# SEWAGE WORKS JOURNAL

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## *Special Features*



**Wartime Conference, Chicago—Oct. 21-23, 1943**
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# FEDERATION OF SEWAGE WORKS ASSOCIATIONS



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# SEWAGE WORKS JOURNAL


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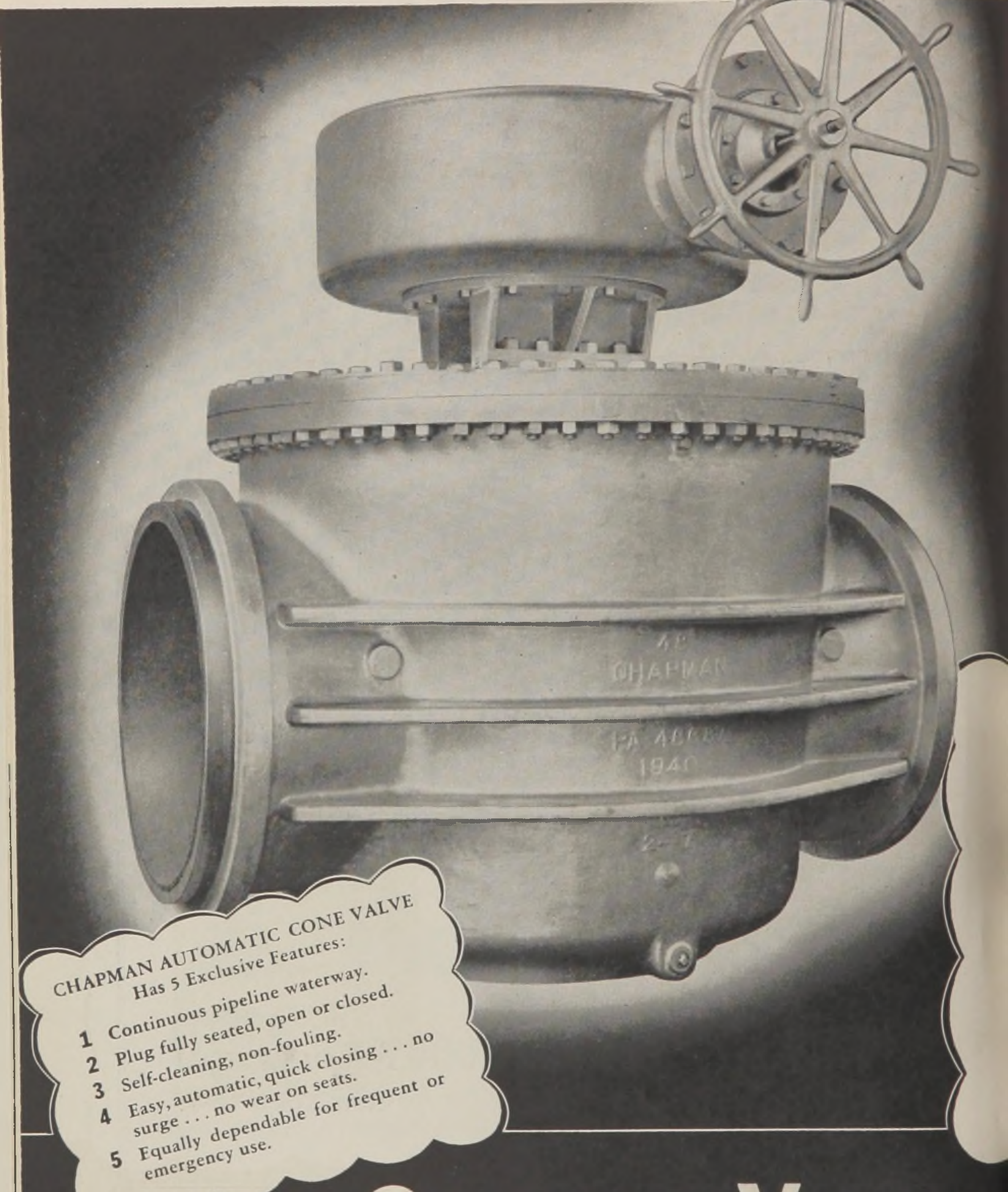


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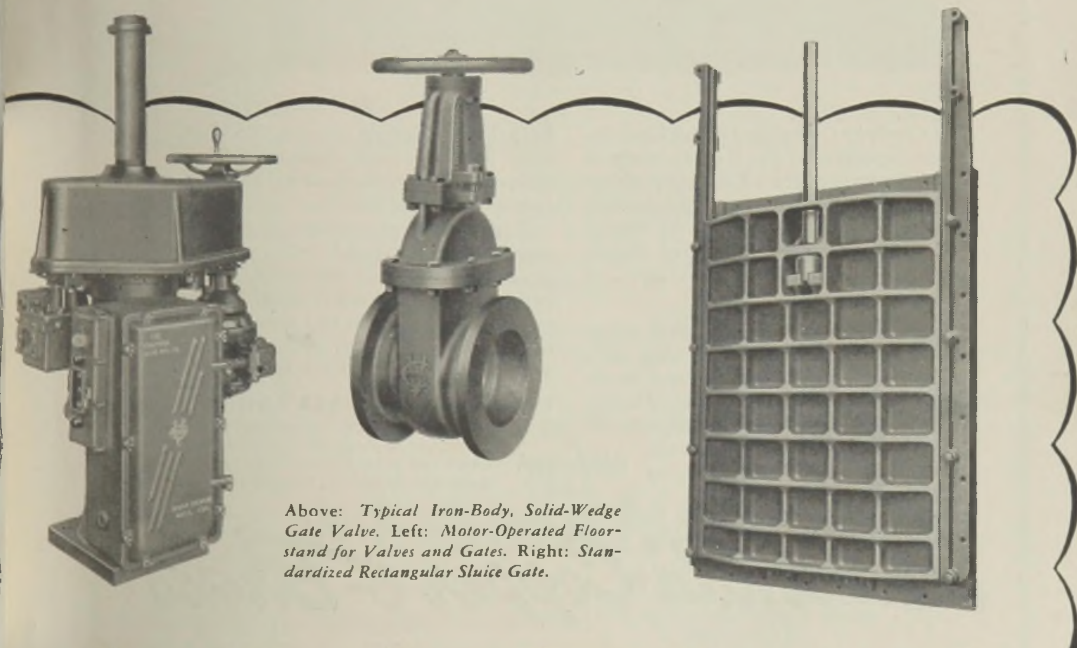

Above: *Typical Iron-Body, Solid-Wedge Gate Valve.* Left: *Motor-Operated Floorstand for Valves and Gates.* Right: *Standardized Rectangular Sluice Gate.*

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Plant Operation:



Sewage Research:



Stream Pollution:



Industrial Wastes:



The Operator's Corner:



Editorial:

# Plant Operation

## THE POST-WAR ROLE OF THE SANITARY ENGINEER *

By Abel Wolman

*Prof. of Sanitary Engineering, The Johns Hopkins University, Baltimore, Md.*

One of the advantages in talking about the future is that there is no limit to your imagination, and there of course can be no controversy about your prediction. Any one in the audience is at liberty to argue with the speaker about the future, but he cannot summon up any data which will controvert any of the prophecies which I may venture to make this evening. I am well aware of that strategic advantage, and I am taking advantage of it primarily to discuss with you, more or less in a conversational mood, what it is that I pretend to envision in the future.

I do it not only to amuse you—which is one of the primary functions of an after-dinner speaker—but really to explore with you, as serious-minded participants in sanitary engineering practice, what the future holds. We may all be wrong. We may all have guessed wrong; and certainly I hope that all of us will have an opportunity to test that out, if fate is kind to us, and, if we survive until after the war, to be able to take stock once again at such a meeting as this, in order to determine how far from accuracy we were.

But certainly there is no harm in taking stock; there is no harm in allowing our imagination to roam over the scene, and to try to visualize if we can what it is that the future holds for us. That particular task has been assigned to me. One of the reasons for it, I assume, is that almost every one in this room, man and woman, is engaged, and has been for the last eighteen months, in the strenuous and primary task of winning the war. As I look around, I see no individual who is not actively engaged in a day-by-day assignment, all of which is directed towards meeting the contingency of war.

It perhaps is a relief that this assignment is directed towards, not the present, but the future. It is a relaxation, let's call it, in the direction of leaving the problems of the day, which are certainly acute enough to warrant devoting all of your time to the present. Perhaps at midnight, when you are exhausted from the present, you should be allowed an opportunity to envision the future. And my function is primarily, according to your Program Committee, to lead you into that future in order to try to see where we may stand in 1944, or 1945 or 1946, when the war is over.

* Address Before the Joint Banquet of the Sanitary Division of the American Society of Civil Engineers and the New York State Sewage Works Association, New York City, Jan. 22, 1943.

## Problems of Demoblization

Now, why talk about what we have learned to speak of as ''D'' day, Demobilization day? All of us are familiar with ''M'' day, the familiar Army term for mobilization of all of our resources for winning the war. We are now turning, perhaps for the next twenty minutes or so, to ''D'' day, that day which will arrive. Very few of us have any doubt but that we shall win this war, and we shall reach the day of Demobilization.

And when that ''D'' day is reached, where will we stand? How will we be prepared for it? And what, if anything, can a group such as this do in preparation for it?

I have pointed out, within the last ten days, in a group similar to this, that there is an official sanction for thinking about the future. Strangely enough, there are a lot of people who believe we should not think about the future, that the problems of today are acute enough to take all of our attention. There are some who believe that we should not be utopian, that we should not be too theoretical or academic, to think that there will be a future.

Officially, however, the Selective Service Act, which provides for mobilization of all of the personnel of the United States for total war, includes a directive for demobilization. I am not sure how many of you are aware of that fact, that there was wisdom in the drafting of the Selective Service Act which recalled that there will be an after-the-war period, and directed the Selective Service group, at the same time that it was busy with mobilization, to concern itself with the equally important and equally imminent job of demobilization, to take care of a post-war United States.

In the past, from the standpoint of sanitary engineers, we had a long record of accomplishment, all of us, of course, quite unsatisfied with the degree of that accomplishment. If we measure it, however, by the number of dollars spent in the installation of sewage treatment devices, in the development of water supply, in the construction of new housing, we have a measure of what that part was in the pre-war period. We can as statisticians indicate what its volume was. In that pre-war period we were accustomed to spend for sewage disposal alone anywhere from $50,000,000 to $150,000,000 a year, and in the water supply field a slightly higher amount.

That was the usual run-of-the-mine type of expenditure normally available to the sanitary field. There were other expenditures, of course, in our country which were related to the general sanitary field and to the control of environment.

Then we entered the present, a highly complicated present, a situation abnormal in the sense of adjustment of all of our perspective, abnormal in the diversion which occurred from our accustomed peacetime activities. When we pass out of the present we have four or five fundamental adjustments to make. I mention them without discussion, merely to bring to your minds the fact that we have to make them in a fashion which should be as logical and as intelligent as a group of engineers can possibly make them.

We will demand a shift in national income towards peacetime purposes of approximately one-half of our total annual expenditure, a prodigious sum, a sum which is now devoted exclusively to wartime expenditure. We will have to find a way to shift ten million people from military occupation to peacetime occupation; to shift twenty million additional people from wartime industry to peacetime industry. We will have to shift all of industry from the making of wartime to peacetime implements. We will have to re-orient the disturbed and upset communities with which we are familiar, the Hampton Roads areas, the Houston, Texas, the San Diego, California, the Baltimore, the Kankakee and Peoria, Illinois, areas to a peacetime status, an adjustment of heroic proportions and one which most people decide to meet by pretending to forget it, but which I submit the engineering profession cannot meet in that fashion.

Those are the problems of the present. What may we expect as to the future, when we attempt to make that adjustment? That is the field in which the sanitary engineers, among many others, as citizens of this country and as professional operatives, are naturally interested. What will that prospect be?

## What of the Future?

The country divides itself, in its popular opinion, into two schools with respect to the post-war period. If we consider the extremes, one expects nothing but the dismal, a collapse of the United States if not of the world. The other expects a prosperous period of unprecedented character, a desire to fulfill a long deferred set of needs of the community. So far as I have been able to determine, there appears to be nothing in the present, in the past or in the future which is on the side of the dismal prospect. There is every reason to suppose that if we are intelligent, if we are courageous, the future need not be anything but helpful and hopeful. There is no reason to suppose that the world will collapse after the peace. It is contingent, most people believe, on how well we are in position to support that world within or outside our country.

I have presupposed for most of my remarks the more optimistic future. I can't talk, at any length, about the kind of a prospect in which the United States is ruined. I see no point in discussing a future in which our own country has collapsed. I choose—not only because I prefer to choose it, but because I prefer to believe that it is the prospect that is most likely to come—that the United States of North America will survive, and that when it survives it will have the courage and the means by which to go on at a high level of prosperity.

## Public Works Needs

One of my reasons for feeling that way, from an engineering standpoint, is that by that time, whether at the end of 1943 or at the end of

1944, or 1945, we will have accumulated a set of deferred engineering demands which will be of heroic proportions. Only a prodigious lack of forethought, a complete lack of intelligence, should result in that dammed-up supply of deferred demands failing to create a prosperity period.

Within our own field, which is relatively restricted, I would estimate that we will have a deferred demand with respect to housing of 3.7 billions of dollars of construction by the middle of 1944. We should have a deferred demand in the general public works field of 1.8 billion dollars of construction; in the water supply and sewerage field, of approximately 0.75 billion dollars. These figures which I am suggesting to you are not pulled out of the air. They represent a careful canvass of what has not been done since 1940; of what we have been accustomed to do in normal intervals and what we have not been doing from 1940 to 1942, inclusive. If we add to that the deferred jobs which we probably will not do in 1943, we arrive at the figures I have quoted to you. Those figures may seem, at first sight, as outlandish, as optimistic. They need not be.

The forthcoming report, for example, on the Ohio River pollution survey, will indicate that in that one drainage basin alone approximately 200 million dollars of sewage treatment, public and private, waits to be accomplished, in that one basin. It represents the requirements of approximately 20 million people. If you were to apply similar figures to the urban population of the United States, the program for private and public abatement of stream pollution approaches, for the United States, approximately 1.0 billion dollars.

I could go on to enumerate all of the possibilities of work in our own country. I think no fruitful purpose would be served if I list statistically for you, with the limited amount of time available, how many millions, if not billions of dollars of work remain to be done in a country which is living and which, as I say, I have assumed will continue to live during the post-war period. I am sufficiently free, at the moment, of hardening of the arteries—although not very far away from it—to feel that the future has to be viewed with sufficient courage to believe that it will be alive, that it will offer challenges in the sanitary field, that there will not be a moribund population, that there will be an expansion, even though perhaps slow, of our country's opportunities and necessities.

## International Aspects

I leave the domestic or national scene to refer, for a moment, to the international problem and possibilities. Obviously, anybody who talks about future prospects on a global basis can talk about it only on the assumption that if and when peace is declared this country again will be a participant in post-war operation. Again I make that assumption because I can make no other in the light of the experience of the past five years. No longer do I think it is possible for the United States to retire—and I use the word "retire" advisedly—to insular and isolated assumption of its world power. I can't conceive that we can withdraw into an insulated, continental, national, North American activity. If that is the case, we then have, in addition to our national obligation and, incidentally, opportunity, an obligation and opportunity in the world at large.

That does not mean, as some people feel, that we become the universal Santa Claus, financially, for the world. It does mean that perhaps for the first time since 1789 we recognize that we are part of the universe, that as citizens of this country we have an obligation to the rest of the world. That perhaps is a new obligation, but it is one which I for one feel that our country will have to assume.

When it is realized that in the course of the last five years the major capitals of the most important countries in the world are no longer more than two days distant from Washington, we can no longer assume that we are insulated and isolated.

Regardless of the technique—and I want to say a word about that later on—regardless of the technique, financial, legal or administrative, we will probably enter a world in which this country will be a participant, not necessarily a dominant factor, in global reconstruction. I can conceive of no global reconstruction in which the sanitary engineer will not be a part.

There is no country in the world which matches the United States in the physical facilities for the protection of life, for the preservation of safety, and for the maximum protection of public health. The standards which we have established must pass to other countries. The experience which we have acquired must be made useful to other people.

If that assumption is correct, I can visualize—and I do not believe I am being entirely utopian or academic—that our examples of operations in the form of co-operative engineering effort will pass to every country in the world, if for no other reason than that the experience which we may have latent and developed in this country must be made available to every other country.

I have no patience—I do not know whether you have—with those groups in this country who scoff at the possibility of enlarging the sanitary safety of every country in the world. It is an ideal which I, for one, feel is a desirable ideal. I can't share the view of the most recent President of the National Association of Manufacturers that that view is a kind of international joke. I can't share the view, for example, that a T.V.A. on the Danube is a kind of Joe Miller resurrected joke. If it means the resurrection of any country in the world, I am for it as an engineer and as a citizen of that world.

In every country in the world there are potentialities in the field of sanitary engineering which have not even approached the possibility of complete consummation. There are many countries in the world which align themselves in the list of trying to reach our standards. Some of those countries I think have surpassed our efforts in certain directions.

There is in this audience, for example, a gentleman from South America who, I think, has moved forward in the direction of providing sanitary facilities in scope, in perspective and in visualization of the necessities of the common people of his country that we in North America might well emulate. I refer to Mr. Sanchez. In his office in Latin America, in Peru, I was tremendously impressed, not only by the scope of his vision but by the general direction in which his Government tends to move. It is a page which I think North American sanitary engineers might well read with care, and might well apply with care.

In England, for example, within the past few weeks, a Parliamentary Commission has reported—mind you, in the midst of the most severe bombing and destruction that the world has ever known, England finds the time to think about the future—one of the most amazing contributions, I think, to planning for the future that we have on the problem, of all things, as to how to extend public water supply to rural areas; how to make available to the small, scattered roadside community of 500 people or less the benefits and the protection of public water supply. It calls attention to the fact that it is feasible, that it is practical, and that it should be done and that it should be done now, not after the war! It is one of the curiosities of sanitary engineering progress.

We have discussed in this country, for example, more or less academically, the problem of passing on to crossroads communities the advantages of central public water supply. In general, it has met with a kind of wonder at the academic, utopian point of view of the man who suggested it. In England it is accepted as a desirability, and they proceed to find out how and why it can be done.

The engineers in this country, at the moment are engaged in discussing the possibility of developing, of all things, and in all places, the River Jordan, your Biblical river of ancestry, the seat of your origins, as a J.V.A., a transplanted Tennessee Valley Authority on the River Jordan! Why? Because such programs seem to have the potentialities of power, the potentialities of making a new life and a profitable life for Syria, for Trans-Jordania, for Palestine, and for Iran.

Within the past week, the report of the Parliamentary Commission in England, for example, has just appeared, on establishing a T.V.A. corporate authority in Scotland, to rehabilitate an area through the auspices of the same type of structure that they describe as successful in the Tennessee Valley. I say they "describe" with a kind of sinister sense of humor, because it is still talked of in our country as one of the curiosities of the New Deal. The English accept it as an advance in public enterprise, as an advance of opportunity in the field of civil and sanitary engineering.

At this very time, China, than which there is no more disconcerted, no more bombed out people in the world, finds it profitable and timely to discuss the reconstruction of China. Again, of all places, in Chungking there has been operating for two years a post-war planning committee. How in the world anybody in Chungking has the time to sit down and think of what you would do with China after you win, is beyond me, but they have a public works post-war program. They have a program for maternity hospitals, for water supply, for sewage disposal, for the correctives which they have been long in arrears in instituting. They have that time, and they are putting it to profitable advantage.

### Expanded Horizons for Engineers

I mention these examples only because they illustrate that in many ways many of these countries look to the United States for precept, for advice, for guidance, for courage, for enthusiasm. They seem to think that we are a new country, an enthusiastic country, that we have had an opportunity to develop ideas and ideals that may be useful to them.

I do not pretend to say to this hard-boiled group of engineers, who preserve, properly, a degree of cynicism about any academic suggestion, that there are not problems attached to such a post-war period within and outside our country. There are many of them. In our own country, there are legislative difficulties, financial ones, administrative ones. On the worldwide basis, they are multiplied a thousandfold. All I do say is that in spite of those obstacles, for which, incidentally, many are preparing in this country and on an international level, in spite of them there is a future for sanitary engineers, a broad, bright, exciting, courageous future.

In the making of that future—I quote from Mr. Prince, the hard-boiled Vice-President of the General Electric Company, who says that "the post-war period is full of opportunities never surpassed in the history of our country." He says, "Those opportunities are worthless, however, unless we can identify them, assay them, and prepare for them." Remember those words, "the opportunities are unlimited, and surpass any of those which have preceded this war; they are useless, however, unless we can estimate what they are and provide for them."

I emphasize them because they require, particularly from engineers, a choice between two roads to travel. That is just as applicable to the sanitary engineer as to any other man, a choice of two roads, a choice of leadership versus cynicism, a choice of courage versus a fatalistic acceptance of the dismal.

I have never been able to understand why the engineer, equipped as he always has been to meet the difficulty technologically, has always stood on the side while the legal or the political interests muddle the situation. The future, to my mind, holds a challenge of a peculiar type for the sanitary engineer. He has many of the technological answers. He has few of the political, legal, administrative or fiscal answers. I submit that the time has arrived for him to devote part of his energy, part of his thinking, to the solution of that subtle group of hurdles which prevent us from making the most of the future. Why shouldn't he be on the side of developing those answers?

Sanitary progress in this country and the world will move forward when we have fiscal answers, administrative answers, and legislative answers. They are not insurmountable, but I leave with this group, as one of the challenges for the future, a diversion from the technological and a hope that the sanitary engineer and his collateral group of engineers will devote their energies to trying to find out how to do a thing, rather than to sit by and merely describe the hopes and ideals of the masses of the people as one of those silly concepts with which he cannot sympathize.

It is not a silly concept. Every group of people in this country and in the world has a right to expect and hope for an advancement in that field of endeavor with which we have been connected over a great many years. We should try to find the device, the road, the technique, the fiscal policy, the legislative authority, which will permit the people of this and every other country in the world to live well, safely and securely in the future.

# SEDIMENTATION OF SEWAGE *

By Royal E. Rostenbach and Earle L. Waterman

*Associate Industrial Specialist, Projects Expediting Unit, War Production Board, and Professor of Sanitary Engineering, University of Iowa*

This study is an analysis of certain forces and factors which affect the efficiency of full-sized clarification units. The operation of the clarifiers at the Iowa City Sewage Treatment Plant was investigated for various rates of flow and under conditions of actual operation.

Many investigations have been made using small models and laboratory equipment for the study of sedimentation but very little work has been reported on the actual operation of full-sized units. In 1889 Seddon (12) noted the need for definite knowledge on sedimentation of suspended matter in waters. Hazen (17) in his paper, "On Sedimentation," presented many of the fundamental factors concerning this subject. Schroepfer (11), Moseley (13b), Slade (14), Carpenter and Speiden (4), Camp (2), Blew (1), Tark (18), Hatch (13b), Weiters (20), Merkel (8), Smith (15), Schlenz (10), and Strell (17) have elaborated upon and discussed the forces and factors instrumental in the sedimentation of suspended matter in water and sewage.

The sewage of Iowa City, Iowa (19), is very largely a domestic sewage from an estimated population of 24,000, containing only the usual industrial wastes found in a residential city. The original sewerage system was designed for combined sewage. In recent years there has been some separation of the storm water from the system and all extensions of the system have been designed for only domestic sewage. At the present time, there is some increase in the sewage flow in times of wet weather. The sewage treatment plant consists of a grit chamber, coarse screens, pumps, control house, two primary clarifiers, three trickling filters, one humus tank or secondary clarifier, primary and secondary digestion tanks, and sludge beds. The plant effluent is discharged into the Iowa River.

The primary clarifiers (Fig. 1) are of the Sifeed type. The units are 45 ft. in diameter, 10 ft. in edge depth, and 11.5 ft. in center depth. The volume of each clarifier is 126,400 gallons.

Sewage enters the clarifier through a vertical feed pipe at the center and passes through the four large openings of a center drum and hence to the distribution baffle. The clarified sewage leaves the tank over a circular weir at the periphery. The vertical feed pipe is expanded from 14 to 22 in. at the influent well. The center drum is 5.75 ft. in diameter. The center distribution baffle is 9 ft. in diameter and 57 in. in depth. Fifty-four inches of the baffle is submerged in the sewage flowing through the tank. A 2-ft. section at the bottom of the baffle is perforated with seven rows of $2\frac{1}{4}$ in. diameter openings. The horizontal distance between the centers of these openings is 3 inches. The total area of these orifices is

* A digest of a dissertation submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in the Department of Civil Engineering in the Graduate College of the State University of Iowa, June, 1939.

15.24 sq. ft. The center baffle is equipped with twelve distribution vanes. These vanes are 26 in. wide and 46 in. in curvature. The curvature has a 40 in. chord. The perpendicular distance from the extended projected circular length on the center baffle by a vane is equivalent to 29 inches. The vanes are located at the bottom section of the baffle and they meet the sewage flowing through the perforations of that section. Originally both primary clarifiers were equipped with distribution vanes attached to the center baffle. The vanes in one clarifier were removed to make possible a study of operation with and without these distribution vanes.

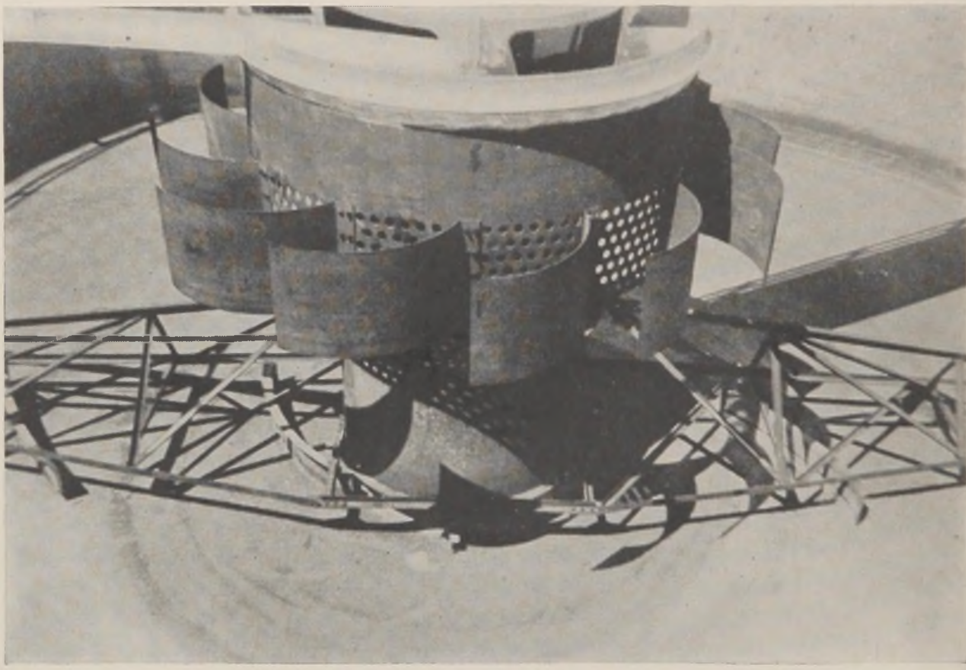

Fig. 1.—Distribution vanes attached to baffle around inlet to clarifier.

The flow of sewage through the primary clarifiers is dependent upon the pump or pumps in operation lifting the sewage from the pump sump to the clarifiers. The clarifiers may be operated separately or in parallel. By experiment it has been found that each primary clarifier can handle 2,000 gal. per min. At greater rates of flow sewage will flow over the center influent baffle and short circuit the clarifier. During the morning hours between twelve midnight and seven o'clock the flow through the clarifiers is stopped about half of the time. The maximum flow under ordinary circumstances during the day is 2,000 gal. per min. At this rate with two primary clarifiers operating in parallel, each receives 1,000 gal. per min. flow of sewage.

The humus tank or secondary clarifier is also of the Sifeed type. It is 60 ft. in diameter and has a side wall water depth of 7.5 ft. and a center depth of 10 feet. The volume of the clarifier is 176,240 gallons. The clarifier is equipped with a circular influent baffle 11 ft. in diameter and

4 ft. in depth. The lower half of the baffle is perforated with openings. The baffle is not equipped with distribution vanes. The effluent weir is $21\frac{3}{4}$ ft. from the influent baffle. The flow of sewage through the secondary clarifier is dependent upon the pump or pumps in operation which lift the sewage to the primary clarifiers. The flow through the trickling filters and secondary clarifier is by gravity. The maximum flow under ordinary circumstances is 2,000 gal. per min.

Motor-operated scrapers move the settled sludge to the center of the tanks and a skimming device moves over the surface of the sewage of the clarifiers.

## Operating Results

In a study of the average performance of the primary clarifiers for the period October 1, 1936 to January 1, 1939, the average flow rate was 1.80 m.g.d., which is equivalent to 625 gal. per min. per unit.

The sewage had the following characteristics:

| | Parts per Million | |
|---|---|---|
| | Untreated Sewage | Clarified Sewage |
| Total Solids | 968 | 765 |
| Total Volatile Solids | 466 | 330 |
| Suspended Solids | 300 | 131 |
| Volatile Suspended Solids | 198 | 89 |
| 5-Day B.O.D. | 358 | 199 |

The average reduction of suspended solids was 56.3 per cent, and of 5-day B.O.D. 44.4 per cent, equivalent to 2,380 lb. 5-day B.O.D. per day.

During the periods June 20 to July 15, 1938, and August 3 to September 1, 1938, only one primary clarifier was in operation. The sewage had the following characteristics during the 53-day period:

| | Parts per Million | |
|---|---|---|
| | Untreated Sewage | Clarified Sewage |
| Total Solids | 868 | 760 |
| Total Volatile Solids | 368 | 294 |
| Suspended Solids | 258 | 127 |
| Volatile Suspended Solids | 176 | 95 |
| 5-Day B.O.D. | 266 | 160 |

The average flow rate was 1.76 m.g.d. which is equivalent to 1,220 gal. per min. The removal of 5-day B.O.D. was 40.0 per cent.

It was noted in comparing the operation of the primary clarifiers from the data at the rates of 625 and 1,220 gal. per min. that the characteristics of the clarified sewage were similar and that the per cent reductions were approximately equal. These observations indicated that approximately 3.5 m.g.d. of sewage can be treated by the two primary clarifiers without reducing the efficiency of sedimentation.

## Effect of Distribution Vanes

For a three-month period, November 13, 1938, to February 13, 1939, the primary clarifiers were operated and composite sewage samples were analyzed to determine the effect of the distribution vanes upon the efficiency of operation of the tanks. One clarifier was operated without the distribution vanes (Fig. 1) while the other clarifier was operated with the distribution vanes. The average daily flow was 1.73 m.g.d. and hence, each clarifier received an average flow of 600 gal. per min. The effluents of the clarifiers had the following characteristics:

| | Parts per Million | |
|---|---|---|
| | Without Vanes | With Vanes |
| Total Solids | 908 | 904 |
| Total Volatile Solids | 392 | 308 |
| Suspended Solids | 131 | 127 |
| Volatile Suspended Solids | 98 | 99 |
| 5-Day B.O.D. | 245 | 246 |
| Oxygen Consumed | 94 | 91 |

In the above comparison there was practically no difference in results of analyses of the effluents at the average flow of 600 gal. per min.

The operation of the clarifiers was next studied to determine the degree of sedimentation of suspended solids at various sections of the units at different rates of flow. The motor-operated scrapers and surface skimmer were in operation at all times. One primary clarifier was operated with the distribution vanes while the other was operated without them.

Samples of the sewage flowing through the primary clarifiers were taken at depths of 2, 4, 6 and 8 ft. from the surface of the liquid and at positions 1, 5, 10, 15 and 18 ft. from the side wall of the tank at the following rates of flow of 600, 1,100 and 2,000 gal. per min.

The samples of sewage of the secondary clarifier were taken at depths of 2, 4, 6 and 8 ft. at the center of the tank. The samples were collected 3, 10, 17, 24 and 26 ft. from the side wall. The operation of the secondary clarifier was studied at 1,200 and 2,000 gal. per min. rates of sewage flow.

All samples were taken from the steel walk-way of the clarifiers. Samples of the clarifier influent and effluent were collected before and after the other samples were collected. The amounts of suspended solids in the various samples were determined by the Gooch crucible method of Standard Methods of Water and Sewage Analysis.

The data were composited on the following basis: The amount of suspended solids in the clarified sewage was taken as a basis for comparison, because the clarified effluent is more uniform in composition and a larger volume of a sample may be used in determining the suspended solids.

The arithmetical average of the amount of the suspended solids of the two effluent samples was taken for a comparison of the other samples. The amount of suspended solids in the various samples was divided by the average suspended solids of the effluent samples to obtain a factor $\theta$. This factor, $\theta$, related the amount of suspended solids at a point in the tank to the suspended solids remaining in the effluent. The factor of the suspended solids in the untreated sewage entering the tank was likewise determined. The factors, $\theta$, for each position in the tank for the several runs were averaged. The average factor, $\theta$ avg., was multiplied by the average amount of suspended solids of the clarified effluent to give an average suspended solids for the various positions. This amount was taken as a representative expression of the suspended solids at the different sampling points.

The average amount of suspended solids in the primary clarifier effluents at the 600 gal. per min. rate of flow was 140 p.p.m. for the clarifier without the distribution vanes and 130 p.p.m. for the clarifier with the distribution vanes. These results were similar to those previously presented, in that the suspended solids were 131 and 127 p.p.m. for the effluents of the clarifiers with and without the distribution vanes, at the daily average flow rate of 600 gal. per min. per unit.

At the rate of flow of 1,100 gal. per min., the clarifier without the distribution vanes showed a greater amount of suspended solids at the 2 and 4 ft. levels at the positions 10, 15 and 18 ft. from the periphery. In the clarifier with the vanes at the position 10 ft. from the periphery, the suspended solids were 185, 160, 150 and 140 p.p.m. for the depths 2, 4, 6 and 8 feet. In the case of the clarifier without the distribution vanes a similar distribution did not appear until a point between the 5 and 10 ft. positions from the periphery. At 5 ft. from the periphery the distribution was 160, 160, 135 and 120 p.p.m. for the depths 2, 4, 6 and 8 feet.

TABLE I.—*Average Suspended Solids in P.p.m. of the Sewage in Primary Clarifiers at Various Distances from the Periphery* *

| Flow Gal. per Min. | Clarifier | Suspended Solids in P.p.m. | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Untreated Sewage | Distance from Periphery in Feet | | | | | Clarifier Effluent |
| | | | 18 | 15 | 10 | 5 | 1 | |
| 600 | With Vanes | 325 | 210 | 160 | 150 | 125 | 110 | 130 |
| | Without Vanes | 320 | 210 | 165 | 140 | 125 | 115 | 140 |
| 1,100 | With Vanes | 375 | 235 | 205 | 160 | 145 | 130 | 150 |
| | Without Vanes | 360 | 250 | 210 | 180 | 145 | 125 | 140 |
| 2,000 | With Vanes | 400 | 290 | 235 | 215 | 200 | 175 | 190 |
| | Without Vanes | 360 | 280 | 230 | 215 | 190 | 175 | 190 |

* Diameter of tank is 45 ft.

At the above rates of flow of 600 and 1,100 gal. per min., approximately one-third of the suspended solids settle out in the center section enclosed within the 9-ft. center baffle. The over-all reduction at these rates was 60.0 per cent for the primary clarifier with the distribution vanes and 56.2 and 61.2 per cent for the primary clarifier without the distribution vanes. The latter clarifier did not have the same uniform distribution and there appeared to be shunting of the tank at a level 4 ft. below the surface of the sewage. At these rates of flow, the amount of suspended solids near the side wall of the tank was less than that in the effluent leaving the tank.

At the rate of 2,000 gal. per min. there appeared to be a shunting of the flow across the clarifier without the distribution vanes at a level 4 ft. below the surface of the sewage. The clarifier operating with the distribution vanes had a more uniform distribution of suspended solids throughout the tank than did the clarifier operating without the distribution vanes. Although there was a variation in the distribution of suspended material within the tanks, the amount of suspended solids in the effluent was the same.

An analysis of the suspended solids data showed that there was a gradual decrease of suspended solids as the sewage approached the side wall and weir of the tank (Table I) and that there were zones near the side wall and bottom of the tank where the concentration of suspended solids was less than that of the effluent. The amount of suspended solids in the effluent appeared to be related to the rate or velocity of flow because the suspended solids of the clarified sewage were 130 to 140 p.p.m. for the 600 gal. per min. rate, 140 to 150 p.p.m. for the 1,100 gal. per min. rate and 190 p.p.m. for the 2,000 gal. per min. rate.

## Secondary Clarifier

The secondary clarifier was investigated at 1,200 and 2,000 gal. per min. rates of flow. At these two rates of flow the suspended solids of the influent were 115 p.p.m. and 175 p.p.m., respectively (Table II). An analysis of the suspended solids data indicated that beyond the 12 ft. influent baffle there was very little difference in the suspended solids concentration. At both rates the effluent had 50 p.p.m. of suspended solids.

Table II.—*Average Suspended Solids in P.p.m. of the Sewage in the Secondary Clarifiers at Various Distances from the Periphery* *

| Flow Gal. per Min. | Suspended Solids in P.p.m. | | | | | |
|---|---|---|---|---|---|---|
| | Influent | Distance from Side Wall of Clarifier in Feet | | | | Effluent |
| | | 24 | 17 | 10 | 3 | |
| 1,200 | 115 | 74 | 64 | 59 | 54 | 50 |
| 2,000 | 175 | 96 | 58 | 61 | 62 | 50 |

* Diameter of tank is 60 ft.

During a 13-month period (1937–38), the average daily flow was 1.75 m.g.d., equivalent to 1,215 gallons per minute. The average reduction in suspended solids by the secondary clarifier was from 75 p.p.m. to 33 p.p.m. and the average reduction of any 5-day B.O.D. for same period was from 64 p.p.m. to 38 p.p.m.

The data for the secondary clarifier indicated that the clarifier may be operated at the 2,000 gal. per min. rate as efficiently as the lower rates of flow, and further suggests that due perhaps to the difference in the character of the suspended solids in filter effluents, the secondary clarifiers should be designed on a different basis than the clarifiers used for primary sedimentation.

## Flowing-Through Period

*Primary Clarifiers.*—One of the important factors in operation of the settling tank is the time the sewage is allowed to settle within the tank. The detention period and flowing-through period are terms used in the design of tanks to express time periods of the sedimentation process.

Capen has defined the detention period as the time equivalent to the volume of the tank divided by the rate of flow, and the flowing-through period as the average time required for a small unit volume of sewage to pass through a tank at a given flow. To determine the flowing-through period, Capen used salt dissolved in water. He emptied the solution into the sewage entering the tank and titrated effluent samples every 5 minutes. The flowing-through period was determined by plotting the chloride titrations of the effluent against time. He noted that the incoming sewage chloride concentration was practically constant and, hence, he took the normal chloride content as a zero value determining the centroid vertical. The time corresponding to the centroid vertical of the area under the curve as determined by the method of moments is called the flowing-through time.

The centroid vertical method was introduced by Clifford. He stated that the centroid vertical indicates the time when the center of gravity of the molecules in the solution passes the sampling section. He also stated that the time of passage of water through a section is directly proportional to the amount of motion of the medium and that it is probable that the average forward movement of the molecules of a solution does not differ appreciably from that of the molecules of the solvent.

In an attempt to determine the flowing-through period of the primary clarifiers as outlined by Capen, a suspension of salt in water was introduced into the center of the clarifier. There was no noticeable rise in the chloride concentration of the effluent. To increase the chloride concentration, a fine grade water-softening salt was poured into the feed pipe in the center of the clarifier and allowed to go into solution with the sewage. This method also failed to give a noticeable rise in the chloride concentration of the effluent. It was noticed, however, that the natural chloride concentration of the sewage varied considerably. Because this of variation in the sewage chloride it seemed advisable to use the natural chlorides to determine the flowing-through period. The chloride concentration was observed to vary in the morning while in the afternoon there was less fluctuation and the content was higher.

Samples were collected every five minutes from the center of the clarifier, where the incoming sewage was flowing from the feed pipe, and at a point where the combined overflow of the periphery left the tank. From these samples 50 ml. portions were titrated with standard silver nitrate solution (1 ml. = 1 mg. Cl) according to the silver chromate method.

In Figs. 2 and 3 the characteristic chloride concentration curves are shown for the period from 9:00 A.M. to 1:30 P.M. and 11:35 A.M. to 3:15 P.M., respectively. The rate of flow during the above periods was 1,200 gal. per min. Since the natural sewage flow exceeded this rate at times,

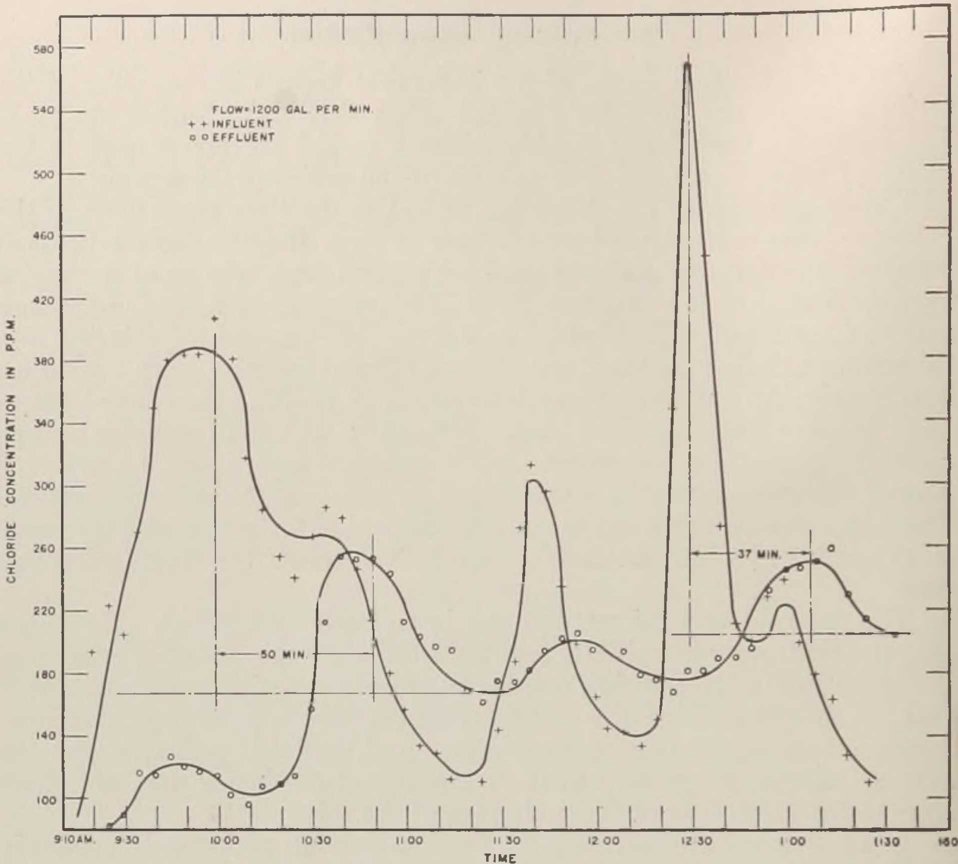


Fig. 2.—Showing variations in the concentration in the influent and effluent of primary clarifier Sept. 2, 1938.

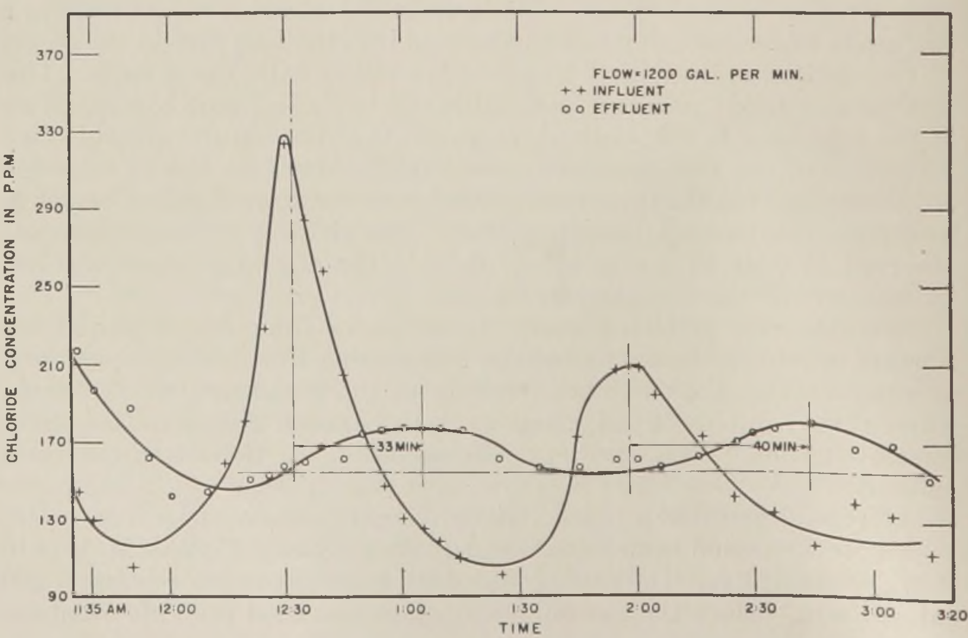


Fig. 3.—Variations in the chloride concentration in the influent and effluent of primary clarifier Sept. 3, 1938.

the excess flow was held back. These graphs show the wide variations in the natural chlorides of sewage. A study of the natural chloride concentration curves of the summer months shows that the chloride concentration of the influent at 9:30 A.M. was usually less than 100 p.p.m. and that a pronounced rise in chloride content occurred between 9:30 and 10:00 A.M. Other increases in chloride content of the influent usually occurred between

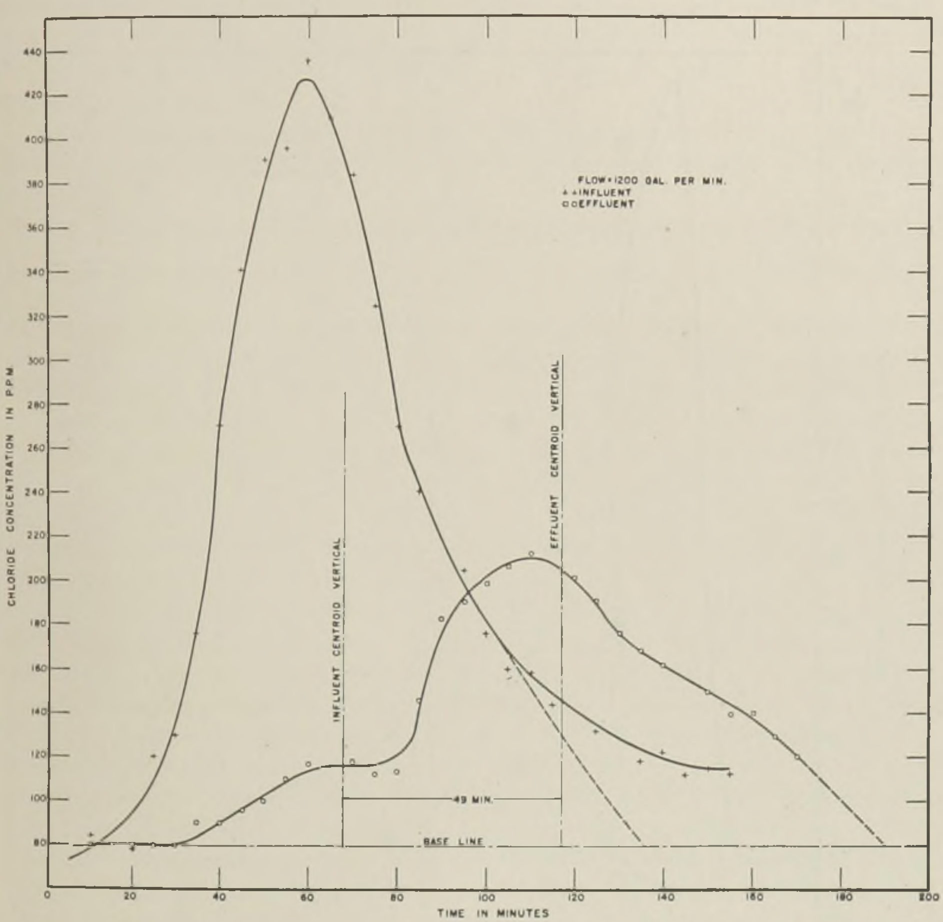


FIG. 4.—Showing average results of five different measurements of chloride concentration in the influent and effluent of primary clarifier at 1,200 p.p.m. rate of flow.

