did the next best thing—either added an additional curve or chipped a tile to the shape necessary, unconsciously creating a trap which will block up upon the least provocation.

There is no doubt that the use of T branch fittings in the main sewer simplifies to a great extent the problem of making a trouble-free connection under adverse conditions. The use of T branches, tipped up so that the T makes an angle of about 45 degrees with the vertical, requires the use of but one 45 degree curve to make the connection to the house sewer. The result is a connection the invert of which is well above the level of the water in the main sewer, much simpler to install and stronger and safer in every way.

Where main sewers are at a very great depth, it is common practice to install a riser pipe on the T or Y connection to a point about six feet below the road surface to save the property owner the expense of excavating to the full depth of the main sewer when installing his house lateral. Here again the problem of whether to use a T or Y branch is much in dispute. The use of Y branches under conditions like these requires that the curve which changes the direction of the connection from the horizontal to the vertical be supported and reinforced with concrete at the point where the connection to the main sewer is made. To my knowledge, there is no such thing as a pedestal type of curve on the market, so the connection is again dependent upon the efficiency of the person who installs it. From our personal experience, however, the use of risers in connection with Y branches where main sewers are laid at considerable depths has been very unsatisfactory, and we have uncovered many risers where trouble had developed only to find that the cause of the trouble was the collapse and failure of the bend connected to the Y. On the other hand, we have used T fittings in connection with riser pipes, and by properly pouring the joint and concreting the connection to the main, have experienced no trouble whatsoever. All in all, we are inclined to favor the T connection for all purposes, since with the use of the proper auxiliary fittings, it is possible to secure a connection which is just as satisfactory as that made with a Y, with the additional advantages of ease of installation, accuracy of fit, and additional strength where strength is needed.

As mentioned before, the connection of the house lateral to the main sewer is usually made by a laborer under adverse conditions, and when a comparatively new house sewer starts to give trouble, we usually suspect the last joint first. Since many T and Y connections face on vacant property, they often lie in the ground for years before the caps are removed to permit connections with house laterals. If the main sewer of which they are a part is overloaded, or becomes surcharged at times with storm water, the connection is usually found to be coated with grease and slime when the cover is removed, often to such an extent that it is almost impossible to pour a tight bituminous joint. Only too frequently will a sewer inspector, who has vigilantly supervised the pouring of bituminous joints in the house lateral from the building to the main, neglect to insist that the joint at the main be made with as much care as the ones along the lateral line. Thus it is not at all uncommon to find a cement joint where the lateral sewer joins the main. Since the disadvantages of the cement joint have already been pointed out, it is readily apparent that a vulnerable spot for the entrance of tree roots has been provided at the point where it is most difficult to remedy trouble, and where, since main sewers are often under pavement, repairs are very expensive. The determination as to where the responsibility of the municipal sewer authority stops and where the responsibility of the property owner begins had never been argued in Lancaster until one irate property owner whose house lateral was stopped up within two years after it had been installed, and who had uncovered the entire lateral from the house to the main to find perfect bituminous joints all the way—and a cement joint at the main—decided that he was entitled to be reimbursed for his expense. It was found that roots from a row of poplar trees over 100 feet from the sewer had found their way into that solitary cement joint and completely stopped up the sewer. Since the making of the cement joint had been approved by the sewer inspector, and since the joint was at the bell of the Y fitting which was a part of the trunk sewer, the Village, after much argument, was finally forced to reimburse the property owner for his trouble.

Similarly, in cases where riser-pipes had been used to raise the connection with deeply-laid mains, and where roots had entered through cement joints in the riser, or where the riser itself had failed, the Village was forced to assume, in several instances, the cost of digging up the sewer connected to the riser, in addition to the cost of digging down to the trunk sewer and properly rebuilding the riser.

If the use of copper rings in cement joints can be definitely proven to be adequate insurance against the entrance of roots at the point where the connection is made to the main sewer, this writer would be inclined to yield a point when it comes to making difficult connections under adverse conditions, but not without the assurance that this system has been tried and found to be successful.

Some sewer authorities advocate the installation of main sewers without placing Y or T branches for connections except for buildings which want immediate connections, and then only where correct locations can be determined at the time of laying the sewer. It is argued that the process of cutting a sewer pipe, installing a "cut-in" type of connection of either cast iron or terra cotta, and placing the surrounding concrete envelope is extremely simple, rapid and economical. It is also pointed out that unused connections, which were originally installed at considerable expense, represent a huge investment if compound interest is added to the cost of the original installation for the length of time that the blind connection has been installed. Providing that a cut-in connection can be made just as fool-proof as one which is installed when the main is laid, the practice of providing connections opposite vacant property is an unnecessary expenditure, and adds greatly to the original cost of installation. But, what was said before regarding the possibility of using copper rings in cement joints applies in this case as well, for a cut-in connection is only as root-proof as the concrete envelope which surrounds it.

The average property owner resents such "new-fangled" ideas as bituminous joints and other modern types of construction. Most of them seem to take the stand that "what was good enough for grandpa is good enough for me." But they probably don't realize how many times grandpa had to dig up the house lateral to the old homestead to remove the roots which had entered through the cemented joints. Although modern construction and modern joints may involve just a little more of an original investment, the trouble-free service which the properly-installed house lateral will give pays generous dividends in trouble-free service and wholesome living conditions.

References

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BARK FROM THE DAILY LOG

May 4—The plant effluent lagoon, cleaned out last winter by means of the N.Y.A. project, was restored to service today. The horse-shoe shaped excavation has a volume of about 500,000 gallons, a surface area of about 25,000 square feet and averages approximately two feet in depth. It will be used to "polish" the plant effluent before discharge to the stream and offers an opportunity to study, under controlled conditions, the natural purification capacity of such a body of water.

May 7—Planted fifty top-water minnows (Gambusia affinis) in the lagoon to control mosquito breeding. If the fish approve of our accommodations, we should have fifty million of them by the end of the summer!

May 13—Began construction of a rubble retaining wall to protect a 75-foot length of intercepting sewer which had been exposed by erosion at the edge of a small stream. The wall is being built of broken concrete laid in cement mortar, averages about six feet in height and varies in thickness from two feet at the footing to twelve inches at the top.

(The job was completed by two men in 6.5 days at a total cost of $158.00 or approximately $2.00 per foot. Before and after views are shown in Figs. 1 and 2.)

FIG. 1.—Intercepting sewer exposed by erosion.

FIG. 2.—Retaining wall protecting section of sewer shown in Fig. 1.

May 20—Several years ago the State Health Department inoculated the trickling filters at Clinton, Illinois, with achorutes viaticus, a species of water springtail, with the intention that other trickling filter plants in the vicinity could conveniently obtain inoculations. We have never had a pooling problem at our filters but there are goodly numbers of psychoda flies in summer months, so we obtained a fair seeding of springtail-infested stone from Clinton today and planted it at four points in our filters. If the inoculation "takes," there should be some results in a year or two.

Our filters have open underdrains and, therefore, cannot be flooded for fly control. Although the flies are sometimes troublesome in the immediate vicinity of the filters, they have never bothered at the Administration Building, located 350 feet away.

May 25—The depression is over! Extra labor at forty cents per hour is no more. At that, fifty cents is certainly not exorbitant for cleaning sludge beds and similar work!

Our best sludge customer last year is back again for 500 cubic yards more. Reports an unusually fine crop of timothy hay from a field treated with sludge last fall.

May 27–28—To Sheboygan, Wisconsin, for a pleasant respite with the Wisconsin Sewage Works Operators Conference.

June 2—The worst corrosion problem in this plant is at the building which houses the dosing tanks. The metal sash here have been badly attacked in the past and we are attempting to curb further damage by a three-coat paint job. Following careful wire brushing, a Bakelite resin, rust-inhibiting primer was applied. Two coats of an acid-resistant paint containing Bakelite completed the work.

June 7—Took down the Gruendler screenings grinder for inspection and repair, this unit having operated for over a year without demanding attention. Turned the hammers (last time this can be done with the present set) and found the only part requiring replacement to be the perforated plate screen. Ordered a new type louvred-slot screen and a new set of hammers, the latter to be installed in the future. When reassembled, the grinder will be given three coats of paint.

June 12—In company with a representative of the local Public Health District, an inspection was made at a milk plant where the wastes from the cheese department were found to be discharging to a storm sewer. Arranged with the plant officials to have all wastes of polluting character connected to the sanitary system.

The whole community was shocked to hear that a four year old youngster fell into an open tank at the local waterworks and was drowned. To prevent a similar accident at this plant, a lock was placed on the gate in the fence surrounding our final sedimentation tank.

June 19–20—Attending the Annual Meeting of the Michigan Sewage Works Association at East Lansing. Visited the interesting plants at Lansing, Michigan (George F. Wyllie, Superintendent), and Gary, Indiana (W. W. Mathews, Superintendent), enroute.

July 8—U. S. Geological Survey construction crew completed repair of the control section used to measure the flow in Saline Ditch, our outlet stream. The work involved lowering the entire concrete section to the present level of the stream bottom, placing cut-off walls of wood and steel sheet piling supplemented by concrete, and rip-rapping the banks above and below the section.

This control, with an automatic stage recorder, gives us an unusually accurate record of the stream flow available for dilution of the plant effluent.

July 11—Entire day (and part of night) spent in preparing an application for a Federal grant under the Community Facilities Bill, to be applied to extension of the primary treatment capacity of the plant. The detailed inventory of the loads, efficiencies and limiting capacities of each treatment unit, which study was made last year, proved its value today.

New separate sedimentation and digestion tanks are sought to augment the existing Imhoff tanks.

July 16—Could riding in an army tank be rougher than a road grader? This evening we somewhat shakily surveyed our freshly graded roads, now ready for surface mat treatments. The main entrance road and parking areas

FIG. 3.—View from parking area of the main entrance road.

FIG. 4.—Resanding sludge drying beds.

at the Administration Building are to be primed with 0.5 gallon per square yard of MC–1 asphalt, followed after 48 hours curing by 0.5 gallon of RC–3 asphalt upon which will be spread 35 pounds per square yard of ¼-inch stone chips. The secondary drives which wind through the 47-acre park will receive one gallon per square yard of E–3 road oil, applied in two "shots," the second one in the fall.

Neither of these treatments will furnish a permanent surface. The main drive is intended to receive another asphalt and stone chip application next summer, which should furnish a good road surface for 5 or 6 years. The road oil treatment, of course, must be renewed annually.

July 24—With the new road completed (Fig. 3), we are starting to resand the north battery of eight sludge beds. It has been three years since these beds were sanded and about three cubic feet of sand per square yard is required to restore them to the original level.

Figure 4 indicates the manner in which the new sand is screened to the level of the industrial track rails.

July 29—"It's the first time I ever saw sand that would float," mumbled our new third shift operator, as he skimmed snail shells (carried back with the trickling filter humus) from the surface of the Imhoff tank settling channels!

DISPOSAL OF LIQUID SLUDGE AT KANKAKEE, ILLINOIS

By Phillip J. Schriner

Superintendent of Sewerage, Kankakee, Illinois

The City of Kankakee is located in the northeastern part of Illinois and is subject to a period of cold or wet weather of approximately six months, during which time it is necessary to store liquid sludge.

The Kankakee sewage treatment plant has two 50-foot diameter digesters equipped with Downes floating covers, and the practice has been to draw the digesters down as low as possible in the late fall and to increase the percentage of solids in the raw sludge during this six month period to conserve the valuable digester capacity. Nevertheless, by the last part of February or the first of March both of the digesters are filled to capacity and the weather is usually unfavorable for sludge bed drying.

Prior to this year, there was a piece of ground directly adjoining the plant grounds to which we were able to pump liquid sludge by utilizing our sludge bed connections and some 3-inch pipe. However, this property has now been taken over by the Village of Bradley as a sewage treatment plant site, thereby making it impossible to utilize this section of land for liquid sludge disposal. (Incidentally, bumper crops have been realized from this section of land in the past two years.) A new operating difficulty had to be faced and it was necessary to find some suitable method of relieving the situation.

The construction of another digester was impossible, but, as the old saying goes, "Necessity is the mother of invention." A survey of the local junk yards was made and a used gasoline tank of 1,000-gallon capacity was obtained for the nominal price of $7.80. A 4-inch nipple and valve were attached to the bottom, and a foot square hole was cut in the top over which was placed a flap gate. The tank was painted and it was ready for service. The total cost for equipping this tank for hauling liquid sludge was not over $15.00. The 4-inch valve was on hand.

A home-made boom was rigged up, utilizing a used telephone pole, pulleys and cables that were also on hand. This made the loading and unloading of the tank a very simple operation.

Using this tank, it was found that approximately 24,000 gallons of liquid sludge could be hauled by one man in an eight hour day. It should be noted that the tank is filled by gravity, utilizing a 3-inch rubber hose and the existing sludge bed facilities.

Comparing this method of disposal with the disposal of air dried sludge, the following figures are submitted:

Average day's hauling of liquid sludge = 24,000 gal.		
Cost of disposal:		
8 hr. labor @ 60¢ hr.	$ 4.80	
Truck use @ $1.00	1.00	
	$ 5.80—use $6.00	
Average sludge bed contains 20,000 gal. of liquid sludge		
Cost of disposal:		
Filling bed (1 hr. labor)	$ .60	
Emptying bed (16 hr. labor @ 60¢)	9.60	
Truck use ($1.00 per bed)	1.00	
Sand replacement @ $1.00 per bed	1.00	
	$12.20	
Spring drying:		
300 lb. alum @ $1.40 per 100 lb.	4.20	
Labor on slurries, etc.	1.20	
	$17.60	
Plus additional 4,000 gal.		
$\frac{4000}{20000} = \frac{1}{5}$ of $17.60 = $3.52	3.52	
	$21.12—use $21.00	
Approximate cost to dispose of 24,000 gal. sludge from drying beds		$21.00
Approximate cost to dispose of 24,000 gal. sludge from use tank		6.00
Approximate saving per bed		$15.00

Comparing the two methods from the financial standpoint, it is easily seen that the disposal of sludge in the liquid form can be of great value and that it effects a considerable saving over a period of time. It should also be noted that, according to available information, liquid sludge has a far greater fertilizing value than air dried sludge.

Another advantage of disposing of sludge in this manner is that it is possible to dispose of it at practically any time during the year and is especially valuable during the winter months when it is nearly impossible to draw off into sludge beds.

It is planned to promote the use of liquid sludge for fertilizing lawns, from which a considerable profit is expected to be realized in the future.

FIG. 1.—Filling tank with liquid sludge.

FIG. 2.—Distributing sludge through 1 in. hose at Riverview Park.

Anyone engaged in sewage treatment and who has a sludge drying or sludge storage problem will find it well worth their time and effort to look into the possibilities of this procedure, providing they have land available which can be utilized for liquid sludge disposal.

WESTERN NEW YORK OPERATORS MEET

The Spring Meeting of the Western Section of the New York State Sewage Works Association was held at Olean, New York, on April 18, 1942. A total of 33 members and 14 guests attended.

Mr. John W. Johnson, Chairman of the Program Committee, introduced Nelson Fuller, Superintendent of Water and Sewage at Olean, who talked on the Olean sewage plant and experiments on sludge digestion.

Utilizing a map of the city, Mr. Fuller showed the sewer system and the interceptors and described the location and design of the plant. The digester capacity is large enough to take both the sewage sludge and garbage. In the spring, due to the fact that a combined sewer system exists, there is such high flow of water and the sewage is so dilute as to reduce the raw sludge loading on the digestion tanks to a very low figure. There is an attendant reduction of gas.

Another factor of interest is the grit received from the Pennsylvania Railroad Shops which settles out along with some garbage and sewage particles in the grit chamber. Because of the difficulties of cleaning this grit chamber by hand, an air lift pump was designed for grit removal. Whereas a mechanical remover would have cost $5,000 by utilizing a 105 cu. ft. air compressor which was on hand, an air lift system was built for $75.00. The grit chamber can now be cleaned in thirty minutes. It formerly took three man days to clean approximately 20 cu. ft. of grit removed per week.

Talking with the aid of large graphs of gas production, and other items concerned with digester operations, Mr. Fuller presented a discussion of their experiments using ammonium sulfate in the digesters. Until the digesters were separately emptied and cleaned last year there had been a considerable accumulation of scum. Since the cleaning, the use of scum pumps located in the covers which jet supernatant liquor out into the scum, has maintained the depth of the scum layer at about a third of what it formerly was.

Following the cleaning of the tank it was observed that although fifty per cent old sludge was used for seeding, the gas production did not return to normal. Therefore, Mr. Fuller began to add ammonium sulfate at the rate of about ten pounds per day, two or three times per week. Thereafter, it appeared, according to Mr. Fuller, that the gas production increased approximately twenty per cent above what it had been in the previous years. But when he began to analyze the theory of digestion and studied the literature, Mr. Fuller stated that he believed the case was against the use of ammonium sulfate rather than for it. Pointing out that there was now less material going into the scum and that the volatile content of the raw sludge was higher, Mr. Fuller indicated that perhaps the increased gas production may have been due to other factors than the addition of the ammonium salts. He did say that regardless of the cause, the increase in gas production had saved about $60.00 in the price of purchased gas.

In discussing the paper, Mr. Linn Enslow told of some of his experiences in Texas a number of years ago, and suggested that part of the increase more than likely was due, not to the ammonium salt added, but to the improvement in the scum condition and the fact that there was a greater percentage digestion of the volatile matter during this period than in the previous year.

"Doc" Symons raised the question as to whether or not there had been an actual increase in solids loading, as well as an increase in per cent volatile matter in the raw sludge and increased per cent digestion. Mr. Fuller replied that the per cent removal of suspended matter had been practically constant. It was pointed out that the actual removal of pounds of solids might have been greater if the suspended matter in the raw sewage were higher, although the per cent removal was the same each year.

Mr. J. T. Howson, the operator at Westfield, N. Y., was introduced and described the plant and problems of operating a sewage treatment plant in a canning factory town. Westfield has considerable tomato waste. Not only does the problem of handling wastes of quite variable compositions keep the operator on his mettle, but ponding of the filters takes place and heavy growths of filter flies are observed in the summer. In an attempt to eliminate ponding of the filters, Mr. Howson tried repeated floodings and dryings of the bed with practically no beneficial results. Treatment with chlorine was then tried and it was found that the addition of chlorine solution directly to the ponded filter surface at the rate of 200 pounds per day, destroyed the biological life of the filter for four to five weeks. Control of the filter fly had been tried by flooding the filter.