10:30 and 11:30 A.M. and 12:00 and 12:30 noon. The chloride concentration curve for the effluent rises and falls more gradually over a narrower concentration range. This indicates that the chloride contentration of the effluent was a resultant concentration of the chloride concentration of the influent and the chloride concentration of the sewage already in the clarifier. The high-chloride sewage might have been the result of the discharge of chlorinated wash waters from dairy plants in the city.

Figure 4 is a composite graph of five curves obtained under the same circumstances at 1,200 gal. per min. rate of flow. It shows a sharp rise in natural sewage chlorides of the influent which was maintained for approximately 60 minutes. It shows a pronounced rise in the chloride concentration of the clarified effluent 50 min. after the rise of the chloride concentration of the influent sewage.

The time of the flowing-through period was determined as the time elapsing between the time of centroid vertical of the influent chloride curve and the centroid vertical of the effluent chloride curve. For the rate of flow of 1,200 gal. per min., the flowing-through period was 49 minutes.

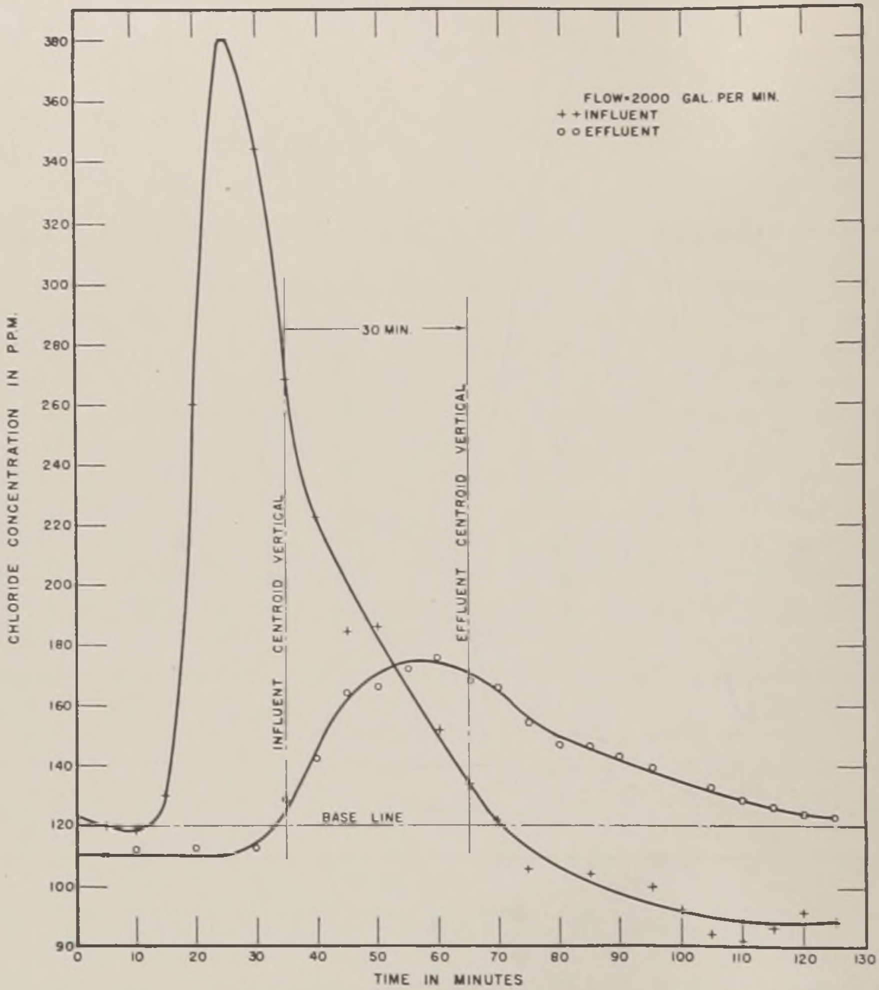


FIG. 5.—Showing average results of five different measurements of chloride concentrations in influent and effluent of primary clarifier at 2,000 g.p.m. rate of flow.

Figure 5 is a composite graph of four curves obtained under the same circumstances at 2,000 gal. per min. rate of flow. It shows a pronounced rise in the chloride concentration of the clarified effluent 25 minutes after the beginning of the rise of the chloride concentration of the influent. The flowing-through period as determined by the above method was 30 minutes.

Since the natural chloride concentration of the sewage cannot be controlled, the chloride concentration of the influent at the beginning of the test was taken as a base line for the determination of the centroid vertical. Because the chloride concentration curves do not always return to the base line concentration, it was necessary to project the curves to the base line. (These lines have the slope of the concentration curves and they complete the cycle of the curve to the base line.)

The rates of sewage flow for the period of each test were determined by dividing the flow in gallons as indicated by the integrator of the venturi meter by the number of minutes of the testing period. The average rates for the pumps in operation under the conditions of the tests were 1,200 and 2,000 gal. per min.

The calculated detention periods for the primary clarifiers at the flows of 1,200 and 2,000 gal. per min. were 105 minutes and 63 minutes, respectively.

The per cent relationship of the flowing-through period to the detention period is given by the equation $\frac{F_t \times 100}{D_t}$, where $F_t$ is the flowing-through time in minutes and $D_t$ is the detention time in minutes. The per cent relationship of the flowing-through period to the detention period was 47.6 for both rates of flow of 1,200 and 2,000 gal. per min. for a primary clarifier.

*Secondary Clarifier.*—The chloride concentration of the influent to the secondary clarifier did not vary greatly. The great variation of the chloride concentration of the sewage entering the plant was smoothed out in flowing through the primary clarifiers and the trickling filters. The following procedure was developed to determine the average length of time the sewage is retained within the tank.

A 100-lb. sack of water-softening salt was laid in the effluent channel of two adjoining trickling filters. The flow from these filters was joined by the effluent from a third filter, and hence the salt solution, or suspension, was thoroughly mixed before it entered the secondary clarifier. The chloride concentrations of the influent and effluent were determined every five minutes by titrating samples of sewage, which were collected at the center of the clarifier and at the discharge of the tank. The chloride concentration of the influent and effluent was plotted against the time. The chloride concentration of the influent rose and fell quickly. The chloride concentration of the effluent remained constant for a period of time and then rose slightly and then remained constant. Since the chloride concentration curve of the effluent does not have the properties required for centroid vertical analysis, the interval of time occuring between the time of the first increase in chloride concentration of the influent and the average time for the increase in the chloride concentration in the effluent was taken as the flowing-through period. This method is similar to the Lawrence Method of Analysis. The average time for five determinations at 1,200 gal. per min. was 75 + 9 minutes and 37 + 5 minutes for the flow of 2,000 gal. per min.

The calculated detention periods in the secondary clarifier at the above rates of flow were 147 and 88 minutes, respectively. The per cent relationship of the flowing-through period to the detention period was 51.0 and 42.0, respectively.

## Summary

The results of investigations made to determine the effects of certain factors on the efficiency of two primary clarifiers and one secondary clarifier, under actual operating conditions, are reported in this paper. The determinations were made at rates of flow of 1,200 and 2,000 gal. per min.

It was found that the use of distribution vanes attached to the baffle around the clarifier feed pipe had no effect on the efficiency of the removal of suspended solids at the rates of flow used. They did affect the distribution of suspended solids in the tank. It was noted that the distribution of suspended solids in the secondary clarifier was quite different from the pattern found in the primary clarifiers.

The variation in the chloride content of raw sewage was used to determine the flowing-through period in the primary clarifiers. For these units and for the rates of flow studied, the ratio of detention periods to flowing-through periods was 47.6 per cent. In the secondary clarifier the ratio was 51 per cent at the 1,200 g.p.m. rate; and 42.0 per cent at the 2,000 g.p.m. rate. A salt method was used in the secondary clarifier work.


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# Sewage Research

## SURVEY OF SEWAGE RESEARCH PROJECTS—1943

### Committee on Research, Section B, Federation of Sewage Works Associations

By Willem Rudolfs, *Chairman;* A. E. Berry, F. J. Brinley, T. R. Camp, H. Ell, E. F. Eldridge, V. P. Enloe, A. L. Genter, W. Q. Kehr, K. C. Lauster, G. Martin, G. Marx, R. Pomeroy, M. E. Rogers, J. H. Ruge, R. J. Stapf, G. Symons, F. S. Taylor, S. R. Weibel, C. H. Young

As an extension of the activities of the Research Committee, a list of titles of research projects and a brief description of the purpose of the work have been collected in an effort to aid research workers in appraisal of their own problems, to indicate the type and scope of the work in progress and to stimulate thought and effort in the field.

With the aid and advice of the secretaries of the member associations, Section B of the Research Committee was established. The members of the Committee represent practically all associations:

| Association | Representative |
|---|---|
| Arizona Water and Sew. Wks. Assoc. | G. Marx |
| California Sew. Wks. Assoc. | R. Pomeroy |
| Central States Sew. Wks. Assoc. | G. Martin |
| Dakota Water and Sew. Wks. Conf. | K. C. Lauster, R. J. Stapf |
| Federal Sew. Wks. Assoc. | S. R. Weibel |
| Florida Sew. Wks. Assoc. | J. H. Ruge |
| Georgia Sew. Wks. Assoc. | V. P. Enloe |
| Kansas Water and Sew. Wks. Assoc. | M. E. Rogers |
| Maryland-Delaware Water and Sew. Assoc. | A. L. Genter |
| Michigan Sew. Wks. Assoc. | E. F. Eldridge |
| Missouri Water and Sew. Conf. | W. Q. Kehr |
| New England Sew. Wks. Assoc. | T. R. Camp |
| New Jersey Sew. Wks. Assoc. | H. Ell |
| New York Sew. Wks. Assoc. | G. Symons |
| North Carolina Sew. Wks. Assoc. | R. S. Phillips |
| Ohio Sew. Wks. Cong. | W. D. Sheets |
| Oklahoma Water and Sew. Conf. | F. S. Taylor |
| Pennsylvania Sew. Wks. Assoc. | C. H. Young |
| Sew. Division—Texas Section S.W.W.A. | F. J. Brinley |
| The Canadian Inst. Sew. and Sant. | A. E. Berry |

The first attempt to collect a list of research projects is incomplete, because of the comparatively short time allowed the members for collection of the information. Nevertheless, the Committee is able to present its first list with considerable pride for the gratifying response. A listing of additional projects received will be published in the next issue of the *Journal*, together with a list of problems which are deemed desirable for investigation and study.

The listing of the projects under study has been made in tabular form. It is hoped that this form of listing will facilitate examination of the projects. The names and descriptions of the projects were secured by the members of the Committee from various institutions, agencies, industries, companies, engineers and operators. Those who have projects actively under way can have them listed by getting in touch with the representative of their respective association.

Although the material listed is undoubtedly only a part of the research work being prosecuted, a glance at the table shows the large amount of research work being done and the variety of problems given attention. Some of the problems are wide in scope, requiring considerable time, effort, money and ingenuity, whereas others pertain to more specific problems of immediate but, nevertheless, general interest.

The problems under study have been tentatively divided into four groups, namely: Sewage, Industrial Waste, Stream Pollution and Methods. It is of particular interest that in this listing about one-third of the problems under active investigation deal with industrial wastes. A considerable share of the problems pertaining to sewage studies deals with the question of sludge (treatment, digestion, supernatant liquor disposal). It is possible that when the second portion of this report is published in the next issue of the *Journal*, a change in the relationship may occur. It is intended to analyze the problems to determine whether they indicate a trend in the development of the science and art of waste disposal.

**Survey of Sewage Research Problems**

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 1 | Storage of Sewage Samples | Study of the suspended solids determination on sewage before and after storage of the samples under various conditions. | K. L. Mick and M. L. Robins, Mpls.-St. Paul Sanitary District, St. Paul, Minn. |
| 2 | Study of Typical Daily B.O.D. and Suspended Solids Characteristics by Hours for Each Day of the Week | | Walter A. Sperry, Aurora Sanitary District, Aurora, Ill. |
| 3 | Sewage Colloids | Study of quantity, type and character of colloidal materials. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 4 | Formation and Control of Sulfides in Sewers | Quantities and causes of sulfide formation and methods of control. | Fred Bowlus and Richard Pomeroy, Pasadena, California. |
| 5 | The Correlation of Hydrogen Sulfide in Plant Gas Versus Organic and Total Sulfur Content of the Raw Sewage | | Walter A. Sperry, Aurora Sanitary District, Aurora, Ill. |
| 6 | Inhibition of Corrosion During Acid Cleaning | Use of aniline oil as an inhibitor of acid corrosion. | M. L. Robins, Mpls.-St. Paul Sanitary District, St. Paul, Minn. |
| 7 | Metal Corrosion | Three-year exposure of some 25 or 30 metals to moist hydrogen sulfide contact to note relative corrosion effects. | Walter A. Sperry, Aurora Sanitary District, Aurora, Ill. |

**Survey of Sewage Research Problems (continued)**

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 8 | Flocculating Equipment | Design of improved equipment | Richard Pomeroy and H. D. Kirschman, Pasadena, Calif. |
| 9 | Disposal of Garbage by Discharge into Raw Sewage Flow at the Treatment Plant | Extent of load effects on primary settlers and loss of gas-producing products by solubility in the sewage flow. | David P. Backmeyer, Sewage Disposal Plant, Marion, Ind. |
| 10 | Addition of Chlorine Directly to the Air being Diffused Through Grease Flotation Tanks | Grease flotation units are American Well Works' standard and chlorine gas is being sucked in with the air by the mechanical aeration unit. | R. Eliassen, Fort Dix Sewage Treatment Plant, N. J. |
| 11 | Preaeration of Sewage and Grease Removal. Conducted at Garner, Iowa, and at Air Corps School, Goldsboro, N. C. | Increasing removal of B.O.D. and suspended solids in clarification process by use of short, intensive period of atomized aeration. | L. E. Langdon, Pacific Flush-Tank Company, Research Department, Chicago, Ill. |
| 12 | Removal of Grease from Sewage | Comparing the efficiency of aeration, aero-chlorination and ozone treatment of sewage for grease removal. | Mass. Dept. of Public Health, Lawrence Experiment Station, Lawrence, Mass. |
| 13 | Scum and Grease | Method of analyses, aeration and chlorine flotation, amount and quality of grease. | F. W. Mohlman, The Sanitary District of Chicago. |
| 14 | Grease in Sewage and Sludge | Nature of grease, methods of determination. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 15 | Use of Hot and Cold Water in Lime Slaking Process | To determine whether there is an advantage in using hot water instead of cold for lime slaking. | K. L. Mick, Mpls.-St. Paul Sanitary District, St. Paul, Minn. |
| 16 | Use of Other Coagulants to Replace Alum | Adaptation of other coagulants than alum for the treatment of various trade wastes before disposal. | Mass. Dept. of Public Health, Lawrence Experiment Station, Lawrence, Mass. |
| 17 | Use of Special Zeolites | Treatment of sewage and wastes for removal of dissolved organic and inorganic matter by specific zeolites. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 18 | Effect of Lime on Phosphates in Sewage | Study of relationship between lime, phosphates and coagulation. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 19 | Chemical Treatment of Sewage | Utilization of new chemicals and combinations of substances for clarification of sewage. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 20 | Aerobic Stabilization of Sludge | The stabilization of sludge derived from primary tanks and aerobic flocculation devices in an aerobic digester. | Aurora, Ill., American Well Works' Testing Station. |
| 21 | Effect of Copper and Chromium on Sewage Sludge Digestion | Effect of copper and chromium upon the rate of digestion of sewage sludges and the amount that may reasonably be permitted in the sewage. | Conn. State Water Commission, Hall Laboratory of Chemistry, Wesleyan University, Middletown, Conn. |
| 22 | Effect of Acids and Temperature on Sludge Digestion | Effect on digestion of increased and altered industrial activity. | Mitzi Heim, Sewage Disposal Plant, Racine, Wis. |

Survey of Sewage Research Problems (continued)

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 23 | Liquefaction of Sludge | Effect of seeding and removal of waste products on the rate of liquefaction. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 24 | Anaerobic Digestion | Rate of fat destruction and changes in nature of fats. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 25 | Stabilization of Sewage Sludge | Long-time experiments to determine ultimate degree of stabilization. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 26 | Aerobic and Anaerobic Digestion | Comparison and continuation of methods to reduce time, under mesophilic and thermophilic conditions. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 27 | Aerobic Digestion | Chemical and biological changes occurring during aerobic decomposition of sludge and factors affecting the rate of volatile matter destruction. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 28 | Effects of Acids, Poisons and Solvents on Sludge Digestion | Determination of effect of quantities and type of chemical wastes particularly on gas production. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 29 | Effect of Temperature Changes during Thermophilic Digestion | Sudden changes in temperature—effect of time and magnitude. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 30 | Thermogenic Sludge Digestion | Effect of moisture, temperature, pH, volatile matter, grease, nitrogenous materials to obtain highest stabilization. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 31 | Anaerobic Digester Supernatant Liquor Stabilization | Treatment of anaerobic liquor by aerated contact filters employing fine media and backwash. | Aurora, Ill., American Well Works' Testing Station. |
| 32 | Methods for the Treatment of Supernatant Liquor from Separate Sludge Digestion Tanks | | Harold E. Babbitt, University of Illinois, Urbana, Ill. |
| 33 | Selection of Supernatant Liquor from Digestion Tanks, Conducted at Camp Shelby, Miss., Fort Sheridan, Ill. and elsewhere | Means of obtaining supernatant liquor lowest in suspended solids content and at uniformly slow rate from digestion tanks. | W. M. Piatt, Pacific Flush-Tank Company, Research Department, Chicago, Ill. |
| 34 | Supernatant Liquor Treatment | Chemical and biochemical methods for the treatment of digester supernatant. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 35 | Treatment of Digester Supernatant Liquor, Conducted at Camp Shelby, Marietta, Georgia | Clarification of digester supernatant liquor and reduction of B.O.D. for return to treatment processes without disturbance of same. | H. E. Schlenz, Pacific Flush-Tank Company, Chicago, Ill. |
| 36 | Concentration of Digested Sewage Sludge Prior to Vacuum Filtration | Reduction of sludge handling costs by sedimentation, concentration of digested sludge solids. | David P. Backmeyer, Marion, Ind. Sewage Disposal Plant. |

Survey of Sewage Research Problems (continued)

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 37 | Study of Mathematical Relationships between Basic Sludge Assays and Ferric Chloride Dosing for Vacuum Filters | Need for fundamental knowledge to advance the art. | A. L. Genter, Consultant, Baltimore, Md. |
| 38 | Conditioning of Activated Sludge Prior to Filtration | Use of chemicals, returned dried sludge, electrolysis of aluminum electrodes, application of current (electrodialysis), inert substances, elutriation, aeration. | E. Hurwitz, The Sanitary District of Chicago. |
| 39 | Filter Cloth Binding on Rotary Drum Filters | Analysis of and use of acid cleaning bath to lengthen life of filter cloth during operation. | G. J. Schroepfer, K. L. Mick, M. L. Robins, Mpls.-St. Paul Sanitary District, St. Paul, Minn. |
| 40 | Sludge Dewatering | Utilization of combinations of organic and inorganic materials, including substances such as sawdust, soil, etc. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 41 | Effect of Phosphates on Sludge Dewatering | Relation between phosphates and other constituents. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 42 | Removal and Prevention of Scale in Vacuum Filter under Drains | Calcium carbonate scales formed in filter underdrains interfere in some cases with proper operation of vacuum filters. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 43 | Liquid Sludge Disposal | Advantages and disadvantages of raw and digested sludge used as fertilizer. | G. E. Botkin, Sewage Treatment Works, Anderson, Ind. |
| 44 | Preparation of Dried Activated Sludge for Fertilizer | Fortifying by treating with ammonia or acid plus ammonium salts under pressure, use of Nitragin, study of bacterial content, availability of nitrogen by chemical tests. | F. W. Mohlman, The Sanitary District of Chicago, Ill. |
| 45 | The Use of Sludge Cake as a Fertilizer | Use of sludge cake as a soil conditioner from actual field growing tests, in comparison with manure-fertilized and untreated plots. | G. J. Schroepfer, K. L. Mick, C. A. Rost, Mpls.-St. Paul Sanitary District and Minnesota Agri. Exp. Sta., Hennepin and Ramsey Counties. |
| 46 | Preparation and Utilization of Dried Digested Sludge | Production of digested filter cake for aiding war effort in "Victory Gardening." | Harry B. Shaw, Washington Suburban San. Com., Hyattsville, Md. |
| 47 | Aeration in the Activated Sludge Process with High Oxygen Content in the Atmosphere | Attempts to speed up oxidation period by increasing concentration of oxygen in the process. | Harold E. Babbitt, University of Illinois, Urbana, Ill. |
| 48 | Pickling Liquor, Chrome Waste, Cutting Oils, and Packing House Waste | Effects of industrial wastes on a Guggenheim Bio-Chemical sludge type sewage plant. | G. E. Botkin, Sewage Treatment Works, Anderson, Ind. |
| 49 | Settling of Mixed Liquor in Activated Sludge Plant | Study of proper weir location in final settling tanks. | L. S. Kraus, Peoria Sanitary District, Peoria, Ill. |

Survey of Sewage Research Problems (continued)

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 50 | Activated Sludge Operation | Addition of fly ash to increase mineral content of sludge, study of relation of dissolved oxygen to other control tests such as sludge index, mixed liquor solids, ash content, quality of effluent. | F. W. Mohlman, The Sanitary District of Chicago, Ill. |
| 51 | Diffusion of Air, Activated Sludge | Study of loss of head and dissolved oxygen using 15, 25, 40 and 80 rating diffuser plates, carbon plates, swing diffusers, perforated tile plates, vertical plates and slotted pipe; study of clogging, use of chlorine, cleaning acid and treated plates. | A. J. Beck and C. T. Mickle, The Sanitary District of Chicago. |
| 52 | Aeration Device | Development of improved aeration design for the activated sludge process. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 53 | The Fate of Grease in the Activated Sludge Process | A grease balance in the liquid and sludge phase during aeration of sewage with activated sludge under various experimental conditions. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 54 | The Influence of Abnormal Diets on the Activated Sludge Process | A study of physical, chemical, and growth characteristics as influenced by high protein, high carbohydrate, and high fat diets. | Clair N. Sawyer, University of Wisconsin, Madison, Wis. |
| 55 | Trickling Pulsations Through a Trickling Filter | Pulsation or intermittency of trickle through trickling filters obtained by varying rate of application and dosing interval rates between 2 and 20 m.g. per acre per day and intervals between 3 and 30 seconds. | Aurora, Ill., American Well Works Testing Station. |
| 56 | Flow of Water Through Porous Materials | Hydraulics of drainage wells and relation to flow through fine-grained filters. | David H. Caldwell and H. E. Babbitt, University of Illinois, Urbana, Ill. |
| 57 | Double Reversible Flow Filtration | Increasing degree of treatment and B.O.D. loading on trickling filters by use of filters in series with or without intermediate clarification and means for periodically reversing sequence of operation of filters. | E. L. Langdon, Pacific Flush-Tank Company, Chicago, Ill. |
| 58 | High Rate Secondary Sand Filtration of Trickling Filter Effluents | High-rate sand filtration of trickling filter effluents at rates of 250,000 to 375,000 gallons per acre per day. | Mass. Dept. of Public Health, Lawrence Experiment Station, Lawrence, Mass. |
| 59 | Biology and Biochemical Changes in Biological Filters | Comparison of flora, fauna and biochemical changes in an operating standard trickling filter and a high rate filter. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |

**Survey of Sewage Research Problems (continued)**

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 60 | An Interstate Study of High Capacity Sewage Filters | Factors which influence operating results and efficiency to be expected under different conditions of operation. | The Upper Mississippi River Board of Public Health Engineers, Minnesota, Iowa, Missouri, Indiana, Illinois and Wisconsin, Graham Walton, Wis. State Board of Health, Madison, Wis., conducted in the Upper Mississippi River Drainage Basin. |
| 61 | Effect of Textile Wastes Upon the Chlorine Demand of Sewages | Effect of spent dye wastes upon the chlorine demand of treated sewage. | Conn. State Water Commission, Hall Laboratory of Chemistry, Wesleyan University, Middletown, Conn. |
| 62 | Chlorination of Sewage and Effluents | Breakpoint chlorination, changes in composition of constituents, effect of various factors. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |

**Survey of Industrial Waste Research Problems**

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 63 | Control of Odors in Lagoons of Cannery Wastes | Use of sodium nitrate to control odors so that lagooning might temporarily be used for the treatment of cannery wastes. | Wisconsin State Board of Health, Wisconsin Canners Association, and National Canners Association, D. L. Snow, State Office Building, Madison, Wis., conducted at Lake Mills, Wis. |
| 64 | Treatment of Sugar Wastes | Stabilizing or developing a treatment process for wastes emanating from the maraschino cherry manufacturing process. | Sanitary District of Rockford, Illinois, and Sanitary District of Belvidere, Illinois, conducted at Edenfruit Products Company, Poplar Grove, Ill. |
| 65 | Stabilization of Sugar Waste | Development of a biological method for the stabilization of sugar wastes from candied fruit with a high oxygen demand and containing sulfur dioxide and salt. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 66 | Treatment of Wastes Resulting from Fermentation Industries | Reduction of suspended and colloidal solids in distillery slop. | Metcalf and Eddy, 1300 Statler Building, Boston, Mass. |
| 67 | Stabilization of Yeast Wastes | Changes in the character of wastes and stabilization during digestion and oxidation. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |

Survey of Industrial Waste Research Problems (continued)

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 68 | Treatment of Wastes from Paper and Allied Industries | To secure more complete removal of fiber from paper and paper board plants so that the discharged effluents will not be objectionable in waterways. | Conn. State Water Commission, Hall Laboratory of Chemistry, Wesleyan University, Middletown, Conn. |
| 69 | Disposal and Utilization of Spent Cooking Liquor from the Manufacture of Sulfite Pulp | Study of methods applicable in a practical way to the problem. | J. M. Holderby, Sulfite Pulp Manufacturers Committee on Waste Disposal, The Institute of Paper Chemistry, Appleton, Wis. |
| 70 | The Digestion of Waste Sulfite Liquor | Economic factors in digestion of waste sulfite liquor. | George Martin, Green Bay Metropolitan Sewerage District, Green Bay, Wis. |
| 71 | Digestion and Oxidation of Paper Waste | Digestion and oxidation with and without pretreatment of kier liquor. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 72 | Kraft Waste Disposal Studies | Study of toxic effects of kraft mill wastes. | C. R. Seaborne, Kraft Waste Disposal Committee, Thilmany Pulp and Paper Company, Kaukauna, Wis. |
| 73 | Rate of Deoxygenation of Certain Organic Industrial Wastes | Progressive biochemical oxygen demand. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 74 | Treatment of Wastes from Textile Printing Plants | Removal of dyes, gums, starches, etc., to permit of their discharge into waterways or sewer systems. | Conn. State Water Commission, Hall Laboratory of Chemistry, Wesleyan University, Middletown, Conn. |
| 75 | Dye Waste Treatment | Utilization of electrodialyses alone and in conjunction with chemicals and biological methods. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 76 | Treatment of Wastes from the Manufacture of Artificial Wool from Casein | The removal of formaldehydes, acids and the high B.O.D. constituents to permit of their discharge into waterways. | Conn. State Water Commission, Hall Laboratory of Chemistry, Wesleyan University, Middletown, Conn. |
| 77 | Treatment of Wastes Resulting from Wool Scouring | Reduction of suspended and colloidal solids and recovery of wool grease. | Metcalf and Eddy, 1300 Statler Building, Boston, Mass. |
| 78 | Treatment to Overcome the Effect of Dispersive Agents in Wool Scouring | Owing to scarcity of soap, more alkali and dispersive detergents have been used to scour wool. This has lowered the degree of removal of wool grease by subsidence and centrifugalization. | Weston and Sampson, Hudson Worsted Co. (Wool Scouring), Hudson, Mass. |
| 79 | Treatment of Laundry Wastes | Includes experimental treatment on trickling filters, coagulation studies and digestion and dewatering of sludge. | Mass. Dept. of Public Health, Lawrence Experiment Station, Lawrence, Mass. |

**Survey of Industrial Waste Research Problems (continued)**

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 80 | Industrial Wastes | Use of raw and treated laundry wastes for watering plants, use of pickle liquor for sludge conditioning, grease recovery. | F. W. Mohlman, The Sanitary District of Chicago. |
| 81 | Pretreatment of Laundry Wastes | Removal of portion of grease, B.O.D. and solids from laundry processes in army camps. | Pacific Flush-Tank Company, conducted at Camp Shelby, Miss., and in progress at Camp Forrest, Tenn. |
| 82 | Chemical Treatment of Laundry Wastes | Effectiveness of various coagulants. | A. E. Williamson and Clair N. Sawyer, (formerly) San. Eng. Lab., New York University, New York City. |
| 83 | Treatment of Cutting and Grinding Compounds from the Machining of Metals | Removal of the objectionable oils and ingredients in the wastes. | Conn. State Water Commission, Hall Laboratory of Chemistry, Wesleyan University, Middletown, Conn. |
| 84 | Treatment of Wastes from Plating Industries | Production of an effluent practically free from cyanides, chromium, copper, cadmium and zinc, satisfactory for discharge into streams. | Conn. State Water Commission, Hall Laboratory of Chemistry, Wesleyan University, Middletown, Conn. |
| 85 | Treatment of Wastes from Brass and Copper Industries | Production of a satisfactory effluent and study of methods for recovery of sulfuric acid, copper, zinc, and chromium. | Conn. State Water Commission, Sterling Chemistry Laboratory, Yale University, New Haven, Conn. |
| 86 | Treatment of Wastes Resulting from Plating and Anodizing | Removal of inorganic toxic substances | Metcalf and Eddy, 1300 Statler Building, Boston, Mass. |
| 87 | Treatment of Wastes from the Manufacture of TNT | Removal of intense color and toxins. | Metcalf and Eddy, 1300 Statler Building, Boston, Mass. |
| 88 | Treatment and Recovery of Pickling and Copperas Liquors | Physical and chemical treatment of wastes with the primary aim of recovery of by-products such as iron, plaster, board, etc. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 89 | Acid Wastes Treatment | Effect of chemicals on neutralization, sludge formation, aeration, mixing, etc. to determine basic principles. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 90 | Disposal of Citrus Canning Waste | Program of study of waste products; preliminary experiments indicate that the problem may be attacked through carbohydrate fermentation. | L. G. MacDowell, Florida Citrus Commission. |

Survey of Stream Pollution Research Problems

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 91 | A Study of Pollution of the Mississippi River in the Vicinity of Moline, Ill. | | A. E. Anderson and A. N. Johnson, Water Department, Moline, Ill. |
| 92 | A Survey of Pollution in the Madison Lakes | Determination of the percentage of fertilizing minerals contributed by natural and by unnatural drainage, and the importance of the fertilizer added from unnatural sources on stimulating additional algal growths. | Clair N. Sawyer, State of Wisconsin, Madison, Wis. |
| 93 | Relation Between Stream Flow and Organic and Inorganic Substances | Determination of origin and fate of materials. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |
| 94 | Germicidal Effect of Dyes | Study of effect of dyes and dye wastes on the pollutional organisms of of a stream. | N. J. Agr. Exp. Sta., Dept. of Water and Sewage Research. |

Survey of Research on Analytical Methods

| No. | Title of Project | Description | Investigator, Organization |
|---|---|---|---|
| 95 | B.O.D. Determination | Comparison of bicarbonate, phosphate and phosphate-ammonium sulfate dilution waters, B.O.D. of settled activated sludge, B.O.D. of river sludge, oxidation of ammonium salts, effect of nitrification and micro-organisms on B.O.D., effect of temperature of storage of samples, effect of acid for preventing oxidation of ammonia in 5-day B.O.D. | F. W. Mohlman, The Sanitary District of Chicago, Ill. |
| 96 | Effect of Minute Amounts of Copper on Results of B.O.D. Determination | Determination of maximum concentration of copper permissible in dilution water. | M. Starr Nichols, Wis. State Laboratory of Hygiene, Madison, Wis. |
| 97 | The Determination of Dissolved Oxygen | Improvement of analytical methods. | Richard Pomeroy and H. D. Kirschman, Pasadena, Calif. |
| 98 | Efficacy of Chemical Treatment as Measured by B.O.D. Removal | Study of B.O.D. removal from domestic sewage and canning wastes utilizing bicarbonate and supplemented bicarbonate dilution waters. | Harold Romer and Clair N. Sawyer, San. Eng. Lab., New York University, New York City. |

# CULTURAL CHARACTERISTICS OF ZOOGLEA-FORMING BACTERIA ISOLATED FROM ACTIVATED SLUDGE AND TRICKLING FILTERS *

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The isolation of a zooglea-forming bacterium, tentatively designated as *Zooglea ramigera*, from activated sludge has been described by Butterfield (3), who also reviewed the literature relating to such bacteria and their functions in sewage purification. Publications of the series of "Studies of Sewage Purification" emanating from the Stream Pollution Investigations Station of the United States Public Health Service at Cincinnati, Ohio, and papers of other laboratories interested in the same field have presented a large amount of data on the function of this type of bacteria in sewage purification processes. Very little information has been produced concerning the bacterial characteristics essential for purposes of description or of identification of species.

The studies of Butterfield et al. (4) indicate that the floc-forming organisms present in activated sludge will develop under aeration an activated sludge in sterile synthetic or sterilized normal sewage. A pure culture sludge, developed by the fill-and-draw-method, will oxidize about 50 per cent of the 5-day biochemical oxygen demand (B.O.D.) during a 5-hour aeration period.

The purification accomplished by a pure culture activated sludge and a normal activated sludge has been found to be very similar by Ruchhoft and his associates (11). The rate and extent of total purification accomplished during a given period is influenced by the quality and quantity of activated sludge and the substrate in the aeration mixture.

The distinctive characteristic of these bacteria which has been emphasized is that they have the ability to grow in a floc, or colony, in a liquid medium even when they are subjected to agitation produced by the aeration sufficient to maintain aerobic conditions. This floc-forming ability is dependent on a gelatinous matrix or capsule which can be demonstrated about each cell. This gelatinous coating of the individual cells apparently becomes the binding agent in the floc.

The purpose of the gelatinous mass which binds the bacteria together is explained by Whitehead and O'Shaughnessy (16). From their experiments they concluded that the fine particles floating in sewage were held by the jelly-like mass and used by the bacteria either for food or as particles for attachment. Butterfield (3) used similar inorganic particles in his studies for bacterial floc attachment. However, the addition of cotton fibers or other inert particles for floc attachment in the development of pure culture sludges in synthetic sewage has been proven unnecessary. Within 48 hours after inoculating, well-developed flocs were formed in sterile syn-

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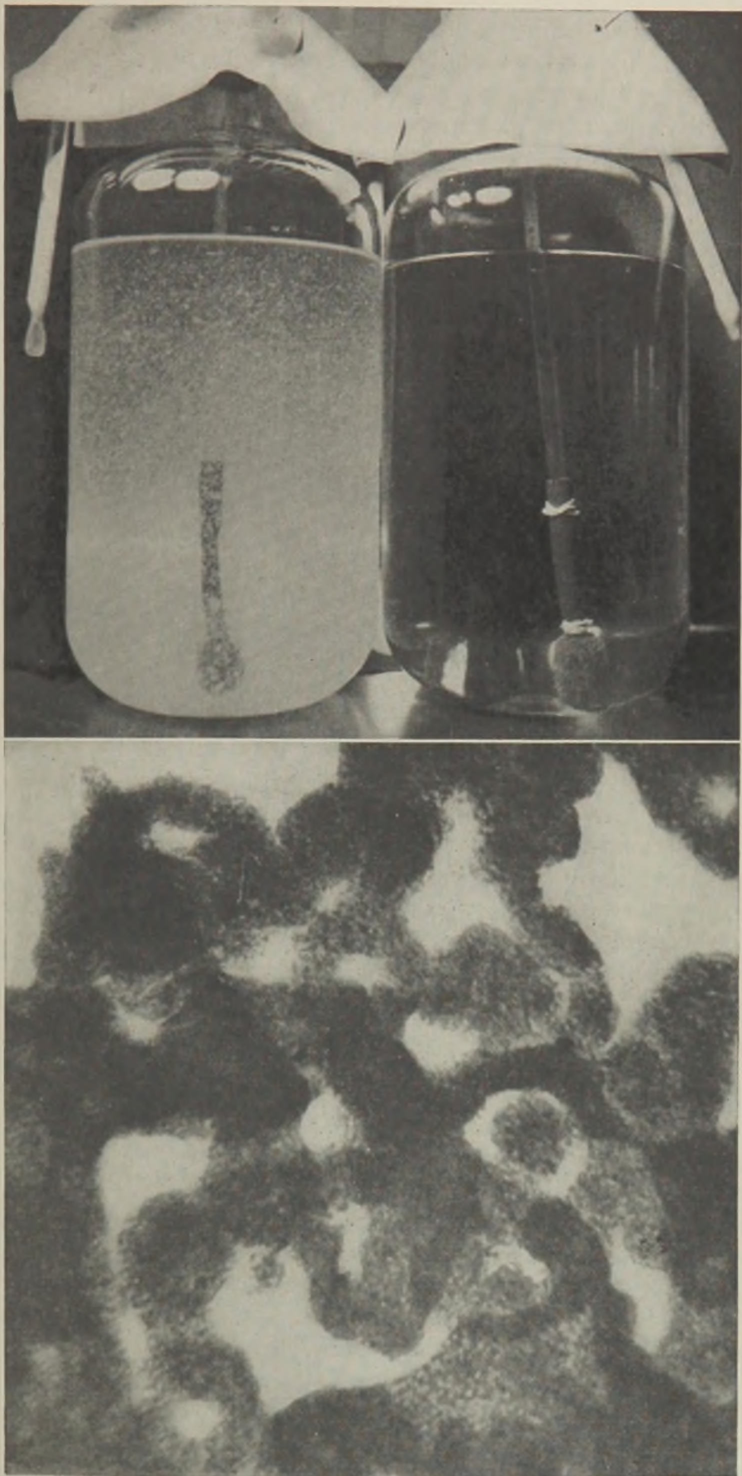

FIG. 1 (a).—Eight-liter culture bottles of synthetic sewage. Bottle on right sterile, bottle on left with 48-hour growth under aeration of zooglea No. 86.

FIG. 1 (b).—Floc of zoogleal culture, magnification 1426 ×.

thetic sewage containing no inert material, as shown in Fig. 1. Microscopic examinations show the flocs are composed entirely of bacterial cells bound together by a gelatinous matrix.

The ability of zooglea-forming bacteria, isolated from activated sludge, to clarify sterile sewage either under aeration or while the sewage is quiescent has been studied by Heukelekian and Schulhoff (9). The characteristics of the organisms isolated are not given. Their results indicate that sterilized sewage inoculated with a floc-forming organism isolated from activated sludge will be clarified more quickly under aeration than when remaining quiescent. In either case, clarification did not exceed that of aerated raw sewage.

Dienert (6) isolated several types of bacteria from the zoogleal masses of activated sludge and trickling filters. He classified them as clarifying, reducing, and oxidizing organisms. The clarification of sewage was produced by a large coccus, but it was not obtained in pure culture. The rate of clarification was decreased after the sludge flocs had been mashed or pressed between glass slides and the zoogleal masses dispersed. The oxidizing zoogleal bacterium isolated was a small, Gram-negative coccus, enclosed in a jelly-like mass. This organism did not ferment sugar. Dienert was not successful in isolating from the zoogleal film the organism causing nitrification but reported the breaking down of $NH_3$ without the formation of $HNO_3$.

Heukelekian and Littman (8) isolated 14 zooglea-forming organisms from activated sludge. All the cultures appeared to be similar. Morphologically and culturally they were indistinguishable from the zoogleal bacteria isolated by Butterfield (3).

Gilcreas (7) stated that large rod-shaped zoogleal bacteria are present in sewage and the film on the stones of a trickling filter is composed principally of zoogleal and filamentous bacteria.

A floc-forming organism was isolated by Buswell and Suter (2) from flocs present in chlorinated water supplies of various Illinois cities. Microscopic examination showed that these flocs were composed of small capsulated cocci or small rods, 0.3 to 0.5 microns in diameter, and larger organisms as well as filamentous bacteria. The organism isolated was nonmotile and formed nitrates from ammonia. This would indicate that the organism is not related to the activated sludge or trickling filter floc-forming organisms being discussed here, but to the family of Nitrobacteriaecae isolated by Winogradsky.

A zooglea organism, Nitrocystis, has been isolated by Winogradsky (17) from activated sludge, as one of the dominant organisms and is mentioned by Bergey (1). Other writers have studied briefly and reported zoogleal growths in sewage purification processes. It appears that a number of strains, possibly types of zoogleal bacteria, have been isolated and studied to some extent. Bergey (1) in his "Manual of Determinative Bacteriology" lists one species, *Zooglea ramigera.* Intensive effort at the Stream Pollution Investigations Laboratory of the United States Public Health Service has been directed to the isolation and to the study of the cultural characteristics of the zoogleal bacteria found in activated sludge and in trickling filters.

## Methods of Isolation of Zoogleal Cultures

Two methods of isolating zoogleal organisms were followed. The first method was similar to the technique used by Butterfield (3)—repeated washing and "teasing" of a zoogleal floc picked from activated sludge, or the film washed from the stones of a trickling filter. Through the use of this method, question might arise as to the failure to select a predominant zoogleal floc from a sludge sample.

In the second procedure, the sample of sludge was mixed thoroughly and a 10 ml. portion was placed in a sterile 30 ml. glass-stoppered bottle containing sterile glass beads. If the sludge used was heavy and dense, it was diluted 1 : 10 with sterile dilution water before removing the portion to be shaken. The bottle was then shaken 10 minutes at high speed on a shaking machine, breaking up the zoogleal flocs and freeing the organisms previously held in the gelatinous masses. When portions of the shaken and unshaken sludge were examined microscopically, a marked difference was noted. A much greater number of free bacterial cells was observed in the shaken sample, but complete dispersion was not obtained since some small flocs remained.

The shaken sludge sample was planted in serial dilution in standard lactose broth as soon as possible after shaking. It has been observed that the bacterial cells freed from their gelatinous mass quickly unite again if allowed to remain quiescent after shaking. Tubes were incubated 48 to 120 hours at 20° C. before examining for typical zoogleal flocs.

Upon examination, tubes of the highest dilution showing floc formation were used for further purification. Two types of flocs were observed—the fingered type and the round, solid, compact type. Plantings were made from these high dilution tubes, using standard nutrient agar diluted 1 : 3 with sterile dilution water. After 96 hours' incubation at 20° C., colonies were picked from the agar plates to standard lactose broth. Planting and picking from dilute agar was repeated several times to insure absolute purity of the culture. Tests were made to determine the ability of the isolated pure cultures to develop, under aeration, an activated sludge in sterile synthetic media of the same composition as used by Butterfield, Ruchhoft, and McNamee (4), and in sterilized domestic sewage.

Samples of activated sludge used in the isolation of zooglea-forming organisms were obtained from various sources. Activated sludges used were from the North and South plants at Lancaster, Pa., Calumet Sewage Treatment Works of the Sanitary District of Chicago, Ill., and the experimental activated sludge plant at this laboratory. Trickling filter zooglea-forming bacteria were isolated from film-covered stones picked from the experimental trickling filter at this laboratory and from the municipal trickling filters at Dayton, Ohio, and at Osgood, Ind.

The experimental trickling filter at the Stream Pollution Investigations Station was constructed in three sections to provide for sampling at various depths. The filter was fed settled domestic sewage at an average rate of 3 million gallons per acre per day. In this experimental unit zooglea-forming organisms were observed after the filter had been in operation about 48 hours.