The next experiment, during the spring and summer of 1941 was to combine chlorination and flooding. It was found that five to eight parts per million of chlorine added to the last two or three feet of water applied to the filter was sufficient to eliminate ponding when treated at least once a month. B.O.D. removal of the filters, likewise increased in spite of the fact that the sewage was somewhat weaker.

In another experiment, recirculation of the effluent from the trickling filter back to the influent of the settling tank was tried. This was done for the double purpose of overcoming the fly nuisance and attempting to improve the filter effluent during the canning season. One filter ran continuously and the other one was operated at normal rate. Mr. Howson said, "The filter flies not only did not disappear, but actually were much thicker on the faster filter, and the effluent from the slow filter was but slightly better than when both filters were running normally. The difficulty in evaluating the effect of this recirculation lies in the fact that tomato waste contains a large proportion of very light solids which settle slowly; when recirculation is used, the sedimentation detention period is reduced to half of the normal time, thus much of this light material is carried on to the filters.

Had the war not intervened, it was planned to alter the piping so that recirculation could be carried out from the filter effluent to the filter influent, but this project has been postponed.

Following lunch, a film on lubrication was presented by Messrs. Howard Mellor and Pat Judah, of the Socony-Vacuum Oil Co. This motion picture showed the part of oil lubrication in the progress of the machine age. By diagrammatic presentations of operating systems, the theory of lubrication for a variety of conditions was shown. These applications included completely flooded and partially lubricated bearings, gear lubrication and lubrication in internal combustion systems. The relation of the type of oil to temperature, pressure and velocity was indicated, and the part which chemical stability of oil plays in proper lubrication was delineated.

In discussing the film and its applications. Mr. Judah answered a number of questions particularly on the subjects of conservation of lubricants; flushing, and how to obtain the right amount of grease for ball- or roller-bearings. Regarding flushing, Mr. Judah warned that kerosene should never be used, stating that light oils cut the lubricity of heavy oils to a greater extent than the proportion present would indicate. "Theoretically a ball-bearing needs no lubrication," said Mr. Judah, "but practically there is a split second when there is deflection of the spherical surface to that of a plane and it is the function of the bearing lubricant to offset this effect. Such lubricants must be good for high pressure and prevent corrosion. Except in the case of high temperature," Mr. Judah continued, "use light oil for the load moves faster than the oil is squeezed from beneath the bearing and therefore lubrication is effected."

As to the amount of grease to use in ball- or roller-bearings, the application should be controlled so that approximately two-thirds of the free space is filled. If the free space contains too much grease, a pumping action will occur within the bearing and this is definitely harmful. It is better to under-lubricate a ball-bearing than to over-lubricate, for once filled, a bearing cannot run dry. In filling the bearing, Mr. Judah suggested that it be run with the plug out for 30 minutes to make sure that all excess grease which might be "pumped" is removed from the bearing. Unfortunately he had no suggestion to offer as to how a bearing could be cleaned without disassembling and he warned against the use of carbon tetrachloride in cleaning ball-bearings.

At 3:00 o'clock an inspection of the Olean sewage treatment Plant took place and in spite of the cold, raw day, most of the group visited the plant where the operation of the air lift grit pump was demonstrated along with other features of the plant.

George E. Symons,
Secretary

GADGET DEPARTMENT

Basket Screen Hoist *

Submitted by Harvey Quam

Superintendent, Lisbon, South Dakota

A device which has proven very worthwhile in attending to a small, isolated pumping station is a home-made hand winch used for hoisting the basket screen at the wet well inlet. Details of the winch and its application are illustrated in Figs. 1 and 2.

* From the September, 1941, issue of Official Bulletin, published by the South Dakota State Board of Health. Photographs by Jerome H. Svore, District Engineer.

FIG. 1.—Basket screen hoisting assembly, Lisbon, South Dakota.

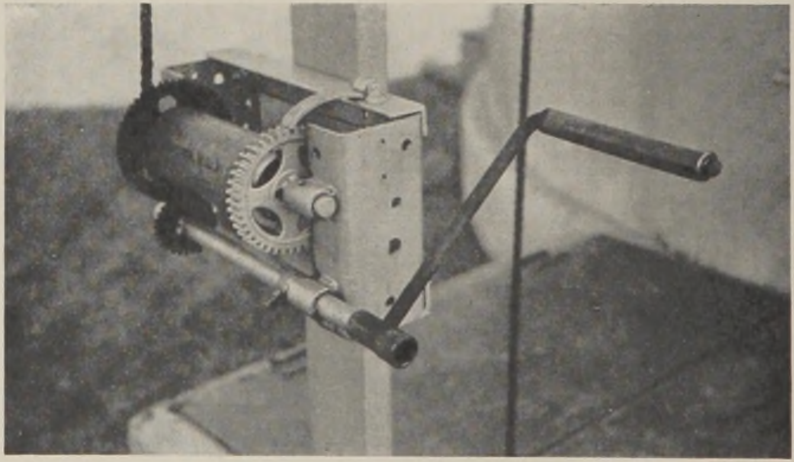

FIG. 2.—Details of basket screen hoist, Lisbon, South Dakota.

The large channel irons on which the bearings are mounted are the ends cut from a truck frame. The bearings may be recognized as the ends of an automobile spring, cut off and welded to the channels. The drum is a section of 4-inch pipe welded to two Ford timing gears, one of which is used for a ratchet and the other for transmitting power. The crank is removable.

Conveyor Tail Pulley Cleaner

SUBMITTED BY CLYDE L. PALMER

Plant Supervisor, Detroit Sewage Treatment Works

Figure 3 shows the tail pulley assembly of a belt conveyor handling sludge cake, screenings and grit (there are 16 such pulley assemblies in the incinerator building alone of the Detroit plant). Even under the best of conditions, it seems impossible to keep the pulleys and idlers clean, and a lump of sludge sticking to the pulley tends to make the belt run off to the high side.

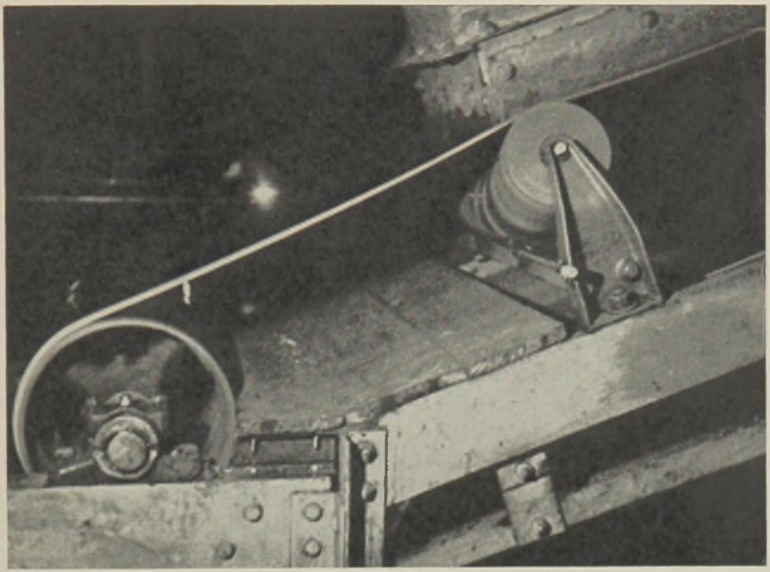

FIG. 3.—Belt conveyor tail pulley scraper, Detroit, Michigan.

The "gadget" is the wooden scraper, set to give one sixteenth inch of clearance with the pulley, and made sufficiently wide to hold considerable materials so as to prevent it from falling back inside the belt. The wood scrapper shown here is to be replaced with a more permanent metal one at the first opportunity.

CALIFORNIA OPERATORS' SYMPOSIUM *

ODOR CONTROL

CHAIRMAN JONES: I will now call on Mr. Gilkey to open the topic "Odor Control."

MR. A. E. GILKEY, *Roseville:* Odor, I think, depends on the care taken by the operator in keeping things clean. The operator must be careful

* Continued from May issue. From program of Fall Meeting of California Sewage Works Association held at Sacramento, October 12, 1941.

that he doesn't get so accustomed to something that might be a source of odor, and thus let it go on. Visitors some times make us notice such things.

I think I have a problem that very few of you have, that is, partially covered digestion tanks. Ordinarily, we do not have much trouble from them, except under certain weather conditions, and we can't do anything about that. Whenever they get upset like they do at my plant a couple of times a year, the only thing I can do is put in lime. The tank holds about 80,000 gallons, and I find that 1,000 to 1,500 pounds of hydrated lime stops the odor in a couple of days. This is not the hydrogen sulfide odor; it is just an objectionable combination of odors that I can't describe.

We chlorinate in our plant at three different points, that is, the raw sewage ahead of the bar screen, at the entrance to the clarifiers, and the effluent channel discharging to the chlorine retention basin. I think that chlorine does more than anything else to keep down the raw sewage odor. We add plenty of chlorine at the first point of application ahead of the screen, because the outfall sewer is rather flat, and solids have a tendency to accumulate in it. In fact, the clarifier sewage level is about 4 inches higher than the bottom of the last manhole on the sewer. If anything happens to cause the chlorine dosage to stop at this point, you can quickly notice the difference in the odor. I don't try to add enough chlorine at the clarifier inlet to get a residual through the tank. I would have to give it about 60 pounds per million gallons to get a residual. The chlorine added to the effluent, of course, is to disinfect it, and is not for odor control.

When we began operating the plant, we tried cleaning the screens with rakes and then burying the screenings in pits. We have found out that it is better for us to wash a lot of the screenings through the screens and just take out the rags, large roots, and so on, which we burn. You can't just let such material lay in the pile, it must be disposed of right away.

In the winter time, we get a sort of fungus—it has another name, but I won't try to pronounce it—which clogs the screen and backs up the sewage in the sewer. I force this through the screen and eventually dispose of it in the digester, where it doesn't seem to cause any trouble. It is a problem all through the winter.

Mr. Woodward: The Laguna Beach sewage treatment plant is located five blocks from the business district of Laguna Beach and only one block from the City Hall, therefore, one of the problems we have to continually consider is the proper control of odors in our plant operation. In every case when we have had trouble due to odors at our plant, we have found that the best solution of the problem is to prevent the occurrence of odors in the first place, therefore, I have come to the conclusion that "odor prevention" is a better term than "odor control."

At the sewage works convention held in Santa Cruz, Mr. Bowlus of Los Angeles presented a paper on sulfide control in the sewer mains in which he reported that they were able to eliminate all hydrogen sulfide odors at various points in their system. I believe that this is the place to start because if you can bring the sewage through the mains to the plant in a relatively fresh condition, you have eliminated the source of a great many plant odors right at the beginning. This is borne out by the fact that in our experience in the Laguna Beach plant, we have found that we must be particularly attentive to the primary clarifier in order to reduce odors to a minimum. We have had very good success in controlling the odors arising from the primary clarifier by treating the incoming sewage with chlorine. We make regular tests on the primary effluent for sulfides and then feed just enough chlorine to eliminate them. Incidentally, we have found that by making a few slight changes to the primary tank and securing a better sludge pumping system, the quantity of chlorine needed can probably be reduced a great deal.

We had trouble for a period of time due to odors arising from our digester. In tests taken at this time, we found sulfide as high as 26 p.p.m. We tried treating with chlorine, various ideas of ventilation, and everything else that we could think of, and still could not control this odor. The heating coils in our digester had corroded to such an extent that they had failed, and we were unable to keep the sludge in the digester heated. We decided to empty the digester, and install a new vertical hot water circulating system a year and a half ago, and have found that since rebuilding the digester, we have no longer been troubled with odors from this source. We have been using a small amount of chlorine in the supernatant discharge line as an extra safeguard, and have been unable to perceive any of the typical hydrogen sulfide odors.

I believe that if a plant is kept clean, and all units are working efficiently, good ventilation will take care of the balance of the odors, at least we have found this to be true at our plant. We are very fortunate, however, in having a good force draft ventilating system. A 24-in. chimney located 206 ft. above the plant on the hill is so placed that breezes from the ocean and canyon on the north carry all odors over the hills and away from the town. All of the air from the plant is forced through an air duct to this chimney. This air duct is equipped with a high pressure pump with a 16-spray nozzle arranged to pump chlorinated water sprays across the air duct. This last mentioned equipment has been used very little because we have been successful to date in controlling our odors in other ways, however, in tests this equipment has proven quite effective. We expect that we may have to use this chlorinated water spray equipment at some future date, due to the growth of our city.

We have had a few complaints of odor, but in nearly every case we have traced them to the hydrogen sulfide gas arising from the decomposition of a certain kind of kelp buried under the sand on the beach. At certain seasons of the year, the tides carry this kelp onto our beach and cover the same with sand, and if it not uncovered, it will begin to decompose, and give off hydrogen sulfide. All complaints that we have received for some little time past have come from this source.

As I indicated at the beginning, I believe more work should be done on the construction and maintenance of the sewer mains, and more thought given in plant construction looking towards the prevention of odors, rather than allowing them to occur and then trying to prevent a nuisance from arising, by trying to control these odors.

Mr. White: I wish to emphasize a few of the points brought out by Mr. Woodward and Mr. Gilkey, and to comment further on the sulfurous and hydrogen sulfide odors.

The production of these odors can be associated with the strength of the sewage, the sulfate content of the water producing the sewage, to the local temperature conditions, the rate of change of the temperatures, and to the design of the collection system itself. There are many things that can be done in controlling these odors.

First, we might list them in the order in which the operator might attempt to solve the odor control problem. As Messrs. Gilkey and Woodward have said, good housekeeping is essential—the prevention of the accumulation of solids that may occur in the collection system. Also, in this connection, the operator can attempt to control the flow of sewage in the system, so as to either increase the velocity or prevent this accumulation, or to minimize the detention time of the sewage in the system. Actually, he would be bringing the sewage to the plant in a fresher condition.

Further, we might attempt to control the sulfate-splitting organisms by chlorination, or to precipitate out the sulfur with chlorine. In connection with this treatment there is, of course, pre-chlorination, the Scott-Darcey method, and also the chemical reactions between the sulfides and heavy metals, such as iron, copper, and zinc. Other control measures are pH control, ventilation of structures, and the use of ventilating mechanisms.

From these, it is obvious that the operator will turn directly to the most practical methods at hand. He cannot do much to change the fundamental design of the collection system, but he sometimes can improve the conditions of flow. If it is not enough, he then goes on to chlorination or the other methods which are available.

Mr. K. Fraschina, *San Francisco:* We are in much the same position as Mr. Woodward, as our plant is located in a park, and odors must be maintained at a minimum. We are using essentially the same methods of odor control as have already been mentioned. Our primary method is by pre-chlorination, and we dose at a rate of 30 pounds p.m.g. Our sewage is fresh, so the problem is not so severe as at some other places. Also, the plant was constructed with the tanks all housed, and with ventilation to control any odors inside and outside the buildings.

We remove grease by aeration, and that aeration, incidentally, helps to improve the oxygen content in the sewage, so that we rarely have trouble from odors from that source. The odors that we get within the buildings are the usual ammoniacal odors. In our sludge control house, vacuum filter room, and at the elutriation tanks, we have draft ventilation. The suction of air is at the ceiling, and discharge is out through the roof. We have experienced several incidents that show the necessity for good housekeeping.

Because of the amount of sand that comes into our plant, we have had to clean out our mixing tanks periodically, and that is usually done in the winter when the plant is by-passed. When this sand is exposed to the air, it gives off considerable odor, which, I think, is largely from organic matter and hydrogen sulfide. The best thing we have found to control this odor is to cover the sand with just a little water, and this seems to be sufficient.

Chairman Jones: I am interested in how long these flues and blowers —ventilators—will last. I would like to hear some discussion on the design and type of ventilators that should be used.

Mr. Benas: We use a blower. We find that it is better to obtain ventilation by blowing in fresh air, rather than to draw out the air in the building. When you blow in fresh air, you lower the humidity.

Dr. Richard Pomeroy, *Harbor City:* Hydrogen sulfide gas is, of course, heavier than air, but even where you have very offensive odors, you will have at most perhaps a hundred parts per million. Two hundred parts per million would be a very bad situation, but even this would have a negligible effect on the density of the air. Whether the odors will rise or settle will be determined mostly by the temperature of the air. The density of the hydrogen sulfide will have practically nothing to do with it. Humidity has some effect, because water vapor is lighter than air, so humid air, provided it doesn't actually have a fog in it, will tend to rise rather than settle.

Mr. Harold K. Palmer, *Los Angeles:* Our experience at Los Angeles has been that it is advisable to draw the air from above, because there seems to be some accumulation of odor at the ceiling. We make the opening at the bottom of the flue somewhat smaller than the flue itself, so that there will be little suction. We have another opening below the flue, through which a little is sucked out, but most of it is taken from the top, and this works very well.

A Comment: Someone asked about ventilators a little while ago. We had considerable trouble with ventilators which were made of galvanized iron. We painted them about every six months, but it did no good—they were all eaten up in about two years. We now make them out of copper, and find that they are lasting quite well.

Mr. G. A. Parkes, *Los Angeles:* I would like to tell you what happened to us in this matter of ventilation. We were asked to control odors in our plant, and decided that one of the sources of odor was the trough around the circular clarifier (Fig. 4) where the sewage splashed over the weirs. It was also considered that quite a bit was coming from the bar screen structure at the plant inlet.

Wooden covers were fitted over these chambers, and also over the supernatant overflow box on the digester. We placed burners around, on the assumption that they would heat the air and cause a certain amount of draft, which would cause movement from under the wood covers which, of course, were not airtight. There was a certain amount of draft, and due to pressure of other work, we did not look under the covers for some time. When we did, we were horrified to discover that the concrete in these structures was eaten away as much as $1\frac{1}{2}$ inches in some places! Apparently we had kept the odors from circulating in the atmosphere by trapping them under the covers. It was a difficult and laborious job to clean that concrete, patch it, and cover it with a protective covering. The answer seems to be that you can't stop odor by merely cornering it with a cover. I think Dr. Pomeroy will bear me

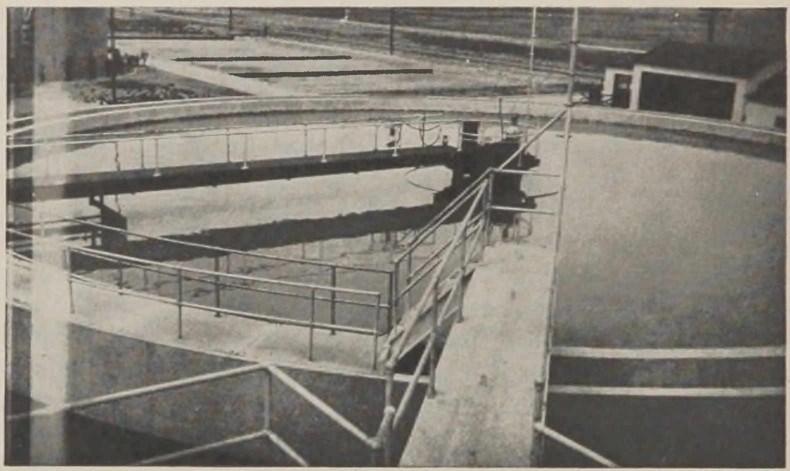

FIG. 4.—Primary sedimentation tank at Terminal Island Sewage Treatment Plant, Los Angeles, California. Attempt to control odors at peripheral channel resulted in damage to concrete.

out in this—a certain amount of oxygen is necessary to make the hydrogen sulfide dangerous. If the oxygen is deficient, the gas will not be seriously corrosive, if you get the right amount of oxygen you will have a bad problem. If you get more than that amount of oxygen—a very large volume of air—you dilute the hydrogen sulfide to a point where it is harmless. This was evident from the conditions we found when the covers were removed. Where the planks of the covers fitted very closely, there was very little attack on the concrete, but where there were cracks between the planks there were streaks where the concrete had been attacked.

It seems to me that if you are going to ventilate, ventilate plenty! Don't just give a gentle and possibly casual replacement of the air—really change it.

Possibly someone can give me information on the profitable percentage on the amount of hydrogen sulfide which makes an atmosphere corrosive. This would be very helpful in designing ventilation equipment.

DR. POMEROY: The conversion of hydrogen sulfide to sulfuric acid, which of course is the reason for the corrosion of the concrete, as you all know, takes place down to extremely low concentrations of hydrogen sulfide, provided the bacteria which bring about that change are present.

Fred Bowlus and I, for example, made experiments in the outfall of the Los Angeles County Sanitation Districts in which there was an atmosphere containing 20 or 30 p.p.m. of hydrogen sulfide, and we stopped the ebullition of hydrogen sulfide from the sewage by stopping the flow of the sewage, because only when there is turbulence is there any hydrogen sulfide involved. And then we watched the concentration of hydrogen sulfide that went down rapidly to zero, especially near the walls where the change was taking place. That shows that extremely low concentrations will be converted to sulfuric acid by these bacteria—concentrations as low as one part per million.

The theory of ventilation, as practiced by the City of Los Angeles, I believe—I have gathered this from a conversation with Mr. Parkes and others—is at least in part one of drying the surface of the concrete, thereby creating an environment in which the bacteria will not work, because we know that if the surface is perfectly dry you will not have that change taking place. So, that at least is one important factor.

A further thing in support of that is this fact. The air which is exhausted from the north outfall of the City of Los Angeles contains a considerable concentration of hydrogen sulfide—a concentration which would be high enough to cause a significant attack on the concrete if there is enough moisture on the walls so that it is being converted into sulfuric acid.

As to this phenomenon that you mentioned at the Terminal Island plant of greater attack near the cracks where there was more air coming in, I haven't had an opportunity to examine that and would hesitate to express an opinion offhand as to why that should occur. But you raised the question of whether it may have needed more oxygen than was present. There is evidence that the change also takes place at very low oxygen concentrations. For example, the north outfall sewer in the City of Los Angeles was originally operated on the theory that if they shut it up tight and keep the air out, they would not have any attack; but experience indicated that in spite of the attempt to shut it up tight there was enough oxygen in there so that bacteria seemed to do very nicely.

Of course, this is getting away from the odor-control problem, but I do certainly subscribe to what Mr. Parkes said; that if you are going to ventilate, especially a sewer, or cover over a flume or some other place where the sewage is flowing, be sure that you ventilate plenty, because it takes a heck of a lot of change of air to either dilute the hydrogen sulfide very much or to dilute the humidity so that the walls will dry out.

Question: How much is "a heck of a lot"?

Dr. Pomeroy: The amount of air that you have to pull—or maybe I can better express it this way: the power requirement increases as the fifth of the length of the sewer that you are ventilating. Suppose it takes ten horsepower to ventilate one mile; to ventilate two miles will take six hundred and forty horsepower to do the same job, because as you try to pull for a longer distance, the attempt to dry out the surface requires a much higher velocity, and the power goes up by the square of the velocity. So, it requires a tremendous amount of air to ventilate a long distance.

Furthermore, the distance which you can effectively ventilate is proportional to the diameter of the sewer. When you get down to a small sewer, I don't think you have any possible hope of effecting the control of corrosion for a distance as long as three miles. I think you would have to come down to shorter distances than that to accomplish very much in the way of control, although your sucking air out of the sewer would accomplish other benefits in that it would prevent sewer gases from going out of manholes and going into house plumbing and through house stacks.

Safety Measures

Chairman Jones: Mr. Sotter is scheduled to start this discussion, but is not here. Mr. Benas is going to pinch-hit for Mr. Sotter.

Mr. Benjamin Benas, *San Francisco:* The other night, Mr. Knox, the Secretary of the Navy, gave a statement before the Safety Congress, in which he stated that there were four times as many man-days lost during the past year by accidents or by loss of time due to safety than there were by strikes, which is really a startling statement. I think he mentioned some figures in the neighborhood of twenty-six million man-days lost through industrial accidents, probably including some losses due to colds or other sicknesses which might have been caused by working conditions. Clearly, the subject of safety is an important one.

To encourage personal safety on the part of plant operators, we place warning signs on those places or locations where there may be accidents. We provide gloves, gas masks, goggles, boots, and coats to keep the men dry and protect their hands, faces and bodies from injuries. We have water and soap available so that the men can wash their hands, and thereby remove any source of contamination as well as possibility of infections at cuts and bruises.

We provide first aid kits at reasonable locations. We have the men work in pairs in any place where there is liable to be an accident, and we also give them instructions so that each individual knows what he is supposed to do and the risks involved before he does it. This is particularly true in the handling of chlorine.

There have been a number of accidents at our plant which have resulted in personal injury. In one case, a man permitted a manhole cover to slip, thereby fracturing his toe. He lost a part of his toe, and will probably be out of work for a couple of months. In another case, one man was holding a hose while another turned on the water, but he did not hold the hose tightly enough, so that the hose whipped around and caused a severe cut. Bruises from the improper handling of tools are common. Such injuries as these can be averted if the operator takes sufficient care and time and keeps his mind on what he is doing. Injuries to operating personnel are directly reflected in plant efficiency, because the substitute is seldom as well equipped to do the job as the man who is off the job because of an injury. This is probably most important in small plants, particularly where everything is done by one man.

Mr. H. W. Schuck, *Burlingame:* I will endeavor to explain two experiences with safety measures at the Burlingame sewage treatment plant.

When we began operation of our plant about five years ago, we found that our gas holder did not rise with the pressure, and that the seal would blow. It was necessary to get inside the holder and burn off some steel railroad rails which had been placed in there to add weight. These had to be cut off with an acetylene torch, as they were welded in there, and this was obviously a hazardous job. In order to expel the gas, we removed the manhole plate and filled the tank to the top of the seal with water, after which we repeated this operation. Air from an air compressor was then pumped into the tank for about five hours, after which we had the gas company men test the air in the tank. When we were assured that it was safe, we went inside the tank, cut out the rails with the torch, and restored the holder to operation.

In another instance, we had a serious accident at our digestion tank, of which some of you may have heard, but I doubt whether you know all of the details. One morning about five months after we began operation, we found that the top of the digester tank had developed some very bad cracks. Gas was coming through these cracks, but the seal had not blown.

The apparent reason that the seal had not blown was that the scum mat inside of the digester had filled the gas dome, and shut off the gas seal, causing excessive pressure in the tank, which lifted the whole roof of the tank in the center. Even when the roof dropped back into place again, this mat keep the seal from blowing until the pressure had been relieved by the escape of gas through the cracks.

The next day we removed the manhole cover at the gas dome and could see the shape of the under side of the gas dome impressed into the mat of scum. The concensus was that this so-called explosion was caused by pressure and not by fire, and probably would happen very rarely. However, it was very expensive, and might have caused injury to our employees.

Mr. Thomas M. Gwin, *Folsom State Prison:* Mr. Schuck states that he hasn't inspected the inside of his gas holder since the weights were taken out. My advice to him would be to go in there at least once a year and paint the inside of the tank with some good paint. If he doesn't he may find that he will have to buy a new tank.

Mr. Schuck: We do use a paint which we place in the seal and also pump on the inside. It is doing very good work on the outside of the tank, and we think it is doing the same thing on the inside, although we are not positive. We give this paint treatment about twice a year.

Mr. R. D. Woodward, *Laguna Beach:* As a rule safety in the plant has not been given the consideration it should have either by the plant operators or the plant designers. I am going to confine my remarks to a few short statements which might be regarded as my safety rules for plant operation.

Many plants are constructed with chlorine tanks in the pits, gas pockets and pipe galleries. If this is done, they should be well ventilated.

Every operator should know all the hazardous points in his plant and should give them a systematic inspection regularly, to see that all valves, flame traps and electrical equipment are in working order at all times. All doors in the plant should open from the outside so that it can be ventilated before entering if necessary.

All operators should know how to use a gas mask. A canister mask should never be used on sewer gas. All gases of this nature require an open air mask where fresh air is fed through a hose to the outside, or with the use of a blower. All masks and first aid equipment should be kept in a central place. At least two operators should have first aid training and know what to do in any emergency. Make a plan of what might happen and be prepared as much as possible.

Don't let your work become so much routine that you become careless, as most accidents happen this way. Operators should figure every way to prevent accidents, and a little more care taken on the job might save a life. After all, safety first is worth more than all you can learn about first aid.

Chairman Jones: In connection with this matter of personal safety, I would like to add that we went to a lot of trouble to find a soap which we had confidence in. We finally located a liquid soap that wasn't very hard on the skin, but which is recommended for use by chemists, doctors, undertakers, etc. I am not selling the soap, but I have brought some pamphlets which describe it, in case any of you are interested.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Fort Dodge, Iowa (Year Ended March 31, 1941)

T. R. Lovell, *Superintendent*

General.—The plant consists of sedimentation and separate sludge digestion units for primary treatment followed by two stages of trickling rock filters for secondary treatment. The sewage entering the plant, first flows through a detritor for the removal of sand and grit. The effluent from this unit then passes through a small aeration tank for the separation of grease and scum. Upon leaving this grease separator, the sewage passes to two 45-ft. diameter primary clarifiers equipped with mechanisms.

The effluent from the primary clarifiers passes to dosing tanks from which, by means of siphons, the sewage is applied to two 151-ft. diameter trickling rock filters equipped with rotary distributors of the reaction type. The filtering medium consists of crushed rock, varying from one to three inches in size, and averaging 8 ft. in depth. The rock in one filter is crushed granite and in the other crushed limestone. After passing through these first stage filters, the sewage enters a rectangular intermediate clarifier for further settling of suspended matter. The effluent from this clarifier flows to the wet well of the secondary pumping station and from this point is pumped, by means of float operated pumps, to dosing tanks which are located near the primary clarifiers. From these dosing tanks, the sewage is again applied to two trickling filters which are the same in size and type as the first-stage filters previously described. The effluent from the second-stage filter flows through a rectangular final clarifier, for final settling of suspended material, before discharge into the river.

The mixture of primary and trickling filter sludge is pumped, at regular intervals, from the primary clarifiers to two 65-ft. diameter sludge digestion tanks equipped with steel floating covers. Digester contents are maintained at optimum temperatures for the digestion process by the exchange of heat from the engine cooling water through iron pipe heating coils installed in both digesters.

The solids pumped to the digester, after the proper period of digestion, are drawn to sludge beds for air drying or, after being conditioned with chemicals, are dewatered by means of vacuum filtration equipment. The dried solids or sludge is finally disposed of as a low grade fertilizer and soil conditioner. Of the total amount of power generated through utilization of sludge gas, the amounts necessary for operation of the pumps, mechanisms and other equipment are used by the sewage treatment plant while the balance is sold to the Fort Dodge Gas and Electric Company.

The sewage received at the plant consists of a mixture of domestic sewage and industrial wastes from the pork packing and processing plants of the Tobin Packing Company. The mixed waste is unusually strong due to the inclusion of the packing waste.

Filter Clogging Corrected.—On April 1, 1940, the sewage treatment plant had been in operation for just a little over two years. All of the plant units were in operation, but the effluent from the plant was not of the best. Unusually heavy loadings were received during the colder winter months, due to exceptionally heavy loadings from the Tobin Packing Company. Much grease and floating solids had been carried through the primary clarifiers and out on to the trickling rock filters, with a resultant loss of efficiency through the filters due to clogging and ponding of the filter media. This was particularly true of the first stage filters and to a lesser degree, the efficiency of the second stage filters had also been affected.

From April 22nd to April 27th, the surface stone of all of the filters was loosened by rodding and by the use of a high pressure water stream from a fire hose. The rock was worked over for at least a foot in depth and considerable solids material was sloughed from the filters. Surface ponding was largely eliminated and a slight increase in the efficiency through the filters was noted.

Effluent Recirculation.—On April 30th, the last work on the installation of the recirculation line and pump was completed and the unit placed in operation. This recirculation unit consists of a centrifugal pump, with a capacity of approximately 1000 gallons per minute, discharging through a 12-in. cast iron main connected into the 16 in. force main just ahead of the inlet to the plant. The suction line to this pump is connected into the outlet end of the final clarifier, so that final or plant effluent is used for recirculation. The electrical starting equipment for this pump is programmed with the starting equipment of the sewage pumps at the main pumping station in such manner, that the only time this pump is put into operation is when all pumps at the main pumping station are idle and no sewage is being pumped to the plant. It is intended by this means, to obtain a minimum rate of flow of about 1000 g.p.m. through the plant, thus eliminating overlong displacement periods in the plant during the low night flows. It is hoped, that by the means of this recirculation, it will be possible to minimize septic conditions that would aggravate odor conditions. It has been noticed that the operation of this unit has increased the power requirements of the plant by about 200 kilowatt hours per day.

Alum Aids Sludge Drying.—During April, digested sludge drawn through the winter months was removed from the sludge drying beds. The beds were then refilled with digested sludge. Bed No. 1 received sludge to which no chemicals were added. All other beds were filled with sludge, to which various amounts of aluminum sulfate were added. Amounts used were from 300 to 800 pounds for each bed of 24,000 gallons drawn. The solids of sludge drawn varied from 6 to 7 per cent on a dry solids basis. The alum was added as a solution and mixed with the sludge as it entered the bed. This released a large amount of carbon dioxide from the sludge, lifting the solids mass to the surface with a separation from the bulk of the water in the sludge, which stayed at the bottom. This permitted most of the water to rapidly drain through the sand of the drying bed.

The drying time for the sludge was shortened considerably over previous conditions, but we were not able to obtain results as reported by other plants. There did not seem to be any advantage in dosages of alum over 400 pounds per bed and this amount is being used for the present. This dosage will probably have to be changed from time to time in accordance with results obtained on small trial batches. Bed No. 1, to which no alum was added, remained on the bed for most of the summer. The solids in this bed of sludge settled to the bottom, sealing the sand, and the water which came to the surface was finally removed through evaporation which was a very slow process.

Chlorine Controls Odors—Helps Filters.—Chlorination of sewage, using small amounts of chlorine, was started in May for the purpose of minimizing the distinct packing house odor of the sewage, which in the past has caused complaints and litigation by persons living near the plant. Considerable reduction in the intensity of the odors was secured but odors were not entirely eliminated. The trial chlorinator in use was quite small. Arrangements were then made to rent a chlorinator with a capacity of 720 pounds of chlorine per day and a carload of fifteen tons of liquid chlorine was purchased, so that it might be determined just what could be done by the use of chlorination. The chlorinator arrived, was set up, and put into operation June 22. Chlorine was introduced at various points throughout the plant and at different rates of dosage.

It was found that from 500 to 700 pounds per day usually eliminated all packing waste odors, when applied to the raw sewage entering the plant. This amount of chlorine was but from ten to fifteen per cent of the amount required, as indicated by chlorine demand tests run on the raw sewage. It was noted further, that if the chlorine was applied to the effluent from the primary clarifiers just ahead of dosage to the trickling filters, a much smaller amount of chlorine could be used and yet obtain practically the same results. Although this practice did not eliminate all odors at the primary tanks, it was quite effective insofar as the odors from the filters, which traveled beyond the limits of the plant, were concerned. It was also found that chlorine requirements varied widely from day to day. About two weeks after the start of chlorination, a large amount of material began sloughing from the trickling filters and the efficiencies of removal through these units was considerably improved. From the standpoint of plant operation, this sloughing of humus materials from the filters was of more importance than was odor control. However, since chlorination was helpful for both purposes, the practice has been continued. A 1000-pound master chlorinator was purchased and by use of this machine we are able to apply quite heavy dosages of chlorine as needed in the plant.

Gas Engine Problems.—During the warmer summer months, it became impossible to dissipate all of the heat from the engine jacket water by heating of sludge digesters and auxiliary cooling in clarifier coils without an increase in temperature of digester contents and a rising temperature of the jacket water. This made it necessary to install a piping arrangement to permit feeding into the jacket water an amount of cold water and a waste of a like amount of hot water to keep temperatures from rising. In order to minimize scale formation, enough Calgon was fed to maintain a content of approximately 2 p.p.m. of this material in the jacket water. During an inspection of the engine made in January it was found that in spite of this practice, a certain amount of soft scale had formed in the jacket water compartments of the engine.

The engine was taken down for inspection twice during the year; once during September and again in January. Cylinder liners showed excessive wear at both inspections, although this wear was but a fraction of what was found on the original liners for a like period of operation, prior to the installation of the gas purifier and the oil refiner. All other parts of the engine were found to be in a satisfactory condition. The wear of the cylinder liners was reported to the Cooper-Bessemer Corporation after the inspection which was made in January. In reply, the Cooper-Bessemer Corporation requested of the city permission to manufacture and install at their expense, a new set of liners of a new iron alloy. They believe that these new liners will give better service than the ones in use at present. Permission to do this has been given and it is now anticipated that these new liners should arrive and be installed some time during June of the coming year.