TABLE I.—*Characteristics of Zooglea-Forming Organisms Isolated*

| Log No. | Source | Form | Diameter | Gram Stain | Capsule | Chains | Photic | $H_2S$ | Voges-Proskauer | Methyl Red | Citrate | Indol | Flagella | Spores | $NO_3$ to $NO_2$ | Gelatin Liquefaction | Relation to $O_2$ [1] | Agar Growth [2] | Agar Slant [3] | Chromogenesis | Peptonization | Carbohydrates 0.5 Per Cent [4]: Arabinose | Xylose | Glucose | Galactose | Mannose | Sucrose | Lactose | Cellobiose | Raffinose | Melizitose | Dextrin | Mannitol | Salicin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | Activated sludge | Rod | 1.0 | − | + | − | − | − | − | − | ± | − | Polar | − | − | − | 1 | 1 | D | − | − | | A± | A± | | | | A± | | | | | A± | |
| 53 | Activated sludge | Rod | 1.0 | − | + | − | − | − | − | − | − | − | Polar | + | + | + | 1 | 2 | G | − | + | A+ | A± | A+ | A± | A± | A± | 0 | A+ | 0 | 0 | A± | A± | A± |
| 55 | Activated sludge | Rod | 1.0 | − | + | − | − | − | − | − | − | − | Peri | + | + | + | 1 | 2 | G | − | − | A+ | A+ | A+ | A± | A± | A± | 0 | A+ | 0 | 0 | A± | A± | A± |
| 58 | Activated sludge | Rod | >1.0 | − | + | − | − | − | − | − | − | − | Peri | − | + | − | 2 | 2 | G | − | − | | 0 | 0 | | | | 0 | | | | | 0 | |
| 60 | Activated sludge | Rod | >1.0 | − | + | − | − | − | − | − | − | − | Polar | − | − | − | 2 | 2 | G | − | − | A+ | 0 | 0 | A± | A± | A± | A± | A+ | 0 | 0 | A± | 0 | A± |
| 62 | Activated sludge | Rod | >1.0 | − | + | − | − | − | − | − | − | − | Peri | + | + | + | 1 | 3 | G | − | + | | 0 | A+ | | | | 0 | | | | | A± | |
| 82 | Activated sludge | Rod | 1.0 | − | + | − | − | − | − | − | Tr | − | Polar | + | + | + | 1 | 2 | G | − | + | A+ | A± | A+ | A± | A+ | A± | 0 | A+ | 0 | 0 | A± | A± | A± |
| 83 | Activated sludge | Rod | 1.0 | − | + | − | − | − | − | − | + | − | Polar | − | + | − | 2 | 2 | G | B | − | A+ | A± | A± | A± | A± | 0 | 0 | A+ | 0 | 0 | A± | 0 | 0 |
| 85 | Activated sludge | Rod | 1.0 | − | + | − | − | − | − | − | − | − | Peri | − | + | + | 1 | 2 | G | − | − | A± | 0 | A+ | A± | A± | 0 | 0 | A± | 0 | 0 | 0 | A+ | A± |
| 86 | Activated sludge | Rod | 1.0 | − | + | − | − | − | − | − | − | − | Polar | + | − | + | 1 | 2 | G | O | − | A+ | A± | 0 | A± | 0 | 0 | 0 | A± | 0 | A± | 0 | 0 | 0 |
| 88 | Activated sludge | Rod | 1.0 | − | + | − | − | − | − | − | − | − | Peri | + | + | + | 1 | 1 | G | − | − | A+ | 0 | A± | 0 | A± | 0 | 0 | A+ | 0 | A+ | A± | A+ | A± |
| 104 | Activated sludge | Rod | >1.0 | − | + | − | − | − | − | − | − | − | Peri | − | + | − | 1 | 2 | G | − | − | | 0 | A± | | | | 0 | | | | | A± | |
| 105 | Activated sludge | Rod | 1.0 | − | + | − | − | − | − | − | − | − | | − | + | + | 2 | 2 | G | − | − | | 0 | 0 | | | | 0 | | | | | 0 | |
| 113 | Activated sludge | Rod | 1.0 | − | + | − | − | − | − | − | − | − | Peri | + | − | + | 1 | 2 | G | − | + | A+ | A± | A+ | A± | A± | A± | A+ | A+ | 0 | 0 | A± | A± | A± |
| 87 | Trickling filter | Rod | 1.0 | − | + | − | − | − | − | − | − | − | | − | − | + | 2 | 2 | G | Y | − | A± | 0 | 0 | A± | A± | 0 | 0 | A+ | 0 | A± | A± | 0 | 0 |
| 100 | Trickling filter | Rod | 1.0 | − | + | − | − | − | − | − | − | − | Polar | − | + | − | 2 | 3 | G | − | − | A+ | 0 | 0 | A+ | A± | 0 | 0 | A± | 0 | 0 | 0 | 0 | 0 |
| 102 | Trickling filter | Rod | 1.0 | − | + | − | − | − | − | + | + | + | Polar | − | + | + | 2 | 3 | G | − | − | A+ | A+ | A+ | A± | A+ | A+ | A± | A± | 0 | 0 | 0 | A+ | A± |
| 103 | Trickling filter | Rod | 1.0 | − | + | − | − | − | − | + | + | + | Polar | − | + | + | 2 | 3 | G | − | − | | | A+ | A+ | | | | | | | | A+ | |

[1] Relation to $O_2$: 1 = strict aerobe. 2 = facultative anaerobe.

[2] Agar growth: 1 = scanty. 2 = moderate. 3 = abundant.

[3] Agar slant: D = dull. G = glistening.

[4] Carbohydrates: A± = pH 6.9 to 6.5. A+ = pH below 6.5. 0 = no change in pH.

Chromogenesis: − = no color. B = Brown. O = Orange. Y = Yellow.

Flocs were more numerous in the film washed from the stones taken from the top section than from the center or bottom sections. Finger-like flocs appeared in the film covering the stones a few inches below the surface of an experimental contact filter after the filter had been in operation 7 days, being fed twice daily with raw domestic sewage.

The film-covered stones selected at random for examination were removed from the trickling filter with sterile forceps and placed in sterile petri dishes. Extraneous matter was washed gently from the surface of the stones with sterile dilution water. The attached film was then scraped from the stones and placed in a sterile bottle containing 20.0 ml. of sterile dilution water. During the period between removing the stones from the filter and scraping off the film, care was taken to keep the surface of the stones sufficiently moist to prevent drying of the film. When a portion of the washed film was examined microscopically, fingerlike flocs were observed, similar to those found in activated sludge flocs. The same two methods were followed in the isolation of floc-forming organisms from the washed film of the trickling filter stones as were used for activated sludge.

The only zooglea-forming cultures retained for further study were those that would produce, under aeration sufficient to maintain aerobic conditions, an activated sludgelike floc in sterile synthetic sewage and in sterilized domestic sewage.

The purification efficiency of a pure culture sludge developed by the various zoogleal organisms isolated in sterile synthetic sewage or sterilized domestic sewage was measured by the total oxidizable material removed from the supernatant. This percentage of the 5-day biochemical oxygen demand of the oxidizable material present in the substrate after 3 or 5 hours of aeration has been calculated for some of the organisms studied.

Isolations of 14 zooglea-forming bacteria have been made from activated sludge and 4 from the films washed off stones taken from trickling filters. For convenience in comparison, the characteristics of the zoogleaforming organisms studied are summarized in Table I.

## Cultures Isolated from Activated Sludge

Culture 50 was isolated from sludge of the experimental activated sludge plant of the Stream Pollution Station, Cincinnati, Ohio. This culture was originally Z–1, reported by Butterfield (3) and is listed by Bergey (1). Pure culture sludges of about 2,000 p.p.m. suspended solids, developed by this culture in sterile synthetic sewage, will oxidize during a 3-hour aeration period an average of 73.3 per cent of the 5-day biochemical oxygen demand of the substrate. Under similar conditions, with sludges of about 792 p.p.m., but using sterilized domestic sewage, an average of 79.3 per cent of the oxidizable material was oxidized. This culture differs from Culture 88, *Zooglea ramigera*, isolated by Soriano (14), in respect to flagella, appearance of growth on agar slant, and liquefaction of gelatin.

Culture 53 was isolated from a sample of sludge received from the South unit of the activated sludge plant at Lancaster, Pa. When the sludge was examined microscopically many fuzzy tree-like protuberances were found, indicating that the sludge at the time of examination was in a poor condition and would settle slowly. Pure culture sludges with suspended solids of about 1,048 p.p.m., during a 5-hour aeration period, oxidized 70 per cent of the 5-day biochemical oxygen demand of the substrate, using sterile synthetic sewage and 89.5 per cent in sterilized domestic sewage by sludges with 1,351 p.p.m. suspended solids. This culture was reported by Butterfield et al. (4) as Culture Z–4. Ruchhoft et al. (11) have reported that there is a remarkable similarity between the purification accomplished by a pure culture sludge developed by one species of zoogleal bacteria, such as Culture 53, and a normal activated sludge. The effect of dispersion of the bacterial flocs in a pure culture sludge developed by this culture has been reported by Butterfield and the author (5).

Culture 55 was isolated from a sample of activated sludge received from the North plant at Lancaster, Pa., during the winter months. A pure culture sludge developed by this bacterium removed 69.1 per cent of the oxidizable material from sterile synthetic sewage and 84.7 per cent from sterilized domestic sewage during a 5-hour aeration period. The North plant sludge appeared to be in better condition than the sludge from the South plant at the various times examinations were made.

Zooglea Culture 58 was isolated from the sludge which was the source of Culture 55. This culture was originally Culture Z–9, reported by Butterfield et al. (4). With pure culture sludges of about 1,905 p.p.m. suspended solids developed by this culture, 78.2 per cent of the 5-day B.O.D. was oxidized during a 5-hour aeration period, using sterile synthetic sewage as a medium, while 88 per cent of the 5-day B.O.D. was oxidized from sterilized domestic sewage, using sludges of about 2,138 p.p.m. suspended solids.

The above zooglea-forming cultures had been isolated from samples of sludge taken during the winter months.

Culture 60 was isolated from sludge collected from the Calumet Sewage Treatment Plant during the summer months. This culture when inoculated into sterile synthetic and sterilized domestic sewage developed sludge-like masses, but the degree of purification has not been determined. As it required several weeks to develop a pure culture sludge suitable for use in purification studies in sterile synthetic sewage and sterilized sewage, such rates have not been determined for Cultures 60, 62, 82, 88, 100, 104, 105, 113, and 85.

Culture 62 was isolated from the experimental sludge plant at this laboratory after the sludge had been treated with toluene, in an attempt to get rid of fungus and other filamentous forms. The percentage of purification accomplished by this culture was not determined.

Culture 82 was isolated from a *Sphaerotilus* culture which had been growing in a medium containing 1,000 p.p.m. of dextrose. No experimental work has been done using a pure culture sludge developed by this organism.

Culture 83 was isolated from sludge developed at this laboratory by aerating settled domestic sewage at room temperature, in an 8-liter serum bottle, fed daily, by the fill-and-draw method, with settled domestic sewage. This culture was the only zooglea-forming bacterium which produced a brownish color when grown on sterile potato. Pure culture sludge was developed by this culture in a sterile synthetic sewage by the fill-and-draw method. This sludge thus developed was used and reported by Ruchhoft (12) in the studies of glucose removal from substrates by activated sludge.

Culture 85 was isolated from the experimental activated sludge plant at this laboratory. This culture developed typical zoogleal flocs in sterile synthetic sewage under aeration, but no purification rates were determined.

Culture 86 was isolated from sludge developed at 20° C. after inoculating 8 liters of sterile synthetic sewage with 5 ml. of domestic sewage. Pure culture sludge of about 1,000 p.p.m. developed under aeration by this culture in sterile synthetic sewage oxidized an average of 64.0 per cent of the 5-day B.O.D. in 5 hours. The per cent purification accomplished by the organism in sterile domestic sewage has not been determined. The culture was the only zooglea-forming bacterium isolated from sludge that produced an orange color when grown on potato or in synthetic media. This culture was used by Butterfield and the writer (19) in a comparative study of the growth and purification of a zooglea-forming bacterium isolated from activated sludge when grown and operated as a trickling filter and as an activated sludge.

Culture 88 was not isolated at this laboratory. It was isolated from activated sludge and classified as *Zooglea ramigera* by Soriano (14). Sludge-like flocs developed in sterile synthetic sewage and sterilized settled sewage under aeration. No purification rates have been determined. This culture is similar to Culture 85 in cultural characteristics.

Cultures 104 and 105 were isolated from flocs picked from a sludge developed by aerating domestic sewage at room temperature. The sludge was fed daily with 1,000 p.p.m. dextrose for a period of 10 to 12 weeks before these isolations were made. Microscopic examinations showed the sludge had the appearance of a good activated sludge at the time the isolations were made. The oxidation rates of these cultures have not been determined.

Culture 113 was picked from flocs formed in aerated domestic sewage kept at room temperature and fed daily with raw sewage. No purification studies have been completed with pure culture sludge developed by this organism in sterile synthetic sewage or sterilized domestic sewage.

## Cultures Isolated from Trickling Filters

All of the zooglea-forming organisms from trickling filters that have been studied have been isolated from the experimental trickling filter at the Stream Pollution Station, Cincinnati, Ohio. Other isolations have been made from full-scale filter units at Osgood, Ind., and at Dayton, Ohio. These cultures all produced, under aeration, sludge-like flocs when inoculated into sterile synthetic sewage or sterilized domestic sewage.

Culture 87 is the only zoogleal culture isolated that has a distinct yellow color. It was isolated from the film covering the stones taken from the top section of the experimental trickling filter during the early spring. The per cent of over-all purification accomplished by pure culture sludges of about 1,180 p.p.m. suspended solids developed by Culture 87 in sterile synthetic sewage has been found to be 73.6 per cent during a 5-hour aeration period. The percentage purification, when the sludge was developed and fed sterilized sewage, has not been determined.

Culture 100 was isolated from the top section of stones. The film was washed from the stone and a typical finger-like floc was picked, washed, and transferred to lactose broth. After flocs had developed, purification was done using the same technique as previously explained. Sludge-like flocs developed under aeration in sterile synthetic sewage or sterilized domestic sewage. No purification studies have been completed with this culture.

Culture 102 was isolated in a manner similar to Culture 100. The floc was picked from film adhering to the stones of the top layer. No purification studies have been carried out using sludge developed by this organism.

Culture 103 was isolated from the film removed from the top layer of stones following the procedure used in the isolation of Culture 87. The over-all purification during the 5-hour aeration period was found to be 82.2 per cent of the 5-day B.O.D. of the sterile synthetic sewage. The purification properties of this organism have not been determined when developed on and fed sterilized domestic sewage.

Cultures 100, 102, and 103 were isolated from the trickling filter during the summer months. Sludges developed under aeration by inoculating sterile media, either synthetic or domestic sewage, are very similar to a sludge developed by a zooglea-forming organism isolated from the filter during colder months. The pure culture sludges developed by all of the trickling filter zoogleal organisms isolated resemble very closely in appearance pure culture sludges developed, under similar conditions and in similar media, by zooglea-forming organisms isolated from activated sludge. The rate of purification in the sterile synthetic sewage and sterilized domestic sewage is practically the same.

The effects of carbohydrates were determined by two methods. Dilute agar was prepared by dissolving in 1 liter of distilled water 5.0 gm. peptone, 7.25 gm. $Na_2HPO_4$, 0.7 gm. $KH_2PO_4$, 1 gm. agar and 5.0 gm. of the carbohydrate being tested. The agar was sterilized by autoclaving at 15 pounds for 15 minutes except when the sugar under consideration would break down by this method; intermittent sterilization was then used. Broth containing the same percentage of the various carbohydrates with the addition of brom cresol blue was also used. All tubes were read after incubating 14 and 31 days at 20° C.

The change of the pH value in the various sugar broths seems to indicate slight use of sugar. No gas production was observed. The results presented by Ruchhoft, Kachmar, and Moore (12) show that a pure culture sludge of a concentration of about 1,395 p.p.m. developed by Culture 83, in sterile synthetic sewage with an average of 840 p.p.m. glucose added, removed 90.5 per cent of the glucose in 23 hours. A pure culture sludge, developed in a similar manner by Culture 86, with initial suspended solids of 686 p.p.m. in sterile synthetic sewage containing 505 p.p.m. glucose, utilized 84.7 per cent in 24 hours. The pure culture sludges in the above experiments were kept under sufficient aeration to maintain aerobic conditions and the amount of sludge used was much greater; whereas in our tests using the pH range as an index of the utilization of sugar, very small amounts of inoculum were used and the tubes remained quiescent. In the experiments by Ruchhoft et al. (12) the glucose was utilized in the production of growth, and appears as bacterial protoplasm without the accumulation of intermediate acid end products. The hydrogen-ion concentration of the substrate as shown by Ruchhoft et al. (12) influences the rate of glucose removal as well as growth and floc formation which will be discussed later in this paper.

The presence of spores was determined by two methods: (1) the heat test—tubes being held after heating 20 minutes at 80° C. for 14 days at 20° C., and (2) staining with the Schaeffer and Fulton (13) modification technique. Liefson's (10) flagella stain was used. The semisolid $KNO_3$ medium of Zobell and Meyer (18) was used to determine nitrate reduction. If, during incubation, gas was produced with or without the reduction of nitrate, bubbles would be held in the media. No gas was produced in any instance.

From the cultural characteristics it is noted that all zoogleal cultures isolated are identical in nine characteristics: form, Gram stain, capsule, nonchain forming, photic, hydrogen sulfide, Voges-Proskauer, and the reaction with arabinose and raffinose. This would indicate that the zoogleaforming organisms isolated from activated sludge and trickling filters were closely related. Considering in addition the results of the following determinations—spores, production of indol, gelatin liquefaction, methyl red, citrate, and the reaction with cellobiose, dextrin, and salicin—the zoogleal cultures studied may be divided into nine groups as follows:

1. Cultures 53, 55, 62, 82, 88, and 113 isolated from activated sludge.
2. Cultures 58, 60, and 104 isolated from activated sludge.
3. Cultures 102 and 103 isolated from trickling filters.
4. Cultures 87 and 105 isolated from activated sludge and trickling filters.
5. Culture 100 isolated from trickling filter.
6. Culture 50 isolated from activated sludge.
7. Culture 83 isolated from activated sludge.
8. Culture 85 isolated from activated sludge.
9. Culture 86 isolated from activated sludge.

By adding the appearance of growth on agar slant, the relation to oxygen and the ability to reduce nitrates, Groups 2 and 4 would be subdivided.

The close but not all-inclusive similarity brought out by the cultural, characteristics is further evidence for the above-mentioned close relationship, implying that we are dealing with several varieties of a single group.

In the first four groups, each including more than one culture, similar reactions were obtained in very few of the additional cultural characteristics studied. The organisms within Group 1 reacted similarly in regard to chromogenesis and their relation to oxygen. However, varying results were obtained from flagella stain, reduction of nitrates, peptonization of milk, and their ability to utilize xylose, glucose, galactose, mannose, lactose, melizitose, and mannitol.

Within Group 2 similar results were obtained from growth in milk, chromogenesis, and the organisms' ability to utilize xylose. Differing results were obtained from flagella stain, their relation to oxygen, the formation of nitrites from nitrates, and their ability to utilize glucose, galactose, mannose, sucrose, lactose, melizitose, and mannitol. Both organisms listed in Group 3 gave similar results with all of the tests used. The organisms listed in Group 4 reacted in the same manner in regard to their utilization of xylose, lactose, growth in milk, their relation to oxygen, and flagella stain. Dissimilar results were obtained by the organisms in Group 4 in the following: reduction of nitrates to nitrites, chromogenesis, and their utilization of glucose, mannose, sucrose, melizitose, and mannitol.

The results of the reactions used for group classification are presented in Table II, and it is shown clearly that the organisms being discussed are

TABLE II.—*Results of the Reactions Used for Group Classification*

| Group | Spores | Indol | Gelatin Lique-faction | Methyl Red | Citrate | Carbohydrates 0.5 Per Cent | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Cellobiose | Dextrin | Salicin |
| 3 | – | + | + | + | + | A± | 0 | A± |
| 1 | + | – | + | – | – | A+ | | |
| 9 | + | – | + | – | – | A± | 0 | 0 |
| 4 | – | – | + | – | – | A+ | A± | 0 |
| 8 | – | – | + | – | – | A± | 0 | A± |
| 6 | – | – | – | – | ± | | | |
| 2 | – | – | – | – | – | A+ | A± | A± |
| 7 | – | – | – | – | – | A+ | A± | 0 |
| 5 | – | – | – | – | – | A± | 0 | 0 |

closely related. From the results listed, Groups 1 and 9 differ only in utilization of carbohydrates. The same difference is observed for Groups 4 and 8. Groups 6, 2, 7, and 5 differ in utilization of carbohydrates and growth in sodium citrate broth. Greater differences are observed in the results of the reactions of Group 3 and the results of the other groups.

## EXPERIMENTAL WORK

The primary characteristics of these zoogleal bacteria were that they must grow in pure culture in flocs or colony formation in liquid media under aeration sufficient to maintain aerobic conditions. Experiments were instituted to determine (1) the minimum food requirement, (2) the effect of hydrogen-ion concentration on growth and floc formation, and (3) the effect of various substances commonly found in sewage in regard to growth and sludge production.

## Minimum Food Requirement

Culture 86 was used in the tests to determine the minimum food requirement for floc production. Sterile synthetic sewage, of varying concentration, was inoculated with Culture 86, incubated at 20° C. under aeration. The results given in Table III indicate that synthetic sewage

Table III.—*Growth of Pure Culture Zooglea in Synthetic Media of Varying Food Concentration*

| Culture | Per Cent Food Concentration[1] | Peptone P.p.m. | Results |
|---|---|---|---|
| 86 | 1 | 3 | No growth, aerated 7 days. |
| 86 | 10 | 30 | No growth, aerated 7 days. |
| 86 | 17.5 | 52.5 | Turbid, no floc, aerated 10 days. |
| 86 | 25 | 75 | Turbid, no floc, aerated 4 days. |
| 86 | 37.5 | 112.5 | Turbid, no floc, aerated 10 days. |
| 86 | 50 | 150 | Turbid and floc in bottom, aerated 4 days. |
| 86 | 100 | 300 | Turbid and floc throughout, aerated 2 days. |

[1] Per cent of standard synthetic sewage added.

of less than 10 per cent concentration would not support growth. A concentration of 17.5 per cent to 37.5 per cent produced growth but no floc formation. In a 50 per cent concentration both growth and floc formation were observed after 4 days, but floc formation occurred sooner in full strength media.

## pH Effects

Observations on the influence of hydrogen-ion concentration on growth were made as follows: Flasks containing 100 ml. of synthetic sewage were sterilized and the pH was adjusted using sterile 10 per cent $H_3PO_4$ or

Table IV.—*Pure Culture 86 in Standard Synthetic Sewage of Varying pH Readings. Flasks and Plates Incubated at 20° C.*

| pH Readings | | Series 1, Bacteria per Ml. | | Series 2, Bacteria per Ml. | | Series 3, Bacteria per Ml. | |
|---|---|---|---|---|---|---|---|
| 0 Hour | 24 Hour | 0 Hour | 24 Hour | 0 Hour | 24 Hour | 0 Hour | 24 Hour |
| 3.5 | 3.8 | | No growth[1] | | | | |
| 4.0 | 4.6 | | No growth[1] | | | | |
| 4.5 | 4.7 | | No growth[1] | | | | |
| 5.0 | 5.5 | 97 | Less than 1 | 156 | Less than 10,000 | | |
| 5.5 | 5.9 | 97 | Less than 1 | 156 | Less than 10,000 | 13 | Less than 10 |
| 6.0 | 6.4 | 97 | 195 | 156 | 400,000 | 13 | 100 |
| 6.5 | 6.8 | 97 | 21,500 | 156 | 650,000 | 13 | 200 |
| 7.0 | 7.1 | 97 | 3,020,000 | 156 | 1,560,000 | 13 | 56,900 |
| 7.5 | 7.2 | 97 | 267,000,000 | 156 | 370,000 | 13 | 82,500 |
| 8.0 | 7.4 | 97 | 68,000,000 | 156 | 35,000 | 13 | 120,000 |
| 8.5 | 7.6 | 97 | 69,000,000 | 156 | 890,000 | 13 | 186,000 |
| 9.0 | 8.7 | | | | | 13 | 57,800 |
| 9.5 | 8.6 | | No growth[1] | | | | |
| 10.0 | 9.8 | | No growth[1] | | | | |

[1] Observations based on turbidity readings.

sterilized 10 per cent NaOH to cover the range from pH 3.5 to pH 10.0. After such adjustment the flasks were inoculated with a suspension of Culture 86, previously shaken with sterile glass beads, and examinations to determine the initial total count per ml. and the pH were made. The flasks were incubated at 20° C. for 24 hours and the pH value and total counts were again determined. From the results presented in Table IV it will be observed that there was a tendency for the lower pH to rise during the incubation period and for the pH values in the higher range to drop.

TABLE V.—*Effect of Various Substances on Growth of Pure Culture Zooglea Organisms*

| Basic Medium | Substance Added | Amount per Liter Added | Culture | Results |
|---|---|---|---|---|
| Synthetic sewage | Soap[1] | 0.1 gm | 53 | Floc developed; few free organisms. |
| Synthetic sewage | Na ricinoleate | 0.1 gm | 53 | No floc developed; few free organisms. |
| Synthetic sewage | Na ricinoleate | 0.05 gm | 53 | Little floc developed; supernatant turbid pink color. |
| Synthetic sewage | Na ricinoleate | 0.025 gm | 53 | Floc developed. |
| Synthetic sewage | Na ricinoleate | 0.05 gm | 53 | Small amount floc developed; pink color. |
| Synthetic sewage | Na ricinoleate | 1.5 gm | 53 | Small amount floc developed; pink color. |
| Synthetic sewage | Na formate | 0.5 gm | 53 | Normal amount floc developed. |
| Synthetic sewage | Na oleate | 0.05 gm | 53 | Normal amount floc developed. |
| Synthetic sewage | Creatine | 0.05 gm | 53 | Very little floc developed. |
| Synthetic sewage | Certo | 5 ml | 113 | Floc developed. |
| Synthetic sewage | Certo | 2 ml | 53 | Supernatant turbid; small amount floc. |
| Synthetic sewage | Certo | 1 ml | 113 | Growth, but no floc. |
| Synthetic sewage | Pectin[2] | 2 ml | 53 | Floc developed; no increase in amount. |
| Synthetic sewage | Pectin[2] | 1 ml | 53 | Small flocs; no increase in amount. |
| Synthetic sewage | Pectin[2] | 0.5 ml | 53 | Small loose flocs. |
| Synthetic sewage[3] | Glucose | 0.1 gm | 53 | Supernatant turbid; no flocs. |
| Synthetic sewage[3] | Glucose | 0.1 gm | 53 | Supernatant turbid; no flocs. |
| Synthetic sewage[3] | Glucose | 0.1 gm | 113 | Flocs; no increase in amount sludge. |
| Synthetic sewage[4] | Glycerine | 0.05 gm | 53 | Sludge developed. |
| Synthetic sewage[4] | Glycerine | 0.05 gm | 113 | Sludge developed. |
| Synthetic sewage[4] | Glycerine | 0.05 gm | 53 | Sludge developed. |
| Synthetic sewage[4] | Glycerine | 0.05 gm | 113 | Sludge developed. |
| Synthetic sewage[4] | Sucrose | 0.05 gm | 53 | No flocs; supernatant turbid. |
| Synthetic sewage[4] | Glycerine | 0.05 gm | 53 | Floc developed slowly. |
| Synthetic sewage[4] | Glucose | 10.0 gm | 53 | No growth. |
| Synthetic sewage | Glycerine | 0.5 gm | 53 | Sludge developed. |
| Synthetic sewage | Glycerine | 0.5 gm | 60 | Sludge developed; no increase in amount. |
| Synthetic sewage[4] | Glucose | 0.05 gm | 53 | No increase in amount; floc developed. |
| Synthetic sewage[4] | Glycerine | 0.05 gm | 53 | No increase in amount; floc developed. |
| Synthetic sewage[4] | Glycerine | 0.05 gm | 83 | No increase in amount; floc developed. |
| Synthetic sewage | Glucose | 0.5 gm | 87 | Amount of floc increased. |
| Synthetic sewage | Glucose | 0.5 gm | 104 | Slight increase in floc. |
| Synthetic sewage | Glucose | 0.5 gm | 104 | Slight increase in floc. |
| Synthetic sewage | Glucose | 0.5 gm | 83 | Amount of floc increased. |

[1] Bell's Castile hand soap.
[2] Pectin extracted from grapefruit rind.
[3] Beef extract omitted from synthetic.
[4] Urea omitted from synthetic.

The number of organisms per ml. increased most rapidly at a pH of 7.0 to 8.0. Incubating the flasks for an additional 24 hours, for a total of

48 hours at 20° C., produced very little change in the flasks of the upper range. Microscopic examination of the flasks at the end of the 24-hour period showed few flocs present in the flasks of pH 6.5 and no flocs at lower pH values. Floc formation increased up to a hydrogen-ion concentration of pH 7.5 and decreased with further increase in pH. In the development of pure culture sludges, this principle has been followed by adjusting the pH value after feeding to pH 6.5. During a 24-hour aeration period the hydrogen-ion concentration increases to pH 7.6. Therefore, judging by the bacterial counts obtained and from the microscopic appearance of the growth, the optimum pH for growth and floc formation appears to be pH 6.8 to 7.5.

## Effect of Various Substances Commonly Found in Sewage

Various substances commonly found in sewage, such as soap, sodium ricinoleate, sodium formate, sodium oleate, creatine, pectin, glucose, glycerine, and sucrose, were added to synthetic sewage in an effort to stimulate growth and floc formation. Glucose was the only substance used which when added increased floc formation materially, as is also shown by the studies of Ruchhoft et al. (12). No increase was observed when glucose was added to synthetic sewage if beef extract or urea was omitted. Cultures 53, 60, 83, 87, 104, and 113 were used for these experiments.

## Summary

The predominant bacteria of activated sludge and of trickling filters have been isolated in pure culture. It would appear that these zoogleal bacteria might be considered in one group. All cultures studied, isolated from activated sludge and trickling filters, were short Gram-negative rods, failed to produce $H_2S$ or acetyl methyl carbinol, produced acid in broth containing arabinose, produced no change in broth containing raffinose, and produced capsules which bound the cells together in a capsular matrix tenaciously enough to remain intact under agitation sufficiently violent to keep the flocs suspended and to maintain aerobic conditions. Such sludge flocs of about 1,500 p.p.m. suspended solids composed entirely of masses of bacterial cells in pure culture will remove in 3 hours 36.3 to 84.2 per cent, and in 5 hours 55.6 to 91.6 per cent of the 5-day B.O.D. of polluted water or sewage.

The cultures isolated may be divided into nine related groups determined by the following characteristics: formation of spores, indol reaction, gelatin liquefaction, methyl red test, growth in citrate media, motility, and the pH reading in broth containing cellobiose, dextrin, and salicin.

The floc-forming organisms isolated from trickling filters will develop, under aeration, an activated sludge and will function similarly to a sludge developed by the floc-forming organisms isolated from activated sludge. This indicates that the zoogleal organisms found in trickling filters and in activated sludge flocs are closely related.

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# GREASE EXTRACTION FROM SEWAGE AND SLUDGE *

By Rolf Eliassen and H. B. Schulhoff

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Research activities and general interest in the removal of grease from sewage have become intensified during the war period. Various principles and mechanisms for grease removal are undergoing experiment in attempts to evaluate the methods most applicable to specific problems in the treatment of sewages and industrial wastes.

The fundamental tool in all research pertaining to grease is the determination of the grease content of the sewage, sludge or scum under consideration. This determination depends on the amount of material extracted from the sample by a solvent which has the property of selecting lipoidal materials to the exclusion of the many other substances present in sewage. Petroleum ether applied to an acidified sample has been accepted as the solvent most suitable for grease determinations in materials of sewage origin. Gehm (1) has presented the reasons for the adoption of this over other solvents.

## Other Methods

Before extraction may be accomplished, the sample must be dried thoroughly. Most of the methods of grease determination have been concerned with the various means of concentrating the sewage or sludge and drying the residue. Standard Methods (2) propose that sewage be boiled down from the original of one (1) liter to dryness. Ludwig (3) recommends boiling followed by refrigeration, filtration and drying. Hurwitz (4) modified the foregoing by using a cotton disc in an aluminum dish in place of the filter paper and funnel suggested by Ludwig. Gehm (5) flocculated the sewage with alum and lime and permitted the coagulated grease particles to settle before decanting the supernatant. The remaining sludge was filtered over a layer of diatomaceous earth and the residue dried. In all cases the dried sample is transferred from the evaporating dish to a Soxhlet thimble which in turn is placed in a Soxhlet extraction apparatus. Extraction may take from 8 to 16 hours.

## Limitations

The accuracy of each of the above methods depends on the ability of the technician to remove all of the dried material from the evaporating dish, or dissolve all of the grease from the walls of the dish. It has been found that in many cases the upper portion of the dish contained a thin hard layer of dried sludge which could not be scraped off readily. Neither could the grease be dissolved in cold petroleum ether. This affected the consistency of the results to a considerable degree.

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Furthermore, the accuracy of the method depends on the ability to extract all of the ether-soluble matter from the sample in the thimble. In a number of instances it was found that certain sewages, particularly those rich in fats, yielded a sticky mass on evaporation to dryness. The solvent penetrated this mass very slowly. Samples have been observed to retain a core of grease even after extraction for 16 hours.

## Object of Experiments

In order to decrease possibilities for error in transfer from evaporating dish to thimble and to assure a more readily extractable sample, experimental work was undertaken. The object in mind was to develop a method utilizing the basic principles of petroleum-ether extractions but eliminating the sources of error noted above. If the extraction could be performed in the same vessel in which the evaporation of the sample was accomplished, the error in transfer could be eliminated. Then, if the dry solids could be dispersed in such a manner that no appreciable thicknesses or cores of grease-containing substances were present, the extraction could be carried out in a relatively short time and with consistent results. Research was carried out along these lines and a method developed which would fulfill the requirements of a rapid and consistent method for the determination of petroleum-ether soluble matter in sewage or sludge.

Fig. 1.—Filter paper cup.
Fig. 2.—Gooch crucible after filtration and acidification.

## Concentration of Sample

For concentration of sewage the method suggested by Gehm (5) was followed, with modification in dosage to account for differences in sewage characteristics. The size of sample depended on the grease content of the sewage. Generally, one liter was sufficient for strong sewages, while with some weak sewages, four liters were necessary. For accuracy in weighing, it was desirable to have approximately 100 mg. of grease extracted from the sewage or sludge. It was found that the clearest supernatant, with negligible grease content, was obtained by first adding 1.5 ml. of a 10 per cent suspension of calcium hydroxide, mixing completely and then adding 4 ml. of a 10 per cent solution of alum. After thorough but gentle mixing the floc was permitted to settle for an hour, or until a clear supernatant was obtained. The quantities of coagulant were varied for different sewages, but in all cases enough lime was added to leave a residual carbonate alkalinity.

After the floc had settled and compacted, the clear supernatant was siphoned off, care being taken that the floating grease, as well as the floc, remained in the vessel.

With most sludges, the process was simplified since no decantation was necessary. Sufficient alum and lime were added to the sludge to develop good filtration characteristics.

## Preparation of Crucible

From this point on, with either sewage or sludge, a radical departure from other procedures was adopted. A 25 ml. Gooch crucible was prepared first by folding an 11 cm. piece of filter paper in such a manner that it lined the interior of the crucible to within a quarter of an inch of the top.

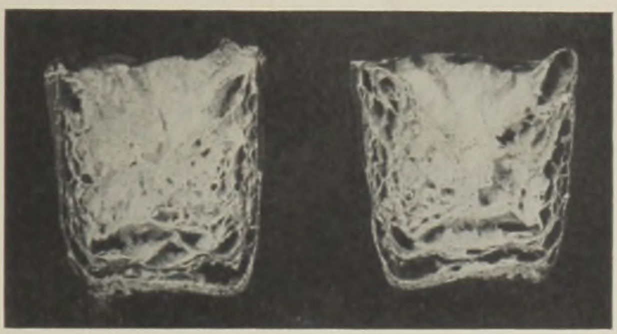

Fig. 3.—Section through porous mass in crucible.

By folding and wetting it was possible to make the paper fit well against the sides and bottom. An asbestos suspension was then added and vacuum applied to form a thick mat on the paper. The paper cup and mat are shown in Fig. 1. It was found that this preparation greatly facilitated filtration as the paper shell prevented the asbestos fibers from entering the bottom holes of the crucible. The asbestos in turn presented a large filtration area to prevent clogging of the pores of the paper.

Having thus prepared the Gooch crucible, $\frac{3}{4}$ gram of short-fibered asbestos was added to the floc remaining in the original vessel after decantation of the clear supernatant. The mixture of asbestos and floc was poured into the Gooch and vacuum applied. It was found that the material adhered to the paper on the walls of the Gooch and also accumulated on the asbestos mat. When the vacuum had partially dried the solids, the crucible was placed in a shallow dish or beaker. Three or four ml. of a 1 : 1 hydrochloric acid solution was added slowly to the exposed surfaces of the paper and mat. Enough acid was added to penetrate to the bottom. Reaction of the acid with the residual carbonate alkalinity in the floc liberated carbon dioxide gas. As soon as this started, the Gooch and beaker were placed in a drying oven at 103° C. More $CO_2$ was liberated under the influence of heat. When the mass had dried sufficiently, any acid or washings which had passed through the Gooch to the beaker were returned to the crucible, which was then thoroughly dried. In addition to gas production, the acid was required for conversion of the calcium soaps to fatty acids in order to be ether-soluble.

The formation of gas in and around the mass in the crucible led to the formation of a structure composed of asbestos, sewage solids and gas, as

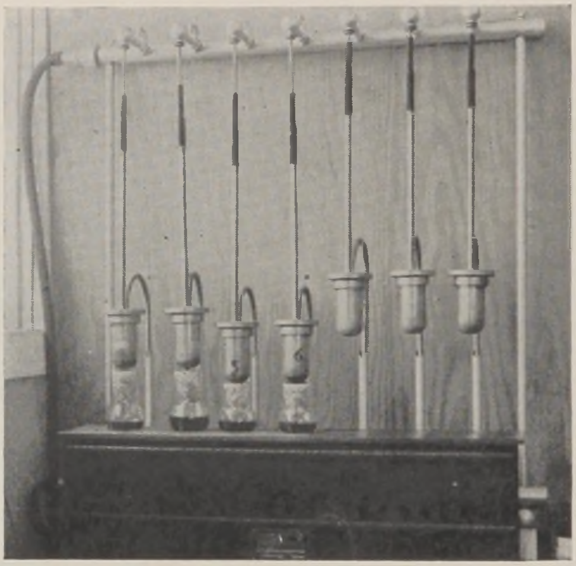

Fig. 4.—Bailey-Walker extraction apparatus.

shown in Figs. 2 and 3. It is this very structure which separates the solids in thin layers so that the extraction to follow may be completed in relatively short order.

After drying the contents of the crucible for 30 minutes, aluminum foil was wrapped around the bottom and sides to form a tight-fitting cup. Small glass beads were placed in the Gooch to within $\frac{1}{8}$ inch of the top. The beads served later to distribute the solvent over the material below. The aluminum foil retarded the flow of the solvent out of the crucible and permitted an adequate contact period between solvent and grease in the solids, still allowing all of the solvent to drain out of the Gooch.

## Extraction Apparatus

The choice of a Gooch crucible to contain the sewage solids permitted the use of a different extraction apparatus from the conventional Soxhlet, with its battery of glass condensers and other breakable units. Figure 3 shows the Bailey-Walker apparatus used in these tests. The Gooch crucible was placed in a specially constructed glass flask which was provided with three glass indentations to support the crucible. This flask was used to contain the solvent and also for weighing. A stainless steel condenser cup fit over the top of the bottle. Cold water passed through the cup which provided a large condensing surface for the solvent. The condensers were mounted in a battery of seven units, as shown in Fig. 4. Each condenser was provided with a stopcock controlled inlet. One outlet manifold served for the entire group. Individual units could be raised to remove or install flasks without disturbing the other units. An electrical hot plate with 3-heat switch controls for each of the seven units was also provided. This apparatus was found to be compact, easy to handle and capable of withstanding considerable shock.

After extraction had been completed, the crucible was removed from the flask. Then the petroleum ether was driven off by placing the flask in a drying oven at 103° C. for 15 minutes. The residue of grease was then weighed in the flask, which had been weighed previously.

## Results

Results are not of value unless consistency can be obtained in a series of check runs. To verify the consistency of this method, numerous tests were made. Results of analyses on three different sewages, from weak to strong, are shown in Table I. It will be noted that the per cent deviation from the mean values was well within the limits of the possible error of sewage sampling.

TABLE I.—*Analyses of Sewage*

| Sewage | Size of Sample Liters | Grease in Sewage—P.p.m. | | | | Maximum Deviation from Mean % |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | Ave. | |
| A | 4 | 8.4 | 8.5 | 8.9 | 8.6 | 3 |
| B | 2 | 51.5 | 54.3 | 54.8 | 53.5 | 4 |
| C | 1 | 143 | 152 | 156 | 150 | 5 |

Similar consistency was obtained in a series of runs on raw and digested sludge, the results of which are presented in Table II.

To obtain a comparison between the improved method and that recommended by Standard Methods, parallel runs were made. Special care was

TABLE II.—*Analyses of Sludge*

| Type of Sludge | Solids % | Method of Analysis | Grease in Sludge—Per cent of Total Solids | | | | | | Maximum Deviation from Mean % |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | Ave. | |
| Digested | 3.1 | Improved | 3.9 | 4.1 | 4.1 | 4.2 | 4.2 | 4.1 | 5 |
| | | Standard | 3.5 | 3.9 | 4.0 | 4.1 | 4.1 | 3.9 | 10 |
| Raw | 6.5 | Improved | 18.2 | 20.7 | 20.7 | 21.6 | 21.6 | 20.5 | 11 |
| | | Standard | 17.5 | 19.2 | 19.4 | 20.0 | 20.1 | 19.2 | 8 |

taken in the transfer of the sample from the evaporating dish to a Soxhlet thimble and in assuring that no thick masses were present to retard solution of the grease. The results in Table II indicate that the values by the Standard Method are slightly lower than those by the Improved Method.

The great difference between the two methods lies in the time necessary for the extraction, during which time careful watch must be kept on the apparatus. With the Standard Method the time of extraction may run from 8 to 16 hours, with the latter necessary for consistency. On the other hand, the improved method requires only 4 hours for complete extraction, even with raw sludges. Tests were conducted on seven samples of raw sludge to determine the length of time necessary to complete extraction. The average results are indicated in Fig. 5. It will be noted

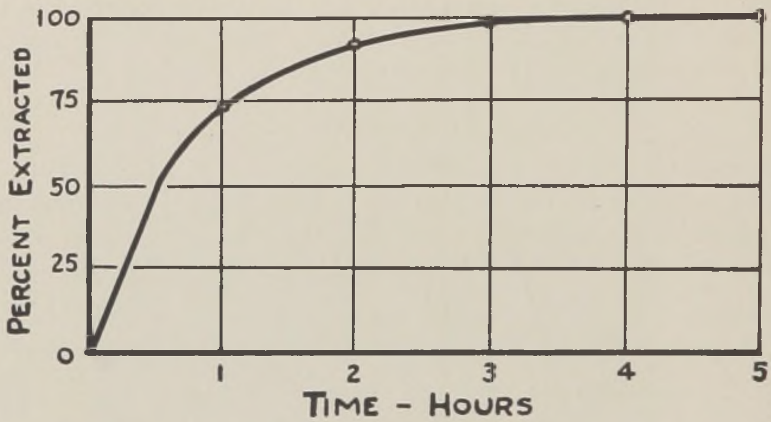


FIG. 5.—Effect of time on extraction efficiency.

that extraction is 98 per cent complete after 3 hours. Even more rapid extraction was obtained on sewages, where a limit of 3 hours could be adopted. Taking into account the Standard Method involving evaporation to dryness of 1 to 4 liters of sewage, followed by extraction, 1 or 2 days may be saved through use of the Improved Method.

## DISCUSSION

A practical method of grease analysis has been developed, which utilizes the accepted principles of the extraction of grease by petroleum ether. By concentration of the solids, filtration through a specially prepared Gooch crucible, dispersion of solid particles by gas ebullition during acidification of the sample, drying and extraction in an improved type of apparatus, the time for analysis of the grease content sewage has been cut from several days to a matter of a single day. Consistency of results is obtained without undue effort such as is necessary in other methods.

Like all other analytical procedures, a technique must be developed in in the preparation of the Gooch crucible. This is not difficult and can readily be mastered by any competent sewage analyst. Care must be taken that enough acid is added to neutralize all of the alkalinity present in order that the calcium soaps may be converted to fatty acids. Also, sufficient volume of acid must be added to penetrate through the mass in the crucible and pass to the dish below. If the sewage or sludge does not have enough alkalinity or dissolved carbon dioxide to leave a residual carbonate alkalinity after the addition of alum and lime in the initial stages of sample preparation, calcium carbonate will have to be added with the lime. Experience on the part of the analyst will soon develop a rapid and effective technique.

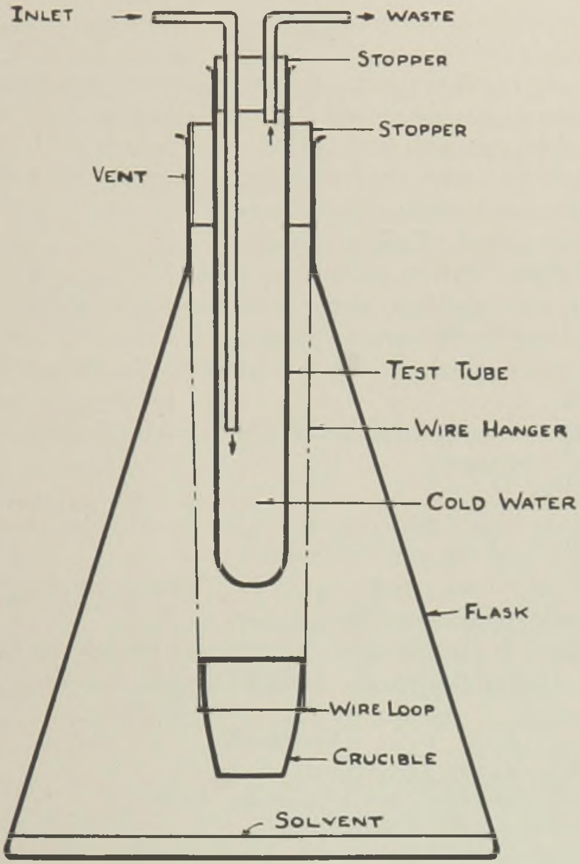


FIG. 6.—Suggested extraction apparatus.