The oil refiner has been keeping the oil in good condition and there has been no evidence of crankcase sludging as was the case previous to the installation of this unit. In practice, the fullers earth cartridge of the refiner is replaced each month. The consumption of lubricating oil has been gradually increasing, due to worn cylinder liners, but it is still not excessive.

The gas purifier has been operating in a satisfactory manner, although the removal of hydrogen sulfide per cubic foot of iron sponge used is not as high as was expected. This makes it necessary that the iron sponge used in the purifiers be changed more often than had been planned. The hydrogen sulfide content of the raw gas has remained quite high, varying from 200 to 400 grains per hundred cu. ft. of gas. The sulfide content of the gas utilized has been kept below 25 grains per hundred cu. ft. by changing the purifier sponge as the sulfide content of the purified gas approaches this amount. During each change, however, for a period of from two to three days, it is necessary that the engine be operated on raw gas with a high sulfide content. This is not a desirable practice, but until such time as it becomes possible to install a duplicate purifier it will be necessary either to operate in this manner or to shut down the engine while changing the iron sponge.

Pump Bearings and Packing.—About two years ago, the lower radial ball bearing, which had given considerable trouble, was replaced in pump No. 1 at the main pumping station. This bearing was replaced with a double row roller bearing and in addition the bearing housing was honed out to permit a pressed rather than a driven fit of the bearing. Since this bearing had operated without trouble for about a year, the bearings of number 2 and number 3 sewage pumps were also changed to roller bearings in May. After an additional ten months of operation, the bearings in all three pumps are still giving satisfaction. This is a much longer period of operation than it was ever possible to get with the old type of ball bearing.

During December, the packing in one of the main pump station pumps blew out, flooding the dry well of the pump station with sewage to a depth of about five feet before it was noticed and the pump shut off. The sump pump was submerged and it was necessary to make a temporary installation of another sump pump in order to pump out the dry well. After pumping out the dry well, it was necessary to dismantle all of the pumps, clean up the bearings and relubricate them. No damage was done to the pumps, but it was necessary to bake out the motor of the sump pump before it could be put back into operation. Upon checking up, it was discovered that someone had attempted to economize on pump packing by using up accumulated short ends of packing in place of cutting all full length rings. The result was that the packing gland did not hold the short pieces of packing in place against pump pressure. It might be mentioned that in view of the additional work that was caused for everyone, it is not expected that this practice will be repeated.

Summary of Operation Data

Item	1940–41 Average	
Population (actual)	22,000	
Equivalent (by sewage analyses)	83,200	
Sewage flow—average daily	2.06	m.g.d.
Per capita daily	94	gallons
5-Day B.O.D.:		
Raw sewage	825	p.p.m.
Final effluent	74	p.p.m.
Removal	91%	
Filter performance:		
First stage loading	1,375	lb. ac. ft. day
First stage removal	665	lb. ac. ft. day
Per cent removal	48.4%	
Second stage loading	710	lb. ac. ft. day
Second stage removal	510	lb. ac. ft. day
Per cent removal	71.8%	
Overall loading	688	lb. ac. ft. day
Overall removal	588	lb. ac. ft. day
Per cent removal	85.5%	
Suspended solids:		
Raw sewage	616	p.p.m.
Final effluent	59	p.p.m.
Per cent removal	90.4%	
Clarifier removals:		
Primary (raw only)	64.1%	
Primary (raw plus humus)	70.5%	
Intermediate	38.6%	
Final	55.2%	
Sludge digestion:		
Raw sludge quantity per m.g. sewage	12,300	gallons
Solids content	5.8%	
Volatile content	79.3%	
Gas production—per lb. volatile added	11.92	cu. ft.
Per capita daily (actual)	5.25	cu. ft.
Based on population equivalent	1.39	cu. ft.
Packing plant waste:		
Lb. 5-day B.O.D. per hog processes	7.14	lb. day
Population equivalent per hog processed	42	persons
Lb. suspended solids per hog processed	4.64	lb. day
Operation and maintenance costs:		
Per million gallons treated	$27.94	
Per capita per year	$ 0.95	
Per 1000 lb. 5-day B.O.D. removed	$ 4.49	

Johannesburg, South Africa (Year Ended June 30, 1941)

Dr. E. J. Hamlin, *City Engineer*

Scum Accumulation with Compressed Air.—It is generally agreed today that no two sewages are alike. The general characteristics may be the same, but the sewage flow from any given community has characteristics peculiar to the habits, customs, and mode of living of that community. It is, therefore, quite natural that the sewage reaching the Johannesburg disposal works has characteristics not found at other disposal works and calls for the solution of problems not found elsewhere.

One of the characteristics of Johannesburg sewage is the amount of fat, grease, oil and "unspent" soap it contains. An inspection of any of the town sewers will reveal that the crown and sides of the sewer above average flow is coated with grease and fat, and it is quite common to find at the disposal works large balls of fat and grease that have come down the sewer.

The following are probably the chief factors accounting for the large quantities of fat and grease reaching the disposal works:

(*a*) At many industrial works little effort is made to recover fat and grease, probably due to the fact that the value of the products recovered does not justify the cost of installing the necessary plant for recovery of these products.

(*b*) Grease traps are not installed as portion of domestic house drainage systems.

(*c*) Johannesburg water being hard, soap has to be liberally used, and, with native servants, is as often as not very wastefully used.

(*d*) Whilst there are several large laundries in Johannesburg, the tendency is still for most people to have their washing laundered at home, and it need hardly be stressed that the amount of "unspent" soap reaching the disposal works from the home laundry is considerable. In fact, it seems that when a cake of soap has been reduced to a small size it is disposed of into the sewer via the gully. The dry and dusty conditions frequently prevailing in Johannsburg—especially during the winter months—result probably in the washing from the average household being larger than that from a similar household in a colder and moister climate.

Apart from the fact that oily and greasy materials have a detrimental effect on the process of sewage purification, they also result in a very unsightly appearance on the surface of sedimentation tanks. Provision of means for readily removing these substances, together with other floating matters, from the surface of sedimentation tanks was a matter of importance in so far as the Johannesburg disposal works were concerned.

At first a fixed trough, the bottom of which was connected to the sludge main, was provided on the inside of the scum board of the sedimentation tank, and the floating solids were hosed and lifted from the surface of the tank into this trough.

In tanks built subsequently, a 6-inch diameter pipe—usually referred to as a "scum pipe"—from which a 90° sector had been cut, was laid radially from the central stilling box with one edge of the opening (resulting from cutting out the 90° sector from the pipe) set just at water level. The discharge from this pipe is controlled by a valve. Any

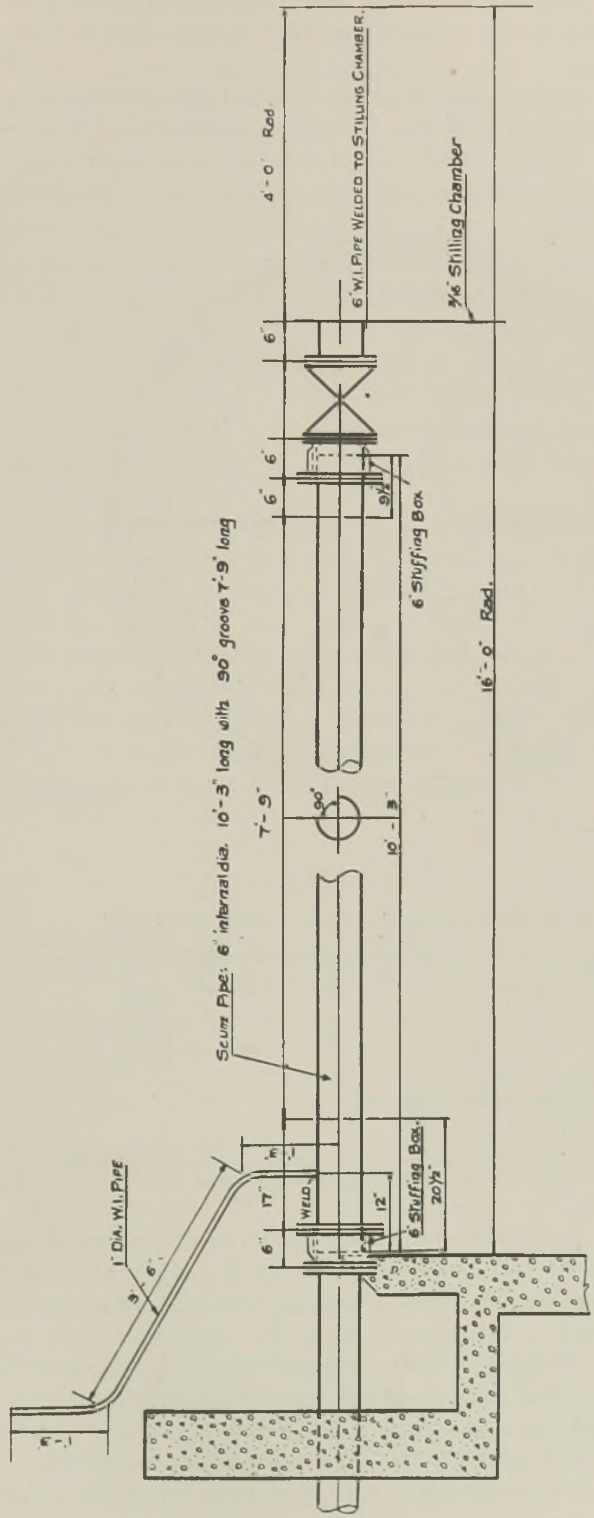

Fig. 1.—Details of scum pipe. Klipspruit Sewage Works.

grease and floating solids on the surface of the pipe are hosed into this pipe, the control valve opened, and the grease and solids washed into the sludge main.

Hosing the grease and floating solids from the surface of the tank has to be frequently done, and it will be appreciated that a fair amount of labor—and water—were required for this operation, and it was with a view to simplifying this operation that a method of removing

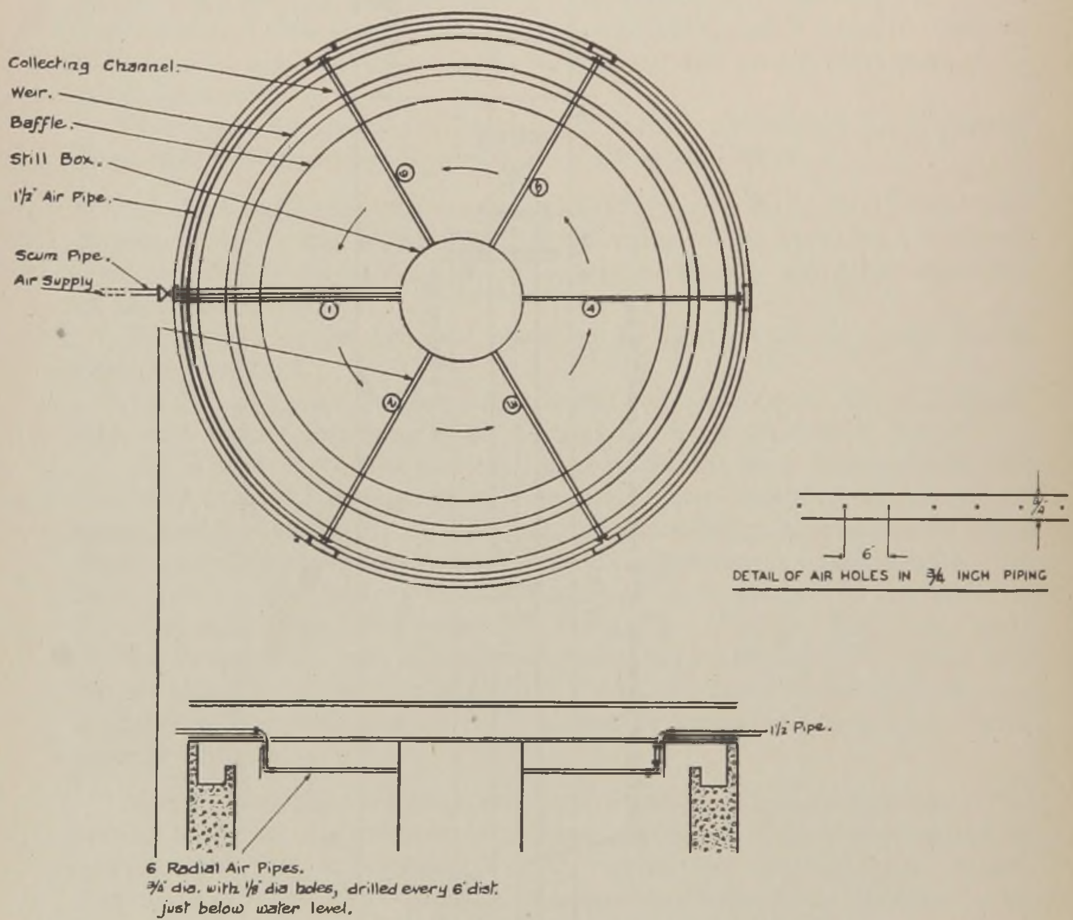

Fig. 2.—Pipe arrangement for removing scum, grease and floating solids from sedimentation tanks by means of compressed air.

grease and floating solids from the surface of sedimentation tanks, by means of compressed air, was devised by Mr. J. J. Pollock, at one time manager of the Council's Delta Disposal Works, and at present in charge of the mechanical workshops of the City Engineer's Department.

The method devised by Mr. Pollock is very simple and effective, and consists of a 1½-inch diameter air supply main laid round the outside of the tank. From this main six ¾-inch diameter leads are taken radially across the tank to the central stilling chamber. The ¾-inch pipes are spaced equidistantly, the first one being immediately behind the 6-inch grease collecting pipe already referred to. The ¾-inch pipes are laid below water level and have ⅛-inch diameter holes drilled at 6-inch spacing, the holes all lie in a plane parallel with the surface of the water and face the same direction, viz., that of the opening in the 6-inch collecting pipe. The air inlet to the ¾-inch pipes is controlled by brass plug cocks.

To remove the grease and floating solids, air is let into the ¾-inch pipe immediately behind the scum collecting pipe, and the air escaping through the ⅛-inch diameter holes drives any grease, scum and floating solids round the tank and past the second ¾-inch radial pipe. The air inlet to the first pipe is then closed and that to the second pipe opened and so on until the last radial pipe is reached. Before opening the air inlet to this pipe the control valve on the 6-inch scum pipe is opened. The air inlet to the last pipe is then opened and the scum, grease and floating solids between this and the 6-inch scum pipe are blown into the opening provided in the latter.

The whole operation is completed very expeditiously; there is no trailing hose pipe, splashing or untidiness resulting therefrom. Compressed air at 10 lb./sq. in. pressure is taken from the mains supplying the activated sludge plant.

In the tanks recently constructed, the scum pipe, instead of being fixed, is movable, and the removal of grease and floating solids from the surface of the sedimentation tanks is thereby further simplified.

Figures 1 and 2 show the arrangements being used in the most recently constructed tanks.

TIPS AND QUIPS

In his Annual Report for the year ended June 30, 1941, City Engineer E. J. Hamlin of Johannesburg, South Africa, states as follows:

> The sewage arriving at Klipspruit is reputed to be the "strongest" in the world. The reason for this is that, due to the topography of Johannesburg, it is necessary from an economic point of view to have several sewage disposal works. The result of this is that practically all the industrial waste is diverted to one works—Klipspruit.

The report does not contain 5-day B.O.D. analyses of the Klipspruit raw sewage for direct comparison with American experience, however, the average oxygen absorbed in 4 hours (from acid permanganate) is reported to be 19.86 parts per 100,000 (199 p.p.m.).

And that is not exactly pristine!

* * *

"Hats Off . . . to Leo Holtcamp . . . Cleanliness Come First," reads a caption in a recent issue of the Webster City (Iowa) *Observer.* The caption titles a column and a half of commendatory comment concerning Superintendent Holtcamp and the efficient sewage treatment plant at Webster City.

This type of recognition, unsolicited in any way but earned through conscientious public service, is of great value from a public relations standpoint. It is a real compliment to Holtcamp's work and the *Corner* extends congratulations.

* * *

The New York State Sewage Works Association's *News Broadcast* announces something new in contest competitions for its plant operator members. These will augment the customary gadget contests.

A Plant Beautification Contest will be based on before and after photographs, supported by information concerning the topography and type of soil, preparation of soil, nature of plants and shrubs used, etc.

A Plant Improvement Contest will permit Operator-Members to present activities which have resulted in improved plant operation. Entries will constitute reports describing conditions before and after the improvement, details of the changes made, with pertinent operating data, photographs and drawings.

Perhaps these contests will overcome the general reluctance on the part of many plant operators to publicize their successful efforts. They should bring forth many valuable suggestions to other operators who are confronted with similar problems.

* * *

Chemist George E. Botkin, Jr., of Marion, Indiana, offers a time-saving tip * in connection with the use of a volumetric flask in measuring and transferring dissolved oxygen samples for titration. A ⅛ to ¼-inch hole in the volumetric flask, located near the bottom, admits air as the flask empties and measurably speeds up the operation. The hole is covered by a finger, of course, while the flask is being filled.

* * *

With further reference to the recovery and purification of asbestos used in determining suspended solids by the Gooch method, the following treatment suggested in *Elementary Quantitative Analysis* by Willard and Farman (D. Van Nostrand Company, Inc.), may be of interest:

> Allow the asbestos to digest with 1:1 hydrochloric acid for several hours at 80–90° C., and then wash it with water until the acid reaction is faint. Allow the asbestos to digest with 20 per cent sodium hydroxide under the same conditions as in the acid treatment; wash as before. Repeat the treatment with acid and wash thoroughly with water. Washing by decantation in a tall bottle or cylinder may be made a semi-automatic process when large quantities of asbestos are treated.

* * *

The *Journal* of the Missouri Water and Sewerage Conference (April, 1942) offers a treatment for controlling algae growths on walls of filters and sedimentation units in water treatment plants, which method may find application in maintaining clean final sedimentation tank channels and weirs in sewage works. The treatment is suggested by Waterworks Superintendent Carl Haynes of Moberly, Missouri:

* From *Sewage Gas*, March, 1942, published by Bureau of Sanitary Engineering, Indiana State Board of Health.

The coating is not permanent and must be replaced. However, after the first application the walls can be easily and rapidly cleaned for succeeding applications. Ordinarily, the cleaning can be done with a fire hose, thereby eliminating the usual time consuming procedure of cleaning with wire brushes and other scraping instruments. Whatever deposit forms on the side walls is removed with the old coating and leaves a clean surface for the fresh application.