The use of this improved method does not depend on the possession of the Bailey-Walker extraction apparatus shown in Fig. 4. If a Soxhlet apparatus is available, it is an easy matter to transfer the filter paper cup shown in Fig. 1 from the crucible to the Soxhlet thimble. All of the organic contents are within this cup. The advantages of rapid and complete extraction are still maintained as the preparation of the sample within the cup is the determining factor and not the apparatus.

As a matter of fact, no expensive extraction apparatus is necessary. Materials and glassware already available in the average laboratory could be utilized to accomplish the same results. A wide-mouthed flask would readily serve as a weighing bottle. In lieu of the stainless steel condenser, a test tube could be inserted through a stopper in the flask. This test tube could also be stoppered and provided with two holes to permit cooling water to pass through the tube. The Gooch crucible could be suspended on a wire ring, which in turn could be hung by wire from the top of the flask. A hot plate or steam bath could be used as the source of heat. The apparatus shown in Fig. 6 indicates the general set-up of equipment. Modifications could be adopted to fit the local situation.

## Summary

This improved method for the determination of petroleum ether soluble matter in sewage or sludge consists of the following steps:

1. To the sewage sample add 1.5 ml. of 10 per cent $Ca(OH)_2$ suspension and 4 ml. of a 10 per cent alum solution.
2. Gently stir and settle one (1) hour.
3. Decant or siphon off clear liquor.
4. With sludges, merely add coagulants.
5. Fold an 11 cm. filter paper into Gooch crucible. Add asbestos suspension and apply vacuum to form mat.
6. Add $\frac{3}{4}$ gram of short fibered asbestos to floc or sludge. Filter through Gooch.
7. Add 4 ml. of a 1 : 1 HCl solution to expand mass of solids and asbestos by $CO_2$ formation.
8. Dry at 103° C.
9. Place glass beads over spongy mass in crucible. Wrap aluminum foil around sides and bottom of crucible.
10. Place crucible or paper cup in available extraction apparatus and extract with petroleum ether for 4 hours.
11. Place flask in drying oven to drive off petroleum ether.
12. Weigh flask and grease. Deduct weight of flask.

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# GREASE IN SEWAGE, SLUDGE AND SCUM.*
# IV. TRANSFORMATION OF GREASE IN ACTIVATED SLUDGE

By H. Heukelekian

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Inasmuch as grease constitutes the most abundant single ingredient in sewage, its effect on the operation of sewage treatment processes has attracted considerable attention. More specifically, the availability of grease as food for bacteria under aerobic and anaerobic conditions has been the subject of inquiry. At present it has been established that at least certain types of greases are available as food for bacteria under anaerobic conditions and are the primary food from which gas-yielding materials are formed in sludge digestion tanks. The origin, chemical composition and physical state of the different types of greases in sewage have an important bearing on the rate of their availability. During digestion the greases are hydrolyzed to fatty acids and glycerol which in turn become available as food for methane bacteria.

The availability and the effect of greases in aerobic sewage treatment processes has not been definitely established. Jenkins (4) published some experimental results on the biological oxidation of stearic acid in biological filters. He concluded that sodium stearate could be oxidized in the filters. With a 250 p.p.m. concentration of stearic acid the filters became choked.

In the activated sludge process speculation as to the effect of grease has been rife. It has been suggested that the grease component of sewage is not so readily available as some of the other ingredients and that high grease content in sewage results in sludge bulking. The present investigation was undertaken to throw more light on the fate of grease in the activated sludge process. The specific questions raised were: "What is the fate of grease in the aeration of sewage by the activated sludge process and, under various experimental conditions, how much of the grease added is decomposed and how much of it remains in the sludge."

## Methods

Two fish tanks with capacities of 50 liters (2 by 1 by 1 ft.) each were used for aeration of the activated sludge mixtures. Aeration was effected by 10 in. long porous tubes placed near the bottom at one end of the tank and circulation was aided by deflection baffles at the surface of the liquid at both ends of the tanks. Air was supplied from a compressor and the volume of air was adjusted to keep the sludge in suspension. The tanks were operated on a fill-and-draw basis under the

* Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Water and Sewage Research. Most of the routine analyses were made by Mr. Frank Bliss of W.P.A. Project 8173–0.

conditions specified below for the various experiments. A strong domestic sewage obtained from a nearby municipality was used. The activated sludge was obtained from the nearby plants. The sewage and the returned sludge were mixed to obtain definite suspended solids concentrations in the mixture.

A minimum of two 1-liter samples were taken at the beginning and after various intervals of aeration. These were allowed to settle for ½ hour and supernatant was removed. The grease content of the liquor and the sludge components was determined by the method developed by Gehm (1) (2).

## Results

The grease content of the liquid and sludge components of a liter of the mixture before and after mixing the sewage and the returned sludge and after various periods of aeration is shown in Table I. The initial

Table I.—*Transformation of Grease in the Activated Sludge Process*
Distribution of Grease

| | Liquor, mgm. | Sludge, mgm. | Total, mgm. | Destroyed, per cent | Adsorbed, per cent | In Sludge, per cent |
|---|---|---|---|---|---|---|
| Before mixing | 200 | 12 | 212 | — | — | 0.9 |
| After mixing | 120 | 62 | 182 | 0 | 25 | 5.0 |
| After 2 hrs. aeration | 28 | 125 | 153 | 28 | 56 | 10.0 |
| After 4 hrs. aeration | 9 | 141 | 150 | 29 | 64 | 11.2 |
| After 6 hrs. aeration | 4 | 94 | 98 | 54 | 41 | 7.5 |
| After 24 hrs. aeration | 3.5 | 26.5 | 30 | 86 | 7 | 2.1 |

Mgm. grease in each component per liter of total mixture. Volumetric ratio of components in initial mixture = 900 cc. sewage and 100 cc. returned sludge. Initial suspended solids concentration, 1,250 p.p.m. Grease content of raw sewage, 223 p.p.m.

suspended solids concentration of this mixture was 1,250 p.p.m. and the grease content of the sewage fed was 223 p.p.m. It is rather striking to note that 80 p.p.m. of grease was removed from the liquor by the initial mixing of the sewage with sludge. Fifty parts per million was recovered in the sludge. The elapsed time for mixing and subsequent separation of the liquor was only thirty minutes, which could not be considered long enough to bring about appreciable biological destruction, in the absence of air, of that part of the grease lost from the liquor which was not recovered in the sludge. The discrepancy should therefore be attributed to experimental error. During the first two hours of aeration there was an additional 92 p.p.m. decrease of grease in the liquor and 63 p.p.m. increase in the sludge, or a net loss of 29 p.p.m. from the mixture. In the subsequent 2 hours of aeration, the grease content of the liquor decreased to 9 p.p.m. and that of the sludge increased to 141 p.p.m. Thereafter the grease content of the liquor did not change materially but the sludge lost appreciable quantities of grease. The per cent of grease destroyed given in the table is on the basis of the total grease content of the mixture before mixing. The decrease in the quantity of grease in the mixture subtracted from the decrease of grease in the liquor before the mixing can be considered as the quantity absorbed and is presented as a percentage value of the initial grease content of the liquors before mixing. It is interesting to note that during 2 hours of aeration, 28 per cent of the grease was destroyed. This value increased to only 29 per cent in 4 hours and took a sudden jump to 54 per cent in 6 hours and to 86 per cent in 24 hours. Twenty-five per cent of the grease in the sewage was adsorbed by mixing alone. The value increased to 56 per cent after 2 hours aeration, to 64 per cent after 4 hours and decreased to 41 per cent in 6 hours. Only 7 per cent of the grease in the initial sewage remained adsorbed after 24 hours aeration. The method of calculation does not credit the grease destroyed as having been previously adsorbed, which naturally is the case, but only that part which is in an adsorbed state.

In the final column of the table the grease content of the sludge is given as percentage values on a dry matter basis. The figures likewise show that the grease content of the sludge increased during the early periods of aeration and then decreased with longer periods.

TABLE II.—*Effect of Sludge Concentration on the Transformation of Grease in the Activated Sludge Process*

| | Susp. Solids, 1,250 p.p.m. | | | | Susp. Solids, 3,450 p.p.m. | | | |
|---|---|---|---|---|---|---|---|---|
| | Liquor, mgm. | Sludge, mgm. | Total, mgm. | Grease in Sludge, per cent | Liquor, mgm. | Sludge, mgm. | Total, mgm. | Grease in Sludge, per cent |
| Before mixing | 64 | 41 | 105 | 3.3 | 55 | 132 | 187 | 3.8 |
| After mixing | 65 | 46 | 111 | 3.6 | 44 | 110 | 154 | 3.4 |
| After 2 hrs. aeration | 23 | 76 | 99 | 6.1 | 8 | 133 | 141 | 3.6 |
| After 4 hrs. aeration | 12 | 89 | 101 | 6.8 | 5 | 141 | 146 | 3.7 |
| After 6 hrs. aeration | 6 | 76 | 82 | 6.2 | 3 | 135 | 138 | 3.6 |
| After 8 hrs. aeration | 5 | 59 | 64 | 4.8 | 5 | 97 | 102 | 2.6 |
| After 24 hrs. aeration | 5 | 36 | 41 | 2.6 | 8 | 87 | 95 | 2.4 |

Mgm. grease in each component per liter of mixture. Volumetric ratios of components initial mixture = 938 cc. sewage and 62 cc. sludge for low suspended solids concentration mixture; 800 cc. sewage and 200 cc. sludge for high suspended solids concentration mixture. Grease content of raw sewage, 68 p.p.m.

In the second experiment, two mixtures of the same activated sludge and sewage, containing 1,250 p.p.m. and 3,450 p.p.m. of suspended solids, were aerated for 24 hours to determine the effect of suspended solids concentration on the transformation of grease. The results are given in Table II and Fig. 1. The removal of grease from the liquid phase was not materially affected by the suspended solids concentration, although there was a tendency, in the higher suspended solids concentration, for the grease to reach lower values earlier, followed by a slight increase with longer aeration periods. Such an increase with overaeration periods was not apparent in the lower suspended concentration. There were striking differences between the two solids concentrations in respect to the grease content of the sludge phase. In the lower solids concentration there was a rapid increase of grease up to four hours of aeration, followed by a decrease, but the grease content remained around the initial value even with 24 hours of aeration. In the high suspended solids mixture the grease content increased only slightly during the initial period of aeration, decreased rapidly below the initial value be-

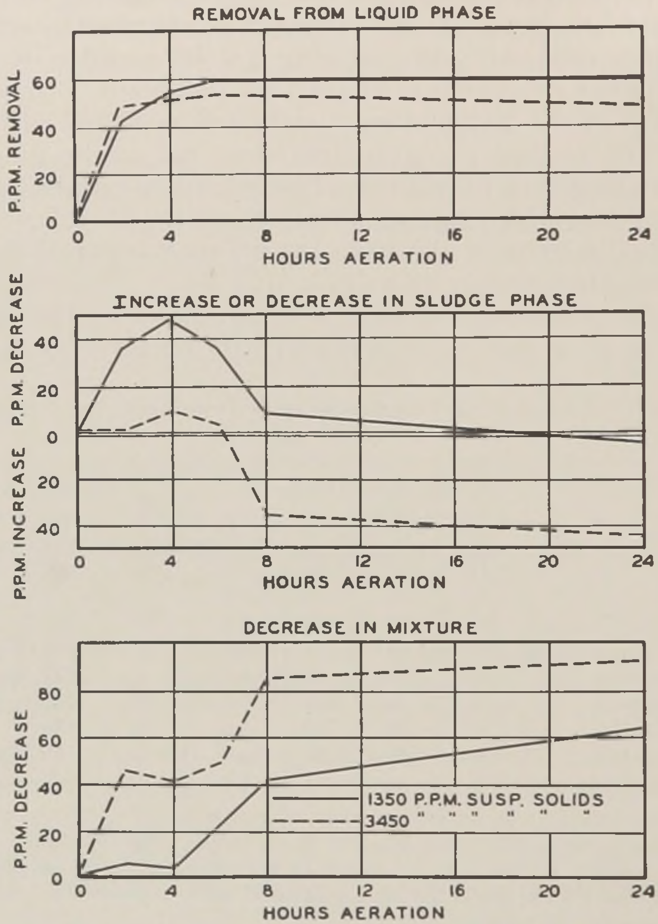


FIG. 1.—Removal of grease from the liquid phase, increase or decrease of grease in the sludge phase, and decrease of grease in the mixture during the aeration of sewage for 24 hours with two different concentrations of activated sludge.

tween 6 and 8 hours and continued to decrease up to 24 hours of aeration. The total quantity of grease lost in the liquid and solid phases decreased more rapidly in the high suspended solids concentration than in the low concentration. Again, the total quantity of grease before and after mixing did not check closely, especially in the high concentration mixture, but this has no effect on the general tendencies, affecting only the magnitude of the difference.

In order to determine whether the difference in the transformation of grease was affected by repeated dosage of sewage to the same sludge, the sludge was dosed seven times with sewage on a fill-and-draw basis. Three doses of sewage during 24 hours were added, with an aeration period of 6 hours each for the two day dosings and 10 hours during the night period. Two mixtures of sludge and sewage were made; one with 1,300 p.p.m. suspended solids and the other with 2,600 p.p.m. The mixtures were dosed with the same sewage, aerated and settled for ½ hour. The liquor was decanted and a new dose of sewage added. Grease and suspended solids determinations were made during the first and seventh doses. The results obtained are given in Table III. In all instances

TABLE III.—*Effect of Seven Doses of Sewage on the Transformation of Grease by Activated Sludge*

| | 1,300 p.p.m. Suspended Solids | | | | | | 2,600 p.p.m. Suspended Solids | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st Dose | | | 7th Dose | | | 1st Dose | | | 7th Dose | | |
| | Liquor, mgm. | Sludge, mgm. | Total, mgm. | Liquor, mgm. | Sludge, mgm. | Total, mgm. | Liquor, mgm. | Sludge, mgm. | Total, mgm. | Liquor, mgm. | Sludge, mgm. | Total, mgm. |
| Before mixing | 85 | 49 | 134 | 65 | — | — | 69 | 134 | 203 | 65 | — | — |
| After mixing | 52 | 85 | 137 | 32 | 172 | 204 | 41 | 157 | 198 | 28 | 213 | 241 |
| After 2 hr. aeration | 23 | 123 | 146 | 7 | 157 | 164 | 7 | 160 | 167 | 3 | 222 | 225 |
| After 4 hr. aeration | 7 | 121 | 128 | 12 | 128 | 140 | 2 | 127 | 129 | 7 | 167 | 174 |
| After 6 hr. aeration | 1 | 103 | 104 | 3 | 91 | 94 | 3 | 125 | 128 | 6 | 125 | 131 |

Grease content of sewage for the 1st dose, 95 p.p.m.; 2nd and 3rd dose, 60 p.p.m.; and 4th, 5th, 6th, and 7th doses, 80 p.p.m.

there was again an immediate removal of grease from the liquid phase merely by mixing the sewage with the sludge; the grease was more or less completely recovered in the sludge. The grease content of the liquor decreased rapidly with aeration and reached a low value of 1 to 6 p.p.m. after 6 hours. The grease content of the sludge increased up to 2 hours of aeration and decreased thereafter. The total grease content of the mixture decreased with aeration. The changes in the grease content of the liquor, sludge, and the mixture during the first dose are presented graphically in Fig. 2. The removal of grease from the liquid phase was not affected by the solids concentration, but changes in the sludge phase were profoundly affected. With 1,300 p.p.m. suspended solids, the increase of grease in the sludge phase was greater and the content did not drop sufficiently toward the end of the 6-hour aeration period to bring it back to the original grease content of the sludge. With 2,600 p.p.m. suspended solids, the initial increase was not so great and the grease content dropped below the original value only after 4 hours of aeration. The decrease of grease in the total mixture, which is a measure of the amount destroyed, was greater with the higher suspended solids concentration than with the lower. In general, the results were in good agreement with those obtained from the previous experiment (Fig. 1).

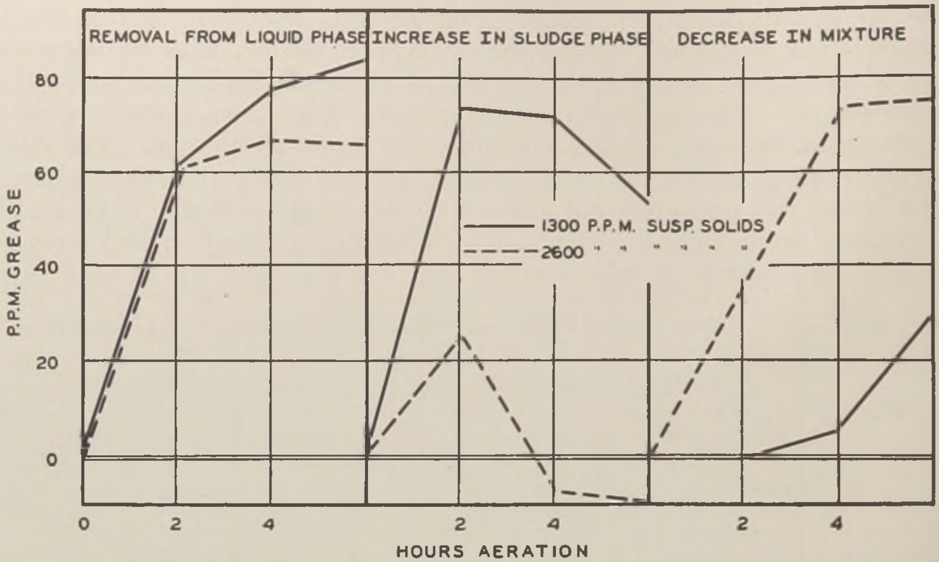


FIG. 2.—Removal of grease from the liquid phase, increase or decrease of grease in the sludge phase, and decrease of grease in the mixture during aeration of sewage for 6 hours with two different concentrations of activated sludge.

The changes in the percentages of grease destroyed and adsorbed during the first and seventh doses are compared in Fig. 3. With the low suspended solids concentration, the percentage grease destroyed was greater during the seventh dose than during the first dose; this was not the case in the mixture with high solids concentration. The per-

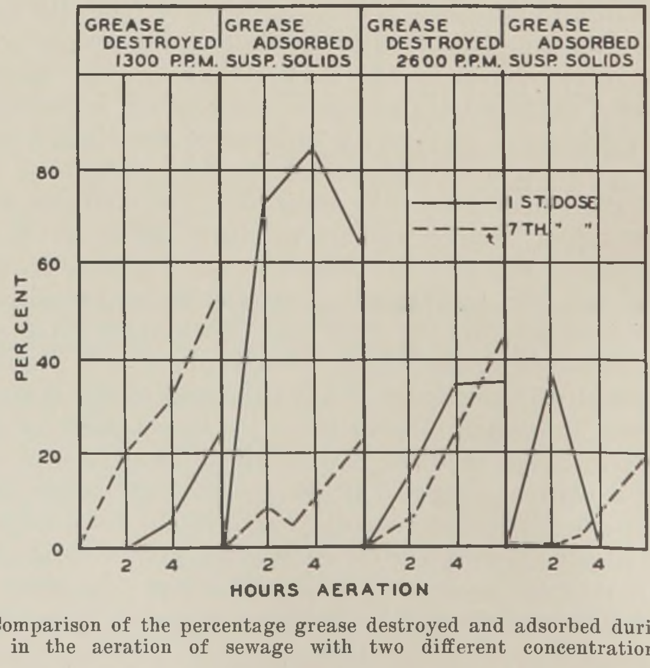


FIG. 3.—Comparison of the percentage grease destroyed and adsorbed during the first and seventh doses in the aeration of sewage with two different concentrations of activated sludge.

centage of grease adsorbed was high during the first dose in the low concentration mixture and decreased during the seventh dose. There was an inverse relationship between adsorption and destruction in the mixture with the low suspended solids but no such relationship was apparent in the high concentration mixture.

The percentage of grease in the sludge used in this experiment is given in Table IV. The results indicate a tendency for the grease content of the sludge to increase during the first aeration period and to decrease during the seventh aeration period with the low solids mixture.

TABLE IV.—*Grease Content of the Sludge*

| | 1,300 p.p.m. Susp. Solids | | 2,600 p.p.m. Susp. Solids | |
|---|---|---|---|---|
| | 1st Dose, per cent | 7th Dose, per cent | 1st Dose, per cent | 7th Dose, per cent |
| Before mixing | 3.8 | — | 5.2 | — |
| After mixing | 6.5 | 11.2 | 6.0 | 8.1 |
| 2 hrs. | 9.4 | 10.2 | 6.2 | 8.5 |
| 4 hrs. | 9.3 | 8.4 | 4.9 | 6.4 |
| 6 hrs. | 8.0 | 6.0 | 4.8 | 4.8 |

Thus the grease content of the sludge after 6 hours of aeration was higher than the initial during the first dose and lower than the initial after the seventh dose. In the high solids mixture, the increase in the percentage grease during the aeration was not so high and the reduction to the original percentage occurred more quickly, irrespective of the number of doses.

The next factor studied was the effect of increase in the grease content of sewage. The grease content of sewage was increased by extracting the grease from scum, mechanically emulsifying the extracted grease in an emulsifier, and adding it to sewage. Two mixtures were made with the same activated sludge: one with the normal sewage and another with the grease-enriched sewage. The mixtures were aerated for a period of 6 hours and operated on a fill-and-draw basis for four periods with fresh additions of sewage during each period. The initial suspended solids in the mixture was 1,550 p.p.m., which increased to 1,800 p.p.m. after the fourth cycle. The results obtained are presented in Tables V and VI. The grease content of the sewage was 38 p.p.m. for the first dose and 57 p.p.m. for the fourth dose. The grease-enriched sewage had a grease content of 110 p.p.m. for the first dose and 125 p.p.m. for the fourth dose. It appears that dosing the sludge with sewage containing about two to three times as much grease did not result in an increased grease content in the liquor after 4 hours' aeration, even if such additions were repeated four times. The grease content of the sludge on a dry basis increased from 5.6 to 6.2 per cent during the first dose and changed from 6.7 to 6.2 per cent during the fourth dose with additions of normal sewage. When grease-enriched sewage was added, the grease content of the sludge increased from an initial value of 5.6 per cent to 8.8 per cent at the end of 6 hours of the first dose. It had increased to 12.2 per cent at the beginning of the fourth dose and ended up with 11.0 per cent after 6 hours aeration. Thus the grease content of the sludge was definitely modified and increased without material change in the grease content of the liquor. The grease content of the sludge had established itself at twice the initial value with a sewage

TABLE V.—*Effect of Increasing the Grease Content of Sewage on the Activated Sludge Process*

| | Normal Grease Content | | | | | | With Grease Added | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st Dose | | | 4th Dose | | | 1st Dose | | | 4th Dose | | |
| | Liquor, mgm. | Sludge, mgm. | Total, mgm. | Liquor, mgm. | Sludge, mgm. | Total, mgm. | Liquor, mgm. | Sludge, mgm. | Total, mgm. | Liquor, mgm. | Sludge, mgm. | Total, mgm. |
| Before mixing | 34 | 86 | 120 | — | — | — | 99 | 86 | 185 | — | — | — |
| After mixing | — | — | — | 30 | 117 | 147 | — | — | — | 60 | 227 | 287 |
| After 2 hr. aeration | 5 | 100 | 105 | 6 | 140 | 146 | 15 | 137 | 152 | 12 | 254 | 226 |
| After 4 hr. aeration | 2 | 88 | 90 | 1 | 126 | 127 | 2 | 146 | 148 | 2 | 226 | 228 |
| After 6 hr. aeration | 9 | 95 | 104 | 4 | 108 | 112 | 8 | 137 | 145 | 4 | 205 | 209 |

Grease in sewage, 28 p.p.m. 1st dose; and 57 p.p.m. 4th dose. Grease in grease-enriched sewage, 110 p.p.m. 1st dose; and 125 p.p.m. 4th dose.

TABLE VI.—*Effect of Increasing the Grease Content of Sewage on the Percentage of Grease Destroyed and Percentage of Grease in the Sludge*

| | Normal Grease Content | | | | With Grease Added | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st Dose | | 4th Dose | | 1st Dose | | 4th Dose | |
| | Destroyed, per cent | In Sludge, per cent | Destroyed, per cent | In Sludge, per cent | Destroyed, per cent | In Sludge, per cent | Destroyed, per cent | In Sludge, per cent |
| Initial | — | 5.6 | — | 6.7 | — | 5.6 | — | 12.2 |
| After 2 hr. aeration | 13.3 | 6.5 | 0 | 8.0 | 17.9 | 8.8 | 7.3 | 13.6 |
| After 4 hr. aeration | 25.0 | 5.7 | 13.5 | 7.2 | 20.0 | 9.4 | 20.6 | 12.1 |
| After 6 hr. aeration | 13.5 | 6.2 | 23.8 | 6.2 | 21.6 | 8.8 | 27.1 | 11.0 |

containing nearly twice as much grease. The percentage grease destroyed was not affected by the high grease content of the sewage. Therefore, the additional grease that could not be destroyed was stored up in the sludge.

The effect of laundry waste on the distribution of grease in the activated sludge process was next investigated. The laundry waste was obtained from a state institution and contained break, soap, and two rinses. Twenty-five per cent of the waste, by volume, was added to sewage. This was mixed with activated sludge. The control consisted of an equal volume of sewage and sludge without addition of waste. The initial suspended solids concentration was 1,550 p.p.m. Seven dosings were made on a fill-and-draw basis with two 6-hour aeration periods during the day and one 10-hour aeration period during the night. Occasionally, sludge was wasted to maintain the initial suspended solids concentration. Results of grease determination made during the first and seventh doses are given in Table VII.

Table VII.—*Effect of Laundry Waste Added to Sewage on Activated Sludge and Grease Balance*

| | Sewage Alone | | | | | | Sewage and Laundry Waste | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st Dose | | | 7th Dose | | | 1st Dose | | | 7th Dose | | |
| | Liquor, mgm. | Sludge, mgm. | Total, mgm. | Liquor, mgm. | Sludge, mgm. | Total, mgm. | Liquor, mgm. | Sludge, mgm. | Total, mgm. | Liquor, mgm. | Sludge, mgm. | Total, mgm. |
| Before mixing | 76 | 109 | 185 | — | — | — | 122 | 109 | 231 | — | — | — |
| After mixing | 43 | 171 | 214 | 13 | 173 | 186 | 63 | 188 | 251 | 22 | 201 | 223 |
| After 2 hr. aeration | 12 | 184 | 196 | 4 | 140 | 144 | 16 | 220 | 236 | 10 | 182 | 192 |
| After 4 hr. aeration | 6 | 180 | 186 | 5 | 123 | 128 | 12 | 213 | 225 | 6 | 163 | 169 |
| After 6 hr. aeration | 2 | 170 | 172 | 2 | 120 | 122 | 8 | 181 | 189 | 2 | 136 | 138 |

Sewage grease, 83 p.p.m. Sewage and laundry waste grease, 132 p.p.m.

The results do not show a material retardation in the removal of grease from the liquid by the repeated additions of sewage containing laundry waste. The percentages of grease destroyed and of the grease in the sludge, given in Table VIII, show that sludge was initially slow in oxidizing the grease, but after seven doses, the oxidizing activity was greatly increased. The mixture containing sewage and laundry waste behaved similar to the mixture receiving sewage alone, in respect to the slow rate of oxidation during the seventh dose. During the first dose, the percentage grease in the sludge increased and remained above the initial value in both mixtures, while the contrary was true during the seventh dose, corroborating the evidence that the sludge initially was

Table VIII.—*Effect of Laundry Waste Added to Sewage on the Percentage of Grease Destroyed and Percentage of Grease in the Sludge*

| | Sewage Alone | | | | Sewage and Laundry Waste | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st Dose | | 7th Dose | | 1st Dose | | 7th Dose | |
| | Destroyed, per cent | In Sludge, per cent | Destroyed, per cent | In Sludge, per cent | Destroyed, per cent | In Sludge, per cent | Destroyed, per cent | In Sludge, per cent |
| Initial | — | 6.8 | — | 9.6 | — | 7.1 | — | 10.8 |
| After 2 hr. aeration | 2 | 11.5 | 21.5 | 7.7 | 2 | 14.4 | 13.9 | 9.8 |
| After 4 hr. aeration | 7 | 11.3 | 31.2 | 6.8 | 6 | 13.9 | 24.2 | 8.8 |
| After 6 hr. aeration | 14 | 10.6 | 34.4 | 6.6 | 21 | 11.8 | 38.1 | 7.3 |

non-reactive in respect to grease, but with repeated dosings, the activity of the sludge was increased. There was no evidence that the laundry waste affected inimically the normal distribution of grease.

It was realized early in this work that results obtained might be influenced by the exigencies necessitated by the laboratory nature of the experiment. Specifically, the factor of large air supply in relation to volume of liquid treated, as pointed out in an earlier work (3), might obliterate some of the minor differences expected. Since it was not possible in these experiments to reduce the volume of air in relation to the quantity of liquid treated, it was thought as an expedient to reduce the aeration period to exaggerate and bring out these differences. Thus, in the following experiment, 1 and 2-hour aeration periods were used with repeated dosages of sewage on a fill-and-draw basis. The results (Table IX) show that, with a 1-hour aeration period, the removal of grease was affected adversely, and with repeated dosings the grease content of the liquor increased. Similarly the grease content of the sludge increased from an initial value of 3.8 per cent to 12.1 per cent at the end of the fifth dose. The grease content of the liquor and the sludge with a 2-hour aeration period was similar to that with a 1-hour period, both at the end of the third dose.

Table IX.—*Effect of Short Period of Aeration on Grease Transformation in the Activated Sludge Process*

| | 1-Hour Aeration Period | | | | 2-Hour Aeration Period | | | |
|---|---|---|---|---|---|---|---|---|
| | Liquor | Sludge | Total | Grease in Sludge | Liquor | Sludge | Total | Grease in Sludge |
| Before mixing | 76 | 66 | 142 | 3.8 | 76 | 66 | 142 | 3.8 |
| After mixing | 40 | 123 | 163 | 7.1 | 40 | 123 | 163 | 7.1 |
| After 1st dose | 28 | 145 | 173 | 8.3 | 22 | 142 | 164 | 8.1 |
| After 2nd dose | 33 | 186 | 219 | 10.3 | — | — | — | — |
| After 3rd dose | 20 | 216 | 236 | 11.4 | 25 | 231 | 256 | 11.3 |
| After 4th dose | 45 | 235 | 280 | 11.3 | — | — | — | — |
| After 5th dose | 42 | 255 | 297 | 12.1 | — | — | — | — |

Grease in sewage, 85 p.p.m.

## Discussion

The changes that occur in the distribution of grease during the aeration of sewage with activated sludge may be viewed from two aspects, namely, (*a*) the amount of grease remaining in the liquor, which is a measure of the purification effect in respect to grease and (*b*) changes in the grease content of the sludge, which indicate changes in the condition of the sludge. These two aspects of the activated sludge process are intimately related, yet distinct. The purification is dependent on the condition of the sludge, yet the sludge can undergo profound physical, chemical, and biological changes with practically equivalent purification.

Confusion in the proper understanding of the process arises from the fact that our primary and most reliable yardstick of the process is the purification effected, which is generally uniform except under very unusual conditions. We have no adequate yardstick for measuring the condition of the sludge. It is true that the sludge index, the ash content, nitrifying power, and the B.O.D. of the sludge and the microscopic examination, give some information regarding the condition of the sludge but these tests are at present not sufficiently delicate and are not adequately correlated with different types of sludge.

The activated sludge is a generic name embracing a number of varieties of processes. The common earmark for all the varieties is that they consist of a biological community which requires oxygen for existence. The biological community is complex and variable in nature. Various liquid wastes are highly purified by aeration in the presence of these biological communities.

The results presented in this paper illustrate the above concepts. The removal of grease from the liquid phase was uniform and complete under the various extreme conditions employed in this study, with the exception of repeated dosings at 1 or 2-hour intervals. The uniform and complete removals of grease from the liquid took place in spite of profound changes in the grease content of the sludge.

Valuable information has been obtained, however, in regard to the fate of grease in the activated sludge process and the mechanism of its removal.

Evidence shows definitely that grease is adsorbed rapidly from the sewage. In fact, considerable removals have been obtained by merely mixing the sewage with the sludge and allowing it to settle. What has been removed from the liquid phase has been recovered quantitatively, within the limits of experimental error, in the sludge. When aeration is started, the adsorption of the grease continues but destruction and oxidation begins to act, at first slowly. As the quantity of grease in the liquid phase decreases, the adsorption loses its momentum and oxidation of the adsorbed material comes to play an important role. This constitutes the recovery or the regeneration stage, in which the sludge is restored toward its original grease content, and the floc is prepared for additional adsorption when sewage is again added. If sewage is added before destruction of the adsorbed grease and restoration of the original grease content of the sludge, the adsorption of the grease from the sewage is not complete and the oxidation of the adsorbed grease in the sludge is not sufficiently rapid. The result is an increasing percentage of grease in the sludge, or in general an overloaded and overpowered sludge which has lost its adsorptive efficiency.

Several factors influence this general sequence of events. Of these, aeration time and sludge concentration, in addition to air supply and aeration efficiency discussed above, are important. When a sludge has adsorbed more grease than it is capable of oxidizing within a specified period of aeration, prolonging the aeration period brings it back to the initial grease content. In fact it is possible with protracted periods of aeration to destroy the grease in the sludge to a value below the initial content. It appears that when the freshly adsorbed and more available grease is exhausted the organisms begin to destroy the older and more resistant accumulations of grease in the sludge.

Under similar conditions, maintenance of higher suspended solids concentrations brings about a more rapid restoration. Grease does not accumulate in the sludge phase to an appreciatable degree, but is oxidized as soon as it is adsorbed. Thus with a given sewage, representing a definite load, there is a very intimate relation between the time of aeration and sludge concentration for the maintenance of balanced conditions. When the food concentration is high, maintaining a high suspended solids concentration will tend to restore the sludge within a fixed aeration period, provided the oxygenation capacity is adequate. The grease content of the sludge will be determined by the grease content of the sewage, the aeration period and sludge concentration. There will be an equilibrium established between these factors which will determine the grease content of the sludge at different plants. It appears, however, that a grease content in the sludge in excess of 10 per cent indicates an unbalanced condition.

In this discussion, the grease content of sewage has been assumed to be indicative of the total load. In other words, as the grease content of sewage increases the other ingredients also increase, although not always in the same rate and hence the total load is increased and vice versa. There is the possibility that grease in general, or certain types of grease, are less readily available than the other ingredients of sewage and hence may exert a specific effect in addition to the load factor. The present investigation was not designed to differentiate between the rate of availability of different types of greases and of the other ingredients of sewage. However, evidence shows a considerable rate of destruction of grease within a relatively short period of time by activated sludge. Incidentally, there are indications that different sludges may have different initial capacities for adsorbing and destroying grease and that this capacity can be enhanced by repeated additions of sewage.

The question of the effect of grease in sludge bulking cannot be answered definitely. Determinations made in conjunction with the various experiments failed to show any increase in the sludge index due to the experimental treatments with repeated additions. This is not surprising since as it has been shown before (4) in order to produce bulking under laboratory conditions, the air supply has to be cut down to a critical value. Dilution of the air with nitrogen gas and aerating with definite quantities of this gas mixture was found to be one way of reducing the quantity of oxygen supplied and at the same time keeping the sludge in suspension. Such a procedure, however, was inconvenient when aerating 40 liters of activated sludge mixtures, which was necessary to obtain sufficient volume of samples for grease determinations. As stated before, the aeration in these experiments was accomplished by passing a sufficient quantity of air to keep the sludge in circulation. The failure to obtain bulking could therefore be attributed to use of a large amount of air. It would be interesting to find out whether grease has a specific effect on sludge bulking or whether it is a part of the total load factor.

## Summary and Conclusions

Experiments were conducted in the laboratory with activated sludge and sewage mixtures under various conditions. An attempt was made to study the progressive change of the grease content in the liquid and sludge phase of the mixtures, with single or repeated additions of sewage. The following conclusions may be drawn:

1. Mixing of sludge and sewage, followed by settling of activated sludge, results in considerable removals of grease from the liquid phase and recovery in the sludge phase.
2. Adsorption plays a major role in the removal of grease from sewage during the early period of aeration. As the quantity of adsorbable grease in the liquor decreases the rate of adsorption decreases.
3. Oxidation and destruction of the adsorbed grease proceeds somewhat slowly in the beginning of aeration but accelerates rapidly on continued aeration.
4. The percentage of grease in the sludge increases during the early period of aeration and then decreases to the initial value with sufficiently long aeration periods.
5. If the grease content of the sewage is high more material is adsorbed, the sludge has a higher grease content and will require a longer aeration period to restore the initial grease content.
6. With high suspended solids concentration, the accumulation of grease in the sludge phase is not great. Oxidation proceeds more rapidly to restore the initial grease content of the sludge.
7. Repeatedly dosing the sludge with sewage with short periods (one to two hours) of aeration brings about a reduction in the efficiency of adsorption of grease leaving relatively larger quantities of grease in the liquor and increasing the percentage of grease in the sludge.
8. Laundry waste, up to 25 per cent of the sewage by volume, did not exert any deleterious effect on the removal of grease from liquor and oxidation of grease, under the experimental conditions.
9. Bulking could not be produced under laboratory conditions by the various factors employed in this study.

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# Stream Pollution

## MATHEMATICAL FORMULATION OF THE OXYGEN SAG

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In a recent article on this general subject (1) (p. 551) the statement is made, "As far as we know, no method has been published by which the variation in the oxygen deficiency in a stream can be mathematically computed when consideration is taken also of the oxygen consumption of the bottom sludge." Yet the same article refers to publications of Streeter (2), (3) in which, as it seems to the writer, a method is given for doing this very thing—not, perhaps, with the completeness of the highly complex formulation of the first article referred to (1), but in a simple and practicable manner. In the present article, the writer will analyze the method of Streeter and the assumptions on which it is based, he will propose one small change to make the formula slightly more general in application (but will not add to the number of terms in the equation) and he will show how a graphical method (4) already partly developed may be employed to facilitate the use of the equation and he will suggest other applications.

In reference (3) (p. 545) Streeter uses a method for the estimation of the reaeration constant $k_2$ which consists in effect of two parts: (*a*) the substitution of actual known experimental values of $L_a$, $L$, and $t$ in the equation:

(1) $$L = L_a\, 10^{-(k_1+k_3)t}$$

to get $k_1 + k_3$ (which he finds in his example to be 0.120); (*b*) the substitution of this value $(k_1 + k_3) = 0.120$ in the equation:

(2) $$D = A\, 10^{-(k_1+k_3)t} - B\, 10^{-k_2 t}$$

where

$$A = \frac{k_1 + gk_3}{k_2 - k_1 - k_3} \qquad \text{and} \qquad B = A - D_a$$

to get $k_2$. He has assumed $g$ to be unity. (Actually in Streeter's article the symbol $k_1$ is used in place of $(k_1 + k_3)$ and $g$ does not appear; nevertheless, his method is consistent with the formulation just given.)

In this form the equation allows for the removal by sedimentation and adsorption of oxidizable matter from the stream water and for various degrees of deoxygenating effect thereon of the deposited sludge as will now be shown.

In order to understand the significance of the constants appearing in this equation a brief derivation is required.

Notation: (similar to that used by Streeter)

$t$ = Elapsed time in days.
$L$ = Oxidizable matter in the water as measured by first stage B.O.D.
$L_a$ = Value of $L$ when $t = 0$, *i.e.* at the beginning of the process or section of stream under consideration.
$O$ = Dissolved oxygen in the stream.
$O_s$ = Dissolved oxygen that would be present if the water were saturated with oxygen.
$D = O_s - O$ = Oxygen deficiency.
$D_a$ = Value of $D$ when $t = 0$.
$K_1 = 2.303\, k_1$ = B.O.D. constant *i.e.*

Proportional change in oxidizable matter, $L$, per unit time caused by biochemical action, defined by

$$-\left(\frac{dL}{L} \Big/ dt\right)_B = K_1.$$

$K_2 = 2.303k_2$ = Reaeration Constant *i.e.* Proportional change in oxygen deficiency, $D$, per unit time caused by reaeration defined by

$$-\left(\frac{dD}{D} \Big/ dt\right)_R = K_2.$$

$K_3 = 2.303k_3$ = Sedimentation and adsorption constant *i.e.* Proportional change in oxidizable matter, $L$, per unit time caused by sedimentation and adsorption defined by

$$-\left(\frac{dL}{L} \Big/ dt\right)_s = K_3.$$

$g$ = ratio of the rate of utilization of the dissolved oxygen of the stream by the deposited sludge at any point to the rate of removal of oxidizable matter by sedimentation and adsorption at that point.

NOTE: Values for $L$, $L_a$, $O$, $O_s$, $D$, $D_s$ may be in any consistent system of units. Streeter sometimes uses parts per million and, sometimes, thousands of pounds per day. But all terms must be in the same units. $K_1, k_1, K_3, k_3, K_2, k_2$ have the dimension day$^{-1}$ or $\frac{1}{\text{day}}$. $g$ is dimensionless.

## Derivation of Equations

Assuming that the total proportional change in $L$ per unit time $\left(\frac{dL}{L} \Big/ dt\right)$ is $-(K_1 + K_3)$, or

$$\frac{dL}{dt} = -(K_1 + K_3)L \tag{3}$$

equation (1) follows by simple integration. Then assuming that the total actual rate of change in $D$, $dD/dt$, is equal but opposite in sign to the corresponding rate of removal of oxidizable matter of the water by biochemical action (*i.e.* $K_1L$) plus the rate of removal of oxygen by the sludge from the water taken as $g$ times the rate of removal of oxidizable matter by sedimentation and adsorption (*i.e.* $gK_3L$) minus the rate of reaeration (*i.e.* $K_2D$) one obtains the differential equation:

$$\frac{dD}{dt} = (K_1 + gK_3)L - K_2D \tag{4}$$

Equation (2) follows by substituting for $L$ its value from (1), multiplying by the factor $e^{K_2t}$, and noting that the resulting equation is exact and then integrating and evaluating the constant of integration and slightly rearranging the terms.

## Discussion of Assumptions Made in the Derivation

The concepts of $K_1$ and $K_2$ are substantially the same (though somewhat differently stated) as those of Streeter. The definition of

$$K_3 = -\left(\frac{dL}{L}\Big/dt\right)_s$$

may need some explanation. Suppose for the moment that $K_3$ is determined wholly by sedimentation. It is here assumed in effect that a constant fraction of the oxidizable matter present in the stream is in the suspended state and that continuous mixing of the suspended matter with the water occurs in such a way as to cause the sediment to be removed at a rate proportional always to the amount present. Using a familiar proposition No. 6 from Hazen (5) (p. 51) it is possible to show (on the assumptions of the proposition) that $K_3$ is equal to the product of the hydraulic subsiding value of the settling matter and the fraction of $L$ which is oxidizable settling matter, all divided by the depth of the stream. The assumptions of the proposition are so uncertain as to make this conclusion doubtful, yet the main implication of the proposition seems plausible, namely that rate of sedimentation is substantially proportional to the amount of suspended matter present. If it be objected that the heavier and larger particles settle out first, thus constantly diminishing the rate of settling of the remaining particles and the fraction of the total $L$ which is sediment, it may be pointed out that biological activity is constantly changing dissolved oxidizable matter into the suspended state and coagulation is increasing the size of the small particles. Though some experiments appear to show differently it would seem to the writer that the rate of oxidation of the dissolved matter would proceed at a faster rate than that of the suspended particles remaining in the stream water. These effects would tend to increase settling velocities and/or the proportion of the total oxidizable matter remaining as suspended matter in the stream water. It is possible, therefore, that all these effects would combine to make $K_3$ nearly a constant and thus yield the relation which has been assumed;

namely that the rate of removal of oxidizable matter by sedimentation and adsorption is directly proportional to the amount of oxidizable matter, $L$, present.

In any case if the average value of $K_3$ is small, the assumption of constancy will introduce but slight error into the resulting equations.

It is further assumed that the laws relating to the removal and oxidation of adsorbed matter are the same as those assumed for settled matter and, therefore, that $K_3$ is, as it were, the sum of the sedimentation and adsorption constants.

To summarize what has just been said: in the equation (1) it is assumed that the proportional rate of change of the oxidizable matter present is a constant throughout the region of the stream to which the formula is to be applied. Therefore the formula would not strictly apply to a stream in which a fixed part of the original organic matter is removed or oxidized at one rate, another fixed portion at another rate, and another at another, etc., nor when multi-stage oxidation takes place, nor when the original settleable matter, only, is removed by sedimentation and nearly all of this just below the beginning of the stream section under consideration. Yet it might happen in any given stream that the several kinds of removal of oxidizable matter actually taking place should, in the aggregate, follow substantially the assumed law. Fortunately it is easy in any given situation to determine whether the assumption holds or not: if a plot of the value of $L$ versus $t$ on semi-log paper is a straight line, the law holds; if not the law does not hold and a more elaborate formulation must be resorted to for completely satisfactory results or else the stream must be divided up into larger number of sections along each one of which the plot of $L$ against $t$ is a nearly straight line. (For example, the upper or corrected curve of Fig. 3 (p. 260) of Reference 2 appears to the writer to be substantially straight from the left end of the chart through four points to the sixth point marked Chillicothe. From there on separate formulations would be needed for each stretch of the river between adjacent stations and possibly even more since the data do not prove the lines to be straight as drawn.)

The rest of the derivation follows along familiar lines except for the introduction of the factor, $g$. Streeter has implied that $g$ is unity for steady or long time conditions in a stream. Fair has stated (6) (p. 1225) that the oxygen used in the decomposition of oxidizable matter in deep sludge blankets on the bottom of streams may be only half as much as it would otherwise be owing to the anaerobic process of decomposition which takes place. This suggests that $g$ may be 0.5 for steady conditions or for the averages of long time records in a stream. Of course when sediment is suddenly introduced into an otherwise unpolluted stream and the sludge blanket accumulates much more rapidly than it decomposes then $g$ would be temporarily much lower than 0.5, or when heavy loading of the stream suddenly ceases, $g$ might be more than unity. In a sedimentation basin where the sludge is continuously removed $g$ might be zero.

Thus it would appear that the introduction of $g$ into the equation provides a potentially useful flexibility making the equation more adaptable to unsteady conditions in the stream or to short time records and to steady conditions in streams in which considerable anaerobic decomposition takes place in the sludge blanket, or even to artificial processes of sewage treatment.

## Graphical Methods for Facilitating the Use of the Equation

In reference (4) the author with F. Farr, Jr., presented a graphical method for dealing with equations of the type of (2). This method consists in plotting two lines, one for each of the two right hand terms of equation (2) on semi-log paper verses $t$ as abcissa as shown on Fig. 1 and obtaining $D$ at any value of $t$ by subtracting the values of the corresponding ordinates of the two lines. The slope of the first right hand term is $(k_1 + k_3)$ with plus or minus sign depending upon the direction of the scale of the ordinate. It is the slope of $L$ versus $t$ plotted on semi-log paper, as can be seen from the form of equation (1). The slope of the second right hand term of equation (2) is $k_2$, the reaeration constant. The value of the ordinate (when $t = 0$) of the first right hand term is the value of $A$ and the value of the second term (when $t = 0$) is the value of $B$. For the use of the method in evaluating $D$ in successive portions of the stream between sewer outfalls the reader is referred to the original article (4).

How may the constants of equations (1) and (2) be evaluated from actual data? In reference (3), p. 545, Streeter has shown how to determine $k_2$ and $(k_1 + k_3)$ when $g = 1.0$. (Note here Streeter's $k_1$ is our $(k_1 + k_3)$.) But if $g$ is not unity then the graphical method already referred to becomes of value.

The use of the method involves the following operations:

(*a*) Plot experimental values of $L$ at various points in the section of stream or process against $t$ as abcissa on semi-log paper (shown as Line I on Fig. 1). The slope of the straight line so obtained is the value of $-(k_1 + k_3)$ or simply of $(k_1 + k_3)$ when the *vertical scale is reversed* as in the author's example cited above. The first right hand term of equation (2) is everythere $L$ times $A/L_a$ in equation (2).

(*b*) Therefore plot this term $LA/L_a$ shown as Line II on Fig. 1 as a straight line parallel to the line representing $L$ and with a trial value of the constant, $A$.

(*c*) Above chosen positions along this trial line plot points representing the second right hand term of equation (2) shown as Line III on Fig. 1. The readings of these ordinates should be made less than the corresponding readings on the lower line by the known experimental values of $D$, the oxygen deficiency, at these points. Now if the trial value of the constant, $A$, were correctly chosen for this plotting, then the resulting line should be straight as it is on Fig. 1. But, in general, by this method the preliminary trial value would not be correct and therefore would not yield a straight line.

(*d*) In that case replot both terms using a new and better value of the constant $A$. (Replotting of the first term consists merely in moving the straight line up or down on the paper parallel to itself.) Repeat if necessary until finally a plotting of the second term is obtained which is sub-

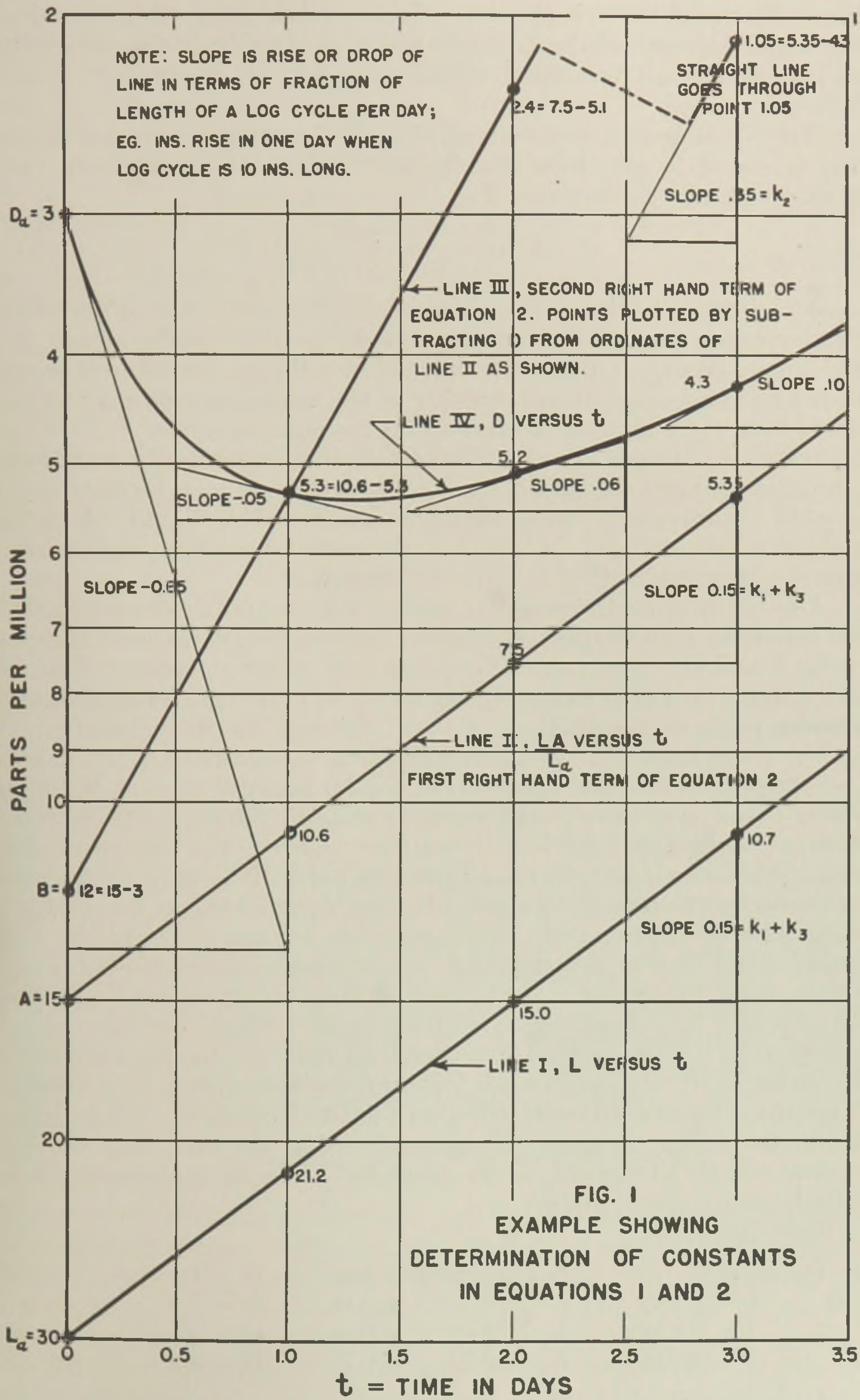


FIG. 1
EXAMPLE SHOWING DETERMINATION OF CONSTANTS IN EQUATIONS 1 AND 2

stantially straight. $k_2$ is the slope of this straight line. $A$ is the value of the initial ordinate of the first line and $B = A - D_a$ is the value of the initial ordinate of the second. Thus equation (2) in the form given is fully determined.

But if it is desired to obtain all the other constants certain difficulties may be encountered. Note that the method up to this point yields values of $k_2$, of $A$ and therefore also of

$$A/L_a = \frac{k_1 + gk_3}{k_2 - k_1 - k_3}$$

since $L_a$ is known, also of the slope of the first term $= k_1 + k_3$. These two equations are insufficient to evaluate the three unknowns $k_1$, $g$, $k_3$ which they contain. But if the value of one of these (as either $g$ or $k_1$) is known or is assumed, then the value of the remaining two may be computed from the equations as shown in subsequent example.

It may be pointed out that the so-called odeeometer (7) or somewhat similar instrument developed by D. Bloodgood (8) may be employed to give the instantaneous rate of oxygen utilization of the liquid. From this and the known value of $L$, $k_1$ may be computed directly by the equation: rate of oxygen utilization $= K_1L = 2.303k_1 L$.

Another method theoretically correct for evaluating the constants of the equations is to utilize the slopes of both plotted experimental curves, *i.e* for $L$ and $D$. From the differential form of the equation (1), namely (3), it appears that the slope of the curve of $L$ versus $t$ when plotted on semi-log paper as suggested above is a constant and is the value of $k_1 + k_3$ and from equation (4), the differential form of equation (2), it is evident that the slope of $D$ versus $t$ plotted on semi-log paper is $(k_1 + gk_3)L/D - k_2$ where $L$ and $D$ are the instantaneous values at the point. (The sign is reversed when the direction of ordinate is reversed.) Knowing these values and the slopes mentioned for two points it is easy to determine algebraically the remaining constants $k_2$, $g$, $k_1$ provided, as before, one of these is known or assumed. Average values for any given section of the stream could then be determined from the computed values from pairs of points along the section. This method does not involve a cut-and-try solution but it is sensitive to drafting table errors. Perhaps the best scheme is to use the method just described to determine the constants of the terms $A\ 10^{-(k_1+k_3)t}$, to plot this and then the second term by subtraction of known value of $D$ to make sure that this line is straight. Slight adjustments could then be made if necessary using the first method. This scheme will be illustrated by an example. (The data assumed are not actual experimental values.)

Example:

| | | |
|---|---|---|
| Data $t = 0$ | $L = L_a = 30$ p.p.m. | $D = Da = 3.0$ p.p.m. |
| $t = 1$ day | $L = 21.2$ p.p.m. | $D = 5.3$ p.p.m. |
| $t = 2$ days | $L = 15.0$ p.p.m. | $D = 5.1$ p.p.m. |
| $t = 3$ days | $L = 10.7$ p.p.m. | $D = 4.3$ p.p.m. |

$L$ versus $t$ was plotted on semi-log paper shown as Line I in Fig. 1. The line is straight and its slope is 0.15, so $k_1 + k_3 = 0.15$.

$D$ versus $t$ was plotted on the same paper (shown as Line IV). The curved line was drawn and slopes of tangents to the curve were measured at the four points. The values of the slopes for the four points are respectively:

When $t = 0$, slope $= -.65$; when $t = 1$, slope $= -.05$; when $t = 2$, slope $= +.06$; when $t = 4$, slope $= +.10$

For the first point $\quad -(k_1 + gk_3)\dfrac{30}{3} + k_2 = -0.650$

For the second point $\quad -(k_1 + gk_3)\dfrac{21.2}{5.3} + k_2 = -.05$

Thus $\quad (k_1 + gk_3)6 = 0.60$

So $\quad (k_1 + gk_3) = 0.10$ and $k_2 = .35$

Similarly using data for 2nd and 3rd point $(k_1 + gk_3) = .104$ and $k_2 = .365$

Similarly using data for 3rd and 4th point $(k_1 + gk_3) = .089$ and $k_2 = .321$

*Average Values*

$$k_1 + gk_3 = 0.10; k_2 = .35$$

$$A = \frac{.10 \times .30}{.35 - .15} = 15 \text{ and } B = 15 - 3 = 12$$

When points on Line III are plotted by subtracting values of $D$ from the values of the ordinates of Line II the Line III resulting becomes straight; thus no further adjustments of the line are needed.

If $g = 0$, $k_3 = .05$; if $g = .5$, $k_3 = 0.10$.

If $g = 1.0$, $k_3$ is infinity so $g$ could not be 1 in this example.

## Suggestions for Use of Equation when Applied to Artificial Processes

It is interesting to speculate on the possible use of these equations and methods when applied to artificial sewage treatment processes. Simple relations exist between the values of the constants appearing in these equations and certain commonly used measures of performance and of operation of sewage treatment plants. For example, the percentage removal of B.O.D., $p$, is given by the equation $p = 100(1 - 10^{-(k_1+k_3)t})$, or

$$k_1 + k_3 = -\frac{\log(1 - p/100)}{t}$$

Perhaps $k_1 + k_3$, itself, might prove to be a useful measure of performance of a plant or process for comparative purposes, since it takes into consideration not only the degree of purification effected but also the time required therefor, consequently also size and, indirectly, cost of the unit in which the purification takes place.

Consider the sludge demand of activated sludge as defined and used by D. Bloodgood (9). It is easy to show that sludge demand is equal to $480k_1L$ divided by the suspended matter of the sludge. Thus when

Bloodgood states that the sludge demand should be 50 or less, he is implying that a sludge whose B.O.D. is equal to its suspended matter and which has a value of $k_1$ about equal to 0.1, *i.e.* similar to that of polluted streams, would be (as far as this measure goes) a good sludge.

Is it not possible that $g$ for a trickling filter or contact bed should be kept above a certain high value in order to ensure good performance, that is to say, that very little anaerobic decomposition should take place? $k_3$ for a settling tank might be found useful since it takes account not only of the settling rates of the sludge but also of other important factors that affect settling performance. $k_2$ might be useful to compare performance of aerators. Would equations (1) and (2) applied to a mixture of sludge and sewage in an activated sludge tank serve to define the variation of oxygen deficiency throughout the tank or portions thereof when $k_3$ is placed equal to zero and could $k_2$ be determined therefrom? Would equation (1) applied to the sewage component alone then serve to determine the value of $k_3$ which measures the amount of adsorption of oxidizable matter by the activated sludge? These examples and queries may suggest that the mathematical formulation of Streeter, here only slightly modified, might further be employed to advantage by plant operators who have contributed so notably to the advance of sewage treatment.

## Conclusion

Graphical methods are now available which make it possible to apply the oxygen sag formula used by Streeter with *slight* modification, but with certain limitations, to a stream in which occurs not only biochemical oxidation of organic matter and reaeration but also sedimentation and adsorption and in which various constant proportional rates of oxygen utilization are being exerted by the sludge blanket. These methods constitute a direct (as against a purely cut-and-try) computation of the constants of the equation from appropriate experimental data. The equation and the methods for using it offer the possibility of mathematical formulation of artificial processes of sewage treatment.

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# Industrial Wastes

## INDUSTRIAL WASTE PRE-TREATMENT AT FORT WORTH, TEXAS *

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This discussion deals with packinghouse waste, since that is the major industrial waste received at the Fort Worth sewage-treatment works. In consideration of packinghouse waste it would be well to give a little thought to the production of the wastes. It seems poor management to dump everything promiscuously into a waste, and then devise elaborate equipment to remove these materials when they could have been kept out in the first place.

The final waste coming from a packinghouse will be made up of a number of wastes originating at various sources. Thus there may be,

1. Blood from the slaughtered animals
2. Floor washings and process waters from the killing floors
3. Wastes from wet rendering processes
4. Paunch contents
5. Boiler blow-down waters
6. Sanitary sewage from the employees.

*Blood* will contain no suspended matter, but the total solids, running about 20 per cent, will contain nitrogen equivalent to about 16 per cent ammonia. The B.O.D. of blood is about 100,000 p.p.m.

It will readily be seen that the inclusion of even the smallest amount of blood will make the wastes extremely strong. This blood can be collected separately, dried and sold as a valuable ingredient of fertilizers. The blood, if carefully collected, can be coagulated and made into blood-sausage which is considered quite a delicacy by some persons. It is also used as an ingredient in certain poultry and stock foods. Therefore the exclusion of blood not only is a source of revenue, but quite beneficial to the waste.

*Floor washing wastes* will contain some blood from washing the carcasses, bits of fat and flesh, some grit and quantities of feces and urine. By thorough draining of the blood from the animals, the amount going on the floor can be kept at a minimum. By sending the floor washings through grease traps, quite a bit of inedible fat can be recovered. These wastes usually contain about 3,000 p.p.m. suspended matter and are quite high in B.O.D.

*Wastes from wet rendering* processes, produced during the rendering of lard, tallow and various greases, contain from 3 to 4 per cent solids and are

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rather high in ammonia content. These wastes also contain a quantity of grease, the amount depending on the thoroughness of the skimming. By passing the wastes through settling tanks, the suspended matter can be removed and recovered for use in fertilizers, and the use of grease traps will recover an appreciable amount of grease. By the adoption of dry-rendering processes, the waste from this source can be completely eliminated and valuable nitrogen-containing materials can be recovered for use in fertilizers.

*Paunch contents*, consisting mostly of partly digested solids, add a heavy burden to any treatment plant. From a 1,000 pound beef, we usually obtain about 1.0 cu. ft. of this material weighing about 40 pounds. The material is rather light in weight and will remain mostly in suspension, and unless removed will form heavy scum layers in settling and digestion tanks. Since it consists mostly of partly digested hay and similar materials, it resists digestion and causes no end of trouble. It does not have any appreciable value as a fertilizer, and consequently it has no market value. Most packing plants handle these paunches separately and do not permit the contents to become included in the wastes.

*Boiler blow-down waters* do not contribute to the biological loading of a sewage treatment plant. On the contrary, they are valuable in diluting the stronger wastes, making them more amenable to treatment.

*Domestic sewage* from the employees is usually kept out of trade wastes, although it may occasionally be included. Domestic sewage should tend to dilute the wastes, as the other wastes are usually of higher concentration.

It has been the experience at Forth Worth that the larger the industry the better the quality of waste produced, that is, for the same kind of industry. The larger companies practice economies that the smaller ones do not consider.

Table I shows the character of these wastes:

TABLE I.—*Composition of Untreated Packing House Wastes*

| | Plant A | Plant B | Plant C | Plant D |
|---|---|---|---|---|
| Flow per day—thousand gallons | 2,688 | 62 | 50 | 10 |
| Hog equivalents daily | 11,256 | 428 | 360 | 70 |
| Gal. per hog equivalent | 243 | 145 | 139 | 143 |
| 5-day B.O.D., p.p.m. | 1,294 | 3,740 | 1,716 | 1,923 |
| Suspended solids, p.p.m. | 2,232 | 4,848 | 2,107 | 2,885 |
| Grease, p.p.m. | 248 | 1,742 | 350 | 645 |
| Nitrogen as $NH_3$, p.p.m. | | 20 | 78 | 55 |
| Nitrogen as organic nitrogen, p.p.m. | | 820 | 311 | 278 |
| Lb. B.O.D. per hog equivalent | 2.6 | 4.5 | 2.4 | 2.3 |

NOTE: The term hog equivalent is used to put all animals slaughtered on the same basis. One steer is equivalent to four hogs, one calf equals 0.8 hog, and one sheep or goat is equal to 0.4 hog.

Notice the high B.O.D. of "B" as compared to plant "A," and also the grease content. In plant "A" blood was kept out of the waste, and the plant had numerous grease traps to recover the grease.

There is also a great difference in the amount of water used. Naturally all of these differences affect the character of the waste, and these analyses only serve to show that much can be done to eliminate waste at the source.

It has been demonstrated in actual practice that wastes of this character can be treated in a properly designed treatment plant, so that they may be discharged directly to a receiving water course. There may be instances where the wastes will not require complete treatment, for example where the wastes are introduced into the municipal system. Just what preliminary treatment will then be required will depend on local conditions.

Here is a situation that demands the closest co-operation between the city and the industry, along with a very intimate knowledge of the problem. A municipality should not impose a regulation so strict that it cannot be complied with, neither should the industry be allowed to introduce wastes which adversely affect the operation of a plant or sewerage system and place an unwarranted burden on the city taxpayers, either by increased operation costs or increased plant construction.

Table II shows the composition of these wastes after preliminary treatment.

Table II.—*Composition of Preliminary Treated Packing House Wastes*

| | Results in Parts per Million | | | |
|---|---|---|---|---|
| | Plant A | Plant B | Plant C | Plant D |
| Suspended solids | 256 | 1,710 | 1,390 | 13,323 |
| 5-day B.O.D. | 740 | 2,580 | 1,890 | 1,382 |
| Grease | 221 | 553 | 415 | Not det. |
| Nitrogen as $NH_3$ | | 67 | 47 | 32 |
| Nitrogen as organic nitrogen | | 469 | 237 | 162 |

The treatment given Waste A consists of passing the waste through fine screens having $\frac{1}{8}$ in. openings, and followed by settling for about $1\frac{1}{4}$ hours in a Dorr Clarifier. The treatment is under careful supervision, having full time operators, and systematic sampling to check up on the performance.

In the case of Waste B there are two main portions, each receiving separate treatment. The first of these is the waste consisting of the paunch manure, which is passed through a plain settling tank, and receives about 52 minutes settling. The second portion, consisting of the remaining wastes, is passed through a grease trap providing about 17 minutes detention. These two wastes are then combined and pass through a third plain settling tank which provides about 45 minutes settling.

In distinction from Plant A, this treatment is under a very lax supervision if any at all and very little attention is given to it, and then only when the tanks become so full of material that they overflow.

In Plant C the wastes are again treated separately in two portions. The paunch contents are dumped into a concrete tank so constructed that the liquid portion will drain off and unite with the balance of the water from the killing floor. This then passes off into a catch basin, which acts as a settling tank and provides about 72 minutes detention. It is estimated that about 25 per cent of the total wastes from the plant pass through this tank.

The other portion of the wastes, coming from the sausage room and other processes, and comprising about 75 per cent of the total, passes through a grease skimming basin, where grease is skimmed off, and other materials settling in the bottom are removed. This provides for about 26 minutes detention. The effluent from this grease basin, and that from the catch basin, is then discharged into one line and no further treatment is given. This plant receives a fair amount of attention.

At Plant D no sausage or other products are made; consequently all wastes are from the killing floor. The wastes pass through a combination grease trap and settling tank providing about 19 minutes detention. This plant operates a grease rendering plant, in connection with packinghouse activities.

The average results of analyses include one sample which was taken from the outlet of a grease separating tank, which accounts for the abnormally high suspended solids content. There was considerable grease in this sample but the quantity was not determined. (It would easily reach 5,000 p.p.m.) This plant does not receive the attention it should, hence the high figures. It has been demonstrated that the B.O.D. can be kept down to about 700 p.p.m. by careful attention.

In this paper only the preliminary treatment of packinghouse wastes as practiced at Fort Worth has been discussed, and nothing has been said about the effect of including these wastes in a municipal plant.

A decision to include such wastes should only be made after a most careful and detailed study of the local conditions. Such a study should include the rate at which the waste is produced, the variation in strength throughout the day, the effect on the sewers as to loading and probable disintegration, the cost of treatment to be assessed, the effect on the existing works, and the probable expansion of the industry.

We have found at Fort Worth that the smaller plants have increased their operations two-fold and three-fold since their preliminary treatments were inaugurated, but only in one case has the treatment plant been expanded.

# SANITARY SEWAGE FLOWS FROM INDUSTRIAL PLANTS

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This paper presents data on the variations in volume of flow and the chemical characteristics of the sanitary sewage from a large industrial plant operating three shifts a day. A large amount of information is available concerning the variations in the amount of flow that may be expected from municipalities and the chemical characteristics of municipal sewage. Among others, Calvert (1) has described the hourly variations in sewage from a large city. However, there have been but few reports on the sanitary sewage flows from large industrial plants employing several thousand people. The present tendency to construct very large industrial plants in locations remote from existing sewer facilities increases the importance of available information concerning the flows that may occur on such projects. Klegerman (2) recently reported on sewage flows from certain large war-industry plants.

Recently an opportunity was afforded the authors to obtain data on the sanitary sewage flows from a small arms ammunition plant employing over 6,000 persons. These data are presented here as an additional example of the volume and character of sanitary sewage that may be anticipated from such projects.

## General Description of Plant

The plant at which this study was made consists of various large manufacturing buildings, power house, water softening plant, administration buildings and shops scattered over a large area. The water supply is obtained from a city located several miles away and is softened for industrial use. The industrial waste, sanitary sewage and storm drainage are collected in separate sewer systems and the industrial waste and sanitary sewage flow by gravity to adjacent treatment plants within the area. The plant buildings are liberally provided with sanitary facilities, including shower baths, and several large cafeterias are operated in certain of the manufacturing buildings.

## Method of Survey

A 90-degree V-notch weir was installed at the inlet to the sanitary sewage treatment plant. For seven 24-hour periods, flow readings and samples were taken every 30 minutes and the samples were composited over the 24 hours in accordance with the measured flows. During another 24-hour period, flow readings and samples were taken every 15 minutes and the samples made into 2-hour composites in accordance with the measured flows. These samples were analyzed for suspended solids and 5-day biochemical-oxygen demand.

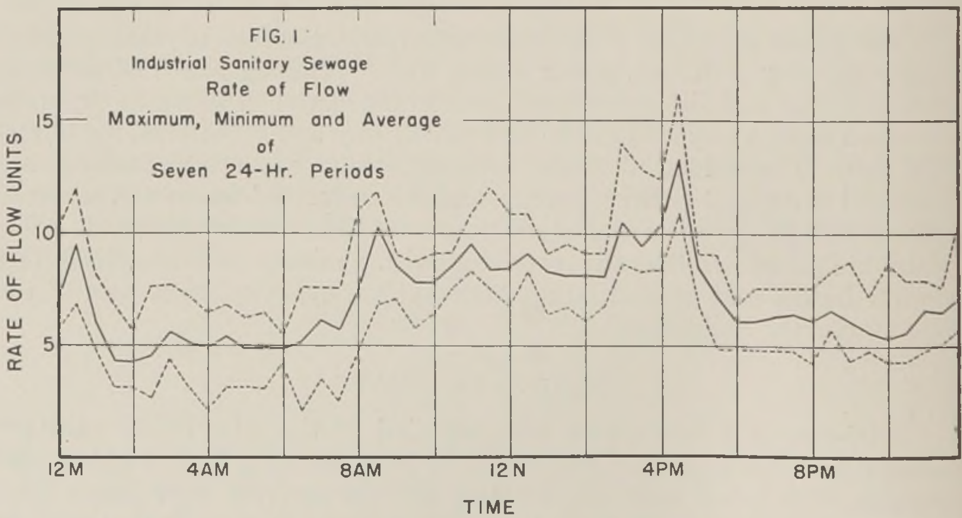
## Results and Discussion

The results of the analyses of the first seven days' samples are given in Table I. It was very evident from the appearance of the sewage that some industrial waste was entering the sanitary sewers, probably from inadvertent cross connections in some of the manufacturing buildings. For

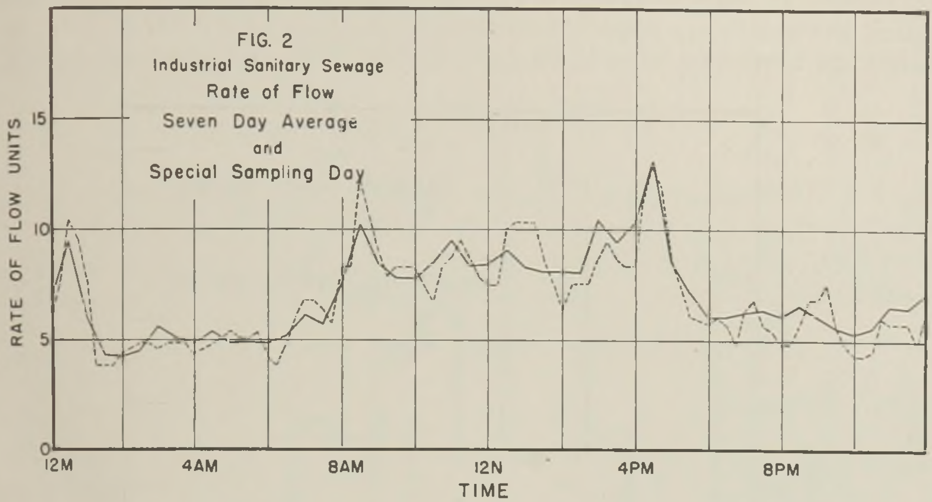
Table I.—*Analytical Results, 24-Hour Composites*

| Period | Flow (Flow Units) | pH | P.P.M. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Methyl Orange Alkal. | Copper | Oxygen Consd. (Dichrom.) | 5-Day B.O.D. | Total Solids | | | Suspended Solids | | |
| | | | | | | | Total | Vol. | Fixed | Total | Vol. | Fixed |
| 1 | 7.35 | 8.4 | 265 | 4 | 251 | 267 | 1120 | 538 | 582 | 330 | 290 | 40 |
| 2 | 7.00 | 8.9 | 264 | 4 | 249 | 243 | 1223 | 623 | 600 | 354 | 270 | 84 |
| 3 | 6.60 | 8.9 | 274 | 3 | 224 | 242 | 1045 | 468 | 577 | 290 | 226 | 64 |
| 4 | 8.30 | 8.8 | 256 | 4 | 185 | 224 | 1035 | 503 | 532 | 292 | 202 | 90 |
| 5 | 6.55 | 8.7 | 264 | 10 | 200 | 274 | 1148 | 471 | 677 | 254 | 182 | 72 |
| 6 | 7.05 | 8.9 | 288 | 4 | 167 | 284 | 1131 | 484 | 647 | 366 | 250 | 116 |
| 7 | 6.65 | 7.7 | 328 | 4 | 184 | 278 | 1185 | 475 | 710 | 360 | 246 | 114 |
| Avg. | 7.10 | 8.6 | 277 | 4.7 | 209 | 259 | 1127 | 510 | 617 | 321 | 238 | 83 |

this reason the samples were analyzed for copper (an important constituent of the industrial waste from this plant), thus permitting an estimate to be made of the amount of industrial waste present. On the basis of the copper content of the sanitary sewage and of the industrial waste it was esti-




mated that approximately five per cent of the measured sanitary flow was industrial waste. The effect of this amount of industrial waste on the suspended solids and the biochemical oxygen demand of the sanitary sewage, as determined, would theoretically be less than two per cent, well within the limits of accuracy of the study. Therefore, the analytical results are reported as determined and no allowance is made for the small amount of industrial waste. The results show that there was comparatively slight variation in the daily flows during the period under discussion and that the sewage could reasonably be compared to a fairly strong domestic sewage.




In Fig. 1 the average, maximum and minimum flows at 30 minute intervals for the first seven days of sampling are plotted. This chart indicates that the daily flow pattern was quite consistent from day to day. This is further indicated by Fig. 2 where the 7-day averages are compared with the flows measured at 15-minute intervals on the eighth sampling day.

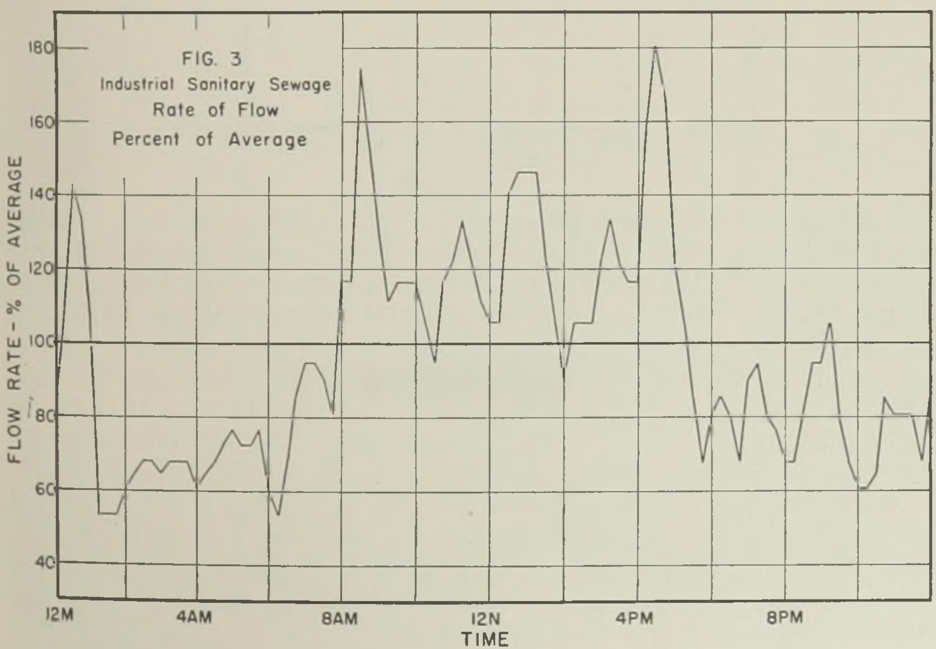
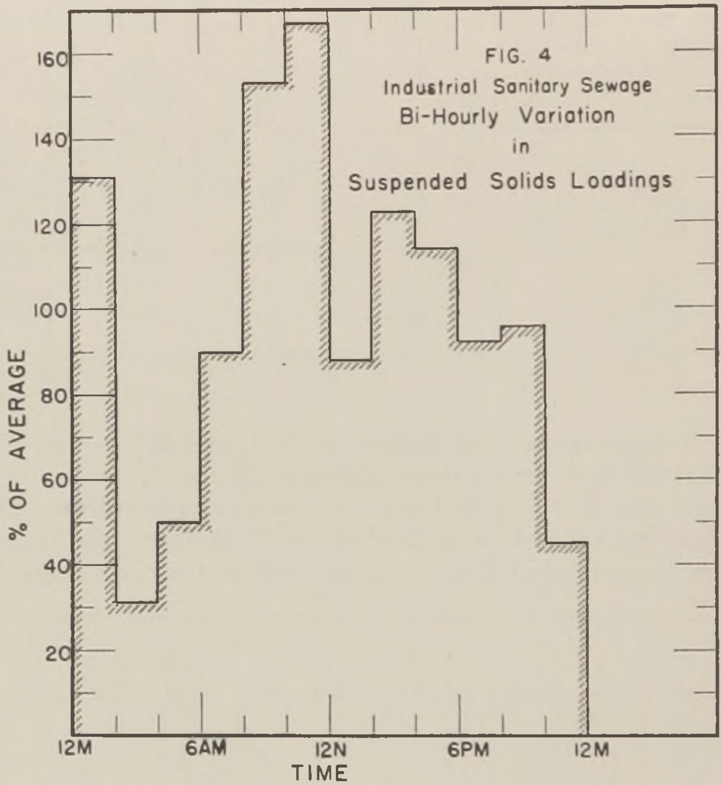


Figure 3 shows very clearly the flow pattern for a 24-hour period. In this figure the individual measurements of rate of flow are plotted as a per cent of the average rate for the day. Major flow peaks are very pronounced at shift change, the maximum flows reaching the treatment plant at 12:30 A.M., 8:30 A.M. and 4:30 P.M. Minor peaks on the curve are noticeable at approximately the lunch period on each shift. Two such minor peaks are very apparent on the 8:00 A.M. to 4:00 P.M. shift. The cafeterias were open from 11:00 A.M. to 1:00 P.M. and personal observa-




tion showed the heaviest loadings on the cafeteria facilities from 11:00 to 11:30 and from 12:00 to 12:30. The plotted peaks correspond very closely to these periods. As would be expected, the heaviest flows occurred on the day shift, because, in addition to any normal day-shift increase in manufacturing personnel, practically all of the administrative section personnel and most of the maintenance forces work only during the day. The 12 to 8 shift included 19 per cent, the 8 to 4 shift 45 per cent and the 4 to 12 shift 36 per cent of the total employees. The relative volume of flow from the different shifts is shown more plainly by Fig. 2 than by Fig. 3.

Figures 4 and 5 show the bi-hourly suspended solids and bio-chemical oxygen demand loadings in weight units as percentages of the day's average. These two figures show the very sharp variations in loading that the treatment plant for such an industrial sewage must be capable of absorbing without detriment to the treatment process.

Except for the period from 2 A.M. to 6 A.M., the strength of the sewage was quite uniform and did not show the characteristic variation of municipal sewage where low night flows are composed of weak sewage. This is indicated by the following tabulation:

| | | | |
|---|---|---|---|
| Shift | 12–8 | 8–4 | 4–12 |
| Flow—per cent of total | 27 | 42 | 31 |
| B.O.D. load—per cent of total | 26 | 40 | 34 |
| Susp. solids load—per cent of total | 25 | 44 | 31 |

The per capita loadings per day are rather surprisingly low. It might be expected that as the personnel are on duty approximately half of their waking hours and one-third of the day, that the loadings would be at least one-third of the loadings to be expected from normal domestic

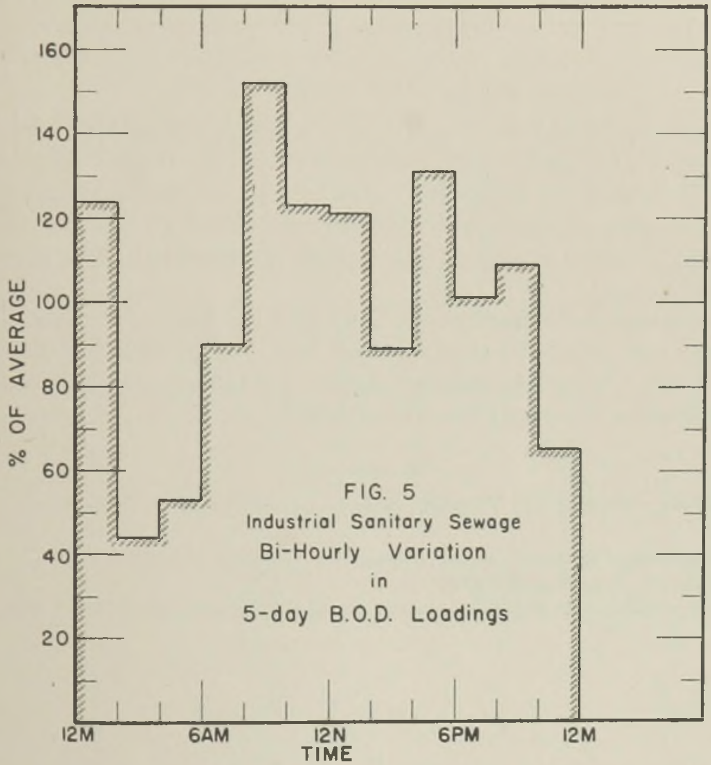



FIG. 5
Industrial Sanitary Sewage Bi-Hourly Variation in 5-day B.O.D. Loadings

sewage. The manual used for the design of sewage facilities in army installations (3) specifies allowances of 30 gallons per capita with 0.10 pound of B.O.D. and 0.13 pound of suspended solids per capita for 8-hour shifts at plant, port and storage projects. The following tabulations show that in this plant the actual amounts are decidedly lower than these allowances.

*Average Sewage Loadings, 7 24-hour Periods. Amounts per Capita*

| Day | Flow—Gals. | B.O.D.—Lbs. | Susp. Solids—Lbs. |
|---|---|---|---|
| 1 | 23 | 0.056 | 0.064 |
| 2 | 22 | .045 | .065 |
| 3 | 21 | .042 | .050 |
| 4 | 26 | .049 | .063 |
| 5 | 21 | .047 | .044 |
| 6 | 22 | .052 | .067 |
| 7 | 21 | .049 | .063 |
| Avg. | 22 | .049 | .059 |

*Sewage Loadings by Shifts. Eighth 24-hour Period*

| | | | | |
|---|---|---|---|---|
| Shift | 12–8 | 8–4 | 4–12 | 24-hr. |
| Flow—gals. per capita | 31 | 20 | 19 | 22 |
| B.O.D.—lbs. per capita | .061 | .040 | .040 | .044 |
| Susp. solids—lbs. per capita | .086 | .063 | .053 | .064 |

## Summary

Data are presented on the sanitary sewage, its volume and chemical characteristics and their variations over 24 hours, from a large industrial plant. The sewage is moderately uniform in strength and may be compared to a rather strong municipal sewage, although the per capita flow and loading is much smaller than would be expected from municipal or residential sewage.

It is recognized that per capita flows and loadings of industrial sanitary sewage may vary with the type of plant and possibly for different plants of the same type. The data presented here are intended only as an example of the conditions that may be encountered.

## References

1. C. K. Calvert, "The Hourly Variation of Indianapolis Sewage." *This Journal*, **4**, 815–820 (1932).
2. M. H. Klegerman, "Sewage Disposal Design for Wartime Industrial Plants." *Engineering News-Record*, **129**, 82–85 (1942).
3. "Engineering Manual." War Department, Chief of Engineers, Washington, D. C.

# THE OPERATOR'S CORNER

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

## FEDERATION MEMBERSHIP

Almost fifteen years have elapsed since the Federation came into existence from a nucleus of seven affiliate Member Associations. These "charter" affiliates represented a total membership of 411 at the end of 1928 and included the following sectional Associations:

Arizona Sewage Works Association
California Sewage Works Association
Central States Sewage Works Association
Iowa Waste Disposal Association
Maryland Water and Sewerage Association
Pennsylvania Sewage Works Association
Texas Sewage Works Association

The remarkable growth of the Federation from this humble beginning to its present position of an international organization is strikingly pictured in the tabulation herewith:

*Annual Membership of Federation Since Organization*

| Year | Number of Member Associations | Membership of Member Associations | | Associate Members of Federation | Total Active, Corporate and Associate Members |
|---|---|---|---|---|---|
| | | Active | Corporate | | |
| 1928 | 7 | 411 | — | — | 411 |
| 1929 | 13 | 1097 | — | — | 1097 |
| 1930 | 15 | 1243 | — | — | 1243 |
| 1931 | 15 | 1325 | — | — | 1325 |
| 1932 | 18 | 1425 | — | — | 1425 |
| 1933 | 19 | 1412 | — | — | 1412 |
| 1934 | 19 | 1468 | — | — | 1468 |
| 1935 | 21 | 1667 | — | — | 1667 |
| 1936 | 25 | 2030 | — | — | 2030 |
| 1937 | 25 | 2327 | — | — | 2327 |
| 1938 | 25 | 2472 | — | — | 2472 |
| 1939 | 25 | 2750 | — | — | 2750 |
| 1940 | 25 | 2819 | — | — | 2819 |
| 1941 | 26 | 2840 | — | 56 | 2896 |
| 1942 | 26 | 2443* | 14** | 58** | 2515 |

* Dues increased from $1.50 to $3.00.
** Corporate and Associate classifications created in 1941.

It is of interest to note that the existence of the Federation has been coincidental with the period of greatest progress in the sewage works field in general; as measured by numbers of municipal treatment works, it is suggested that progress in the field has been proportionate to the membership increase in the Federation. The Federation and its affiliates have been a prime factor in the development of the field and may properly take pride in the advances accomplished.

The year 1942 brought a decrease of 397 active members in the membership of Member Associations, a loss of fourteen per cent from 1941. This loss, though appreciable, is considerably less than had been anticipated would result from the increase in dues which became effective on January 1, 1942, as part of the reorganization which has placed the Federation on a firm, sound financial basis. The greatly expanded field of activity by the Federation, also made possible by the reorganization in 1941, is certain to make the loss a temporary one and to foster future growth.

As to 1943? Strangely enough, the war has appeared to stimulate membership interest and many new members are being added because of their engagement in war time sanitation activities. Early returns for the current year offer promise of an overall increase which may make up much, if not all, of the 1942 membership loss. As of March 31, seven Member Associations had already shown increases over their 1942 totals and three others were "knocking at the door." This is unusual for so early in the year.

The Federation should have at least 4500 active members at this time! If every member in 1942 would retain his own active status and enlist just *one* of his co-workers during this year, that goal would be easily exceeded.

Won't you accept appointment as a "Membership Committee of One" to participate in the further development of your own sectional Association and the Federation?

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## ANNOUNCEMENT

### Membership Prize

To stimulate interest in membership promotion in the Federation's Member Associations, the *individual* who secures, during 1943, the most new Active or Corporate members of the Association to which he belongs will be awarded a $25.00 War Bond. The prize will be awarded as soon as the winner can be determined at the end of the year. Rules governing the award follow:

1. All members affiliated with the Federation shall be eligible to compete *except* officers of the Federation and Directors on the Board of Control. Member Association officers shall be eligible.

2. Only those who have never previously belonged to any Member Association shall be counted as new members.

3. All new members must be in either the Active or Corporate classification as provided in Article II of the Federation's By-laws (see SEWAGE WORKS JOURNAL, **13**, 2, 337, March, 1941).

4. The individual who secures the greatest number of new 1943 members in each Member Association shall be determined by the Secretary of that Association on December 31, 1943. The Member Association Secretary will then furnish the Executive Secretary of the Federation with the name of the entrant and a list of the new members he has secured. Such list of new members shall be subject to revision in accordance with the records of the Federation, as regards compliance with Rule 2 above.

5. All entries must be postmarked not later than January 15, 1944.

6. The prize shall be a $25.00 denomination, Series E, U. S. War Bond. In case of ties, duplicate prizes shall be awarded.

You have plenty of time to win. Get started now!

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## SELECTIVE SERVICE AND SEWAGE WORKS EMPLOYEES

A definite policy as regards the deferment of critical employees in sewage works is expressed in Activity and Occupational Bulletin No. 30, issued by the Selective Service System on March 1, 1943. The Bulletin is reprinted in its entirety herewith:

NATIONAL HEADQUARTERS
SELECTIVE SERVICE SYSTEM

WASHINGTON, D. C.

### ACTIVITY AND OCCUPATION BULLETIN NO. 30 ISSUED: 3/1/43

### SUBJECT: HEATING, POWER, WATER SUPPLY, AND ILLUMINATING SERVICES

#### PART I. POLICIES THAT APPLY TO THIS ACTIVITY

General policies govern this activity.