Ingredients are hydrated lime (50 lbs.), flour (5 lbs.), copper sulfate (5 ounces), salt (5 lbs.). Mix the lime, flour and salt thoroughly in a dry state. Add sufficient water to this mixture until a thin paste is obtained that will not run when applied to the walls. Powder the copper sulfate and dissolve in one gallon of water. Add this solution to the above mixture and stir.

Clean the walls thoroughly, removing the algae and other coating with a wire brush if necessary. Apply the mixture with a bill poster brush or with a spray gun. Allow to dry for three or four hours.

* * *

Draft Board quotas grow.
First thing you know,
They say you've got to go—
And *yagottago!*

* * *

BUY WAR BONDS

* * *

Editorial

W.P.B.—WATER PRIORITIES BOARD?

The course of industry is now completely controlled by a system of priority allocations which have been accepted, in general, cheerfully and willingly in the knowledge that such restrictions and prohibitions are necessary if we are to win the war. Supplies and equipment are released to those types of industry which produce war materials, even though this may mean appreciable deterioration in the standards of living to which we have been accustomed. Therefore a revision of our standards of normal life is necessary and we must adapt ourselves to a more rigid economy.

Since we are glad to accept lower standards of living, restricted diets, inconvenience in transportation, and heavy taxes in order to throw all resources into the war effort, it seems quixotic and unreasonable for our sanitary administrators to expect to maintain standards of stream cleanliness that are difficult to attain even in peace times. Wastes from industries, even in pre-war days, were rarely treated to a high degree before discharge to the nearest stream, although much progress has been made in the past decade toward abatement of industrial waste pollution. Now, however, with the enormous expansion of industrial production, this progress will be halted, or reversed, and not much can be done about it, except to use the best judgment possible in allocation of stream flow, to the end that health will not be impaired nor production hampered. Aesthetic standards of beauty, recreational facilities, fish life, and normal stream uses may suffer and deteriorate without harm to the people's health, and if the production of war materials results in such deterioration, we will have to make the best of it, realizing that it will be temporary and that giving up fishing and boating, or even colorless and tasteless drinking water, may be necessary in order to free production from all restrictions based on aesthetic considerations.

Even in ordinary times, all wastes can be treated, or kept out of streams, if cost is not considered. Elaborate processes of treatment, or at the worst evaporation, can always be utilized if equipment can be obtained. But now, even though unlimited funds might be available, materials should not be used in waste treatment if such materials are necessary for manufacture of war supplies. Therefore, the need for treatment of wastes must be most urgent before priorities should be given for use of critical materials. In fact, only considerations of actual and proven sickness or damage to health, resulting in loss of time of war workers, warrants the diversion of critical material to the treatment of wastes. Health authorities who are inclined to demand super-excellent quality of water supply, no dead fish, no odors, no color, no iron discoloration nor scum on watercourses, must defend their position if their standards require diversion of critical materials for treatment of wastes to make such standards possible.

We ought to have a National W.P.B.—Water Priorities Board—which would have authority to issue priority orders for all watersheds where war industries must use streams for disposal of wastes. At present there is no nation-wide uniformity, and no rational allocation of critical materials for waste treatment, as is known by those familiar with the problems of waste disposal on a nation-wide scale.

Various authorities, including the U. S. Public Health Service, the Ordnance Department, the Corps of Engineers, State Sanitary Engineers, the National Resources Board, and even municipal officers, prescribe policies and regulations that vary from place to place, overlap, or even conflict. A National Water Priorities Board, with Executive authority, might be able to unify and rationalize the almost chaotic state of regulation of stream pollution.

F. W. Mohlman

Note: We regret to announce the death, on June 27, of Robert Allton of Columbus, Ohio, and on June 9, of Prof. Charles R. Hoover of Middletown, Conn. Mr. Allton, Superintendent of the Columbus sewage treatment works, had been in ill health for some time. Prof. Hoover's death occurred dramatically in the crash of two naval dirigibles at sea.

Mr. Allton was well known as a sewage works engineer, and he was to have been on several committees of the Cleveland Convention. Prof. Hoover had been at Wesleyan University since 1915, and was known widely for his work on the disposal of industrial wastes.

Both men will be greatly missed.

Proceedings of Local Associations

MICHIGAN SEWAGE WORKS ASSOCIATION

Seventeenth Annual Conference

Michigan State College, East Lansing, March 25–27, 1942

The seventeenth annual conference of the Michigan Sewage Works Association was held at Michigan State College, East Lansing, Michigan, on March 25, 26 and 27, 1942. As in the past, the conference followed the short course school given at Michigan State College. The school and conference are both sponsored by the College, the Association, and the Michigan Department of Health. Attendance at the school numbered 53 and at the conference 104.

Vice-President L. R. Jennings ably handled the duties of chairman of the meetings in the absence of President Arthur B. Morrill who is on leave from Detroit and is with the U. S. Public Health Service, serving with a special commission along the Burma Road at last reports.

The following papers were presented:

"Decontamination" by Dr. W. L. Mallmann, Professor of Bacteriology, Michigan State College; "Bio-filtration" by Dr. A. J. Fischer, The Dorr Co., Inc., New York City; "Garbage Disposal in Sewage at Midland Plant" by Paul Stegeman, Supt., Midland, Michigan; "Operation of Wayne County Sewage Disposal System" by A. T. Kunze, Supt., Wyandotte, Michigan; "The Oxidized (Activated) Sludge Process" by E. B. Mallory, Director of Research, Lancaster Iron Works, Hackensack, N. J.; "Problems of a Consulting Engineer in the Design of Sewage Treatment Plants" by Harvey P. Jones, Consulting Engineer, Toledo, Ohio; "Chlorinator Maintenance" by Walter E. Smith, Wallace and Tiernan Co., Detroit, Michigan; "Chlorine Residuals in Sewage—High—Low—Sub" by A. E. Griffin, Wallace and Tiernan Co., Newark, N. J.; "Pollution and Priorities" by Milton P. Adams, Executive Secretary of the Michigan Stream Control Commission, Lansing, Michigan.

The "Breakfast Roundtable," an innovation on the program, proved very popular. The subject before the group was titled "The Art of Sampling," and the session leaders, who are experienced "provokers of discussion," were A. B. Cameron, Supt. of Sewage Treatment, Jackson, Michigan, and N. G. Damoose, formerly Engineer-Manager of Sewage Treatment, now Director of Public Service, Battle Creek, Michigan. Mr. Damoose, as banquet speaker, gave a very outstanding and inspiring talk entitled "What Democracy Means to Me."

At the annual business meeting held on Thursday, March 26, 1942, the following list of officers were selected for the year 1942–43:

President	George F. Wyllie, Lansing
Vice-President	Clarence Stielstra, Midland
Directors	L. R. Jennings
	R. A. Greene
	C. A. Habermehl
Secretary-Treasurer	R. J. Smith
Representative to the Federation Board of Control	N. G. Damoose

Mr. W. F. Shepard is Liftime Director.

Robert J. Smith, *Secretary*

NEW YORK STATE SEWAGE WORKS ASSOCIATION

Annual Spring Meeting

Albany, New York, June 5–6, 1942

The Annual Spring Meeting of the New York State Sewage Works Association was held in Albany, N. Y., on June 5 and 6, 1942, with headquarters at the Ten Eyck Hotel. Approximately 100 members and guests were registered. This number is somewhat less than the attendance at any previous spring meeting but it was felt that this decrease was due to war conditions, which have not only increased the work of most of the members but has limited travel by automobile.

General arrangements for the Saturday morning portion of the technical part of the meeting as well as the arrangements for the entertainment were made by the Capital District Section of the N. Y. S. S. W. A., who acted as the hosts for the meeting.

Following a brief business meeting on Friday morning, June 5, the technical session opened with a paper by Newell L. Nussbaumer, Commissioner of Public Works, Buffalo, entitled "Changes in Public Works Administration Due to War Time." In this paper Mr. Nussbaumer discussed changes in his office personnel, changes in methods of construction due to shortages or scarcity of various materials, use of substitute materials, and in general the revised set-up of his department caused by emergency conditions. An interesting discussion followed this paper concerning "freezing in" of city employees taking the place of the regular employees who have entered the armed service or some other phase of national defense. Mr. Nussbaumer considered this a rather serious problem, since unless some action is taken, less competent men would obtain permanent jobs, replacing those called to the armed service.

The second paper of the morning was a paper by William Raisch, consulting engineer of the Borough of Queens and Borough Chief, Public Works Emergency Division, Citizens Corps, New York City. Mr. Raisch in his position as Borough Chief, Public Works Emergency

Division, has charge of all emergency public works services under jurisdiction of the Civilian Defense in the Borough of Queens. Mr. Raisch outlined in detail the organization of his staff to cope with any possible emergency which might arise due to bombing, sabotage, etc. Mr. Raisch stated that practically his entire Civilian Defense organization is composed of city employees with very few volunteers. Most of the volunteers in that organization were doctors, dentists and the like, who have volunteered for work in the decontamination squads. Other civilians recruited were selected contractors who will furnish their own men under contract for specific jobs. This paper by Mr. Raisch was received with a great deal of interest, and considerable discussion resulted.

Entries were received in the plant beautification contest and the plant improvement contest. A total of three entries were received for the plant beautification contest and four entries for the plant improvement contest. These exhibits, which turned out to be well presented and very interesting, were on view during the morning session. Following the technical session Friday morning the plant beautification contest entries were balloted upon, the winner being announced at the Saturday morning round table discussion.

At the noon luncheon Friday, A. F. Dappert, Chairman of the Rating Committee, presented the rating award to Messrs. N. M. Fuller, A. H. Mann and C. A. Hardy, the operators of the sewage treatment works of the city of Olean. Following this presentation Colonel W. A. Hardenbergh, Sanitary Corps, Office of the Surgeon General, U. S. Army, Washington, D. C., spoke on "The Army, the Sanitary Corps and Their Engineering Problems." Colonel Hardenbergh presented a very interesting paper, in which he pointed out in general that prevention of malaria and other insect and mosquito borne diseases was of paramount concern to army authorities as malaria in tropical regions constitutes a constant menace to the health of troops. Following his talk Mr. Hardenberg, as is his usual custom, gave a very inspiring "recruiting" talk.

Friday afternoon was devoted to an inspection trip to the New York State Department of Health Laboratories. The group was greeted by Dr. Mary B. Kirkbride, Associate Director, Division of Laboratories and Research, following which the group were informed by various staff members of the types of work undertaken at the laboratory and conducted on a very interesting tour of inspection.

The informal banquet and entertainment was held Friday evening, which was followed by a very delightful and constructive entertainment, the General Electric Company of Schenectady presenting "The House of Magic."

The Saturday morning program opened with a "sunrise" breakfast at which the winners of the plant beautification contest and the plant improvement contest were announced. Frank Hall of Mineola won first place in the plant beautification contest; and Thomas A. Vickers, Great Meadow Prison, Comstock, and William C. Hamm, Port Washington, tied for second place. The plant improvement contest was won by Glenn E. Pinkney of Webster with Arnold Hale of Brighton second and E. A. Marshall of Geneva third place, with honorable mention going to Clarence Kellogg of Mt. Morris. On the whole it was felt that although the entries were rather limited the contest was quite successful especially since this was the first such contest held by the Association. The entries were well presented and did show either plant beautification or plant improvement worthy of notice and recognition.

The Saturday morning round table on "War Time Problems in Sewage Treatment" led by Morris Cohn of Schenectady, N. Y., developed into a real lively and interesting session. This subject was discussed by Dr. George E. Symons of Buffalo, W. Fred Welsch of Nassau County, and A. F. Dappert of Albany. Major J. H. Brewster, Office of Civilian Defense, gave a very inspiring talk on the problem under discussion. He warned against complacency on the part of civilians and pointed out that so far we have been taking a good licking in this war. Among the points covered by Major Brewster were: Need of protection of all facilities against sabotage and restoration of same if damaged; and need of coordination between various agencies as fire department, public works department, water works department and other utilities. Major Brewster also pointed out that the War Department holds the facilities or utilities directly responsible for maintaining 100 per cent operation of war industries. Earl Devendorf of the New York State Department of Health then spoke briefly on the subject and particularly the public health problems arising from the depletion of essential personnel engaged in sewerage work. A brief discussion ensued and the following resolution was prepared and unanimously adopted:

"WHEREAS, a balanced national program of defense and war requires not only an active military organization but a strong and dependable system of public health conservation at home, and

"WHEREAS, the continuation of effective sewerage and sewage treatment facilities is an essential element in the preservation of the high and decent standards of living for which we are fighting and through the preservation of the public health serves to protect the industrial strength which is so vital to our fighting forces:

"*Now, Therefore, Be It Resolved,* that the New York State Sewage Works Association assembled at its Spring meeting in Albany on June 6, 1942 appeals to the Federation of Sewage Works Associations to make proper contact with the Selective Service Organization and the U. S. Public Health Service, and to urge the safeguarding of public health by preventing the depletion of that personnel which is vital, essential and irreplaceable in municipal, national and institutional sewerage and sewage treatment systems, and

"*Futher, Be It Resolved,* that the Federation be urged to offer every assistance which the profession can render in the war effort and the vital defense of the home front.

(Signed) CHARLES R. VELZY,
President, New York State Sewage Works Association"

It seemed to be the general consensus of those members attending, that this meeting, which dealt entirely with conditions due to the impact of the war, was one of the best meeting of this Association. The papers were all of unusual interest because of the present world condition, and every paper was followed by some lively discussion on the subject.

The next meeting of the Association will be the Annual Meeting to be held in New York City in January, 1943.

A. S. Bedell, *Secretary*

CENTRAL STATES SEWAGE WORKS ASSOCIATION

Fifteenth Annual Meeting

Minneapolis, Minnesota, June 18 and 19, 1942

The Fifteenth Annual Meeting of the C. S. S. W. A. was called to order at the Hotel Nicollet, Minneapolis, on June 18, 1942. The total registration was 121 members and guests.

Opening Session

President Martin presided and Mayor Marvin L. Kline of Minneapolis gave an address of welcome to the convention. The report of the Secretary was read and accepted. The Treasurer's report was received, subject to the approval of the Auditing Committee.

The following committees were appointed by President Martin:

Auditing Committee

Mr. John C. Mackin, *Chairman*
Mr. E. C. Slagel
Mr. W. E. Ross
Mr. B. K. Hartman

Resolutions Committee

Mr. John C. Sager, *Chairman*
Mr. Robert Frazier
Mr. L. R. Mathews

Nominating Committee

Dr. M. Starr Nichols, *Chairman*
Dr. F. W. Mohlman
Mr. Carl B. Carpenter
Mr. W. F. Richmen

(Mr. Carpenter and Dr. Mohlman were substituted for Mr. C. W. Klassen and T. J. Burrin due to their absence.)

Awards Committee

Mr. K. V. Hill, *Chairman*
Mr. W. W. Mathews
Mr. Graham Walton

Papers presented at the meeting were as follows:

Technical Program

"Priorities"—Mr. Willard F. Kiesner.

"The F.B.I.'s Fight Against Espionage and Sabotage"—Mr. Walter M. Sirene.

"An Analysis of Stream Pollution and Stream Standards"—Mr. G. J. Schroepfer.

"Educational Acceleration in Sanitary Engineering"—Prof. H. E. Babbitt.

"Plant Operation"—Mr. John C. Sager.

"Application of Laboratory Data to Plant Control"—Mr. K. L. Mick.

"Mechanical and Electrical Maintenance of a Sewage Treatment Plant"—Mr. S. J. Larson.

"Treatment of Industrial Wastes and Sanitary Sewage at South St. Paul"—Mr. W. H. Cropsey.

All of the above papers with the exception of Prof. H. E. Babbitt's were delivered by the authors. Mr. W. H. Wisely read Prof. Babbitt's paper.

Annual Banquet

The annual banquet was held in the Main Ballroom of the Hotel Nicollet. The banquet was well attended and an interesting program of entertainment was given. Mr. W. H. Wisely, Executive Secretary of the Federation, presented a cup to President Martin and the Association in recognition of the fact that the Central States had accumulated the most man-miles in attending the 1941 meeting of the Federation in New York City. This is a traveling cup, to be awarded annually.

Operators' Breakfast

A three hour discussion was held on Friday morning. Third Vice-President Dr. W. D. Hatfield presided. The following is the outline of the discussion:

1. Cooperation with O.C.D.
2. Serving.
    a. War Industries.
    b. War Industries' Wastes.
    c. Sanitation-Trailers and Camps.
3. Holding Personnel.
4. Priorities and Inventories.
5. Plant Protection.
6. Plant Operation.
7. Laboratory Control.

The discussion was very lively and educational and was entered into by all in attendance. Shorthand notes were taken of the discussion, which will be published in the Operators' Corner of the Journal.

Inspection Trip

Due to present government ruling on bus regulations, the reservations were cancelled, and a street car was chartered to transport the members to a point about one mile from the plant, at which point personnel of the St. Paul Sanitary District supplied transportation in private automobiles. A supper was served at the sewage treatment plant.

A limited number inspected the sewage treatment plant at South St. Paul. This plant handles packinghouse wastes plus a small proportion of sanitary sewage. The plant was described by Mr. Cropsey.

Awards

The award for the best paper presented at the annual meeting in 1941 or published in the Sewage Works Journal from October 1940 to October 1941, was presented to Mr. Walter Sperry of Aurora, Illinois for his paper "Alum Treatment of Digested Sludge to Hasten Dewatering." This award is known as the Radebaugh award and is accompanied by a check for $20.00.

Several gadgets were entered in the gadget contest and first prize was won by Mr. Paul L. Brunner of Fort Wayne for his "B.O.D. Calculator"; second prize was voted to Mr. Matt Kirn of Waukegan, Illinois, for his "Sludge Level Measuring Device"; third prize went to the Minn.-St. Paul Sanitary District for their "Sludge Pump Piston Cleaner."

Business Meeting

The auditing committee reported favorably on the Treasurer's report which was duly accepted. The auditing committee recommended a portion of the associations' funds be put in a government bond. The Resolutions Committee entered a resolution giving a vote of appreciation to the Program Committee and Local Arrangements Committee. The Nominating Committee recommended the following slate and a motion for unanimous election was regularly passed:

Mr. K. L. Mick of Minneapolis and St. Paul, *President.*
Mr. Don E. Bloodgood of Indianapolis, *First Vice-President.*
Dr. W. D. Hatfield of Decatur, *Second Vice-President.*
Mr. E. J. Beatty of Neenah-Menasha, *Third Vice-President.*
Mr. J. C. Mackin of Madison, *Secretary-Treasurer.*
Mr. B. A. Poole of Indianapolis, *Director* to the Federation after October 24, 1942.