#### PART II. ESSENTIAL ACTIVITIES

*Engaging in:*

Electric light (utilities)
Gas utilities
Heating services
Power utilities
Steam-heating services (distribution of steam for heating and power purposes)
Tree trimming for power and communication lines
Water supply and sewerage systems
Water-well drilling

## Part III. Essential Occupations

Accountant, Audit
(Included under this title are those persons who design and install accounting systems for the activity listed above; who assume extensive responsibility for the examination and verification of accounting records and prepare comprehensive financial reports based thereon. It does not include persons who perform routine auditing duties under general supervision such as verifying, checking, etc.)
Armature Winder
(This title covers those persons who install, repair, and wind coils to motors, generators and transformers in electric power systems.)
Auxiliary-Equipment Operator (All Around)
(This title includes only those persons who actually control and adjust boiler and turbine auxiliary equipment such as condensers, fans, pumps, and pulverizers. It does not include such occupations as oilers and wipers.)
Bacteriologist
Batteryman, Large Emergency Storage
Blacksmith, Maintenance
Boiler Operator
Boilermaker, Maintenance
Booster-Pump Operator
Bricklayer, Maintenance Refractory
By-Product Operator, Gas
Cable Splicer
(This title covers persons who install, repair, and maintain overhead or underground power cables.)
Carpenter, Maintenance
Chemist
Chief Operator, Water Purification or Softening
Crane Operator
District Serviceman (Electric Power)
Draftsman, Engineering
Driller, Water Well
Electrical Tester
Electrician, System or Plant
Engineer, Professional and Technical
(This title covers persons who are actually engaged as engineers in the operating and research phases of the activity described above, regardless of educational background.)
Engineer, Turbine or Diesel
Foreman
(This title covers foremen who are actually engaged in supervisory duties in connection with the activities described above and who exercise independent judgment and assume extensive responsibility for the services. It does not include laboring gang foremen.)
Gas Equipment and Control Man
Gas Maker
Heavy Mobile Equipment Operator (Maintenance and Construction)
(This title covers persons who operate and make minor repairs to one or more of the following types of equipment (ditching machines, hole diggers, pole-raising devices, winches, etc.), for the activities specified above. It does not cover truck drivers or tractor drivers.)
Inspector
(This title covers persons who are responsible for inspection duties involving standards of operating efficiency, safety, specifications on construction, etc., to insure the continued uninterrupted services specified in this list.)
Instructor, Training Program
(This title covers only those persons engaged in the occupations included in this list who, because of their skill and experience, are detailed as instructors in an established training program.)
Lead Burner
Lineman
Load Dispatcher, Power or Gas
Machinist, Maintenance
Manager, Employment and Personnel
Mechanic, Maintenance
Meter Repairman, Gas and Water
Patrolman, Transmission Line
Piper Fitter, Maintenance
Purification Operator, Gas
Pusher Man
Radio Technician
Rigger, Construction
Rigger Supervisory, Underground Cable
Sheet-Metal Worker, Maintenance
Storekeeper, Chief
(This title includes those persons responsible for the operation of a store, department, or major subdivision. It does not include such persons as stock clerks, bin clerks, or stock-handlers.)
Substation Operator
Superintendent or Manager (Division, District, Plant and Department)
(This title covers those persons who are actively engaged in supervising directly, or through subordinates, various technical or operating departments in the heating,

power, water supply, and illuminating services. This title covers those assistants who are directly responsible to such managers on a division or district level for the efficient functioning of the technical or operating departments. It does not cover managers or their assistants who are concerned primarily with sales, promotional, legal, tax, clerical, insurance, rate structure, and other aspects of nontechnical or nonoperating activity.)

Switchboard Operator, Power

System Operator (Load Dispatcher)

Tree Trimming Supervisor (Overhead Power Lines)

Welder (All Around)

Although procedures are revised from time to time, the following general routine must be undertaken by the employer to obtain deferment of an essential worker as classified above:

1. When the employee receives his occupational questionnaire, the employer should file Form 42A requesting deferment. The blank form may be obtained from the Local Board and should be returned to that office when filled out. The employee may also further his claim for deferment by attaching to his questionnaire a statement emphasizing the critical nature of his civilian services.

2. If the Local Board denies deferment on the basis of the information submitted as above, the employer will receive a classification notice (Form 59). The employer must then go to the office of the Local Board and sign the appeal form on the back of the employee's questionnaire, or make written request for an appeal, within 10 days of the date of the employee's classification notice. It is suggested that *both* of these actions be taken to make certain of the appeal.

3. In the event that the Appeal Board refuses deferment, the employer is so advised and requested to file a second Form 42A with the Local Board, also to place an order with the local U. S. Employment Service office for a replacement for the employee. If the Employment Service provides a satisfactory replacement within 30 days, the employee is inducted. If no replacement is secured, the Local Board will usually grant deferment. During this 30-day period, the employer may again appeal directly to the State Director of Selective Service for reconsideration of the case.

It must be kept in mind that all deferments are temporary and that consent of the employee is not necessary for deferment to be requested. Co-operation and a proper attitude toward the problems of the Local Board on the part of the employer will nearly always prevent the imposition of a real hardship.

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# OVERHAULING AND REPAIRS TO METHANE GASHOLDER *

By C. George Andersen

*Superintendent, Sewerage and Sewage Disposal, Rockville Centre, N. Y.*

The gasholder at Rockville Centre sewage treatment plant receives its supply of methane gas from eight digestion tanks and has been in

* Presented at the Fifteenth Annual Meeting of the New York State Sewage Works Association, New York City, January 22, 1943.

operation for fifteen years. Indications of corrosion became apparent, which made inspection and preparations for repairs necessary.

The digestion units supplying the methane gas to the gasholder have been described, and maintenance of the units has been elaborated on, in an article published in the May, 1938, issue of *This Journal,* Vol. X, No. 3, "Sludge Digestion and Inspection of Tanks."

Rockville Centre's sewage treatment plant designed by Potts Engineers, was built and put into operation in 1929. The designed capacity is 2.0 m.g.d. and at this writing the plant is taking 2.3 m.g.d. and is doing a very efficient job of treating the sewage. Mechanical vacuum filters, a subsequent addition, were installed in 1933 for further clarification of the activated sludge effluent which discharged into a stream which flows through private property. Considerable "bulking" was

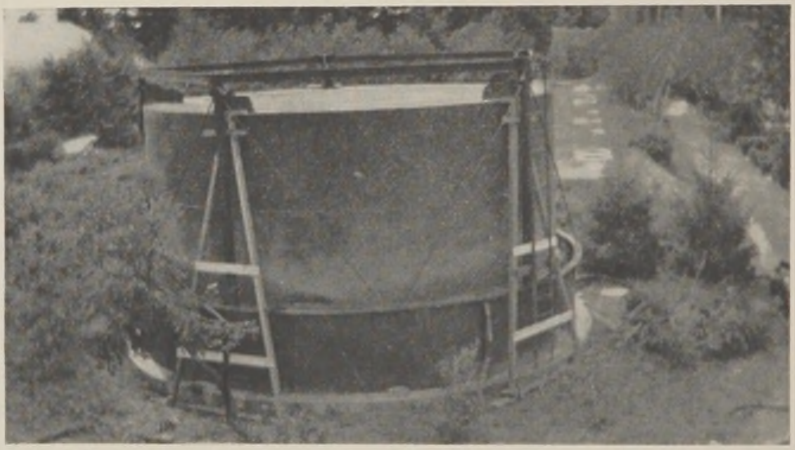

Fig. 1.—Gasholder at Rockville Centre, New York.

experienced at that time but we have been very fortunate in eliminating it in the past eight years. At the time of this installation, a filter was also built for dewatering the waste pulp-paper pulp being used as a filter medium for the clarification process. This filter, using the paper pulp instead of chemicals, dewaters approximately 20 per cent of our total sludge.

The gasholder herein described and shown in Fig. 1, with the digestion tanks in the background, is not large as gasholders go, but operating and maintaining it is nevertheless just as hazardous as handling a larger installation. And having in mind the present prohibition of the use of steel for other than war use, I thought our experience and method of handling the preparation and repair of the gasholder would be of interest to operators and engineers.

The gasholder has a capacity of 5,000 cu. ft. and is composed of two units, the "lift" and the "tank" (Fig. 2). The lift, which is 25 ft. in diameter, is made up of 3/16 in. welded steel sheets, 10.5 ft. high, with a circumference of 78.5 ft. The roof is composed of segments (Fig. 3) which are also made of 3/16 in. metal. The lift moves up and down by the action of the gas and is so designed that its weight gives a gas pressure equal to 4 in. of water without counter weights. The weight of the lift is about 5 tons and when the lift is empty it rests on stops on

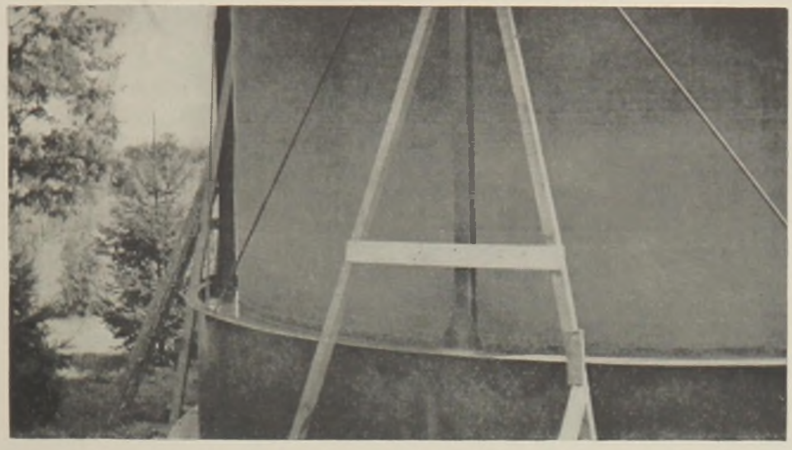

FIG. 2.—View of gasholder at water seal.

the frame and guide posts. The roof rests on a frame made for that purpose (Fig. 3).

The tank is 27.5 ft. in diameter, 85.6 ft. in circumference and 10.5 ft. in depth, and it too is made up of 3/16 in. welded steel sheets set in concrete within 4 ft. of the top (Fig. 1). The total inside surface area of the lift and tank is approximately 2,800 sq. ft.

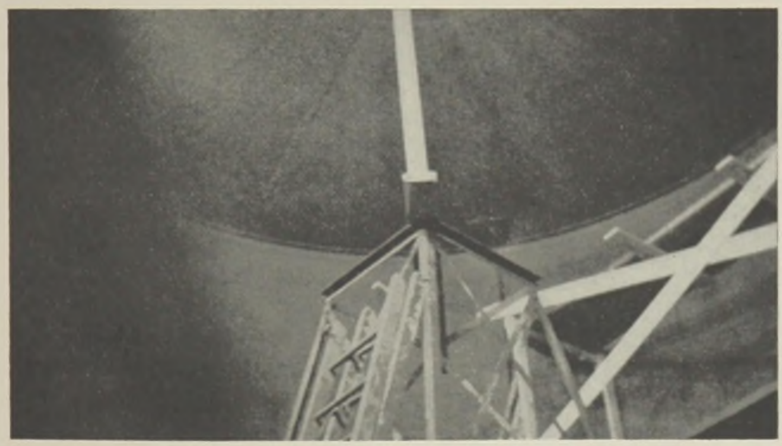

FIG. 3.—Interior of holder. Note segmental roof and center support.

The gas, after leaving the meter, flows to and from the gasholder through 4-in. pipes supplying the gas for operation of heaters and engines. If there is excess gas it escapes underneath the lift when the lift is completely full. A manhole plate with a manual release valve is on the top of the lift. When the gasholder is completely full, the top of the lift is approximately 15 ft. above the ground level, and when empty, the top of the lift is about a foot above the water-seal in the tank.

Procedure in preparing the gasholder for inspection and repair was as follows: The lift was raised to its highest point within the guides by increasing the water level in the tank. This permitted more light to come through when the tank was empty and in that position the whole inside surface could be worked on at one time.

When the lift was at its highest point we proceeded to place wedges between the guide rollers, fixed on top of the lift, and the tank frame, also tied the two together with cable. These were precautions or aids to the A frames that we placed under the five rollers to support or hang the lift (Fig. 1). The A frames were made of 3 by 4 in. timbers. After securing the lift, all gas connections to and from the gasholders were broken. Temporary lines of rubber and pipe were used to convey the gas from the digesters to the gas consuming units. By that installation we removed the gas hazard in the vicinity of our work and saved considerable heat in the operating digesters. In our case it was the saving of dollars because the gas from the utilities is available to us.

With the lift secured and all gas connections broken, the gas release valve on top was slowly opened, releasing gas pressure and testing the security of the supports that were to hold it. Then the water was drawn from the tank. It was necessary for us to raise and suspend our lift in order to repair the sides of the tank, but by doing this we were also spared the fear of possible collapse of the lift when the water had been drawn off. If a gasholder tank is dewatered with the lift down, the lift should be vented by removing plugs or manhole on top; otherwise it will collapse when the water is removed because of the vacuum. An operator understanding the hazards of gas does not need much imagination to realize that at the time of the breaking of the waterseal in this operation, extreme care must be taken. Each step must be planned before execution to prevent trouble. Our method of eliminating the gas quickly from the lift was to remove the manhole plate on top and use a blower to expel the gas. The blower was placed some distance from the bottom of the lift to prevent ignition of the displaced gas.

After the gas had been removed from the lift, an inspection was made of the interior of the lift and the tank. On the bottom there was a deposit of 4 inches of red sludge which gave off poisonous gases on being disturbed and which could not be removed until we operated the blower and then only by men wearing gas masks. Such a deposit of sludge is dangerous in any tank, whether used for sewage or for industrial operations, because of chemical combinations that create poisonous gases. The sludge in our tank had collected over the years from dust, decaying leaves and from the iron corrosion, and recognizable by its well known red color.

On first inspection the tank appeared to be covered with scale and rust. However, after cleaning, the incrustation looked like wormwood

(Fig. 4). The lift was in very good condition, showing only the crumbling of the paint that had been applied originally. The bottom was clean black polished metal.

After the inspection, plans were made to clean, make repairs, and paint. Cleaning the tank was a problem, as investigation had proved that preparation of the metal before the application of paint was essential, and a reasonably sure job could not be done by hand, for hand-scraping and brushing could not clean the incrusted and grooved corrosion present. Sand blasting was decided on as the method of cleaning and we were very fortunate in being able to obtain that service at this time. After the sand blasting the metal showed up as in Fig. 4. Several holes were discovered and marked off. Repairs were made by patching and reinforcing any noticeably weak spots. It was apparent that hand cleaning would not have brought out the defects and to have painted over partially cleaned iron would have resulted in a botch job, a waste of time and money.

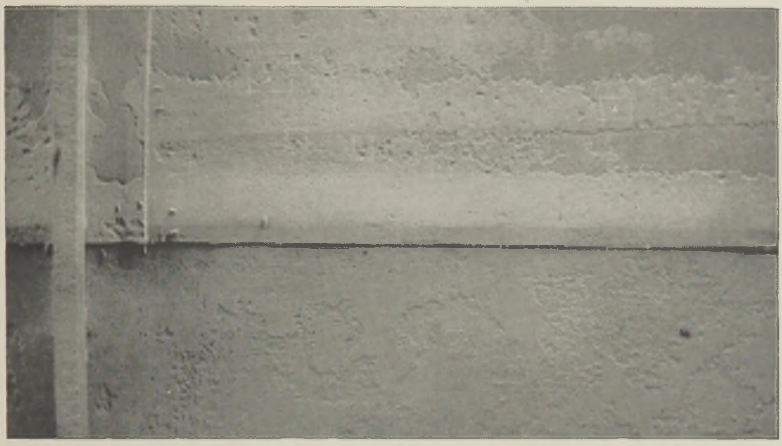

FIG. 4.—Underside of roof after sandblasting. Note pitting and holes marked with chalk.

For painting the inside surface of the lift and tank, we decided on Bitumastic No. 50. A generous first coat was applied and thereafter two coats were painted on. Figure 5 illustrates the manner of patching holes as well as the hard, glossy surface resulting after painting.

When all the repairs to the gasholder were finished, the tank was filled with water and all gas connections were made up, to and from the digesters. The manhole cover on top of the lift was bolted on and the gas release valve was left open. The gas was then allowed to flow to the lift until it became quite rich as it came from the valve, at which time the valve was closed until the lift was under pressure. The lift was then tested for tightness by floating. When it was certain that the lift was tight, all the A frames were removed and the gas release valve was opened to empty the lift—a precaution against possible explosive mixture within, the lift having been full of air when the gas entered. The lift after dropping until empty, was again filled. It then resumed its regular operation.

While the gasholder has given excellent service for fifteen years and will for another five years at least, after these repairs, it is apparent that the life of vessels of this type, and much of our equipment, can be preserved by more frequent inspections and counter-actions against corrosion. We have found by regular periodic tests since repairing the gasholder that there is a very strong acid condition in the "tank" water, and even though lime has been added and the alkalinity is over

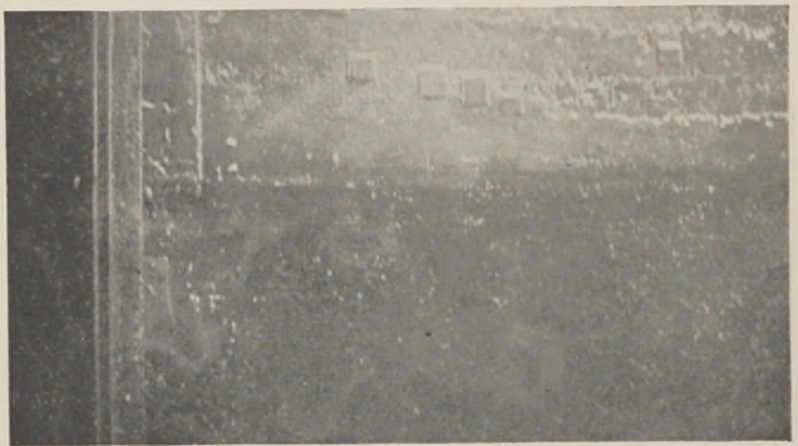

FIG. 5.—Same view as Fig. 4 after patching and painting.

200 p.p.m., the pH remains 5.2. This, we believe, is due in a large degree to the fact that excess methane gas breaks through the water seal, causing absorption of carbon dioxide. Tests have shown that carbon dioxide is 200 p.p.m. Although our tank has been heavily coated with paint, there remains the possibility that crevices will develop in the paint as a result of expansion and contraction of the metal. To counteract that tendency we shall try in some way to decrease the corrosive quality of the water. In my investigation of possible correctives, I have studied F. N. Speller's theory on under-water corrosion and quote some of the material, as follows:

"Iron under water inherently tends to go into solution in the form of electrically charged particles called ions. In order to enter the water, positive ions of some other element must be displaced. In the case of the steel tank, hydrogen ions are plated out on the surface of the tank. The hydrogen ions form a thin invisible film on the iron surface. The film acts as an insulator, protecting the iron from contact with the water and further dissolving action. When the film is destroyed, however, the action proceeds. The film is usually destroyed by the hydrogen combining with free oxygen to form water or by escaping in the form of hydrogen gas. The air bubbles commonly seen on the sides of the corroding tanks are bubbles of hydrogen gas. The greater the free oxygen present, the quicker is the hydrogen film destroyed and the more rapid the rate of corrosion.''

By the application of the bituminous material on the inside surface of our tank and lift, we have isolated the metal from the tank water. However, we are endeavoring to provide chemical treatment as an added precaution.

Knowing that our tank water has a high $CO_2$, or acid content, we are adding sodium hydroxide in solution to increase the pH and preventing as much as possible excess gas from breaking through the water seal.

The cost of repairs was as follows: The cost of labor which was done by our own personnel was estimated at $6.00 per day per man and totaled approximately $400. Materials, tools, lumber, paint, etc., $150—welding and iron work, $55—sandblasting, $420—total $10.25, for 2800 sq. ft., at approximately 36 cents per sq. ft.

Considerable time was spent in getting the scaffolding set up and, as described before, in the hanging of the lift. It was also known as hazardous work which placed a certain responsibility upon us. Because of the hazard, much of the preparations were made by our personnel, and for that reason we decided to undertake the job ourselves. The job took about three weeks. While we were unable to get a contractor to bid on it, estimates averaged over $1,800. It will thus be seen that we effected a considerable saving.

## BARK FROM THE DAILY LOG *

**December 7**—All plant operation problems took a back seat today to the historic news that the Japs had bombed Pearl Harbor. (Today, a year later, the news from the Pacific fronts reveals that this despicable act is being suitably avenged!)

**December 10**—Mailed out a report to the District trustees containing an analysis of the points of vulnerability of the intercepting sewers and treatment works to damage by sabotage, the probable effects of such damage on our service and recommendations for war-time protection. The recommendations covered patrolling of property, improved locking facilities at isolated buildings, additional fire control equipment, control of visitation, etc.

For obvious reasons, the report was kept confidential and given no publicity.

**December 15**—Called on officials of the local fire department to find out something about fire extinguishers. Was advised as follows:

Soda and Acid Type (capacity 2.5 gallons, cost $12.00, recharge cost 50 cents annually) good for general fire control purposes but must be handled carefully for fires at switchboards and electrical equipment. When used under latter conditions, must stand far enough away to hit fire with spray and not stream.

* From daily record of Urbana and Champaign (Illinois) Sanitary District.

Pyrene (carbon tetrachloride, capacity 2 quart, cost $9.00), best for electrical equipment fires.

Foamite type best adapted to oil or gasoline fires. Soda and acid type also satisfactory in such cases, however.

Placed order for the additional extinguishers considered necessary.

**December 20**—Imhoff Tank Number 4 on a foaming spree—probably "boiling mad" at those !x?x?x! Japs! Reduced flow and load thereto to one-third normal.

**December 23–24**—Routine intercepting sewer observations have indicated an unsatisfactory condition in an old 18-in. line which supplements one sec-

FIG. 1.—Roots and debris removed from 580 feet of 18-inch sewer. Note "drag" at right made of 15-inch root cutter wrapped with barbed wire.

FIG. 2.—Roots removed from 300-foot section of 18-inch sewer. Bucket at left shows size of root clumps.

tion of our intercepter. With the excellent cooperation of the City of Champaign Street Department, which assigned men and equipment for the job, 1000 feet of this sewer was dragged, yielding about two cubic yards of roots, cinders and miscellaneous trash.

Some of the larger chunks of roots removed are shown in Figs. 1 and 2. The object at the right in Fig. 1 is a 15-inch cutter (the largest conveniently available) that was wrapped with barbed wire to make it effective as a drag in the 18-inch sewer. The yield from the job amply proves that it was effective.

Observations following completion of the work indicated that the capacity of the line had been increased about 50 per cent.

**January 3**—Cleaned up sewage pump motors using an old vacuum cleaner to pull out all dust and dirt. The metal nozzle was removed from the cloth and rubber suction hose to preclude damage to the wiring and insulation. Found this to be a much better way to clean out the motors because the compressed air jet formerly used scattered so much dust and dirt about the pump room and switchboard.

**January 8**—Twelve below zero this A.M. Cracked the drain valves at the filter distribution systems to prevent freezing in the nozzle risers.

**January 14**—Still too cold for outside work. Overhauled mowing equipment in preparation for next summer.

**January 18**—A priming pipe on one of the sewage pumps burst at a corroded joint this evening, filling the dry well with three feet of settled sewage before being noted. No damage done but what a mess!

**January 22**—Routine weekly outlet stream inspection revealed considerable floating oil at all stations. (These observations and notes proved very useful later, in absolving the sewage treatment works of blame when complaints were made to the State Sanitary Water Board and Conservation Department. The oil was found to have been discharged at an industrial plant several miles upstream from us.)

**January 28**—Took advantage of the recent spell of very mild weather to clean 12 sludge beds. 'Tis a very satisfying feeling to have so much drying bed space available at this time of year!

**February 1**—As is justly deserved by any sewage plant operator who becomes smugly overconfident with a bit of good luck, we were put back in our place today by finding that the same mild weather which permitted the sludge beds to be cleaned also had spurred digestion at the Imhoff tanks into activity. In consequence, the sludge in all tanks was found to be "bulked" from its winter state and causing foaming in the center gas vents.

**February 3**—Took drastic steps to settle down the Imhoff tanks. First we drew two beds (38,000 gallons) of sludge from each tank, then hosed down the heavy 7-foot accumulations in the gas vents to maintain adequate "seed" in the sludge digestion chambers. The patients recovered!

**February 12**—Considerable gray fungus being received in the raw sewage, a common occurrence in the early spring in this part of the country. The fungus seems to grow in the sewers and to break loose as temperatures moderate in the spring.

The only difficulty caused by the fungus in this plant is that it passes through the screenings grinder and floats as an unsightly scum on the sedimentation channels of the Imhoff tanks. To correct this condition we are temporarily discontinuing use of the grinder and will dispose of all screenings by burial for the 10 to 14 day period that the fungus is received.

**February 23**—Salvaged and sold 700 pounds of scrap metal from about the plant for delivery to the "Japanazis" via Flying Fortress.

**February 26**—The writer entered the hospital today for a sinus operation. Will probably be very "odor control conscious" next summer!

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# DESCRIPTION OF A PHOTOELECTRIC COLORIMETER

By D. H. Caldwell

*Public Health Engineer, Bureau of Sanitary Engineering, State Dept. of Public Health, Berkeley, California*

Many routine chemical determinations in water and sewage laboratories are made colorimetrically or turbidimetrically. In most of these determinations it is necessary to prepare standards which may or may not be permanent. A photoelectric colorimeter eliminates the necessity of preparing standards and, after calibration, routine examinations can be made more rapidly and with a greater degree of precision than by other means.

Among the many determinations which can be made with a photometer, those of interest to the water and sewage chemist include the following: turbidity; residual chlorine; organic, albuminoid, nitrite, and nitrate nitrogen; silica; dissolved oxygen; pH; phosphate; iron; manganese and potassium. Detailed procedures for most of these analyses can be found in recent literature and in Standard Methods.

A photometer consists essentially of a light source, a constant voltage transformer to regulate the intensity of light, an absorption cell in which the solution to be analyzed is placed, a photoelectric cell, and a sensitive microammeter. The instrument is shown diagrammatically in Fig. 1 and illustrated in Fig. 2.

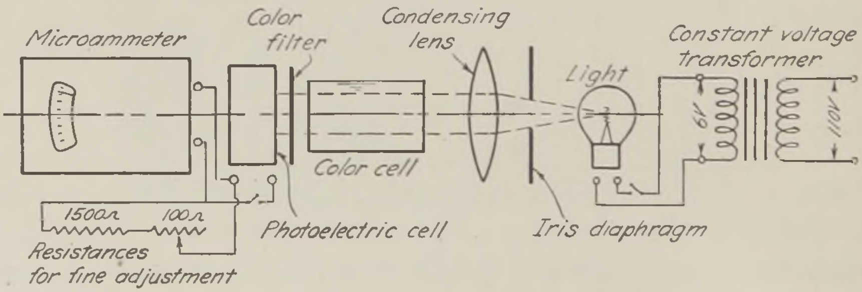


Fig. 1.—Wiring diagram.

The colorimeter described herein embodies several improvements to be found only in the highest grade commercial instruments. It has been found that when the light beam in passing from the source through the absorption cell encounters a liquid-air interface, distortion and scatter-

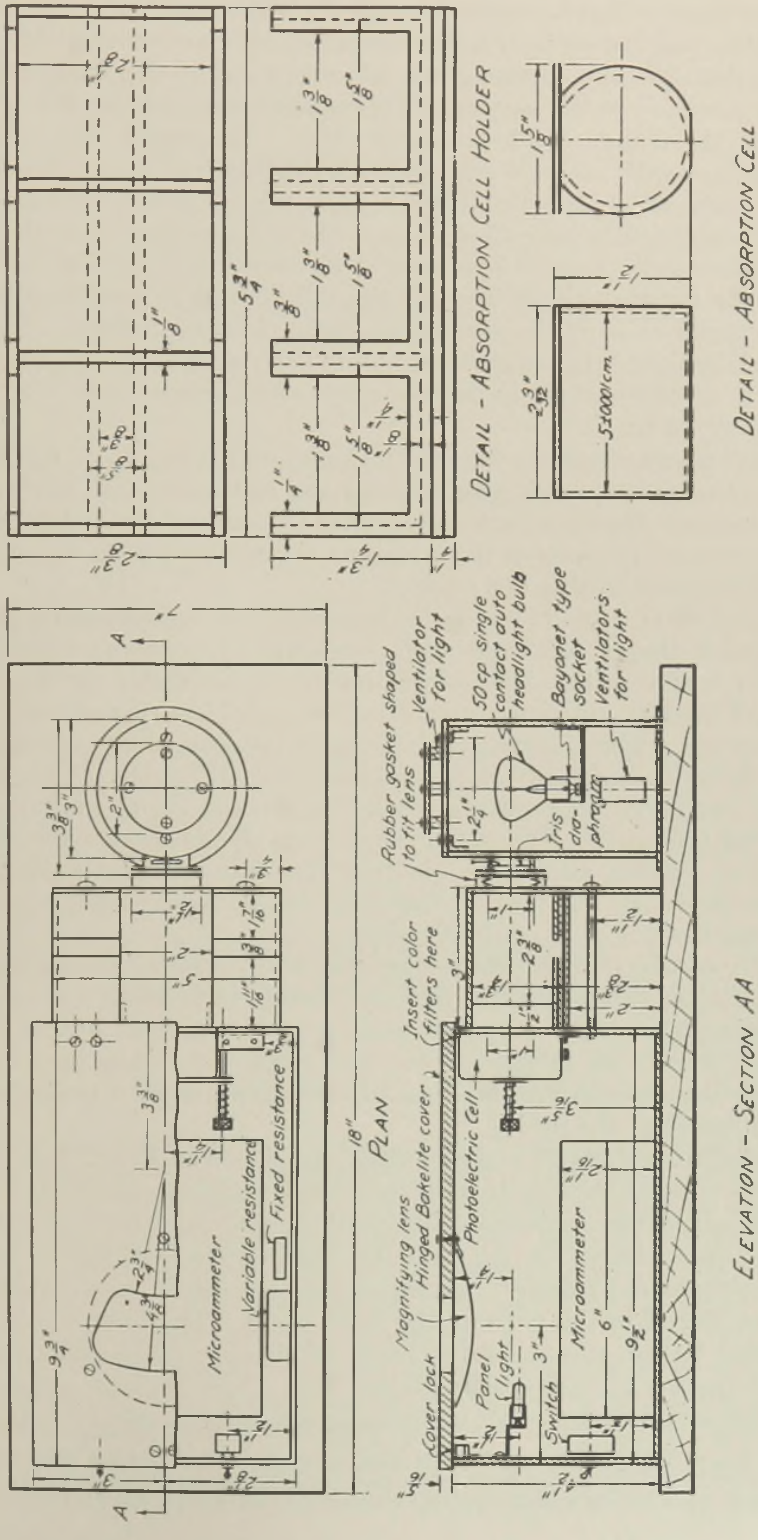


FIG. 2.—Photoelectric colorimeter.

ing of the beam of light results. Similarly, if the light beam strikes the sides of the absorption cell, a light condensing or concentrating action occurs. Both of these phenomena, when present in a photometer, impair the precision of the results. This instrument, it is believed, eliminates both these undesirable characteristics. The first is eliminated by the use of an easily cleaned and filled absorption cell with optically flat ends through which the light beam passes in a horizontal direction. The cell is sufficiently long (5 cm.) to give good sensitivity for the usual sewage laboratory tests. The second characteristic is eliminated by limiting the cross sectional area of the light beam as compared to the cross sectional area of the absorption cell. In this instrument the diameter of the light beam is approximately 0.25 in. at the largest opening of the iris diaphragm while the diameter of the absorption cell is approximately 1.5 in.

Voltage fluctuations are kept to a minimum by means of a constant voltage transformer which produces current at 6 volts with fluctuations of less than one-fourth of one per cent. The use of the constant voltage transformer eliminates the previous objections to the simple electrical circuit used in this instrument.

The electrical properties of the barrier-layer type of photoelectric cell are such that a low-resistance, low current microammeter is required for best results. The microammeter used in this instrument is graduated 0—100 divisions with the 100 mark corresponding to 15 microamperes. The internal resistance is 150 ohms and the external critical damping resistance is approximately 1,000 ohms. This microammeter when used in conjunction with the Weston Photronic cell shows a linear light intensity—current curve with no observable fatigue effects. A sensitive vernier adjustment is provided for setting the microammeter needle on the 100 mark. One turn of the vernier dial moves the pointer approximately 5 scale divisions.

Results obtained with this instrument will compare favorably with results from the best photoelectric colorimeters obtainable. It is practically constant in calibration and due to the low current output of the photoelectric cell no fatigue effects are apparent. Readings can be made immediately and are the same at the beginning of a period of use as near the end of the period.

Dimensions and construction details are shown in Fig. 2. All parts were made from ⅛-in. copper plate, but other material can be used. All joints and seams were soldered. The bill of material is given in Table I.

In the operation of the photometer, the light is first turned on and then the proper light filter * and an absorption cell filled with distilled water are placed in the path of the light beam. The microammeter is set to read 100 on the scale by means of the iris diaphragm and the vernier adjustment at the side of the case. The absorption cell containing the unknown solution to be analyzed is then quickly slipped in

* An excellent article on the use of a photoelectric colorimeter in water and sewage analysis with complete data on the proper color filters to be used in standard procedures is given by W. D. Hatfield in *Industrial and Engineering Chemistry, Anal. Ed.* 13, 430 (1941).

place in the light path and the microammeter is read. From a calibration previously prepared using known solutions the amount of unknown substance in solution is easily determined in terms of any convenient units such as parts per million or grains per gallon.

TABLE I.—*Bill of Material*

| | |
|---|---|
| 1 Constant voltage transformer, 45 VA, 110V. to 6V. Central Scientific Co. | $ 25.00 |
| 2 Absorption cells—pyrex with fused optically flat ends, 5 cm. length. Central Scientific Co. | 20.00 |
| 1 Microammeter—Western Model 440, internal resistance 150 ohms, external critical damping resistance 1,000 ohms | 41.60 |
| 1 Photoelectric cell, Weston Photronic, Model 594YR Type 3 | 7.00 |
| 1 Iris diaphragm—maximum opening approx. 0.5 in., (second-hand Kodak) | —— |
| 1 Fixed resistance 1500 ohm, ½ watt; 1 Variable resistance 100 ohm, 2 watt } Radiotype | 1.00 |
| 1 Light bulb, 50 c.p., single contact, bayonet base | .25 |
| 4 Light filters complete—Eastman Kodak Co. | 1.70 |
| 2 Switches—single throw toggle | .60 |
| 1 Panel light—radio type 6 V. | .20 |
| 1 Condensing lens—3.5 cm. diam., 5 cm. focal length | .35 |
| 1 Magnifying lens—3½ in. diameter | .50 |
| Miscellaneous metal, bolts, etc. | 2.00 |
| | $100.00 |

An instrument built according to these specifications has been in daily use at the Springfield, Illinois, Water Treatment Plant since 1941, and has replaced the usual visual methods of analysis. The instrument also has been used successfully in routine turbidity measurements.

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# FILTER ROOM PRACTICE
# VACUUM FILTER ECONOMY

By Clyde L. Palmer

*Supervisor, Detroit Sewage Disposal Plant*

Many investigations have been made and much has been written concerning chemical dosages and the resultant economy in operation of vacuum filters for dewatering sewage sludge. Important economies may also be realized by improved operating methods from a strictly mechanical point of view. The following discussion describes experiences at the Detroit Plant with methods of placing new filter cloths on vacuum filters and the resulting economy.

Filter room equipment at Detroit includes eight Filtration Equipment Corporation vacuum filters, each of 500 sq. ft. of filtering surface. Originally the filter cloths were held in place by ⅝-in. square bronze bars 14 ft. long, fitting into recesses in the filter drum segment division strips and secured by screws, and with the usual wire wrapping on a

1¾-in. spacing. The removal and replacing of these bronze bars at each cloth change was soon recognized as a time-consuming and laborious task, the principal difficulties being the removal and replacing of the screws and the unwieldiness of the long flexible bars. The substitution of ½-in. sash cord for the bronze bars has cut in half the time of re-clothing the filters and the required number of workmen by one-third. This method of substituting sash cord for the metal bars did not originate at the Detroit Plant, but is described here as an introduction to

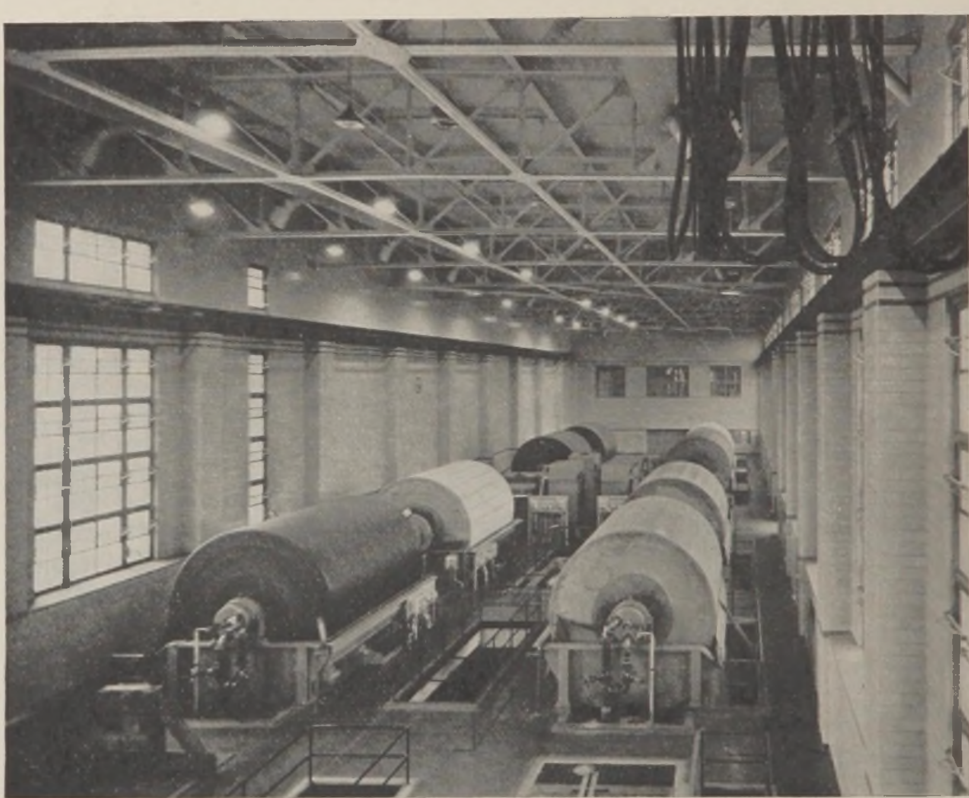

FIG. 1.—Vacuum filter room, Detroit Sewage Treatment Plant.

further developments that were carried on in Detroit, the results of which are also reported herewith. The following pictures illustrate the operation of placing filter cloths using sash cord.

Figure 2 shows how the filter cloth is started on the stripped and cleaned filter drum by tacking it several points along one of the segment division strips.

The filter drum, after the cloth has been tacked on, is revolved, carrying the new cloth around with it, until the position of the next segment division strip is accessible. The cloth is straightened and held in position by a small piece of sash cord, placed in the recess as visible in the right hand of the picture. Placing of the sash cord is done with the use of a rubber mallet and is started from the opposite end of the filter, as shown in the picture, and carried across the entire width of the filter. The sash cord used is of such size that it fits tightly into the recess and after being placed as indicated needs no further fastening until the wire

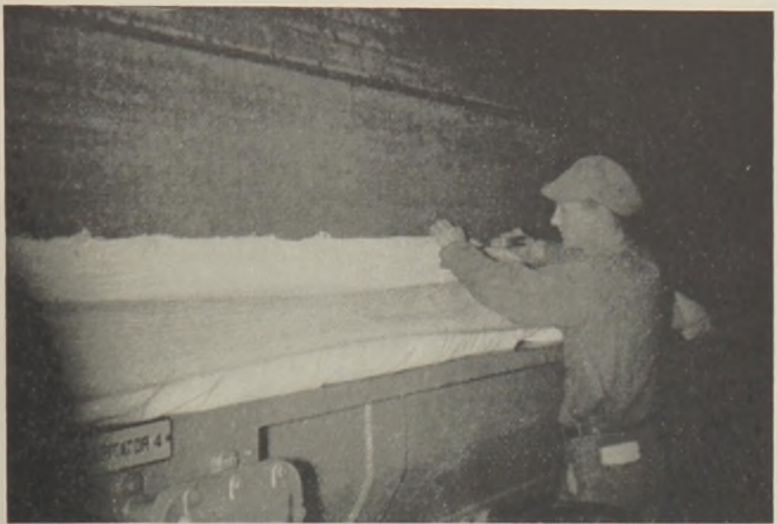

Fig. 2.—Starting new cloth on vacuum filter, Detroit, Mich.

wrapping is in place, which finally secures both the sash cord and the new cloth in position for filtering operation.

Fig. 3.—Placing sash cord segment insert during application of new cloth.

Successive segment divisions are treated in the same manner. Smoothing and straightening of the cloth is carried forward with the operation of placing the sash cord.

After all sash cords are in place the filter is wrapped with wire in the usual manner.

Over a year's use of the above described method has disclosed no difficulty and besides the economy effected has proved satisfactory in every way. The sash cord has a useful life of about three re-clothings, after which it is usually so distorted in shape and disintegrated that it must be discarded, but the expense of renewing the sash cord is more than offset by the savings in labor time and the reduction of the loss of filter service time.

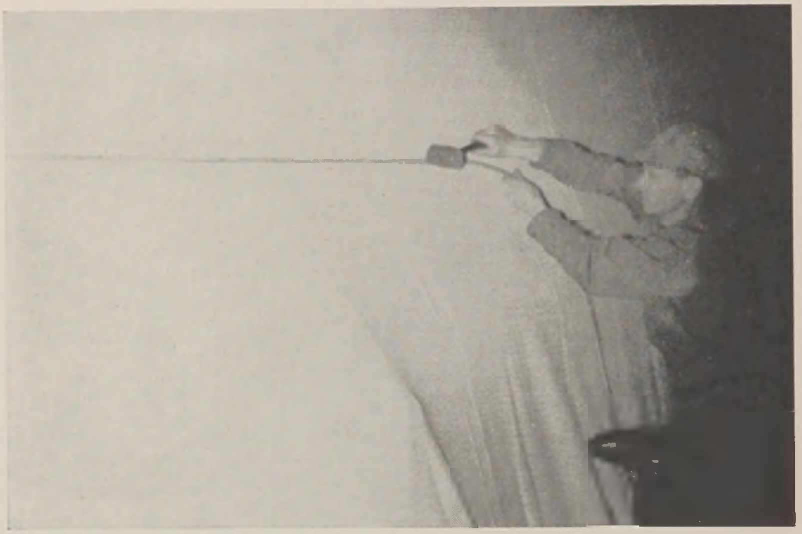

FIG. 4.—Driving sash cord into place.

In addition to the adoption of the above described method of placing filter cloths, the following procedure has also been adopted and has proved to give important increases in filter capacity.

Filter operations at Detroit are checked as to production by two methods. One is by an integrating weightometer and the second is by taking and weighing two sq. ft. samples of the cake as it comes off the filter drum and computing the production. The two methods have given results having a quite consistent difference. Tests to check the discrepancy between the weightometer records of filter production and those obtained from cake sampling method disclosed the fact that even on filters having new cloths and where no blinding was apparent, there is a residual discrepancy of from 7 to 10 per cent between these two methods of measuring filter production, the weightometer giving the lighter weight.

The consideration of the problem just described focussed attention on the fact that there is a loss of productive filter surface at each segment division strip in greater or less degree, depending on the hours of service on the particular filter cloth. It was also observed that as the service hours increased, an appearance of blinding always first occurred along the division strips of the filter segments. This led to the conclusion that the blinding was due to a loss of effectiveness of the air blow used to release the cake from the cloth. The filter cloth, being held tightly to the segment division strips by the sash cord or bronze bar, whichever is used, restricted the air blow and action of the cloth to such a degree that a portion of the cake would not be released and was subsequently worked into the cloth by the vacuum, finally developing into a blind surface. Reasoning along these lines indicated that if it were possible to operate satisfactorily leaving out the sash cords holding the filter cloths, the production of the filter might be greatly increased. After numerous trials it was determined that with the present blower

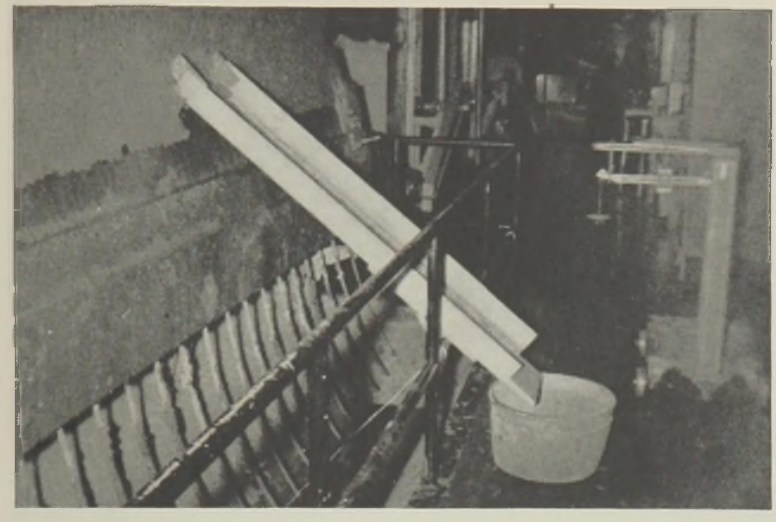

FIG. 5.—Sampling chute at filter discharge.

installation, the most practical limit was obtained by placing a sash cord at every third segment division, and the following tests were run to determine the economy of this practice.

A chute with a metal cutting edge, exactly 12 in. wide, was made. The chute was so placed against the filter scraper plate as to cut a 12-in. ribbon of cake as the material moved down the face of the scraper. The chute carried the ribbon of cake so cut to a container placed on the floor in front of the conveyor hopper as shown in Fig. 5.

The routine of the tests consisted of cutting the 12-in. ribbon completely around the filter drum, after which the weight of the material was determined and recorded as the "observed weight." Immediately after the cake ribbon was cut and in the same location on the filter drum from which it was obtained, a series of four 2-sq. ft. samples were taken at equidistant points around the circumference. In taking the 2-sq. ft. sample an effort was made to get a sample from the middle area of the panel where the cake was the most uniform in weight and where a full 2-sq. ft. sample could be obtained. The average result of the four samples reduced to a square foot basis and multiplied by the circumference of the filter drum was recorded as the weight of the cake on the filter by the 2-sq. ft. method.

It should be noted that the "observed weight" by virtue of the method of collecting the sample will include the effect of any blinding or

FIG. 6.—Taking 2-foot square sample.

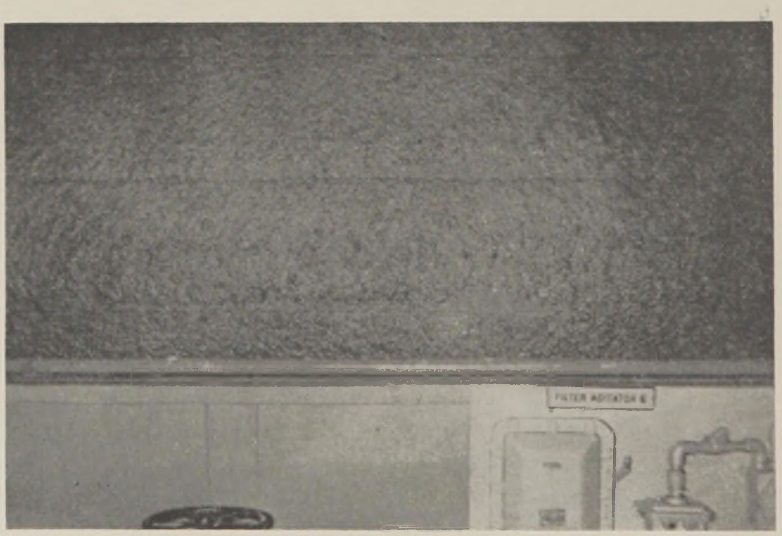

FIG. 7.—Illustrates "blinding" at segment division strips. Filter No. 6, with cloth fastened at all segments.

loss of productive area that may be present. Whereas the 2-sq. ft. sample method will produce a result that would obtain only if the cake were uniform in thickness over the entire circumference, it indicates what the production of cake would be if there were no effects of blinding at the panel division strips. Conversely, had there been no blinding, the weight of the 12-in. ribbon would be very closely the same as the weight as determined by the 2-sq. ft. method.

In order not to include too much detail of the test data, one set of results representative of the whole will be presented. Filters 6 and 8, which were in operation at the time, were used for the tests and the following data relate to the two for comparative purposes. The pictures give visual evidence of the conditions during the tests, particularly the extent of the blinding along the panel divisions and the greater number of these panel divisions showing on No. 6 filter as compared with No. 8.

FILTER No. 6

Sash cord in place in every panel division strip.
Time for one revolution of drum—6 min.
Operating hours on filter cloth—318 hours.
Average cake production at time of test:
From 2-sq. ft. sample—17.83 lb./sq. ft./hr. (wet)
From 12-in. ribbon—14.69 lb./sq. ft./hr. (wet)

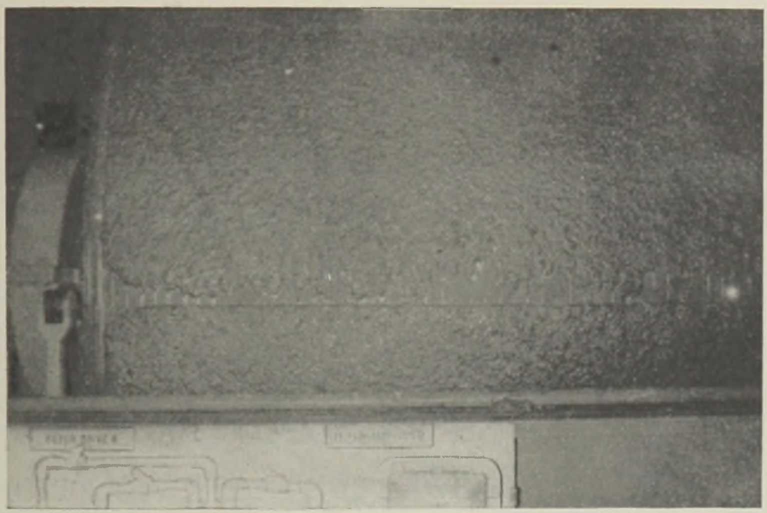

FIG. 8.—Showing increased production resulting from elimination of cloth fasteners at ⅔ of panel division segments on Filter No. 8.

FILTER No. 8

Sash cord in place in every third panel division strip.
Time for one revolution of drum—4.5 min.
Operating hours on filter cloth—145 hours.
Average cake production at time of test:
From 2-sq. ft. sample—17.3 lb./sq. ft./hr. (wet)
From 12-in. ribbon—15.99 lb./sq. ft. /hr. (wet)

It will be noted that had these two filters been judged on the basis of the 2-sq. ft. samples alone, they would have appeared practically identical, but from the continuous 12-in. ribbon sample method the difference in cake production is at once apparent. In other words, from either filter where the cake existed and a sample could be obtained, the results for all practical purposes were identical, but the important difference between the filters appears as a greater or less non-productive area of filter surface or non-uniform thickness of cake where the blinding is not fully developed.

Assuming that blinding is more or less uniform along all panel divisions where the sash cord is in place, it would be expected that if leaving the sash cord out would prevent blinding, then if every other one of the sash cords had been left out the loss due to blinding would have been reduced 50 per cent. And further, if only every third sash cord had been placed, the loss would have been reduced 66⅔ per cent. These assumptions are born out by the test data which are appended hereto and from which the following conclusions can be drawn:

1. With all panel sash cords in place the loss in cake production may easily amount to more than 20 per cent.
2. With every third panel sash cord in place the loss in cake production can be reduced to less than 7 per cent.

From tests on new cloths (not recorded herewith) and with all panel sash cords in place, the loss in cake production due to the restriction at the panel division, is indicated to be about 10 per cent. Using the method here proposed would reduce this loss to 3⅓ per cent. Thus it can be said that over the whole life of the cloth the production can be increased 6⅔ per cent when the cloth is new and about 13 per cent when near the end of the cloth life, or an average over-all increase of filter production over the whole period of approximately 9⅔ per cent.

The above described procedure has been in use at Detroit for about one year and has proved satisfactory in every way. The very significant increase in filter capacity, although not readily apparent from operating records, is nevertheless an easily demonstrated fact and a very important step to better plant economy.

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# INTERESTING EXTRACTS FROM OPERATION REPORTS

## ARMY POST XVII (HALF YEAR ENDED JUNE 30, 1942

By J. T. Franks

*Assoc. Sanitary Engineer*

*General Information.*—Work on the original plant, consisting in general of the following units: comminutor basin and bar screen, two clarifiers, two rapid or biofilters, chlorinating basin and separate digester, together with necessary appurtenances, for a design population of 7,500 was started January 7, 1941, and was substantially completed and put into operation during the month of March, 1941. It was found that the plant was inadequate for even the design population and, with the increase in population to 9,500, it was found imperative to enlarge the existing facilities. Work on the enlargement was commenced on October 28, 1941, and was completed and put into operation on January 17, 1942. The enlargement consisted in general of the following units: grease and grit chamber, additional bar screen, final filter and final clarifier, and additional chlorinating basin.

## Plant Description

Raw sewage enters the plant from a 15 in. tile outfall and passes through the grease and grit chamber where some of the grease, floating solids, etc. are removed and the sewage is pre-aerated. The chamber is 8 ft. by 26 ft. 8 in. by 9 ft. and is equipped with twelve National Carbon tear-drop diffusers with air furnished by a 72 c.f.m. Root Connersville blower. This chamber also receives the supernatant liquor from the digester and the returned sludge from both the secondary and final clarifiers. Upon leaving the grease and grit chamber, the sewage enters the comminutor basin and flow in excess of 700 g.p.m. pass through the bar screen. From this point the sewage flows either of two ways, to wit:

(A) *Single-Stage Roughing Filters.*—The flow, upon leaving the comminutor and bar screen, enters the primary clarifier; here after plain sedimentation the effluent is pumped to the Biofilters which are operated in PARALLEL. The flow to these filters is at a constant rate and is composed of settled sewage from the primary clarifier plus a sufficient quantity of previously filtered and settled sewage from the intermediate clarifier to make up the necessary amount to keep the pumps operating at a constant rate. This is the usual mode of operation. A quantity of treated sewage equal to the amount of raw sewage entering the plant flows from the intermediate clarifier to the pump wells supplying the final stage. The Biofilters are each 50 ft. in diameter and 3 ft. deep, with river gravel media and equipped with Jenks Distributors.

(B) *Two-Stage Roughing Filters.*—The flow upon leaving the comminutor and bar screen is mixed with the effluent of the primary filter and enters the primary clarifier where upon sedimentation the effluent is pumped to the Biofilters which are operating in SERIES. Settled sewage in excess of the amount necessary to operate the primary filter at a constant rate; *i.e.,* the same in amount as the raw sewage flow plus the required amount of previously treated sewage from the secondary filter and intermediate clarifier necessary to operate the pump at a constant rate is pumped to the secondary filter. A quantity of treated sewage equal in amount to the raw sewage flows from the intermediate clarifier to the pump wells supplying the final stage.

The final filter is 108 ft. in diameter and 8 ft. deep, with crushed granite media and equipped with a Dorr 4-arm distributor. From the pump wells supplying the final filter the effluent from the intermediate clarifier plus sufficient of the effluent from the final clarifier to operate the pumps at a constant rate is pumped to the final filter. The effluent from the final filter is settled in the final clarifier and the effluent from this clarifier in the same amount as the raw sewage is passed into the chlorinating basin and finally into Crow Creek.

Sludge from both the intermediate and final clarifiers is returned to the grease and grit chamber for resettling. Sludge from the primary only is pumped to the digester, which is a tray-type Dorr Multdigester unit having equal primary and secondary digestion volumes of 10,580 cu. ft. and equipped with heating coils and stirring mechanism.

Comparison of Design Basis and Actual Loadings

| | Design Basis | Actual | Per Cent of Design |
|---|---|---|---|
| Population served | 9,500 | 10,521 | 110.9 |
| Avg. daily per capita flow | 85.0 | 73.9 | 87.0 |
| Avg. daily sewage flow m.g.d. | .808 | .779 | 96.4 |
| Daily B.O.D. load—lb. | 2,745 | 2,730 | 99.5 |
| Per capita B.O.D. load—lb/day | .289 | .259 | 89.7 |
| Daily suspended solids load—lb. | 1,957 | 2,305 | 117.8 |
| Per capita suspended solids load—lb/day | 2.06 | .219 | 106.2 |
| Degree of treatment—Per cent | | | |
| 5-day B.O.D. | 90 | 82 | 91.1 |
| Suspended solids | 85 | 81 | 95.3 |
| Sewage Characteristics—p.p.m. | | | |
| 5-day B.O.D | 408 | 421 | 103.2 |
| Suspended solids | 290 | 355 | 122.5 |
| Avg. Loadings—lb/B.O.D./c.y./day | | | |
| Biofilters | | | |
| Raw | 6.29 | 6.27 | 99.8 |
| Settled | 3.78 | 5.14 | 135.9 |
| Final Filter | .30 | .46 | 153.2 |
| 5-day B.O.D. removals | | | |
| Primary clarifier—lb/day | 1,099 | 508 | 46.2 |
| Biofilters—sec. clar. | 823 | 1,054 | 128.2 |
| Total primary treatment—lb./day | 1,922 | 1,562 | 81.3 |
| Final filter—final clar. | 494 | 745 | 150.8 |
| Total—lb/day | 2,416 | 2,307 | 95.5 |

*Grease Removal.*—This unit has been in operation since January 17, 1942, and has given satisfactory service insofar as grease removal is concerned. The pre-aeration also seems to make secondary grease removal more complete, but it is possible that it has been a contributing cause to the poorer removal of suspended solids by the primary clarifier. However, inasmuch as the removal of grease has probably allowed the Biofilters to operate more effectively and also removed some of the load from the digester and, in this manner, caused a better overall performance of the plant, it is worth while. The grease removed by the unit proper is for the most part a more or less pure grease. That removed by the skimmer on the primary clarifier is mostly in the form of a greasy soap.

The grease is removed to the dump for disposal and the skimmings are pumped to the digester, where they have been the cause of some trouble.

It would seem that this grease could be removed to better advantage at the source.*

* Since this report was submitted grease salvage drives and more adequate supervision of grease interceptors have eliminated a large portion of this trouble.

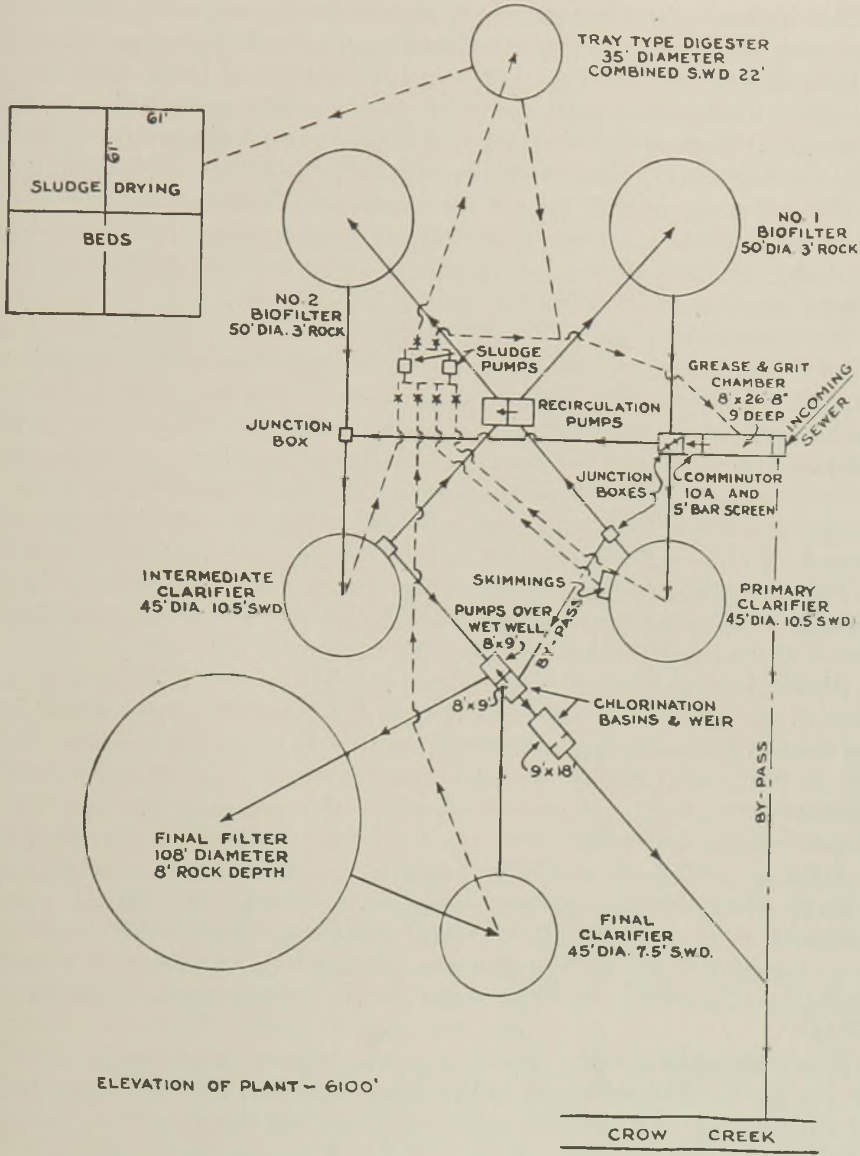


Fig. 1.—Army Post XVII, Sewage Treatment Plant.

## Grease Removed

| Month | Grease, *lb.* | Skimmings from Primary Clarifier *gallons* |
|---|---|---|
| January | None | 44,590 |
| February | 2,300 | 29,960 |
| March | 3,000 | 38,920 |
| April | 3,300 | 38,910 |
| May | 4,400 | 35,350 |
| June | 5,000 | 63,190 |
| | 18,000 | 250,920 |

The increase in removal from month to month, and especially in June, may be due in part to increased sewage and air temperatures.

*Primary Sedimentation.*—This unit of the plant is the only one not exceeding design expectations, with the possible exception of the digester and the exceptions noted under grease and grit unit. However, it is felt that a reduction of 40 per cent is possibly an ambitious figure, but the reduction in both B.O.D. and suspended solids is more real than apparent inasmuch as the supernatant liquor from the digester and the sludge from both the intermediate and final clarifiers is returned to the primary clarifier for resettling.

The poor percentage of removal by this unit was due in large part to inadequate removal of sludge, due in turn to the overload in the digester, which condition is taken up in more detail in a following item. The percentage of removal of suspended solids has never been so high, at this plant, as would be expected, due in some extent to the character of the sewage. A large percentage of the suspended solids is in the form of pseudo colloids and true colloids, which do not settle even after several hours or until the settled solids become septic and start to digest.

The detention period and overflow rate even at peak flows is conservative and good removals should be expected; however, the abruptness of these peaks seems to upset the tank.

*Biofilters and Intermediate Clarifier.*—These are listed as a unit because of the nature of rapid filters, and it is felt that the removal is all that could be expected, considering the overload of the original design, both in flow and B.O.D. Mainly for operating reasons, two stages of biofilters are now used only to freshen the primary clarifier, as the overall results are much the same, if not better, when operated as a single stage. This type of filter approaches the ideal as a roughing or primary filter, smoothing out the peak loads and furnishing a fairly uniform load to the final filter. While this stage does not seem to come up to the manufacturer's expectations, the removal per cubic yard is equal to, or in excess of, that shown in any literature available to the writer.

*Final Filtration.*—The final stage was placed in operation on January 17, 1942. The average B.O.D. load has been 0.46 lb. 5 day B.O.D. per cu. yd. per day or in various other expressions of filter loadings as follows:

| | Lb. 5-day B.O.D. per Day |
|---|---|
| Per acre of filter, 8 ft. in depth | 6,000 |
| Per acre foot | 750 |
| Per 1,000 cu. ft. of stone | 17.15 |
| Cu. ft. of stone per lb. B.O.D. | 58.4 |
| Removal of 5-day B.O.D. per acre daily, (8 ft. depth) 3548 pounds | |

This would be considered moderately heavy loading and the removals are all that would be expected.

It should be noted that this filter is operated at a constant rate; that is two constant rates depending on which pump is used. It has been the common operating practice to use the 7½-hp. pump for rates of flow up to 1.1 m.g.d. and the 10-hp. pump for flows in excess of this amount. This has resulted in dosing rates of 5.5 and 8.2 m.g.a.d. respectively.

These rates place this filter outside the category of conventional filters as they are commonly rated. Also, in order to furnish a constant flow to the pumps, some recirculation is necessary, which is not regular practice on low-rate filters. Even the average dosing rate of effluent from the intermediate clarifier to the filter of 3.7 m.g.a.d. is in excess of usual standards. Just what the ultimate possibilities of this filter are has not yet been determined.

The detention periods and overflow rates of the final clarifier are normal and removals are on the whole satisfactory.

*Sludge Digestion and Drying.*—The following history of digestion and drying for the past six months is related in some detail as it is felt that the digester and drying beds are the weak points in an otherwise satisfactory sewage treatment plant. The digester entered the year with a temperature of 97 deg. F. in the upper tank and 65 deg. in the lower tank, with digestion going on at a good rate. Foaming occurred on January 28th due to rapid digestion. Early in February the temperature had dropped to 82 deg. F. in the upper tank and had increased to 68 in the lower tank. Digestion became violent at this time, and it was necessary to lower the level of sludge in the upper tank. This allowed some of the gas to waste, but seemed to allow the digester to quiet down. The temperature continued to drop in both tanks and on March 9th was down to 68 deg. F. in the upper tank and 57 deg. in the lower tank. Digestion slowed down.

After the middle of the month the temperature started to increase in both tanks and digestion resumed at an increased rate. This caused incipient foaming which was very bothersome. Temperatures continued to increase and reached 82 deg. in the upper tank and 68 deg. in the lower tank at the end of June; the digester settled down and has not foamed since May 15th. During this six-month period, the volatile content of the sludge transferred to the lower tank decreased from 70.8 to 55.8 per cent, and the volatile content of the sludge drawn to the drying beds decreased from 71.9 to 64.4 per cent. Reduction of volatile material increased from 54 to 68 per cent.

The drying beds have a capacity of about 120,000 gal. and, at the beginning of the year, by dosing the beds twice, about 92,000 gal. of this capacity was available for use. Even by holding raw sludge pumping to a minimum this space was used up at the end of March. Freezing weather prevented the removal of sludge during these months. In April, in spite of wet cold weather, sludge was removed from the beds to allow continued withdrawal of sludge from the digester, but it was not until the latter part of May that it was possible to remove all the sludge drawn during the winter months from the beds. In the meantime, continued minimum raw sludge pumping caused the primary clarifier to become septic and digestion started in the clarifier, this in turn upset the balance in the plant and only fair removals were made during May. It was only by a narrow margin that serious results were averted.

At the end of June all the drying beds were full and it was necessary to remove some very wet sludge in order to make withdrawals from the digester. The cause of the drop in temperature of the digester during the early part of the year has not been fully determined. The heating coils were not encrusted enough to have caused this condition. It is felt that either the sludge was thickened up to a point where heat transfer was slow or the radiation surface of the coils is inadequate or a combination of the two. Also, it is possible that the stirring mechanism is either broken or worn off, but it is impossible to determine this without emptying the upper tank. This has not been done in the hopes that the temperature would come back up, which may occur as the temperature of this tank was only 85 deg. F. last summer and increased to 92 in December.

In further reference to the drying beds and the drying of the sludge, the sludge drawn early in the year showed good drying qualities while that drawn later has been very slow to dry. The wind during the early months may have been a contributing factor to the better drying. It should be noted here that the mean temperature for the first three months of the year was below freezing and freezing temperatures occurred even in June. Also the precipitation for the first six months was 5 inches in excess of normal.

While the digester has a capacity of 2.0 cu. ft. per capita based on actual population during the past six months, it should be born in mind that this type is heated in the upper or primary tank only. The average temperature in the lower tank during this period has been only 63 deg. F., which is low for satisfactory digestion in a reasonable length of time. The lower tank is equal in size to the upper tank, but has only about one-half the digestion capacity, acting more as a storage and settling tank, but it has been so heavily loaded that very little supernatant liquor was returned to the primary clarifier except in an emergency.

Very little design data is available, but the following comparison gives some idea of actual operation against probable original expectations:

| | Design Basin | Actual |
|---|---|---|
| Population | 7,500* | 10,521 |
| Daily gas production cu. ft. | 11,250* | 8,137† |
| Daily suspended solids load-lb/day | 1,858* | 2,305 (a) |
| Percentage of volatile solids | 75 | 84 (a & b) |
| Capacity, cu. ft. per capita | 2.83* | 2.00 |
| Per capita suspended solids-lb/day | .248 | .219 (a) |
| Suspended solids, lb., to digester daily | 1,578 | 1,866 (a)<br>2,250 (b) |
| Volatile solids, lb. per day | 1,175 | 1,572 (a)<br>1,895 (b) |
| Vol. solids reduced daily, lb. | 725 | 897 (a)<br>1,081 (b) |
| Digestion time in days | 25 | 26 (c)<br>50 (d) |
| Per cent volatile in digested sludge | 55 | 69 |
| Percentage reduction of volatile material | 61 | 57 |
| Sludge to drying beds—lb./sq. ft./year | 15 | 22 |

* Only information given in design basis-remainder assumed or calculated.

† Considerable amount of gas wasted and not metered.

(a) From flow analysis; (b) from digester analysis; (c) upper tank; (d) lower tank.

From the above it would seem that the digester is doing about all that was expected of it. From the standpoint of volatile content it is heavily overloaded. Also it should be noted that to obtain a sludge that is 55 per cent volatile, it would be necessary to reduce the volatile material 76 per cent, which would require a detention period longer than it is possible to give and maintain any kind of efficiency in the primary clarifier. The writer believes that the digester is approaching this large reduction on days when the gas production exceeds 16,000 cu. ft. from the upper tank alone. This violent gasification causes the tank to become upset and sometimes results in foaming and nearly always results in a slowing down in digestion.

## Conclusions

The preceding interim summary and memorandum of sewage treatment plant operation is submitted for two reasons: first, to show the results obtained by the use of the new units put into operation on January 17, 1942, and second, because of the need to determine possi-

*Summary of Operation Data (Six Months Ended June 30, 1942)*

| | Average for 6-Month Period | Average During Single-Stage Operation | Average During Two-Stage Operation |
|---|---|---|---|
| Average connected population | 10,521 | | |
| Total flow—m.g. | 141.022 | 99.000 | 42.022 |
| Average flow—m.g.d. | .779 | .763 | .818 |
| Average maximum flow—m.g.d. | 1.369 | 1.368 | 1.372 |
| Average minimum flow—m.g.d. | .358 | .353 | .370 |
| Per capita flow—g.c.d. | 74.0 | 72.4 | 73.6 |
| Percentage of flow sampled | 26.8 | 24.0 | 33.3 |
| Mean temperature—degrees F. | 38.6 | 43.7 | 25.8 |
| Suspended solids—p.p.m. | | | |
| Raw sewage | 360 | 359 | 362 |
| Primary clarifier effluent | 290 | 299 | 256 |
| Intermediate clarifier effluent | 141 | 141 | 141 |
| Final effluent | 67 | 61 | 78 |
| Per cent removal | | | |
| Primary clarifier | 20 | 17 | 29 |
| Intermediate stage | 51 | 53 | 45 |
| Total—primary—intermediate | 61 | 61 | 61 |
| Final stage | 53 | 57 | 45 |
| Total | 81 | 83 | 79 |
| Five-day B.O.D.—p.p.m. | | | |
| Raw sewage | 427 | 458 | 372 |
| Primary clarifier effluent | 350 | 377 | 303 |
| Intermediate clarifier effluent | 190 | 194 | 180 |
| Final effluent | 76 | 79 | 71 |
| Per cent removal | | | |
| Primary clarifier | 18 | 18 | 18 |
| Intermediate stage | 46 | 49 | 41 |
| Total—primary—intermediate | 56 | 58 | 52 |
| Final stage | 60 | 59 | 61 |
| Total | 82 | 83 | 81 |

*Summary of Operation Data (Six Months Ended June 30, 1942)—Continued*

| | Average for 6-Month Period | Average During Single-Stage Operation | Average During Two-Stage Operation |
|---|---|---|---|
| Dosing rate—biofilters—raw—m.g.a.d. | | 8.5* | 18.3 |
| Dosing rate—biofilters—total—m.g.a.d. | | | |
| Primary filter | | 28.2* | 21.5 |
| Secondary filter | | | 45.1 |
| Recirculation ratio—biofilters | | | |
| Primary filter | | 2.3* | .18 |
| Secondary filter | | | 1.5 |
| Dosing rate (final filter—inter. clar. effluent)—m.g.a.d. | 3.7 | 3.6 | 3.9 |
| Dosing rate (final filter—total)—m.g.a.d. | 6.0 | 6.2 | 5.7 |
| Recirculation ratio—final filter | .62 | .72 | .46 |
| Avg. raw loadings—biofilters—lbs./c.y./day | 6.43 | 6.72 | 5.86 |
| Avg. settled loadings—biofilters—lbs./c.y./day | 5.26 | 5.54 | 4.76 |
| Avg. loading final filter—lbs./c.y./day | .46 | .46 | .46 |
| Avg. clarifier overflow rate—gal./s.f./day | | | |
| Primary | | 483 | 1,128 |
| Intermediate | | 1,592 | 1,275 |
| Final | 794 | 820 | 753 |
| Avg. Detention period—hr. | | | |
| Primary | | 3.87 | 1.60 |
| Intermediate | | 1.67 | 1.47 |
| Final | 2.73 | 2.85 | 2.62 |
| Lb. B.O.D. removed | | | |
| Primary clarifier | 508 | 528 | 460 |
| Intermediate stage | 1,054 | 1,172 | 865 |
| Total primary—intermediate | 1,562 | 1,700 | 1,325 |
| Final stage | 745 | 730 | 840 |
| Total | 2,307 | 2,430 | 2,065 |
| Lb. B.O.D. removed per cu. yd.—biofilters | | | |
| Raw | 3.58 | 3.89 | 3.05 |
| Settled | 2.42 | 2.71 | 1.95 |
| Final filter | .28 | .27 | .28 |

* Biofilters in parallel recirculation through intermediate clarifier only.

bilities of accommodating the additional sanitary sewage flow resulting from an increase in post population.

In regard to the first, the plant as a whole is approximating expectations; however, there are certain features of operation, aside from the regular efforts to improve efficiency, that will bear more detailed study. They are in brief: (1) higher percentage of removals by the primary clarifier, (2) determination of the reason for inability to raise the temperature in the digester and also to improve the quality and quantity of digested sludge, (3) improve the drying quality of digested sludge, possibly by the use of alum and the reconditioning of the drying beds. Even with improvement in drying, some additional drying area or sludge storage space is needed in view of past experience and with a normal expectancy of five months with a mean temperature at or below freezing and seven months with an average minimum temperature below freezing. Of the above, each is to some extent a function of the others. Work on all three is being done and progress will be reported at a future date.

In regard to the second, no recommendations are made, this not being considered a function of the writer; however, the following suggestions are submitted for consideration: (1) It is believed that the plant, excepting digestion and sludge drying, will accommodate a population of up to 15,000 without additional facilities, provided that the biochemical oxygen demand does not exceed seriously the present average of 0.26 lb. per capita per day and that the sewage flow does not exceed greatly 70 gal. per cap. per day for any extended period. (2) It is felt that any increase in population cannot be accommodated by the present digestion equipment. It is feared that any substantial increase in the amount of solids sent to the digester will cause serious operating troubles, if for no other reason than an inability to retain a seeding of digested sludge. In any event additional drying beds or sludge storage space will be required. The positive removal of a large percentage of grease at the source and some separate method of handling the skimmings from the primary clarifier would undoubtedly allow some, though not too great, an increase in digester capacity.

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# TRI-CITY (PASADENA), CALIFORNIA (YEAR ENDED JUNE 30, 1942)

By William A. Allen

*Superintendent*

*Fertilizer Production.*—A total of 153.8 million gallons of excess activated sludge was filtered during the year, producing an average of one ton of fertilizer from each 36,939 gallons of sludge filtered.

Fertilizer production during the year was 4,163.55 tons, a decrease of 134.35 tons compared to the previous year. Fertilizer produced averaged 1.185 tons per million gallons of sewage treated. Deliveries from the warehouse totaled 4,023.25 tons, packaged as follows:

| | |
|---|---|
| 100 lb. burlap | 1,612.25 tons |
| 100 lb. paper | 2,265.20 tons |
| 50 lb. paper | 145.80 tons |
| | 4,023.25 tons |

The amount packaged in paper was more than double that of the previous year due to the scarcity and high cost of burlap.

Revenue from the sale of fertilizer was $74,625.48 which is equal to 51.68 per cent of the cost of operating the entire plant, exclusive of capital charges. This compares to 57.14 per cent for 1940–41.

Maintenance and repairs during the year were limited to work necessary to keep the plant operating until the waste sludge line was in operation.

The fertilizer sales situation has continued very satisfactory, and while the market improved we could not benefit by rising prices under our existing contract.

*Summary of Operating Cost*

| | 1940–41 | 1941–42 | 1940–41 Cost per million gallons treated | 1941–42 Cost per million gallons treated |
|---|---|---|---|---|
| Sewage treatment | | | | |
| Screening, aeration and clarification | $ 61,435.37 | $ 60,265.97 | $17.35 | $17.15 |
| Sludge disposal | | | | |
| Filtering | 39,483.30 | 42,051.65 | 11.15 | 11.97 |
| Fertilizer manufacture | 37,312.52 | 42,079.31 | 10.54 | 11.98 |
| | $ 76,795.82 | $ 84,130.96 | $21.69 | $23.95 |
| Gross operating cost | $138,231.19 | $144,396.93 | $39.04 | $41.10 |
| Revenue—fertilizer sales | 78,987.80 | 74,625.48 | (22.31) | (21.24) |
| Net operating cost | $ 59,243.39 | $ 69,771.45 | $16.73 | $19.86 |

*Summary of Operation Data*

| Item | 1941–42 Average | |
|---|---|---|
| Tributary population | 145,581 | |
| Sewage flow—total treated | 3,513.7 | m.g. |
| Average daily | 9.63 | m.g.d. |
| Per capita daily | 66.1 | gal. |
| Activated sludge data: | | |
| Applied air (c.f. per gal.) | 1.73 | |
| Analytical data: | | |
| 5-day B.O.D.—raw sewage | 149 | p.p.m. |
| Plant effluent | 13.2 | p.p.m. |
| Per cent reduction | 91.1 | per cent |
| Organic nitrogen—raw sewage | 16.4 | p.p.m. |
| Plant effluent | 7.1 | p.p.m. |
| Free ammonia—raw sewage | 24.0 | p.p.m. |
| Plant effluent | 16.5 | p.p.m. |
| Nitrite nitrogen—plant effluent | 0.99 | p.p.m. |
| Nitrate nitrogen—plant effluent | 2.19 | p.p.m. |
| Suspended solids—raw sewage | 303 | p.p.m. |
| Plant effluent | 27 | p.p.m. |
| Per cent reduction | 91.1 | per cent |
| Volatile solids—raw sewage | 259 | p.p.m. |
| Plant effluent | 24 | p.p.m. |
| Settleable solids—raw sewage | 9.9 | ml. per l. |
| Plant effluent | 0.2 | ml. per l. |
| Per cent reduction | 98.2 | per cent |
| Alkalinity—raw sewage | 297 | p.p.m. |
| Plant effluent | 251 | p.p.m. |
| pH—raw sewage | 7.2 | |
| Plant effluent | 7.6 | |
| Dissolved oxygen—plant effluent | 3.8 | p.p.m. |

*Sludge Dewatering and Drying Discontinued.*—Disposal of excess activated sludge by means of filtration and drying was discontinued June 30, 1942, and the new waste sludge line connecting to the Los Angeles County Sanitation Districts' system placed in use. The waste sludge line consists of a pumping station, 1,600 ft. of 8-in. cast iron pressure line and 5,788 ft. of 10-in. vitrified clay gravity line. The cost of the line was $21,149.48.

Plans for the line, exclusive of the pumping station, were prepared by the office of the City Engineer of Pasadena; inspection during construction was also by the City Engineer's office.

Construction of this waste sludge line eliminated the necessity of a large capital outlay to enlarge and rehabilitate the filtering and drying plants.

*Plant Operation Costs.*—Gross operating cost per million gallons of sewage treated was $41.10, an increase of $2.06 compared to last year. Net operating cost was $19.86, an increase of $3.13 per million gallons.

The net operation cost per capita (connected) was 47.9 cents for the year.

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## IMPORTANT REVISIONS IN SEWAGE WORKS PRIORITIES FORTHCOMING

With the recent appointment of the Federation's Vice President, A. M. Rawn of Los Angeles, as engineering consultant to the Governmental Division of WPB, sewage works administrators are assured of expert handling of their priority problems by a man familiar with sewerage and qualified by experience and training for this task. Mr. Rawn assumed his new duties about the middle of April and immediately undertook the task of revising Preference Rating Order P–141, issued to cover public sanitation services when Order P–46 was revoked last February. Order P–141 as originally issued does not conform completely to CMP Regulation Number 5A, which regulation applies the new Controlled Materials Plan to all governmental agencies, including provision for maintenance, repair and operation of sewage works. On April 24 Mr. Rawn advises that "order P–141 is being carefully revised to eliminate many of the features not applicable to sewerage and it will also be the endeavor to include in it a supplemental rating order for storm drains and rubbish incinerators."

It is also gratifying to note that simplification of project priorities is receiving consideration. Concernng this, Mr. Rawn reports:

"The form of application for construction of new projects or extensions of old ones is also being revised to include a specific questionnaire which the applicant may send in preliminary to making his formal application for project rating. The questions thereon are asked in such a manner that the applicant can almost judge for himself whether or not his project is an acceptable one.

"It has also been my intention with the authority of those in charge of the Governmental Division of WPB to issue enough information to the Federation so that they may prepare a brochure which will indicate to the prospective applicant the criteria in the light of which an application will be judged. This should prove a benefit and should limit applications to those which have a good chance of being acceptable.

"It may seem that supplementing the Form PD-200 with an additional questionnaire is merely adding another job to be done. Such, however, is not the case. The PD-200 requires an accurate breakdown of the job into its component material parts, thus prior to making the application, the job must be completely designed. The supplemental questionnaire does not require this detail. Its questions are general and the answers thereto will simply be used to establish the essentiality of the project, not to rate strategic materials for any other purpose. Then after the essentiality is established the applicant may proceed with more detailed design with more confidence."

In the meantime, Order P-141 (February 27, 1943) and CMP Regulation Number 5A (see below) will continue to apply to maintenance, repair and operation requirements. As the revised orders and regulations are issued, the Federation will endeavor to keep its members informed, either through the JOURNAL or by separate mailing.

## WAR PRODUCTION BOARD

### CMP Reg. 5A

### March 19, 1943

PART 3175—REGULATIONS APPLICABLE TO THE CONTROLLED MATERIALS PLAN

[CMP Regulation 5A]

MAINTENANCE, REPAIR AND OPERATING SUPPLIES FOR GOVERNMENTAL AGENCIES AND INSTITUTIONS

§ 3175.5a *CMP Regulation 5A*—(a) *Purpose and scope.* (1) The purpose of this regulation is to provide for governmental agencies and for institutions a uniform procedure for obtaining maintenance, repair and operating supplies, both in the case of controlled materials obtained by use of allotment symbols under the Controlled Materials Plan and in the case of materials or products obtained by preference ratings. Any agency or institution affected by this regulation requiring maintenance, repair and operating supplies, in any form, in such quantities as are available from warehouses or distributors under CMP Regulation No. 4, or at retail without preference ratings or allotments, may obtain the same without using the procedure provided in this regulation, but subject to all applicable limitations in War Production Board regulations and orders.

(2) The provisions of this regulation shall not apply to any governmental agency or to any institution to the extent that it is engaged in the following services or industries: gas, light, power, water or central heating, or to communications (in so far only as communications are provided for in Order P-130 and P-132).

(b) *Definitions.* The following definitions shall apply for the purpose of this regulation.

(1) "Governmental agency" means any governmental agency in the United States, its territories or possessions, federal, state, county, municipal or local except claimant agencies as defined in CMP Regulation No. 1 and except any agency specifically excluded from this regulation by order of the War Production Board.

(2) "Institution" means any institution within the United States, its territories or possessions, public or private, including but not limited to, schools, colleges, libraries, hospitals, welfare establishments and churches.

(3) "Maintenance" means the minimum upkeep necessary to continue a facility in sound working condition, and "repair" means the restoration of a facility to sound working condition when the same has been rendered unsafe or unfit for service by wear and tear, damage, failure of parts or the like: *Provided,* That neither maintenance nor repair shall include the improvement of any plant, facility or equipment, by replacing

material which is still usable, with material of a better kind, quality or design, except as provided in paragraph (b) (5) of this regulation.

(4) "Operating supplies" means any material or product which (i) is essential for conducting any activity or rendering any service by any governmental agency or by any institution and (ii) is consumed in the course of conducting such activity or rendering such service and (iii) does not constitute capital equipment. Materials included in any finished product produced by a governmental agency or an institution which are normally chargeable to operating expense may also be treated as operating supplies.

(5) In addition, there may be included as maintenance, repair and operating supplies, minor items of productive capital equipment and minor capital additions or replacements not exceeding $100 (excluding cost of labor): *Provided,* That no capital equipment, addition or replacement aggregating more than $100 in cost shall be subdivided for the purpose of coming within this definition: *And provided further,* That the acquisition and use of materials for construction shall be subject to the provisions of Conservation Order L–41, as amended from time to time.

(6) No item specified in List A attached shall be included as maintenance, repair or operating supplies, even if it would otherwise come within the foregoing definitions.

(7) Production material required by a governmental agency or an institution for physical incorporation in products manufactured by it, which products it sells for use as maintenance, repair or operating supplies, may be obtained as provided in CMP Regulation No. 1 and and in CMP Regulation No. 3, and such production materials shall not be deemed maintenance, repair or operating supplies, as to such agency or institution.

(c) *Controlled materials.* (1) Subject to the quantity restrictions contained in paragraph (f) of this regulation, any governmental agency or any institution engaged in any activity or rendering any service listed in Schedule I or Schedule II attached to this regulation, requiring delivery after March 31, 1943, of any controlled material (as defined in CMP Regulation No. 1) except aluminum, for maintenance, repair or operating supplies in the conduct of such activity or service, may obtain the same by placing on or accompanying its delivery order with substantially the following certificate (or the optional standard certificate provided in CMP Regulation No. 7) signed manually or as provided in Priorities Regulation No. 7:

> CMP allotment symbol MRO 5A—The undersigned certifies, subject to the criminal penalties for misrepresentation contained in section 35 (A) of the United States Criminal Code, that the controlled materials covered by this order are required for essential maintenance, repair or operating supplies, to be used for a purpose listed in Schedule I or Schedule II of CMP Regulation No. 5A and that delivery thereof will not result in a violation of the quantity restrictions contained in paragraph (f) of said regulation.

An order bearing such certificate shall be deemed an authorized controlled material order and shall have the same status as an order bearing an allotment number under all applicable CMP regulations unless otherwise expressly provided.

(2) Any governmental agency or any institution engaged in any activity, or rendering any service listed in Schedule I or II, requiring aluminum in any of the forms or shapes constituting a controlled material, for essential maintenance, repair or operating supplies, where the use of other materials for the purpose is impracticable, may obtain the same from a controlled materials producer or from an approved aluminum warehouse, in amounts of not to exceed 100 pounds from all sources during any one calendar quarter: *Provided,* That any order placed pursuant to this paragraph (c) (2) shall be endorsed with or accompanied by substantially the following certificate (or the optional standard certificate provided in CMP Regulation No. 7) signed manually or as provided in Priorities Regulation No. 7:

> The undersigned certifies, subject to the criminal penalties for misrepresentation contained in section 35 (A) of the United States Criminal Code, that the materials covered by this order are required for essential maintenance, repair or operating supplies to be used for a purpose listed in Schedule I or Schedule II of CMP Regulation No. 5A; that the use of other materials for such purpose is impracticable; and that the amount of aluminum covered by this order, together with all other amounts received by, or on order for delivery to the undersigned, from all sources, for such purpose during the same quarter, will not exceed 100 pounds.

Any producer or warehouse receiving an order bearing such certificate shall be entitled to rely thereon and may fill order, unless he knows or has reason to believe the certificate to be false.

(d) *Preference ratings for maintenance, repair and operating supplies.* (1) Subject to the quantity restrictions contained in paragraph (f) of this regulation, and subject to the restrictions of paragraphs (a) (2) and (g) of this regulation, orders by any governmental agency or institution calling for delivery after March 31, 1943, of maintenance, repair or operating supplies other than controlled materials (regardless of whether such supplies be Class A products, Class B products, or other products or materials) are hereby assigned preference ratings as follows:

(i) AA–1 for maintenance or repair of facilities required for any activity or service listed in Schedule I or for necessary operating supplies for such activity or service;

(ii) AA–2X for maintenance or repair of facilities required for any activity or service listed in Schedule II or for necessary operating supplies for such activity or service;

(iii) A–10 for necessary maintenance or repair facilities required for any activity or service not listed in Schedule I or Schedule II or for necessary operating supplies for any such purpose.

(iv) For maintenance, repair and operating supplies for any building devoted primarily to any service or activity listed in Schedule I or Schedule II, the rating assigned to that service is hereby assigned.

(2) Any agency or any institution which maintains a central stores system where it is impracticable to charge purchases for inventory against a particular service or activity, may establish a scale of percentages for each rating, for each class of items, based upon withdrawals from the central stores system during the calendar year 1942 (or its fiscal year ending nearest to December 31, 1942) by the various agencies and institutions (and departments thereof) and may apply the appropriate percentage of each rating to its purchases for the central stores system.

(3) A preference rating assigned under this paragraph (d) shall be applied only by use of the following certification (or the optional standard certificate provided in CMP Regulation No. 7) in lieu of the endorsement specified in Priorities Regulation No. 3, signed manually or as provided in Priorities Regulation No. 7:

Preference rating .................. (specify rating): MRO 5A. The undersigned certifies, subject to the criminal penalties for misrepresentation contained in section 35 (A) of the United States Criminal Code, that the items covered by this order are required for essential maintenance, repair or operating supplies; that this order is rated and placed in compliance with CMP Regulation No. 5A and that the delivery requested will not result in a violation of the quantity restrictions contained in paragraph (f) of said regulation.

A delivery order bearing the above certification shall have the status of a delivery order bearing a preference rating with an allotment symbol as provided in CMP Regulation No. 3.

(e) *Departments engaged in several activities.* If any governmental agency or any institution, or any department or unit thereof, is engaged in several activities which are not assigned the same preference rating and if it is impracticable to apportion maintenance, repair and operating supplies between such activities, the principal activity alone shall be considered for the purpose of determining whether controlled materials may be obtained under paragraph (c) of this regulation, and also for determining which preference ratings may be applied under paragraph (d).

(f) *Quantity restrictions.* (1) No governmental agency and no institution shall use the allotment symbol or preference ratings assigned by this regulation to obtain any item of maintenance, repair or operating supplies during any calendar quarter in an aggregate amount exceeding thirty per cent of its aggregate expenditures for items of maintenance, repair and operating supplies of the same class during the calendar year 1942 (or its fiscal year ending nearest to December 31, 1942) except that any governmental agency or any institution engaged in an activity which normally requires a greater amount of maintenance, repair or operating supplies during certain seasons than others, may use such allotment symbol or preference rating to obtain, during any calendar quarter up to but not in excess of, its aggregate expenditures for maintenance, repair and operating supplies for items of the same class during the corresponding quarter of 1942 (or such fiscal year). In neither case, however, shall any governmental agency or any institution use such allotment symbol or preference ratings to obtain maintenance, repair and operating supplies during the twelve months ending March 31, 1944, in an amount exceeding its aggregate expenditures for items of maintenance, repair and operating supplies of the same class used by it during the calendar year 1942 (or such fiscal year). As an illustration of the meaning of the term "items of the same class" purchases of sand and gravel during 1942 may not be taken into account in computing authorized purchasers of builders hardware in 1943.

(2) A governmental agency or institution which has several departments, branches or units which maintain separate records of maintenance, repair and operating supplies, shall treat each of them separately for purposes of complying with the provisions of subparagraph (1) of this paragraph (f).