Invitations for the next annual meeting were received from Green Bay, La Crosse, Oshkosh and Sheboygan. The Executive Committee has tentatively chosen Green Bay, Wisconsin, for the 1943 meeting, which will be held in June.

E. J. Beatty, *Secretary-Treasurer*

Federation Affairs

Editor's Note.—Morris Cohn, Chairman of the Publicity and Attendance Committee, has released the following statement concerning the Third Annual Convention of the Federation.

The Federation of Sewage Works Associations, in conjunction with the Ohio Conference on Sewage Treatment, will stage its Third Annual Convention at the Hotel Statler, Cleveland, on October 22–24th, 1942. This national sewage meeting of the recently reorganized Federation, will bring together the leading sanitary engineers, plant operators, educators, manufacturers' representatives and public officials from all sections of the country. The meeting dates now announced are a week later than originally planned, and have the advantage of permitting members to attend the A. P. W. A. meeting which immediately precedes the Federation meeting in the same city, and to go to the A. P. H. A. meeting at St. Louis, which immediately follows the sewage sessions. This dove-tailing of meetings is in keeping with war economy measures.

In view of the effect of war on sewage flows, sewage composition, industrial wastes and other aspects of sewage treatment, the Convention will be devoted primarily to a timely technical evaluation of these pressing national wartime problems. The country's leading authorities will discuss sewage works, student training, state health control, army camp sanitation and industrial waste problems which have developed as a result of war conditions. Progress of sewage works construction during war times and the question of priorities and conservation of materials will be featured in the discussions. Plant operators will present their experiences in a symposium on plant maintenance in war times which will cover mechanical units, electrical equipment, sewers, structures, personnel, and sabotage protection.

In this period of stress, sanitation plays such an important role that it is expected that the attendance will be swelled by those who deem it essential to attend a war conference at this time. The meeting should be a "must" for every active worker in this field.

Preparations for the Convention are already going forward under the guidance of committees chosen from all sections of the country. The personnel of the Convention committees follows:

Convention Management Committee:

Messrs. William L. Havens, *Chairman*
John J. Wirts, *Vice Chairman*
F. P. Fischer (Local Finance)
Clinton Inglee (Entertainment)
W. J. Orchard (Financial Advisory Committee)
A. H. Niles
Arthur S. Bedell, *Ex-officio* Member
Arthur T. Clark, *Ex-officio* (Exhibits)
Charles A. Emerson, *Ex-officio* Member
W. H. Wisely, *Ex-officio* Member

Program Committee:

Messrs. F. Wellington Gilcreas, *Chairman*
F. C. Roberts, Jr.
W. S. Mahlie
R. S. Phillips
Rolf Eliassen
J. L. Ferebee
W. W. Towne
F. W. Mohlman

Publicity and Attendance Committee:

Messrs. Morris M. Cohn, *Chairman*
Edward J. Cleary, *Vice Chairman*
J. Bernard Baty
L. H. Enslow
A. Prescott Folwell
T. R. Kendall
F. D. Young

Local Host Committee:

Messrs. Angus MacLachlan, *Chairman*
G. C. Ahrens
Norval R. Anderson
A. B. Backherms
George E. Barnes
E. D. Barstow
Floyd G. Browne
A. B. Cameron
James Collier
William A. Dundas
C. B. Hoover
C. C. Larson
J. B. Lower
R. F. MacDowell
C. D. McGuire
W. W. Morehouse
Maxfield Pease
B. A. Poole
T. C. Schaetzle
H. E. Schlenz
W. F. Shephard
R. F. Snyder
Walter A. Sperry
H. W. Tatlock
J. R. Turner
F. H. Waring
C. H. Young

Ladies' Entertainment Committee:

Mrs. Arthur S. Bedell, *Honorary Chairman*
Mrs. John J. Wirts, *Chairman*
Mrs. Mortimer A. Clift
Mrs. F. P. Fischer
Mrs. G. Albro Hall
Mrs. Wayne A. Kivell
Mrs. Newell L. Nussbaumer
Mrs. Willard F. Schade
Mrs. Harry E. Schlenz
Mrs. Walter A. Smigel
Mrs. Edward J. Smith
Mrs. F. D. Young
Mrs. W. Denton Young

Registration Committee:

Messrs. Curry E. Ford, *Chairman*
T. C. Bresnan
Walter A. Smigel
Charles Fant
Frank Woodbury Jones, for the Quarter Century Operators' Club

Inspection Trip Committee:

Messrs. J. W. Ellms, *Chairman*
G. E. Flower
W. E. Gerdel
John J. Wirts

Entertainment Committee:

Mr. J. M. Craun (Assisting Mr. Inglee)

GENERAL POLICY COMMITTEES

Membership of Committees Recommended in the Report of the General Policy Committees Presented at the Second Annual Convention, October, 1941

At the meeting of the Board of Control of the Federation of Sewage Works Associations held in New York in October, 1941, a report of the General Policy Committee was presented, and approved by the Board, and the necessary committees to motivate the recommendations in that report were authorized. The complete text of this report was published in the November, 1941, issue of the SEWAGE WORKS JOURNAL. Briefly, the recommendations provided for the attack of a number of problems affecting the Federation, with a view, primarily, of enhancing the position of the sewage plant operators. The committees have been functioning, in spite of the many demands on their time by activities, and will present reports for action by the Board of Control at the meeting in Cleveland on October 22, 23 and 24.

The membership of various committees, with a brief statement of objectives, follows:

(1) *Awards Committee.*—This committee will make recommendations concerning awards in recognition of meritorious papers, as well as citations for the member performing the most outstanding service to the Federation during the year.

Personnel: E. S. Chase, Boston, Mass.
G. P. Edwards, Wards Island, N. Y.
C. G. Hyde, Berkeley, Calif., *Chairman.*
C. C. Larson, Springfield, Ill.
H. E. Moses, Harrisburg, Penn.

(2) *Operating Report Committee.*—It is proposed that the Federation stimulate recognition by member associations of outstanding operating reports prepared during the year. Those reports receiving certification would be submitted by member associations to a Federation Committee for determination of Federation Award. Notification to those honored would include, concurrently, notification of public officials and release to local newspapers.

Personnel: H. E. Babbitt, Urbana, Ill.
A. F. Dappert, New York, N. Y., *Chairman.*
W. S. Mahlie, Fort Worth, Texas.
L. W. VanKleeck, Hartford, Conn.

(3) *Publicity and Public Relations Committee.*—The purpose of this committee's activity is the development and promotion of a broad general program of public relations to acquaint the public with the accomplishments and activities of engineers, chemists and operators engaged in the sewage treatment field.

Personnel: D. E. Bloodgood, Indianapolis, Ind.
H. R. Hall, Hyattsville, Maryland.
W. L. McFaul, Hamilton, Ontario.
N. L. Nussbaumer, Buffalo, N. Y., *Chairman.*
Prof. E. L. Waterman, Iowa City, Ia.
Prof. R. G. Tyler, Seattle, Wash.

(4) *Operator's Qualifications Committee.*—This committee would collect and compile data on present procedure in various states in connection with licensing of operators, etc., and submit to Member Associations for their use. In general, the aim of this activity would be the maintenance of desirable standards of sewage plant operators.

Personnel: Prof. H. G. Baity, Chapel Hill, N. C., *Chairman.*
Benj. Benas, San Francisco, Calif.
A. F. Dappert, Albany, N. Y.
P. J. Kleisser, So. Bend, Ind.
M. W. Tatlock, Dayton, Ohio.

(5) *Civilian Defense Committee.*—This committee will cooperate with committees of other organizations and with governmental agencies in matters relating to the protection and insured operation of sewerage and sewage treatment facilities.

Personnel: R. E. Fuhrman, Washington, D. C., *Chairman.*
R. F. Goudy, Los Angeles, Calif.
Dana Kepner, Denver, Colo.
L. S. Kraus, Peoria, Ill.
W. B. Redfern, Toronto, Ontario.
W. F. Welsch, Hempstead, N. Y.

(6) *Post War Planning Committee.*—This committee will work in collaboration with planning groups and Federal Agencies relative to scheduling needed work in this field in the post-war period.

Personnel: Earl Devendorf, Albany, N. Y.
Langdon Pearse, Chicago, Ill.
Wm. Piatt, Durham, N. C.
Wm. Raisch, Forest Hills, N. Y.
A. M. Rawn, Los Angeles, Calif., *Chairman.*
Wm. Storrie, Toronto, Ontario.

(7) *Miscellaneous Activities.*—To increase further the field of usefulness of the revitalized Federation, the Committee recommended and the Board authorized the coordination of technical activities of the various Member Associations, efforts to maintain high standards of committee endeavor, the investigation of the possibility of publishing a Sewage Works Manual, or similar alternatives, as well as other related activities. All these matters were referred to standing committees of the Federation for investigation and report.

George J. Schroepfer,
Vice-President.

Reviews and Abstracts

THE TREATMENT AND DISPOSAL OF WASTE WATERS FROM DAIRIES AND MILK PRODUCTS FACTORIES

Department of Scientific and Industrial Research, Water Pollution Research. Technical Paper No. 8. 125 pages. H. M. Stationery Office, York House, Kingsway, London, W.C. Price 4s.

It is estimated that the volume of milk produced in England and Wales in 1936–37 was 1,314 million gallons. There has been a tendency towards increased centralization of milk distribution and in the manufacture of milk products. Many of the milk depots and factories are situated in rural districts and the waste waters are often discharged into small streams creating a heavy pollution problem. To develop a satisfactory method of treatment of milk wastes the Water Pollution Research Board sponsored investigations in 1933 which were continued up to 1938. The experiments were conducted both in the laboratory and on a plant scale basis. The work was done at Rothamsted Experimental Station, at Birmingham Tame, Rea District Drainage Board, and at Ellesmere in Shropshire. Both chemical and biological studies were made. Anaerobic fermentation, biological filtration and the activated sludge process were studied.

GENERAL CHARACTER AND QUANTITY OF WASTE WATERS FROM MILK INDUSTRY

Waste waters from milk collecting and distributing depots consist mainly of water mixed with milk and sometimes contain soda and other detergents. Milk washings containing 1 per cent whole milk have a 5-day B.O.D. of 1,100 p.p.m. The waste is generally produced over an 8–hour period during the day and varies greatly in volume, strength and pH during this period, and also from day to day. This necessitates the use of a storage tank to equalize the flow in any system involving continuous treatment of the liquid. The volume of milk washings is independent of the volume of milk handled. Thus the concentration of milk in the washings increases with an increase in the volume of milk handled.

The average volume of milk in the washings depends on the precautions taken to minimize loss, and differs considerably at different depots. Generally 0.5–1 per cent of the volume of milk handled is lost. This value may be decreased to 0.2 per cent when measures are taken to minimize the loss. The volume of waste water is usually 0.5 to 1.5 times the volume of milk handled.

Waste waters from butter making consist mainly of the water used for washing. The chief constituents of these washings are buttermilk, some cream and skimmed milk. Waste waters arising from butter making may be 1–2 times the volume of milk used, with a B.O.D. of 1,500–3,000 p.p.m. provided that buttermilk is not discharged into the waste. Buttermilk has a B.O.D. of 20,000–30,000 p.p.m.

Waste waters from the cheese making process consist mainly of washings from the vats, floors, presses and other equipment. The main impurity is whey, and some milk. The B.O.D. of whey washings varies from 1,500 to 3,000 p.p.m. provided that the whey is not discharged.

METHODS OF REDUCING THE QUANTITY OF MILK AND OF MILK PRODUCTS AND BY-PRODUCTS CARRIED AWAY IN WASTE WATERS

The first essential in attempting to reduce the quantity of polluting matter in waste waters is to prohibit the discharge of whole whey or buttermilk with the waste waters. These should be treated as valuable by-products. There is considerable quantity of milk retained in the cans after emptying. Keeping the cans in an inverted position for 1–2 minutes after emptying reduces the quantity of milk lost to 0.25 to 0.5 per cent of the volume of milk handled. When adequate precautions are taken to prevent splashing of milk and to provide optimum period of drainage the loss can be cut down to 0.09 per cent of the milk handled. This represents the minimum loss.

Similar reductions in the quantity of waste from cheese and butter making can be brought about by preventing splashing from vats, and washing the vats after removal of the whey with small quantities of water which may be added to the whole whey.

LABORATORY EXPERIMENTS ON METHODS OF TREATMENT OF WASTE WATERS

Treatment by Fermentation.—Since dairy wastes are produced only during the daytime in any system of continuous treatment of such wastes it is necessary to store a part of the liquid in order to obtain a more uniform flow to the treatment plant. During this period of storage some anaerobic fermentation occurs. The following changes take place during storage: (1) Separation of cream, (2) acid fermentation of lactose, (3) coagulation of casein, and (4) proteolysis of casein. The B.O.D. of liquid separated from milk waste drops rapidly during the first day of fermentation (43 per cent) due to the separation of fat and casein from the liquid. Strong putrefactive odors are given off during the proteolysis of casein.

Fermentation of whey washings for a period of 48 hours bring about little change in the B.O.D. but the lactose decreases and the acid content increases.

Treatment by Addition of Chemical Precipitants.—The addition of lime alone to milk washings had little effect on the B.O.D. Aluminoferric added in concentrations of 500–2,000 p.p.m. brought about considerable reduction of B.O.D. (86 per cent with 0.25 per cent whole milk in washings). The addition of lime in conjunction with aluminoferric in some cases increased the removals and in other cases decreased it. But lime used with aluminoferric kept the precipitated solids in the bottom.

Treatment in Percolating Filters.—Laboratory experiments with treatment of milk waste (1.3 per cent milk to which various amounts of soda was added) were performed in cylindrical jars (12 in. high and 4 in. wide) filled with 0.5 to 1.0 inch gravel at the rate of 100 gallons per day per cubic yard. After the film was established 80–90 per cent reduction of B.O.D. was obtained. However, after about 3 weeks the filters began to choke with a dense mass of fungi in which fat globules were imbedded. The film consisted of 5 per cent total nitrogen and 65 per cent fat on the dry basis. When 1 per cent milk was first treated anaerobically for 1–2 days and then applied on a filter containing 0.25 to 0.5 inch gravel at the rate of 100 gal. per day per cu. yd. an excellent effluent was obtained (with less than 20 p.p.m. B.O.D.) and at the end of 17 weeks there was no sign of ponding.

Experiments with double filtration with periodic change in the order of the filters with 0.2 per cent milk at the rate of 50 gal. per cu. yd. per day through two filters gave satisfactory results (B.O.D. in effluent from secondary filter of 3.0 p.p.m.). The whitish-grey deposit on the top of the primary filter disappeared when the order of the filters was changed at intervals of a fortnight and the filters were kept free of excessive growths.

Experiments were made with double interchangeable filters with different whey and milk combinations and concentrations. The filters were 2 ft. long and 6 in. diameter drain pipes filled with 0.75–1.5 inch coke. There was no sedimentation between the two filters. The rate of treatment was 50 gal. per day per cu. yd. of medium in the two filters together. Satisfactory effluents were obtained when mixtures containing 1.0 per cent whey and 0.5 per cent milk were treated. Using the same procedure but with settlement of the primary filter effluent before application to the secondary filter, well purified effluents were obtained (effluent from secondary filter with B.O.D. less than 20 p.p.m.) when a mixture of 1.0 per cent whey and 0.25 per cent milk was treated at a rate of 100 gal. per day per cu. yd. of medium in the two filters together. No trouble was experienced from clogging. The quality of the final effluent in these experiments was not improved when the crude liquid was allowed to ferment for 24 hours before application to the primary filter.

Treatment by the Activated Sludge Process.—Laboratory experiments on the treatment of 0.25, 0.5, and 1.0 per cent of milk by the activated sludge process were performed. Without lime addition, B.O.D. reduction ranged between 63–83 per cent with 1 day aeration, 73–89 per cent with 2 days aeration and 87–93 per cent with 4 days. The addition of sufficient lime to raise the pH value of the crude liquor to 10 greatly retarded purification. When the activated sludge had become mature the B.O.D. of mixtures containing up to 0.5 per cent whey and 0.9 per cent milk was reduced from 300–400 p.p.m. to less than 20 p.p.m. by aeration for a period of 22 hours. The B.O.D. reduction for 1.0 per cent whey and 0.25 per cent milk was from 500 to 10 p.p.m. after 22 hours aeration.

Comparison of surface aeration (cylindrical brush revolving about a horizontal axis across the width of the tank at 200 r.p.m.) and diffused air showed that B.O.D. reduction by surface aeration ranged from 88 to 94 per cent and diffused air 92 to 96 per cent.

Studies on the effect of previous anaerobic fermentation on the purification by aeration with activated sludge showed that the best results were obtained when the diluted milk (1 per cent) was fermented in an open vessel at room temperature and the worst result when the fermentation was under strictly anaerobic conditions. When similar experiments with 1 per cent milk were conducted on a continuous basis, both in the anaerobic fermentation and the activated sludge process, with 24 hours detention period in each for a period of about 8 weeks, the average B.O.D. of the effluent after settling of the activated mixture was 25 p.p.m. from an initial in the crude liquor of 1,100 p.p.m.

Additions of lactose or lactic acid not exceeding 0.1 per cent to 0.5 per cent milk did not greatly affect the quality of final effluent after aeration for 3 days though they reduced the degree of purification obtained after 1 day. Additions of 0.25, 0.5, and 1.0 per cent of whey to 0.1 per cent milk for a period of 5 months did not affect the purification brought about by the activated sludge after aeration for 22 hours each day. Effluents containing less than 10 p.p.m. B.O.D. were obtained with as high as 1.0 per cent whey and 0.2 per cent milk.

Studies on the effect of temperature covering a range from 2° C. to 45° C. on the purification of 0.75 per cent milk by the activated sludge process after aeration for 24 hours for a period of 20–40 days showed that the optimum temperature was at 30° C. from the standpoint of both maximum B.O.D. reduction (4 p.p.m. B.O.D. in the effluent) and good settling. At 2° C. the sludge settled much less readily and the average B.O.D. of the effluent was more than 200 p.p.m. Most of the oxygen absorbing material at this temperature was in suspension while at 45° C., where equally high B.O.D. values were obtained, the oxygen absorbing materials were in solution. The percentage of fat in the sludge was least at 30° C. and highest at 2° C. At 30° C. the period of aeration for 0.75 per cent milk could be reduced from 24 hours to 8 hours without seriously affecting the quality of the effluent.

EXPERIMENTS ON A LARGE SCALE

Treatment in Two Percolating Filters in Series with Periodic Change in the Order of the Filters

These experiments were conducted at Ellesmere at United Dairies, Ltd., which distributes milk and manufactures cheese. Milk washings and whey washings drain into separate drains. In order to equalize the flow of waste to the filters throughout the 24-hour period equalizing tanks were provided. The liquid was pumped from the collecting tanks to a chamber and passed through a metal screen. It then flowed by gravity to a sedimentation tank from which sludge was withdrawn periodically. The purpose of the sedimentation tank was to further equalize the flow and remove coarse solids. Liquid from the sedimentation tank flowed by gravity to a small tank where it could be mixed with a measured proportion of river water or final effluent from the plant. The latter was the common practice during the period of the experiment. There were two circular beds provided with rotating distributors. The beds were 25 ft. in diameter and were filled to a depth of 4 ft. 3 in. with coke 0.75–1.5 in. in size. Adequate drainage was provided in the bottom. Effluent from the primary filter entered a sedimentation tank and was then pumped into the second filter followed by a second sedimentation tank. Sludge from the two humus tanks could be removed by gravity or by pumping.

During most of the operation period, the order of the two filters in series was changed at intervals of about 3 weeks.

Treatment of Milk Washings.—During the first 8 months of operation the rate of application was 81 gal. of milk washings per day per cu. yd. of medium in the two filters. The average B.O.D. of crude waste was 820 p.p.m., the settled primary bed effluent 24 p.p.m., and the settled secondary bed effluent 8 p.p.m. Nitrites and nitrates were present in the effluents from both beds. During the cold weather in this period the quality of final effluent deteriorated slightly. When by accident a strong flush of milk washings was applied to the filters the B.O.D. of the final effluent increased to 31 p.p.m. but the next day it was back to 7 p.p.m. again.

The next period covers 6 weeks in which the rate of application was 124 gal. of milk washings per day per cu. yd. of medium in both filters together. No excessive growth of film or deposition of solids occurred and effluents of good quality were obtained.

For a period of 22 weeks the rate of application was increased to 164 gal. per day per cu. yd. The average B.O.D. after sedimentation and dilution of the waste was 210 p.p.m. The filters could handle this load readily giving an effluent with a B.O.D. of 3 p.p.m. and large quantities of nitrates. On a single occasion slight ponding occurred on the primary filter. When the order of filters was changed the ponding entirely disappeared within a week. The discharge of humus from the beds was great and consequently the amount of film on the surface of the filters was small. The humus discharged from the filters settled rapidly. The sludge from the primary humus tank had 3.3–4.3 per cent solids and that from the secondary 4 per cent solids. The ash content was 40–60 per cent of the dry weight.

Increasing the rate of application to 240 gal. per day per cu. yd. of medium in the two filters with an average B.O.D. of the diluted and settled waste applied to the filters of 300 p.p.m. gave an average B.O.D. of the final effluent of 10 p.p.m. To prevent ponding during this period the order of the filters was changed once a fortnight.

Treatment of Mixtures of Whey Washings and Milk Waste.—Mixtures of one volume of whey washings and three volumes of milk washings diluted with treated effluent to provide a liquid with 250–300 p.p.m. B.O.D. were applied on the filters at the rate of 160 gal. per day cu. yd. of medium on the two filters. The B.O.D. of final effluent obtained was 5 p.p.m. When mixtures containing equal volumes of whey washings and milk washings were treated at the same rate equally well purified effluents were obtained but the type of growth on the surface of the medium was not as soft, was more difficult to remove when the order of the filters was changed and was lighter in color than when milk washings alone were applied.

The filters could handle a rate of application of 240 gal. per cu. yd. of equal volumes of whey and milk washings with an average of 260 p.p.m. B.O.D. However, towards the end of this period, covering 2 months, the filters showed signs of ponding due to the formation of an impervious layer of film on the surface. Mixtures containing three volumes of whey washings with one volume of milk washing were treated satisfactorily at the rate of 160 gal. per day per cu. yd. No difficulty was encountered when whey washings alone were treated at the rate of 160 gal. per cu. yd.

A study of the weight of film deposited on the surface layer of the medium revealed that it increased during the period in which the filter was being used as the primary filter and decreased when the order of the filters was reversed. The fat content in the material on the medium increased when the filter was used as a primary filter and decreased when it was used as a secondary filter.

In general the results showed that milk and whey washings can be satisfactorily purified when the B.O.D. of the applied liquor is 200–300 p.p.m. and the rate of application is 160 gal. per day per cu. yd. Milk washings of the same strength can be satisfactorily treated at a rate of 240 gal. per day per cu. yd. provided that the operation of the plant is carefully controlled. Milk washings are more easily purified than whey washings of similar strength because the film formed with whey washings is tougher than that formed by milk washings. Purification in percolating filters proceeds more rapidly at relatively high temperatures (20–30° C.) than at lower temperatures. Application of milk and whey washings of abnormally high strength for a short period causes only a temporary deterioration in the quality of final effluent when double filtration is used.

Irrespective of the pH of wastes applied which often were as low as 5.8 the final effluent was always alkaline.

The effluents from both primary and secondary filters contained large quantities of dissolved oxygen (7.2 p.p.m. in primary effluent and 9.5 p.p.m. in secondary).

EXPERIMENTS ON A LARGE SCALE

Treatment by the Activated Sludge Process

The plant included a primary sedimentation tank, two aeration tanks and a final sedimentation tank. Provisions were made for the dilution of the wastes with water or purified effluent. The aeration tanks were operated in parallel in these investigations. Aeration was by means of porous plates placed in the bottom near the long walls. The operation was on a continuous basis.

During the first two months a supply of activated sludge was built up by aerating diluted milk washings. With an aeration period of 17.5 hours and returned sludge of 25 per cent by volume of diluted milk washings, the B.O.D. of crude diluted milk washings after sedimentation was reduced from 190 p.p.m. to 33 p.p.m. There was no fat in the effluent although the milk washings supplied to the aeration tanks contained 40 p.p.m. of fat. The effluent contained 8.0 p.p.m. D.O. and only 0.2 p.p.m. NO_3–N. The volume of sludge settled from the mixed liquor fluctuated within wide limits from day to day due partly to changes in the character of the sludge.

The volume of crude liquid supplied to the aeration tanks was reduced, keeping the volume of returned sludge the same as before (37.8 per cent by volume of returned sludge) so that the aeration period was increased up to 36 hours. The final effluent was not of good quality partly due to rising of sludge. Nitrate was present in the final effluent in high concentrations when rising of sludge occurred. The aeration period was then reduced to 24 hours, well purified effluents with an average B.O.D. of 12 p.p.m. were obtained and no difficulty was encountered in the settlement of the activated sludge. When the strength of the waste supplied was increased to give an average B.O.D. of 500 p.p.m aeration for 24 to 38 hours gave effluents of good quality. When the aeration period was reduced to 18 hours with a load applied of 500 p.p.m. B.O.D. sludge began to bulk.

Mixtures containing one volume of whey washings with three volumes of milk washings containing 370 p.p.m. B.O.D. were satisfactorily treated with an aeration period of 24 hours. Increasing the ratio of whey washings to milk washings to 1 : 1, satisfactory effluents were obtained with 24-hour aeration period and a B.O.D. of 350 p.p.m. in the applied liquor. When the strength of the applied liquor containing equal volumes of whey and milk washings was increased to 520 p.p.m. and the aeration period was reduced to 18 hours the quality of the effluent did not change materially but the condition of the activated sludge deteriorated and additional aeration became necessary.

Whey washings alone with an average B.O.D. of 440–650 p.p.m aerated for a period of 36 hours gave poor quality effluent but when the strength of the crude liquid was reduced and aeration period increased to 48 hours the quality of the effluent improved considerably. This improvement may have been due in part to the higher prevailing temperature during the latter period. During the summer high quality effluent was obtained with an average B.O.D. of 660 p.p.m. and aeration period of 36 hours.

The results indicate that the efficiency of treatment of milk and whey washings by the activated sludge process is influenced considerably by the temperature. There was some indication that whey washings were rather more difficult to treat than milk washings. In cold weather it would be necessary either to reduce the strength of crude liquid supplied to the aeration tanks or increase the period of aeration.

The average concentration of D.O. during the whole period of operation was 6.9 p.p.m.

On the whole the effluents obtained by treatment of milk and whey washings by the activated sludge process were not of such good quality as the effluents obtained by the treatment of similar wastes by the process of double filtration. Considerable care is needed in the treatment of milk and whey washings by the activated sludge process to maintain the sludge in good condition. Difficulties may be caused both by rising and bulking of sludge. Rising of sludge may be prevented by increasing the strength of crude liquid or reducing the period of aeration. But on the other hand when the strength of crude liquid is too strong or aeration period too short bulking results. In general, the treatment of milk and whey washings by the activated sludge process is more difficult to control and is more easily upset by flushes of liquid of abnormally high strength than the double filtration method developed by interchanging the order of the filters.

BIOLOGICAL INVESTIGATIONS

Treatment of Waste Waters by the Process of Double Filtration

Organisms on the Surface of Filters.—Within a week after operation of the filters with clean medium was started, a white film developed on the surface of the primary filter consisting of different types of bacterial zoogloeae with numerous protozoa, and tough filaments of *Sphaerotilus.* When the rate of filtration was increased from 164 to 240 gal. per day per cu. yd. the amount of film increased and for the first time the fungus *Saprolegnia* sp. became subdominant and the film as a result became tougher and less easily washed away. The addition of whey washings to the crude liquid encouraged the growth of fungi, especially *Saprolegnia,* on the top layer of the medium of the primary filter. Other fungi on the top layer included species of *Fusarium, Sporotrychum, Oospora* and *Rhodotorula.* These disappeared more readily than *Saprolegnia* when the order of the filters was changed. In addition to the fungi there was an abundance of protozoa, nematodes, rotifers, *Psychoda* larvae, and other metazoa during the period when whey was included. Yeasts were never abundant in the film at any time. Algae occurred on the surface of the medium, mainly on the secondary filter. The most abundant forms were: *Protococcus* sp., *Stigeoclonium tenue, Ulothrix subtilis,* and two species of *Phormidium.*

The protozoa found were: Flagellates: *Cercomonas crassicauda, Heteromita globosa, Oikomonas termo, Tetramitus spiralis, Bodo saltans, Peranema* sp., *Astasia.* Ciliates: *Paramoecium putrinum, Colpidium colpoda, Glaucoma scintillans, Euplotes charon, Lionotus fasciola, Chilodon cucullulus, Vorticella putrinum, Epistylis* sp., *Aspidisca costata, Pleuronema chrysalis,* etc. Rhizopods: *Hartmanella hyalina, Arcella vulgaris, Trinema lineare, Centropyxis,* etc.

During spring and summer swarms of *Psychoda* inhabited the filters.

Distribution of Organisms in Different Parts of the Filters.—On the primary filter concentric rings of thick films were formed in the track of each jet of the distributor. Between these rings the medium was only lightly covered. The film on the surface in the track of distributor jets was characterized by the orange color of the fungus *Fusarium.* Below the layer of this fungus was the dark brown growth of *Phoma.* Protozoa were rarely found in the surface film. In between the concentric surface rings, on the relatively dry portions, there were found large numbers of *Psychoda* eggs. Immediately below the surface of the medium occurred the fungi *Fusarium, Oospora, Leptomitus* and *Saprolegnia* which sometimes bound the pieces of coke together. Ponding, which occurred on a few occasions, was due chiefly to the fungi in this zone. Bacterial zoogloeae and packets of *Sarcina* were also abundant. Below this zone to one foot depth the film resembled black mud with *Beggiatoa alba* the predominant organism. Protozoan fauna of this zone was very variable and appeared to be influenced by the amount of oxygen and organic matter available. Psychoda larvae were always present in this zone. At depths greater than one foot there was little growth of new film. It contained mats of *Saprolegnia, Beggiatoa.* The number of flagellates increased with greater depth and were found in large numbers in the underlying black parts of the film.

When the order of the two filters was changed, the growth of fungi forming the concentric rings, erstwhile on the surface of the primary filter was gradually removed by about the fifth day after changing. After this algae began to grow of which the most abundant was *Stigeoclonium tenue* and *Ulothrix subtilis.* Below the surface of the secondary filter the fungi and bacterial zoogloeae dispersed. Large numbers of *Psychoda* larvae, nematodes, and a red oligochaete were found. At depths greater than one foot the material consisted of an indefinite mass of debris, *Beggiatoa,* and ciliates.

The zoogloeal masses formed on the primary filter largely disappeared when it became the secondary filter. In the presence of food, zoogloeal mass tended to increase in volume as well as in the amount of gelatinous matter forming the matrix. In the absence of food the zoogloeae lost this gelatinous consistency, shrank in volume and became brown and papery in texture. Under starvation conditions the gelatinous matter holding the zoogloeae together may act as a source of food.

Sludge Discharged from the Filters.—Sludge discharged from the secondary filter was black in color while sludge from the primary filter was grey in color. Towards the end of the period a large amount of sludge was discharged from the secondary filter whereas the amount of sludge discharged from the primary filter was much less.

Laboratory Experiments on the Effect of pH Value on the Composition of Biological Film.—In the large-scale double-filtration plant it was found that, when milk washings alone were treated, the film consisted largely of bacteria zoogloeae; when whey washings were introduced with the milk washings the proportion of fungi in the film increased. This might be due to other factors such as pH value or temperature. The pH value was lower when whey washings were introduced. Laboratory experiments showed that the film in the primary filter receiving whey washings at a pH value of 4.8 was tough and contained a large proportion of *Saprolegnia,* while at a pH value of 7.0 the film was much softer, contained considerable proportion of bacterial matter besides *Saprolegnia,* and on reversing the order of the filters the film was dispersed more readily. Usually not more than two or three species of bacteria were present in abundance in the effluents from the filters. Large and frequent fluctuations occurred in the relative abundance of the different bacteria.

BIOLOGICAL INVESTIGATIONS

Treatment of Waste Waters by the Activated Sludge Process

Organisms in Activated Sludge.—The flocs of activated sludge were formed of *Zoogloea ramigera.* Zoogloeal colonies were found on glass slides suspended in the aeration tanks and they were also found floating freely in the liquid when the strength and volume of milk and whey washings were high. Later other organisms such as *Sphaerotilus, Vorticella* and *Epistylis* became attached to the floc. The protozoan population consisted of: Ciliates: *Aspidisca, Euplotes, Lionotus;* Flagellates: *Peranema;* Rhizopods: *Trinema, Centropyxis, Arcella.* These protozoa occurred when the plant was in satisfactory operation. When the results of operation were not satisfactory in addition to these protozoa there was abundance of *Sphaerotilus* and an increase in the numbers of small flagellates.

Growth of Organisms on Glass Slides Immersed in the Aeration Tanks.—It was found that growth on the glass slides immersed in the aeration tanks were bacterial colonies which developed *in situ.* The quantity of growth increased with higher strength of liquor fed to the aeration tanks. On slides near the inlet of aeration tanks vigorous growths usually occurred; on slides near the middle of the tanks vigorous growth only developed when the strength of liquor fed was high. Colonies of bacteria were never found on slides near the outlet of the tanks. When the strength of liquor supplied to the aeration tank was low, the zoogloeal colonies growing on the glass slides were circular with a lobed edge. When the strength of waste was high and aeration period low a thread-like zoogloea grew on the slides.

The results indicated that at any one time only one or two types of bacteria were dominant.

Bulking of Sludge and Occurrence of Sphaerotilus.—Bulking was accompanied by the presence of an unusually large amount of *Sphaerotilus* which impeded the settling. *Sphaerotilus* was abundant in activated sludge during the colder months. It disappeared when the sludge was aerated without the addition of crude liquid.

H. Heukelekian

COLESHILL WORKS ENLARGEMENT

(Report by Birmingham, Tame and Rea District)

The Surveyor, 101, 116 (April 3, 1942)

The Coleshill works serves a portion of Birmingham which it is estimated will eventually have a population of 385,000. Population for which the first works were designed (in 1934) was 67,000. It is planned to add units to the existing works as they are needed. Increases in quantity of sewage reaching the works during the last six years have been 1936—100 per cent; 1937—142 per cent; 1938—199 per cent; 1939—227 per cent; 1940—245 per cent; 1941—256 per cent.

The original works were designed for a daily dry-weather flow of 2 M.G.D. and provided for 4 hours' preliminary sedimentation, pre-aeration with surplus activated sludge, 11½ hours' secondary sedimentation, 16 hours' secondary aeration and 4 hours' final sedimentation. Two-stage digestion of sludge was provided.

In 1937–38 extensive trials showed that 50 per cent more sewage could be aerated successfully in the aeration tanks. The capacity of the first plant was, therefore, increased to deal with a daily dry-weather flow of 3 M.G.D. by providing additional activated sludge sedimentation tanks and sludge digestion tanks.

Construction of a second unit was started in 1939; but work has been largely suspended due to the war. The original works are now treating 4.3 M.G.D. and producing an effluent satisfying accepted standards of purity.

K. V. Hill

HIGH RATE DOSING OF GRAVEL PERCOLATING BEDS

The Surveyor, 101, 117 (Apr. 3, 1942). *The Surveyor,* 101, 124 (Apr. 10, 1942)

Following excerpts from discussions of paper on this subject by John T. Thompson (*The Surveyor,* 101, 85–87 (Mar. 6, 1942)).*

Dr. J. Nixon (Huddersfield) thought it would be cheaper and more advisable in many cases to enlarge the filter beds and keep the rate of dosage low enough to produce a stable effluent. Where a strong sewage was concerned and the site limited for bed extensions, high-rate filtration followed by sedimentation, and lower-rate secondary filtration might be the ideal treatment. A point in favor of high-rate primary filtration was the view that a strong sewage was more easily purified in the early stages when the dose could be higher, and more difficult to purify in the later stages when the dose was reduced. Dr. Nixon's observations on the role of macroorganisms in preventing ponding coincided with Mr. Thompson's.

Mr. M. Lovett (West Riding Rivers Board) asked whether the rest periods given the filters were for convenience in supervision of the experiments or essential for the type of high-rate filtration investigated and cited Halvorson's thesis that rest periods could not be justified biologically. He thought ponding might be the result of anoerobic conditions as well as the cause of them and advanced the possibility that insufficient natural ventilation during periods when air and sewage temperatures were alike caused the difficulty.

Dr. T. B. Reynoldson (Huddersfield) mentioned factors in the data presented by Thompson which bore on the relation between ponding and rainfall. Prolonged rainfall would usually produce sewage containing dissolved oxygen which would encourage the profuse growth of sewage fungi on the sides of channels and conduits. These growths might be washed onto the bed, and if heavy, cause ponding. Weak sewage would afford less food and cut down growth within the bed and the degree to which this took place depended upon the rate of dosage. Prolonged rainfall might also lower the bed temperature and slow down the activity of the macro-fauna. He felt that the relation be-

* Abstracted in *This Journal,* 14, 746–747 (May, 1942).

tween ponding and rainfall was very variable, in some cases rainfall might cause clogging and in others clearing of the beds. Reynoldson was also interested to know that Thompson was able to increase the dose to 1,200 gal. per cu. yd. per day without causing serious ponding, in the light of Halvorson's statement that there was a "twilight zone" between 4.0 and 10.0 M.G.A.D. dosing rate at which ponding occurred, and that above this rate it was prevented by the flushing action of the sewage. He could not see how increasing the dosage would flush out the beds unless the macro-organisms also increased and converted the growth and sludge into humus.

Dr. W. Watson (Shipley) observed that a few years ago it seemed as though the activated sludge processes were trying hard to oust the percolating filter, but now the filter appeared to be staging a "comeback." He pointed out the apparent importance of the time contact of the sewage within a percolating filter.

Dr. S. H. Jenkins (Birmingham) also discussed the significance of time of contact in a percolating filter. With filters operated at conventional rates suspended matter could be allowed to accumulate within the filter with the certain knowledge that it would unload. High-rate filters had to depend upon the continuous discharge of suspended matter. Jenkins pointed out that in Thompson's experiments the data on suspended matter in influent and effluent indicated that the filter retained a good deal of suspended matter. This failure to discharge an adequate amount of suspended matter explained why the filter choked periodically and had to be rested. He suggested 3 ways of maintaining continuous high rates of dosing, (1) by alternating double filtration which promotes alternate development and disintegration of growths in filters operated alternately as primary and secondary filters in series, (2) by increasing the rate of dose and thereby distributing the load more uniformly throughout the depth, and (3) by reducing the speed of the distributor still permitting a heavy dose, but allowing dose more time to drain before the next application.

K. V. Hill

INDUSTRIAL STREAM POLLUTION PROBLEMS AND THEIR SOLUTION

By Richard D. Hoak

Chemical Industries, 49, 170 (Aug., 1941)

The concurrent concentration of population and industry along the waterways of the country has resulted in population problems of vast extent and complexity. Originally, the business mind regarded the primary usefulness of a stream simply as a means of transportation, and in the early days business and the community alike discharged their wastes into the most convenient water course and forgot about them. Pollution problems were not serious because rivers and streams were generally able to absorb the nuisances the relatively small volumes of wastes created.

However with the disappearance of geographic frontiers, streams began to serve other purposes than navigation. For example in 1936 the Ohio River Board of Engineers listed the priority uses of the Ohio River as: (1) public health; (2) drainage; (3) navigation; (4) industry; and (5) recreation.

The value of clean streams was recognized as early as 1872 by the Massachusetts Legislature which inaugurated studies of stream pollution and in succeeding years more and more attention has been given to this national resource which has been found to pay large, though sometimes undefineable, dividends in public health and industrial production. It is only in relatively recent years however that there has been an intelligently voiced and well defined public opinion on stream pollution problems.

The three major sources of stream pollution are municipal sewage, mining waste, and wastes from various industries. Materials from these sources are introduced into the water courses which may result in obnoxious tastes, colors and odors, corrode river structures and production equipment, destroy recreational areas, despoil the natural habitat of aquatic and wild life, and in sundry other ways affect the public interest.

The disposal of municipal sewage is of outstanding importance in the section of the country extending from St. Louis to Chicago northeastward to the Atlantic coast. In this area 75 per cent of the sewage of the country is produced most of which finds its way into the drainage basins of New England, the North Atlantic, the Ohio River, the Great Lakes and the upper Mississippi River.

A little more than half the population of the country (73,000,000 persons) are served by sewers. This serviced population plus the industrial waste produces roughly 5½ billion gallons of sewage daily. About 1½ billion gallons receives primary treatment only, another 1¾ billion gallons receives primary plus some form of secondary treatment and about 2½ billion gallons are discharged daily with no treatment whatever. While this untreated portion corresponds to less than one-half of one per cent of the combined flow of all the streams in the country, coming from 5,000 municipalities scattered throughout the nation, it causes widespread damage.

Waste from the mining industry consists of acid drainage and culm from the coal mining regions east of the Mississippi; brines from the Mid Continent, Gulf Coast, Michigan and California oil wells; and debris from hydraulic mining operations in California.

Prior to the recent W.P.A. program for sealing abandoned bituminous mines, an estimated 2,700,000 tons of 100 per cent sulfuric acid was discharged annually into the streams of the country. Sealing operations have substantially reduced this quantity by preventing the oxidation of pyrites to sulfuric acid in the presence of moisture. The degree of reduction is proportional to the effectiveness of the seals and to the care with which they are maintained.

Large quantities of culm and silt are washed into the streams from the wet processes for cleaning anthracite. Also large volumes of acid water are pumped from active and inactive anthracite mines. Some effort has been made to reduce the amount of culm reaching the water course by providing settling basins and by publicizing the damage to aquatic life from this source.

About three barrels of brine are produced for each barrel of crude oil brought to the surface. Some of this brine flows into streams, some is carried into disposal wells and some is discharged into surface disposal systems. Ordinarily the concentration of rare salts in oil brines is too low to make recovery economical.

Hydraulic mining has been improved and supplemented by construction of storage dams and levees so that the deleterious effect of silting on water bodies is now of much less significance.

Eldridge has classified industrial wastes as organic, toxic and inert. Under organic he lists the wastes of milk products plants, beet sugar, tanneries, canning factories, meat packing, breweries, distilleries, paper, strawboard, laundries, textile and dye works. Under toxic he places the wastes from metal plating, metal manufacturing, gas plants, chemical plants, coal and other mines. Under inert he classes the wastes from water softening plants, oil wells, saw mills and gravel pits.

There is no single unit by which the intensity of pollution can be accurately expressed. The population equivalent of domestic sewage which is used to evaluate the intensity of organic wastes, fails to take account of such factors as toxicity, color, nonsettleable solids, etc. However it does provide a basis for comparison and for evaluation of the relative effect of industrial wastes on streams.

The effects of water pollution are wide spread and various. Pollution is inimical to the public interest and frequently effects it in an indirect manner. There are four classes of matter harmful to waters available for public use: (1) organic; (2) active inorganic; (3) inert substances; (4) bacteria.

Organic material consists of domestic sewage and wastes from industries using animal or vegetable matter as a source of raw material. The waste is usually very putrescible and consists of a great many unstable compounds which have a strong tendency to break down into simpler, more stable forms. This stabilization can be brought about by the action of air and bacteria on these wastes in such devices as trickling filters and activated sludge though often only at excessive cost for the degree of treatment produced. Wastes which receive no treatment or inadequate treatment prior to discharge into the water-course must be treated by the stream, which is in effect a biochemical treatment plant. The water of a clean stream will be saturated with oxygen obtained from the air and from aquatic plants. The discharge of organic matter into it depletes this supply of oxygen and since the rate of re-oxygenation depends on the temperature, degree of exposure to air, character of the stream flora, sludge deposits, etc., the reserve supply of oxygen will be depleted as the ratio of organic waste to stream dilution increases. A point will be reached at which the aerobic bacteria die off and anaerobic conditions prevail. A stream in this condition will have long since ceased to support fish life. It will be unsuitable for consumption or recreational purposes and may become an aerial nuisance and otherwise aesthetically offensive.

Active inorganic chemicals consist of acids, alkalies, oxidizable salts, toxic substances and a wide variety of chemicals of every character. They are responsible for most of the taste, odors and colors in municipal water supplies. Some are poisonous to man in sufficient concentration and many are toxic to the flora and fauna of streams in very minute concentrations. Under such circumstances they impede or retard the biological processes of the stream. Their presence adds greatly to the cost of purifying water for domestic use and in addition the corrosive action of many, on river structure and manufacturing equipment often produces a serious economic problem.

Inert substances produced in the refining of petroleum, hydraulic and drift mining, glass polishing and some metal refining are mainly objectionable because they blanket stream beds, smothering aquatic plants and destroying feeding and spawning grounds of fish. Culm and silt may increase the cost of water purification and make a stream unattractive for recreational purposes. Oil may injure aquatic life and reduce the capacity of a stream for repurification by retarding the interchange of gases between air and water. Efficient devices have been developed for removing inert suspended matter and oil from inert wastes before discharge into streams.

Bacteria are indigenous to streams and play an important part in stream economy. Most bacteria are helpful to man in various ways and large numbers are not in themselves objectionable. Some bacteria reach the stream from municipal or industrial sewers which may carry harmful types. Fortunately most intestinal pathogens live only a few days when transferred from the body to surface streams. However there are harmful micro-organisms which multiply through sporulation and the spores which survive greater extremes of temperature and environment than the organism itself, remain potential dangers for long periods and are amazingly resistant to common sterilizing agents. Because there is no reasonable simple method for distinguishing the beneficent bacteria from the harmful, all bacteria in a stream must be regarded as harmful to public health. Therefore a large bacterial population will limit the usefulness of a stream for domestic water supply, recreation or shellfish culture.

Organic matter forms a source of food for bacteria and an increase in organic waste will be accompanied by increased bacterial population. These bacteria will exert a beneficial influence on the ability of a stream to purify itself so long as aerobic conditions exist or they will be instrumental in creating severe stream nuisances if the deposition of organic matter is such that anaerobic conditions exist.

Progress in the investigation of means whereby a reasonable degree of abatement of pollution could be effected disclosed the desirability of established standards of stream cleanliness so that a manufacturer or a municipality could be given definite advice concerning the degree of waste treatment which would be required before discharge into the stream would be permitted. A variety of standards have been proposed many of which attempted to include too large an area. No single standard can serve in all cases. In arriving at the quality of waste which it is permissible to discharge into a given stream, cognizance must be taken of the capacity of the stream to handle the wastes under both dry and wet weather conditions without serious depletion of dissolved oxygen or creation of conditions inimical to the successful treatment of its water for domestic purposes where the stream is so used. Standards for any given stream could best be established after careful study by inter-state commissions who would familiarize themselves with the pollution problems of an entire drainage area and be in a position to correlate the efforts made by officials, public groups and industry concerned with pollution abatement.

In general terms, waste treatment comprises a relatively few simple processes but these are often combined and modified by conditions in so many different ways that final solution of a waste treatment problem is frequently extremely complex.

The first expedient which should be employed by a manufacturer in solution of any pollution problem is the reduction of the quantity of waste water. Frequently valuable materials are lost through leakage and often rinse waters can be used for cooling and make up. The second step should be segregation of strong wastes from those weak enough to be discharged without any treatment. The final step should be a study of the best method of treatment for the particular waste and careful examination for means of economical recovery of useful materials before discharge to the treatment plant of the stream.

Estimates of the cost of a pollution abatement program which includes every drainage basin in the county is given in a report of the National Resorces Commission as "at least 2 billion dollars" and is distributed as follows: municipal waste treatment, 1 billion dollars; mining wastes, 150 million dollars; other industrial wastes, 900 million dollars. Most of the expenditure would be made in a few basins where dense population, industrial concentration, serious pollution and high costs for abatement are found in association.

The load of polluting material imposed on the nation's water courses impairs the production capacity of the American people and reduces the usefulness of one of its greatest resources. However since the stream pollution problem is the result of industrial expansion of the country and has been allowed to become extremely complex through neglect of both the municipality and industry, a program for its solution should be made only after careful examination in the light of its impact of the national economy.

E. Hurwitz

TREATING CORN CANNERY WASTE

By Hayse H. Black

Canning Age, May, 1942, 3 pp.

Lagooning as a method of disposal for vegetable cannery wastes was studied approximately 30 years ago by the Illinois State Water Survey. The principal advantage of this method is its economy. The disadvantages include potential stream pollution source, mosquito breeding, and creation of objectionable odors. Nitrate treatment of the wastes can be resorted to as a means of odor control. This type of treatment was tried at one corn canning company which packed various types of whole grain and cream style corn. Concentrated wastes from the cannery are passed through a 40 mesh rotary screen. Screenings are disposed of along with the shucks. Screened wastes drain by gravity to a sump from which they are pumped by a 450 g.p.m. pump, to the lagoons near the cannery property. The general arrangement of the disposal system is shown by a flow sheet.

Agricultural sodium nitrate containing 16 per cent nitrogen and 54.7 per cent oxygen was employed for odor control and was solution fed to the screened wastes. The amount used was such that the nitrate oxygen supplied was equivalent to 20 per cent of the 5-day B.O.D. of the wastes which is estimated to average 3,500 p.p.m. Cooling water was excluded from the process wastes. The cost of the sodium nitrate was 0.35 cent per case of number 2 cans packed. The success of this type of treatment was demonstrated by the absence of odor complaints during and following the 1941 canning season. Natural purification of the lagooned wastes is accelerated by the addition of sodium nitrate since, in addition to oxygen, the sodium nitrate provides nitrogen which is considered a desirable nutrient for biological life. Microscopic and bacterial examination of lagooned cannery wastes were made to identify the types of organisms responsible for the natural purification. Facultative or strictly anaerobic bacteria act to digest concentrated wastes in the initial phases of purification. During the intermediate stages flagellates and ciliates appear. Chlorophylaceous ciliated protozoa have also been observed.

Two charts indicating the trend of natural purification in lagoons are given. These show the relationship between pH, total solids, 5-day B.O.D. and time of storage. Mass curves of waste discharged to lagoons are also given. Marked reductions in solids and B.O.D. are indicated. The natural purification occurring in the lagoons is an important factor in favor of this method of disposal. Clarified and partially stabilized lagooned waste can be slowly released during early spring thaws (high stream stages and low water temperatures) without causing objectionable stream pollution.

PAUL D. HANEY

THE PORTEOUS PROCESS

Correction.—Mr. W. King Porteous, Managing Director of the Porteous Process of heat treatment of sludge prior to filtration, has called attention to an error in the abstract "Horsham Sewage Works," by Arthur Marshall, which appeared in our January, 1942, issue, page 236. The coke used as fuel for heating sludge was given as 26,200 lb. per day, whereas it should have been only one-tenth this amount, or 2,620 lb. per day. Mr. Porteous states that even the latter is high, and is being lowered.

LOCAL ASSOCIATION MEETINGS IN 1942

Association	*Place*	*Date*
Canadian Institute of Sewage and Sanitation	Toronto, Ontario (Royal York Hotel)	Oct. 22–23
Missouri Water and Sewerage Conference	Hannibal, Mo.	Sept. or Oct.
New England Sewage Works Association	New London, Conn. (Ocean Beach Pavilion)	Sept. 25
North Carolina Sewage Works Association	Durham, N. C. (Washington Duke Hotel)	Nov. 2–4
North Dakota Sewage Works Association	Williston, N. D.	Oct., 1942
Ohio Sewage Works Conference	Cleveland, Ohio (Statler Hotel)	Oct. 22–24 *
Pennsylvania Sewage Works Association	Harrisburg, Pa. (Penn Harris Hotel)	Aug. 24–26
South Dakota Water and Sewage Works Conference	Huron, S. D. (Marvin Hughitt Hotel)	Sept. 28–29

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

Third Annual Meeting, Statler Hotel, Cleveland, Ohio, October 22–24, 1942 *

* Date changed from that previously announced.

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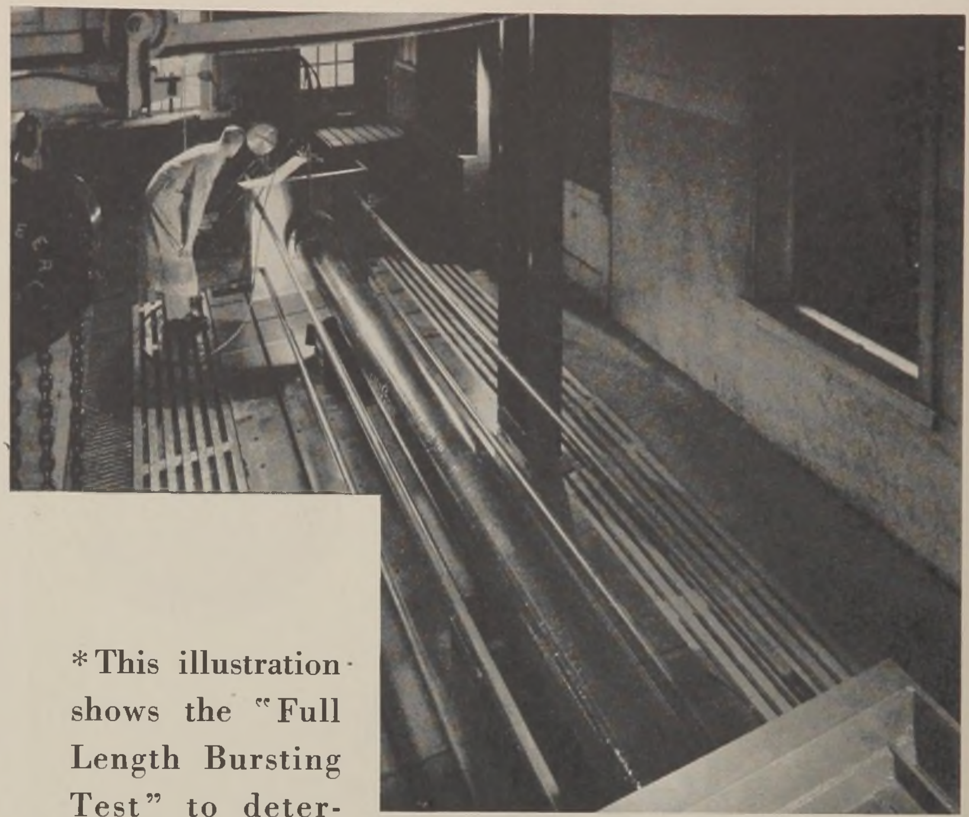

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