(3) In the case of any building or facility operated by any governmental agency or any institution which was not in operation during the base period specified in subparagraph (1) of this paragraph (f), the governmental agency or institution operating the same may take as a base its expenditures for maintenance, repair and operating supplies during the first quarter of 1943, or during the portion thereof when the building or facility was in operation, reasonably adjusted for seasonal, or other variable factors: *Provided,* That it first notifies the War Production Board in writing of the base which it is taking, the reasons therefor, and the nature of any adjustments made. In the case of a building or facility starting operations after February 28, 1943, maintenance, repair and operating supplies may be acquired pursuant to this regulation in the minimum amounts necessary for operation, without other restrictions, up to $500 per quarter. If more than this amount is required, application should be made in writing to the War Production Board for a specific quota. In any case where the base provided in subparagraph (1) or by this subparagraph (3) is deemed too low for necessary operations, application may be made in writing for modification thereof.

(4) The restrictions contained in this paragraph (f) shall apply in addition to any quantitative restrictions contained in any order in the "P" series, unless the particular P order expressly provides that the restrictions of this regulation shall be inapplicable. The restrictions contained in subparagraphs (1), (2) and (3) of this paragraph (f) shall not apply to any controlled material or other product or material for which a rating is assigned on Form PD–408, as provided in paragraph (g) of this regulation.

(5) The War Production Board may, by further regulations or orders, require specified persons or classes of persons, to file applications or reports regarding their requirements of maintenance, repair and operating supplies and may prescribe specific quantitative limits for the same either larger or smaller than the limits provided in this paragraph (f).

(g) *Restrictions on use of ratings by agencies and institutions using Form PD–408.* No governmental agency or institution and no branch, department or unit thereof, to which a rating for maintenance, repair and operating supplies is or may be assigned on Form PD–408, shall, during the calendar quarter for which such rating is assigned, use any rating assigned by this regulation to obtain maintenance, repair and operating supplies. Any such agency or institution which is assigned a preference rating on Form PD–408 for controlled materials (other than aluminum) for maintenance, repair and operating supplies, may place authorized controlled material orders for the amount so rated, if, but only if, the same are required for essential maintenance, repair and operating supplies in connection with any activity or service listed in Schedule I or Schedule II attached to this regulation. Such orders shall be placed in the manner provided in paragraph (c) (1) of this regulation including the use of the certificate and symbol therein specified. Any governmental agency or any institution which is assigned a preference rating on Form PD–408 for aluminum for maintenance, repair and operating supplies may obtain the same pursuant to the provisions of paragraph (c) (2) of this regulation subject to the quantity restrictions contained in said paragraph, if, but only if, the same is required for essential maintenance, repair and operating supplies, to be used for a purpose listed in Schedule I or Schedule II of this regulation, by using the certificate specified in paragraph (c) (2) of this regulation. Any governmental agency or any institution which is assigned a preference rating on Form PD–408 for any material or product other than controlled materials, for maintenance, repair and operating supplies may, in applying such rating for the purchase of maintenance, repair and operating supplies, use the optional standard certificate provided in CMP Regulation No. 7 with the symbol MRO 5A, and a delivery order bearing such certificate and symbol shall have the status of a delivery order bearing a preference rating with an allotment symbol as provided in CMP Regulation No. 3. Any such agency or institution may, at its option, use the certificate specified in Priorities Regulation No. 3 without the symbol. The quantity restrictions prescribed in paragraph (f) of this regulation shall not apply to any controlled material or to any other material or product for which a rating is assigned on Form PD–408 for maintenance, repair and operating supplies.

(h) *Penalties for misrepresentation or diversion.* (1) The placing of any order bearing a certification or symbol as provided by this regulation shall constitute a representation, subject to the criminal penalties of section 35 (A) of the United States Criminal Code (18 U. S. C. 80), that the person placing the order is entitled, under the terms of this regulation to the use of the symbol or preference rating indicated thereon.

(2) No person shall use for any purpose other than essential maintenance, repair or operations, any supplies obtained pursuant to this regulation, or use any supplies obtained under a preference rating assigned by this regulation for a purpose to which a lower rating, or no rating, is assigned. Any such use shall constitute a crime punishable by fine or imprisonment or both. Physical segregation of inventories is not required, provided the restrictions applicable to any specific lot of material or product are observed with respect to an equivalent amount of the same material or product.

(i) *Inventory restrictions.* Nothing in this regulation shall be deemed to authorize any governmental agency or any institution to receive any delivery of maintenance, repair or operating supplies if acceptance thereof would increase its inventory above a practicable working minimum as provided in Section 944.14 of Priorities Regulation No. 1, or would exceed the inventory limitations prescribed for such person by CMP Regulation No. 2 or by any other applicable regulation or order of the War Production Board.

(j) *Additional assistance in individual cases.* Any governmental agency or any institution requiring maintenance, repair or operating supplies which it is unable to obtain pursuant to the foregoing provisions of this regulation, may apply to the War Production Board for additional assistance on such form as may be appropriate, having regard to the material required and the service or activity involved. If no particular form is specified by applicable orders or regulations of the War Production Board, such application may be made on Form PD–1A or, in the case of a PRP unit, on Form PD–25F. Such application shall be filed with the Governmental Division of the War Production Board, Washington, D. C.

(k) *Effect on other orders and procedures.* (1) The preference ratings assigned by this regulation shall supersede the preference ratings assigned by all orders in the "P" series for maintenance, repair and operating supplies with respect to materials or products to be delivered after March 31, 1942, except as may be otherwise provided by amendments of such orders specifically provided to the contrary.

(2) Subject to paragraph (k) (1) of this regulation, all of the terms, provisions and restrictions contained in all orders in the "P" series, including definitions, requirements for making applications and filing reports and other restrictions, except as otherwise provided in paragraph (f) (3) of this regulation shall, subject to the inventory restrictions of CMP Regulation No. 2, remain in full force and effect until modified or revoked.

(3) In addition, each governmental agency or insitution which, in accordance with existing priorities procedures not covered by "P" orders, is required to file applications or reports with respect to its requirements for, or use of, maintenance, repair or operating supplies, or is limited in the amount of such supplies, which it is permitted to acquire or use shall continue to comply with such procedures until the same are modified or revoked.

(4) Nothing in this regulation shall be construed to relieve any governmental agency or institution from complying with any applicable priorities regulation or order

of the War Production Board (including orders in the "E," "L" and "M" series) or with any order of any other competent authority.

(l) *Reclassification of activities.* Any governmental agency or any institution which is of the opinion that any activity in which it is engaged should be assigned a rating different from that assigned by this regulation, may apply to have such activity reclassified, by filing a letter in triplicate with the Governmental Division, setting forth the relevant facts and the reasons why applicant considers that such request should be granted.

(m) *Records and reports.* Each governmental agency and institution acquiring maintenance, repair or operating supplies pursuant to this regulation, shall keep and preserve for a period of not less than two years, accurate and complete records of all such supplies so acquired, and used, which shall, upon request, be submitted to audit and inspection by duly authorized representatives of the War Production Board and shall execute and file with the War Production Board such reports as may from time to time be required by said Board.

(n) *Communications.* All communications concerning this regulation should be addressed to: Governmental Division, War Production Board, Washington, D. C., Ref: CMP Regulation No. 5A.

Issued his 19th day of March 1943.

CURTIS E. CALDER,
*Director General for Operations.*

## LIST A

The following items are excluded from maintenance, repair and operating supplies as defined in paragraphs (b) (3), (b) (4) and (b) (5) of CMP Regulation No. 5A regardless of whether they would otherwise come within such definitions.

1. Fabricated containers (in knock-down or set-up form, whether assembled or unassembled), required for packaging products to be shipped or delivered.
2. Printed matter and stationery.
3. Paper, paperboard, and products manufactured therefrom; molded pulp products.
4. Fuel or electric power.
5. Office machinery or office equipment.
6. Clothing, shoes or other wearing apparel, if made of leather or textiles, except that the following types may be included in operating supplies when specially designed and used to furnish protection against specific occupational hazards (other than weather):
   a. Asbestos clothing,
   b. Safety clothing impregnated or coated for the purpose of making the same resistant against fire, acids, other chemicals or abrasives,
   c. Safety industrial rubber gloves and hoods and linemen's rubber gloves and sleeves,
   d. Gauntlet type welders' leather gloves and mittens, and electricians' leather protector or cover gloves,
   e. Other safety leather gloves or mittens but only if steel stitched or steel reinforced,
   f. Safety industrial leather clothing other than gloves or mittens,
   g. Metal mesh gloves, aprons and sleeves,
   h. Plastic and fibre safety helmets,
7. Fire hose, hose dryers, racks, reels and related products.
8. Fire extinguishers.
9. Any device, equipment, instrument, preparation or other material designed or adapted for use in connection with
   a. air raid warnings or detection of the presence of enemy aircraft; or
   b. blackouts or dismounts; or
   c. the protection of civilians, either individually or collectively, against enemy action or attack.

## SCHEDULE I

### PREFERENCE RATING AA–1

Sewers—sanitary and sewage disposal.
Hospitals
Refuse collection and disposal.
Communicable disease control.
Alcan, Panamerican and Trans-Isthmian highways.
Public transportation facilities.
Docks, wharves and terminals.
Police and law enforcement agencies.
Fire protection.
Beacons, markers, and radio devices employed as aids to navigation.

SCHEDULE II

PREFERENCE RATING AA–2X

Streets and highways providing immediate access to military or war production facilities, and the strategic network and its extensions into and through municipalities.

Federal aid system of highways.

Primary state highways, together with their extensions into and through municipalities and arterial streets and highways.

Airports and flight strips.

Dams, levees and revetments.

Canals—waterways.

Flood control facilities.

Storm sewers.

Public dispensaries, clinics and health stations, governmentally-owned or operated not for profit.

Penal institutions including prison industries.

Mine safety.

Printing and publishing.

United States Mint.

United States Bureau of Printing and Engraving.

Processing, warehousing, distribution, preparation, serving and inspection of food by Governmental agencies only.

Over-all administration including staff services, such as fiscal, procurement, personnel, etc., by Governmental agencies only.

Repairs made necessary by reason of any breakdown of plumbing, heating, electrical wiring or equipment, or elevator service in any building or to provide against imminent breakdown of any such facilities by Governmental agencies only.

Educational institutions.

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## TIPS AND QUIPS

A change from crystal to liquid ferric chloride for sludge conditioning has effected an annual savings of $700 per year at Marion, Indiana, reports Superintendent David Backmeyer. Cost of the rubber-lined storage tank installation necessary to handle the liquid chemical was $2,650.

* * *

Three British sanitary engineers, evidently having some extra time at hand during their temporary detention as prisoners of war in Germany, took advantage of the opportunity to prepare themselves to pass the entrance requirements and examination of the Institute of Sanitary Engineers, one of the Federation's British Member Associations. The British Red Cross made arrangements for the examination to be given and for transmission of the papers to England. All of the three passed the examination and were elected to membership in the Institute. The incident was considered to warrant special recognition and each of the three candidates was presented with a substantial award in the form of technical books.

Here is a case of very practical "post-war planning." Furthermore, it reveals something of the character of our intrepid British allies.

* * *

The many friends of Professor Max Levine of Iowa State College will be interested to know that he has recently been promoted to the rank of Lieutenant Colonel in the Sanitary Corps. He is now stationed at Brooke General Hospital, Fort Sam Houston, Texas.

Three of Lt. Col. Levine's sons are also commissioned officers in the Army: Lt. Norman D. Levine, Sanitary Corps; Lt. Edgar Levine, Corps of Engineers, now in India; and Lt. Melvin L. Levine, Field Artillery, presently attached to the Chemical Warfare Service.

* * *

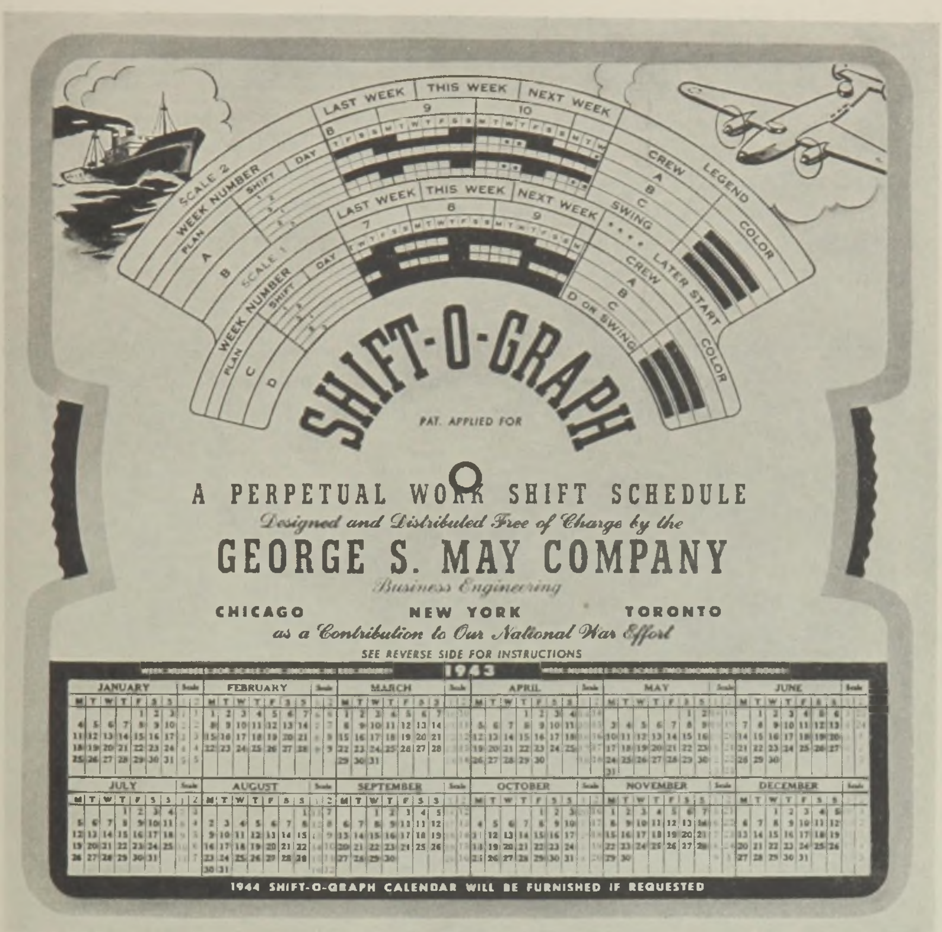


FIG. 1.—The "Shift-o-Graph."

The industrial waste survey conducted at Springfield, Missouri by Superintendent George L. Loelkes * has paid excellent dividends, both financially and in improving efficiency at the municipal sewage treatment works. The survey was initiated after an abrupt increase in industrial and domestic wastes brought about a severe overload at the recently enlarged Southwest plant.

* Reported in the *Journal* of the Missouri Water and Sewerage Conference, January, 1943.

Flow gagings and sampling of wastes gave the information necessary to enable industries to bring about compliance with the city's industrial waste ordinance. In the course of the collection of these data, nine industries and 65 residences outside the city limits were found to be connected to the public sewer system, all of which users now pay for the service. Results of the survey—reduction in flow at the Southwest plant from 13 to 9.5 m.g.d., reduction in raw sewage B.O.D. from 830 to 300 p.p.m. and an additional $2,000 to $4,000 per year into the coffers of the City Treasurer!

* * *

Sewage works superintendents in plants of moderate and large size may be interested in obtaining a "Shift-o-Graph," a sort of circular slide rule which makes it possible to determine and keep up with a wide variety of rotating work shift schedules. The device, illustrated in Fig. 1, is being distributed free of charge by the George S. May Company, 2600 North Shore Avenue, Chicago, Illinois, as a contribution to the war effort.

* * *

Another tip comes from Williard Pfeifer, assistant of Supt. Walter A. Sperry at Aurora, Illinois—a simple arrangement for cleaning gooch crucibles. A crucible holder (Fig. 2) is connected to the water faucet by

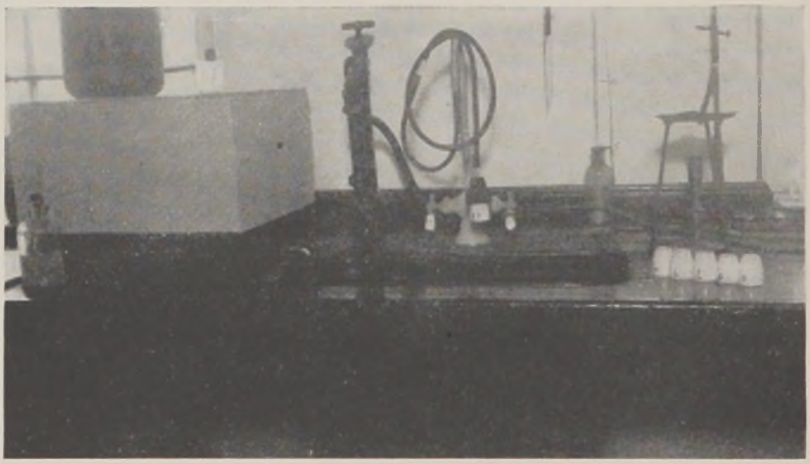

Fig. 2.—Gooch crucible washing arrangement. Note glass connector tube for detaching when not in use.

a length of rubber hose, by which means the perforated bottom of the crucible may be subjected to water under pressure. Obviously, the crucible must be gripped firmly with the holder when the water is applied. Cleans 'em quickly and thoroughly.

* * *

Did you know that income from advertising and sources other than membership fees made it possible for the Federation to render services to the extent of $7.80 for each Active Member in 1942? And this is just the beginning!

How about inducing one (or more) of your fellow workers to become a member of your Sewage Works Association? By doing so, you will be doing him a great favor.

* * *

Enlist a member—
Or two—or three
And we'll have 3000
In '43!

# Editorial

## SEWAGE RESEARCH—NOW!

The simultaneous publication in this issue of a partial list of research projects now under way in this country (p. 466), and of Abel Wolman's address "The Post-War Rôle of the Sanitary Engineer" (p. 445), should serve to catalyze the lagging progress of research in sewage treatment that seems to have occurred since the start of the war. Of course, account must be taken of the decreasing number of chemists, bacteriologists and engineers in civilian life, but on the other hand, the incentive to initiate new studies and to develop new ideas should be so much more urgent that those who remain in the research laboratories, testing stations, and treatment plants should redouble their efforts to add to our knowledge of sewage treatment. Construction and remodeling of civilian sewage treatment works has ceased for the past year or more and will continue dormant until the close of the war, but this only means that there will be a pent-up flood of new construction and remodeling necessary in the next few years, and the question therefore is—have we developed, through research, any significantly improved processes or modifications of processes during this time? Will our new works differ appreciably from those installed prior to the war? Will the operating results obtained in army camp sewage treatment works be applicable to municipal and industrial waste treatment works, so that we may know much more about high-rate filters, contact aerators, sludge digestion and odor control than we did before the war?

It is obvious that a great deal of attention is now being paid to the operation of army sewage treatment works—far more than in the last war—but it is doubtful whether there is enough technical control available to provide adequate and informative data that could be classed in the category of research. It is more likely that the records will indicate mainly a log of efforts to cope with overloads, odors, mediocre effluents and maintenance problems. There is no time nor justification for research in army camp sewage treatment works, and it is therefore doubtful whether the records will define any important advance in the design and operation of civilian sewage treatment works.

Laboratory research is practically non-existent in army camps, but there is still a large amount of work going on in various sewage works laboratories, as shown in Dr. Rudolfs' list of projects, which will be completed in our next issue. This type of research could be expanded if all laboratory leaders would make a more determined effort to initiate research studies.

Another attractive source of research lies in the technical staffs of the larger equipment companies and apparently they are taking advantage of the lull in sales of equipment to study and promote new devices for improving plant operation. Most of the projects at present relate to scum and grease flotation, and while this is of some importance in plant operation, it is not a major advance in the field of sewage treatment.

Studies of considerable importance appear to be under way on a plant scale, such as stage addition of activated sludge, diffusion of air, re-circulation of sludge-containing effluents from trickling filters and improvement of the efficiency of mechanical filtration of sludge. In most cases these and similar studies are rightly confined to certain phases of plant operation and not promoted as new and superior processes or methods of operation.

These four fields of research—army camps, research laboratories, equipment company research departments, and full-scale sewage treatment works—have been cited to indicate the various possibilities for advances in the treatment of sewage. Other problems are also urgent—industrial waste disposal, sludge utilization, pathogens in sewage, stormwater disposal and stream pollution control.

Marked advances in the art of sewage disposal occurred during the depression of 1933 and thereafter, when construction was paralyzed and time was available for research and development. The present times should constitute a recurrence of this cycle and we may hope for new and better things in sewage treatment after the war.

If Abel Wolman's prophecies come true we will need all the resources of our nation to meet the post-war needs of sanitation, and not the least of these will be the need for improved methods of sewage treatment. Therefore, let us not falter in fostering sewage research, but keep our minds actively and intently on how we can improve the present methods of sewage treatment.

F. W. Mohlman

*Editor's Note:* The discussion by A. M. Rawn on page 178 of the March, 1943, issue, was out of place and should have been inserted following page 189, as a closure to the "Forum: Influence of the War on Sanitary Engineering," and not as a discussion of Mr. Langdon's paper.

# Reviews and Abstracts

## THE POSSIBILITIES OF AND ECONOMICS RELATING TO ORGANIC MANURES AS APPLIED TO AIR-DRIED SEWAGE SLUDGE

BY JOHN FINCH

*The Institute of Sewage Purification Journal and Proceedings,* 98–103 (1941)

The paper is a continuation of an earlier report dealing with the program of the use of air-dried sludge as manure at Rotherham, England, during the last two years of the war period.

The production of food, by the utilization of all available soil resources in general and the utilization of sewage sludge in particular, during the emergency in England today, is of prime importance. The problem is how to produce increased quantities of food from land without impoverishing it materially as well as how to utilize poor soil for food production. The maintenance of the productivity of the soil depends primarily upon the supply of humus material. Town refuse and different forms of sewage sludge which are normally wasted, can meet this need. The value of organic manures such as sewage sludge do not depend for their value primarily on their fertilizer content but on the physical effect upon the texture of the soil. Sandy soil can be made fertile to a large degree by the application of sludge over a period of a few years, by the improvement of the mechanical condition of the soil, even before considering the use of artificial fertilizers. The author refers to the construction of an activated sludge plant during the last war to replenish the shortage of artificial manures. Judicious presentation of the facts without over-emphasis to prospective users is essential. At Rotherham the dried sludge is delivered to the users within the economic radius (15 miles) of haulage during the summer time at a cost of 6 to 7 d. a ton delivered. The real monetary value of sludge is difficult to evaluate on the basis of fertilizer constituents because of the lack of information regarding the chief constituent—humus. Naturally the monetary value of activated sludge is higher due to the greater fertilizer ingredients. To manure a farm exclusively by means of sewage sludge would require 30 tons an acre. This should be supplemented with a light dosage of potash. The experience in Rotherham area has been gratifying in the practical results. The Ministry of Agriculture maintains that if 15 tons per acre are used, on potatoes and vegetables, both sewage sludge and dung give considerable increases above the level produced by complete artificial fertilizers alone. On the whole, dung is somewhat more effective than an equal weight of sludge but the difference is seldom important.

H. HEUKELEKIAN

## NOTES ON THE SIMULTANEOUS DISPOSAL OF SEWAGE SLUDGE AND HOUSE REFUSE BY COMPOSTING TO PRODUCE AGRICULTURAL FERTILIZERS

BY C. T. READ

*The Institute of Sewage Purification Journal and Proceedings,* 285 (1941)

This is a short description of a process developed in Maidenhead, England, which has been operating for about seven years, for the economical disposal of sewage sludge and house refuse and the production of a fertilizer. It is based on the principle that sewage sludge acts as a powerful ferment on pulverized house refuse.

The operation is as follows: (1) separation of ash cinders, etc., by screening; (2) salvage of saleable materials such as paper, textiles, glass, metal and bones by hand picking; (3) pulverization of the residue; (4) magnetic separation of tins; (5) the deposit of the pulverized matter into beds about 3 feet deep; (6) impregnation of the bed with crude sewage sludge; (7) frequent turnings of the impregnated refuse under cover; (8) maturing in dumps in the open.

In answer to questions the following points were elucidated: (1) the nitrogen content of the compost may be as high as five times that found in farmyard manure; (2) the temperature reached during fermentation is high enough to destroy weed seed; (3) the moisture content is not constant since during the latter part of the process the material is stored in the open; (4) whole output of sludge and refuse is used; (5) composting bays should be under cover; (6) the composting is done within 200 yards of nearest habitation; (7) the refuse collected is 110 tons per week and the compost produced about 45 tons per week.

H. Heukelekian

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## THE STRENGTH OF SEWAGE: SOME COMPARATIVE RESULTS

By L. Klein

*Institute of Sewage Purification Journal and Proceedings*, 174–185 (1941)

This is a comparison of the different methods of assessing the strength of sewage in England. The strength of a number of sewages was determined by the following chemical methods: N/80 $KMnO_4$, 4 hr. at 80° F.; N/8 $KMnO_4$, 4 hr. at 80° F.; N/80 $Ce(SO_4)_2$, 4 hr. at 80° F.; N/8 $K_2Cr_2O_7$, as well as ammonia nitrogen, albuminoid nitrogen and organic nitrogen. From the nitrogen values, the strength was assessed by certain formulae and compared with the chemical and B.O.D. methods of determining strength. Without going into details of comparisons of methods which are not in vogue in this country, the following points are of interest: (1) The oxygen consumed values from N/8 potassium dichromate are many times greater than values obtained by the other chemical methods tried. The author proceeds on this basis to favor the former method as the best single chemical method for determining the oxidizable organic matter in sewage. (*Abstractor's note:* More complete destruction of organic matter and higher oxygen consumed values obtained thereby may not necessarily correspond to the availability of organic matter to biological oxidation.) (2) N/8 ceric sulfate method, when used in strong sulfuric acid solution and digested at 100° C., gave high oxygen consumed values equal in most cases to two-thirds of the corresponding dichromate figure and there was a remarkable constancy of ratio between these two methods. (3) There is no relationship between the 5-day B.O.D. and the oxygen consumed values by the various chemical methods. (4) Per cent purification as measured by the B.O.D. test was always higher than the corresponding values obtained by chemical methods. This higher purification value was due to the very small value found for the B.O.D. of the effluent. The question is raised as to whether the B.O.D. figure really gives a true measure of the quality of an effluent. (*Abstractor's note:* It is unusual to place the values obtained by chemical methods as being more reliable for domestic sewage than the B.O.D. on the basis of the higher values obtained by chemical methods, and also on the basis of the variations obtained by the different dilutions of the B.O.D. Part of this difference in experience as to the value of chemical *vs.* biochemical methods which exist between this country and England may be attributed to the larger quantities of industrial wastes present in the sewage in the latter country.)

H. Heukelekian

## MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH DIVISION OF SANITARY ENGINEERING ANNUAL REPORT (1941)

The following is an abstract of certain sections of this report:

*Determination of Grease in Sewage.*—The grease content of sewage using various solvents was as follows:

| | Soxhlet Method P.p.m. |
|---|---|
| Ethyl ether | 66.1 |
| Chloroform | 74.4 |
| Petroleum ether | 48.1 |
| Carbon tetrachloride | 61.3 |

A modification of the wet extraction method for determining grease in sewage was developed. The acidified sample is boiled over a reflux condenser for 30 minutes. It is then cooled, chloroform added and refluxed for 3 to 5 hours. The chloroform layer formed in the separatory funnel is filtered, dried and weighed. The comparison of this method with Soxhlet extraction method, using chloroform is given below:

| | Wet Extraction P.p.m. | Soxhlet Extraction P.p.m. |
|---|---|---|
| Sample A | 107.7 | 119.7 |
| Sample B | 84.7 | 107.5 |
| Sample C | 58.2 | 63.0 |

*Trickling Filters. Effect of B.O.D. Load.*—Various filters were operated with loads varying from 2,600 to 11,400 lb. B.O.D. per acre foot per day. The results showed a decreasing percentage of B.O.D. removal up to about 5,000 lb. (about 70 per cent removed with 5,000 lb. loading). Thereafter the curve flattened out and remained constant. The albuminoid nitrogen reductions are inversely proportional to the load. The average relative stability of the low rate filters was 73 per cent while that of the high rate filters was 19 per cent.

*Recirculation of a High-rate Trickling Filter Effluent.*—One filter is operated at the 20 m.g.a.d. rate. On two half-days a week the filter is operated without recirculation and the balance of the week the effluent is recirculated in a ratio of 3 to 1. The average results for the year gave a B.O.D. reduction of 70 per cent during recirculation and 53 per cent without recirculation. The corresponding suspended solids reductions were 71 and 65 per cent, respectively.

*Effect of Refiltration of a High-rate Trickling Filter Effluent.*—The effluent from the high rate recirculated filter discussed above is applied to a trickling filter at the rate of 11 m.g.a.d. The effluent approaches in quality that obtained from a low rate filter. The effluent is nitrified. The average rate of the combined system of double filtration is about 7 m.g.a.d.

*Secondary Filtration of Trickling Filter Effluents.*—In locations where a high degree of treatment is necessary only in the summer months it has been proposed to treat the sewage on high-rate filters, except during the summer months when further treatment through sand filters at relatively high rates might be given. Sand filters including effluents from high rate recirculated filters were capable of handling flows as high as 250,000 gal. per acre per day without clogging.

## TREATMENT OF LAUNDRY WASTES

By Joseph A. McCarthy

*Treatment by Trickling Filters.*—Raw laundry waste with a pH of 11.0 was applied to trickling filters at a rate starting with 1.0–1.5 m.g.a.d. The beds ripened quickly and showed a high degree of purification. The effluent was free of turbidity, practically all the caustic alkalinity was removed and the grease content was reduced from 267 to 35 p.p.m. There was no accumulation of grease and some nitrification was observed when the rate was raised abruptly to 10 m.g.a.d. and the filter was unable to take care of this load.

*Treatment of Laundry Waste by Coagulation and Settling.*—The laundry waste treated with alum at the rate of 23 gr. per gal. produced a rapid settling floc giving a removal of 89 per cent in turbidity, 84 per cent in fat and 74 per cent in B.O.D. Ferric sulfate (32 gr. per gal.) produced slightly better results than alum. The sludge produced with alum contained 41 per cent fat and 74 per cent volatile matter. The sludge from the iron salt was similar in composition to the alum sludge. The sludges dried rapidly and were not putrescible.

The use of sulfuric acid in conjunction with alum or ferric sulfate greatly reduced the cost of treatment. The acid could be added either before or with the alum. With ferrisul the acid should be added first. As much as 70 per cent of the alum and 80 to 90 per cent of the ferric sulfate requirement can be saved by the use of acid. Most economical results were obtained with alum and acid at a final pH between 4.5 and 5.0. A pH value between 3.0 and 3.6 gave the lowest costs with iron and acid. The use of less than optimum amount of coagulant gave poor results and poor economy. The most concentrated sludge was obtained from acid and ferric sulfate.

H. Heukelekian

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## THE SETTLEMENT OF DETRITUS IN SEWAGE THE DESIGN OF DETRITUS CHANNELS

By L. B. Escritt

*Civil Engineering* (London), 38, 14–16 (January, 1943)

Detritus does not flocculate, but settles at a constant rate, although the particles are larger than those which behave according to Stokes' Law. It is to be expected that there would be developed theory for the design of detritus chambers. In this country, however, until recently, most sewage works have been provided with detritus tanks of "Royal Commission" capacity, in which no theory of design has been used, with the result that detritus and heavy sludge have been settled out together.

There are in England a few constant velocity channels in which the flow is controlled by an outlet weir of rectangular form, or better, by a standing wave flume with side contractions only. The velocity is maintained by suiting the cross section of the channel to the weir formula. If the weir or flume is rectangular, the channel is of parabolic section.

Constant velocity channels controlled by standing wave flumes were installed at the Mogden works of the West Middlesex Main Drainage scheme. The channels were trapezoidal in section but closely approximated a true parabola.

In the design of constant velocity channels, they should be proportioned or arranged that at all rates of flow the velocity never exceeds, and never falls much below, 1 ft. per second. This is the velocity at which granular particles can settle and remain settled in the presence of normal turbulence found in long channels of constant section. The length should be sufficient to permit settlement time for the smallest particles falling from the surface level to the invert. Additional length should be provided to allow for turbulence at the inlet.

In order to give more complete control of settling the channel may be designed so that the velocity may be varied between 6 in. and 1 ft. per second. If the sewer discharges into a channel with the same invert level as the sewer, and which is drained by a flume or weir of the same invert level, it is possible to insure constant velocity by shaping the channel to a parabolic curve. Calculations may be simplified by setting up a table which shows discharge per foot width of flume, width of channel per foot width of flume, and area for various heads. To allow variations in velocity a flume of variable width, or a gate which closes laterally may be used.

When the velocity is 1 ft. per second it will be sufficient to allow for the particle which requires 16½ seconds to fall a distance of one foot. Thus, the absolute minimum length of channel would be 16½ times the depth. It is not possible to calculate with accuracy the necessary length of channel because the falling rates under turbulent conditions are not known. It is advisable to make a calculation on the assumption of quiescent conditions and allow a large factor of safety.

In most cases it may be considered unnecessary to allow for any adjustment of velocity but to design only for a fixed velocity of 1 ft. per second. This applies particularly to small works where adjustable velocity would result in very shallow flow at the higher velocity of one foot per second.

The particular advantage of constant velocity detritus channels is that, provided they are of sufficient length to give storage of detritus, the sediment is so free from organic matter that removal of grit is necessary only at infrequent intervals.

A paper by Mr. C. B. Townend, "The Elimination of the Detritus Dump," contains an excellent description of the design of the modern constant velocity channel. His method is briefly as follows:

$$X = 3Q/2H,$$

where $Q$ = cu. ft. per second, $H$ = depth of flow in flume in feet, $X$ = width of parabolic cross section at maximum water level.

Mr. Townend points out that in cases where the depth of the channel is the same as that of the incoming circular sewer, the width of the channel will sometimes be excessive. In such cases the sides of the channel will not be steep and organic matter may strand at low flows. This condition calls for two or more channels of equal total width.

One difference between Mr. Townend's method of design and the writer's is that the former, at Mogden, used a settling rate of 1 ft. in 10 seconds as compared to the writer's figure of 16½ seconds. The figure of 1 ft. in 10 seconds may be satisfactory in practice if it is not desired to settle the finest detritus. The Mogden channels are designed on the assumption of frequent removal of detritus by mechanical means. The writer considers that one of the advantages of the constant velocity channel in smaller works is that it eliminates the need of frequent removal of detritus, and also considers it necessary to give sufficient length of channel to provide storage.

T. L. Herrick

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## PURIFICATION OF STRONG SEWAGE BY RE-CIRCULATION THROUGH A PERCOLATING FILTER

By W. Watson

*The Institute of Sewage Purification Journal and Proceedings,* 129–135 (1941)

The sewage at Shipley, where the experiments were conducted, contains gas liquor, crude ammonia liquor, wool scouring waste and piece scouring and dye wastes. The settled sewage has a B.O.D. of 646 p.p.m. and a grease content of 600 p.p.m. The regular plant filters give an average purification of about 45 per cent without nitrification. The rate of application on these filters is 80 gal. per cu. yd. per day. In the winter, ponding occurs on the filters covered with a greasy gray slime. It was therefore thought that recirculation might alleviate this condition.

A filter 72 ft. diameter and 6 ft. deep was chosen for the experiment with recirculation. The arms of the distributors were cut to 50 ft. diameter and the holes enlarged and increased in number. The filter was provided with a separate settling tank and a 2 in. centrifugal pump.

Initially, for about a period of two months, the rate of application on the experimental filters was kept the same as on the regular filters (80 gal. per cu. yd.) but two volumes of effluent were returned in addition. The filters, which had been ponding before the alteration, ponded seriously after recirculation at this rate was started. Although the filter effluent had small quantities of dissolved oxygen, it was not sufficient with strong sewages to carry an appreciable quantity of dissolved oxygen to the filter feed after passage through the settling tank. Therefore, the sewage feed was cut to 15 gal. per cu. yd. and the recirculated effluent to 220 gallons. The effluent showed instantaneous improvement, the effluent contained humus and dissolved oxygen was present in the recirculated effluent after settling to the extent of 2 to 4 p.p.m. Within a month, the filter was cleared of surplus humus and was clean. Then the sewage flow was increased gradually to 80 gal. and the recirculated effluent put to 160 gallons. At the end of this period when equilibrium was established, purification as measured by B.O.D. figures was 80 per cent in the experimental filter as against 49 per cent in the regular plant filters. (Ave. for seven months.) Dissolved oxygen results during this period showed that the strongest sewages did not carry a surplus of oxygen around in the recirculated effluent but at other times it was present. There was no further sign of ponding in the experimental filter while the regular filters were seriously ponded. In the summer there were only a few *Psychoda* larvae.

The author concluded that it is the presence of dissolved oxygen in the filter feed which has the effect of dislodging the sludge accumulation and building up of an entirely different type of life. When dissolved oxygen is present, large quantities of slime do not form in the filter irrespective of whether there is high flushing velocity or not.

H. Heukelekian

## SHORT PERIOD MESOPHILIC SLUDGE DIGESTION AT DAVYHULME

By A. Holroyd

A written contribution to the above paper and an addendum to the paper by C. Jepson and L. Klein.

*The Institute of Sewage Purification Journal and Proceedings,* 157–161 (1941)

This discussion deals with the method of grease determination of sludge. The method used is as follows: (1) Digest 10 grams of dry sludge sample with 20 c.c. of concentrated HCl and 40 c.c. of water for 20 minutes, using a reflux condenser. Then cool. (2) Filter on a 7 cm. Buchner funnel washing with distilled water until filtrate is colorless. (3) Dry the residue on the paper. (4) Extract the dried residue. The following table gives the results obtained with four solvents by such treatment as compared with untreated samples.

*Series A—Sample simply dried before extraction.*

| | Pet. Ether | $CS_2$ | Ethyl Ether | Chloroform |
|---|---|---|---|---|
| Per cent extracted | 23.7 | 22.7 | 23.7 | 29.1 |
| Per cent ash in extract | 14.7 | 17.2 | 16.1 | 15.3 |

*Series B—Same sample acid treated and washed before extraction.*

| | Pet. Ether | $CS_2$ | Ethyl Ether | Chloroform |
|---|---|---|---|---|
| Per cent extracted | 17.8 | 17.8 | 18.3 | 19.3 |
| Per cent ash in extract | 0.15 | 0.1 | 0.15 | 0.38 |

In the A series, soaps are included, however, assuming that the whole extract is calcium stearate, the ash content should not exceed 10 per cent. In the B series, the extracts consist of fats and fatty acids. There should be a standardization of the quantity of acid added as it is substantial. The washing procedure may result in the loss of small quantities of acetic and butyric acids but none of the higher fatty acids.

An addendum to the original paper by C. Jepson and L. Klein.

The results of grease extraction of digested sludges using Mr. Holroyd's technique and the untreated method were as follows:

| | Untreated Sludge | | Acid Treated Sludge (Holroyd) | |
|---|---|---|---|---|
| | % Extracted | % Ash in Extract | % Extracted | % Ash in Extract |
| Ethyl ether | 7.2 | 7.2 | 9.9 | 0.2 |
| Chloroform | 9.8 | 9.6 | 11.2 | 0.44 |

The ash in the grease extracted by ether contained 42 per cent $Fe_2O_3$ and 20 per cent CaO. The ash in the chloroform extract contained 44 per cent $Fe_2O_3$ and 19 per cent CaO. The higher results obtained by using chloroform are due to the extraction of larger proportions of soaps as is borne out by the iron and calcium contents of ash in the extract. The following table based on experimental results substantiates this view:

| | % Extracted by Ether | % Extracted by Chloroform |
|---|---|---|
| Calcium oleate | 7.2 | 96.5 |
| Calcium stearate | 2.4 | 3.8 |
| Ferric stearate | 25.2 | 94.3 |
| Calcium salt from commercial soap flakes | 1.4 | 28.5 |
| Ferric salt from commercial soap flakes | 88.2 | 96.1 |

Extraction of calcium stearate by Holroyd's acidification method gave 87.7 per cent extracted by ether and 87 per cent by chloroform.

When these various calcium and iron soaps were digested anaerobically with ripe sludge, the gas produced in 20 days was greatest from ferric salt of commercial soap flakes (850 c.c. per gram volatile matter in soap) and least from ferric stearate (575 c.c.) while calcium stearate did not undergo digestion. The weight of gas produced was slightly greater than the weight of organic matter destroyed.

H. Heukelekian

## ORGANIZING AND FINANCING SEWAGE TREATMENT PROJECTS

By Samuel A. Greeley

*Proc., American Society of Civil Engineers,* 68, 1727–1742 (December, 1942)

This paper is limited to special organizations created for the one purpose of sewage treatment which have been organized under enabling acts in many of the states. Such special organizations fall into three general classes of administrative functions and procedures. One class comprises organizations created to function as an arm of the state. The Metropolitan District Commission of Massachusetts is an organization of this type. A second class is one created as an arm of the city, county, or other municipal organization. An organization of this class functions under the municipal governing bodies. The Milwaukee Sewerage Commission is an organization of this type. The third class is one organized as a new, independent, overlapping municipal organization. Once organized, it functions independently of other local bodies. Special organizations of this type are the Sanitary District of Chicago, and the Minneapolis-Saint Paul Sanitary District.

The classification of special organizations, in accordance with their geographical character, includes local, metropolitan, and regional. Local organizations are those having the same area and boundary as an existing municipality. Metropolitan organizations are those comprising a large city and surrounding municipalities, and possibly some unincorporated territory. Regional organizations are those comprising a large area, including a number of municipalities, not necessarily contiguous. They often include considerable county, township, or unincorporated area. The North Shore Sanitary District, Illinois, is an example of this type.

There are other kinds of special organizations. In California, for instance, organization is effected through contracts between adjoining municipalities. In 1925, the River

Conservancy District Act was passed in Illinois for the special organization of areas co-extensive with the drainage basins of rivers.

A major reason for the creation of special organizations has been to secure taxing and financial powers in addition to those permitted incorporated municipalities by constitutional restrictions. In states with constitutional limitations, special enabling acts cannot give this additional power direct to an existing municipality.

Special organizations have been called sanitary districts, sewerage commissions, authorities, and joint meetings. The term "sanitary district" is used in this paper. Most sanitary districts have the power to finance, construct, and operate sewage disposal projects, including intercepting sewers, pumping stations, treatment plants and appurtenances.

The first special organization to be organized in the United States was the Boston Main Drainage, which was created in 1876. The second to be created was the Sanitary District of Chicago, organized in 1889. The State of Illinois has had a long and complete experience in the organization of sewage treatment projects. The North Shore Sanitary District was organized in 1913, following an enabling act in 1911. The first to be organized in Illinois under the Enabling Act of 1917 was at Decatur.

Special organizations for sewage disposal projects have been organized in eleven states. There are fifty-eight such organizations, with a total population served in 1940 of 13,073,030. Illinois is represented by 46 per cent of the organizations by number and by 36 per cent of the population.

Prior to the year 1900 there were 45 sewage treatment plants in the United States. These plants were in eleven states and served a population of approximately 546,000. In 1940 there were 1,726 plants in these eleven states serving a population of 21,501,000, and in the entire United States the population served was 40,000,000.

## Part I. Organization

In the organization of sanitary districts, civic leaders have been prompted either to initiate an enabling act, or to lead the community to avail itself of existing legislation. They are organized to obtain funds beyond the statutory limitations of the municipality or component municipalities, and to provide for a continuing qualified personnel to administer the project.

Enabling acts for the creation of sanitary districts are either mandatory or permissive. Those which are mandatory bring the district into existance with the enabling act, or following the appointment of trustees. All of the Illinois acts are permissive. The area to be organized must petition for an election to determine the question of organizing a district. This step takes careful accounts of the rights of the small or local municipality. The trend is to continue to safeguard the rights, powers, and interests of the local municipalities.

The boundary of the area to be organized is generally included in the originating petition. Some enabling acts require a competent preliminary engineering investigation and report, the purpose of which is to assist the reviewing body in determining the area to be included. There is no such requirement in Illinois. Amendments have been made to existing Acts, providing for annexation or disannexation.

In Illinois, the administrative board is appointed by the county judge, except in the case of the Sanitary District of Chicago, where they are elected. The trend seems to be toward appointment of the board. In general, compensation of the members of the administrative board has been nominal. The Trustees of the Sanitary District of Chicago are compensated on a relatively liberal basis as it is a very large and complex undertaking and requires a considerable portion of their time. In the other districts in Illinois each Trustee receives $300 per year. The trend is toward relatively small compensation.

Sanitary districts in Illinois are empowered to levy and collect taxes, and to issue bonds upon favorable vote by the people. Amendments to the 1917 Act in Illinois provide that the district may apportion and collect an additional charge for the disposal of industrial sewage, and may also levy special assessments upon benefited property for the construction of collecting sewers. None of the districts in Illinois can establish and collect charges for sewage disposal service. The Buffalo Sewer Authority and the Hampton Roads Sanitation Commission are limited to the issuing of revenue bonds for raising money. The trend is to consider a sewage disposal project as a utility, to be operated on a revenue basis.

Illinois sanitary districts are empowered to levy and collect taxes as soon as organized. They may issue tax anticipation warrants, or borrow moderate sums for administrative purposes before tax money is collected. The Buffalo Sewer Authority had no means of securing funds until they issued and sold revenue bonds. The first funds were advanced by the Public Works Authority (PWA). Administrative boards should not be so limited in their early available funds as to handicap the progress of completing the project for which they were created.

Powers granted sanitary districts are more or less similar throughout the United States. The district has the power to engage engineers, lawyers, accountants, and clerks, to acquire right-of-way and property, to make contracts, and to build and operate structures. In some cases the district may contract with other districts for sewage disposal.

Throughout the United States there are relatively few new organizations. The most recent is the Hampton Roads Sanitation Commission (1941) and the Buffalo Sewer Authority (1935). There are two reasons for fewer new organizations in recent years: availibility of federal funds, and powers given municipalities to issue revenue bonds.

## Part II. Financing

The following methods of financing have been used by special organizations for sewage disposal projects:

(*a*) Taxes and borrowings through general obligation bonds;
(*b*) Funds contributed by constituent municipalities within the district;
(*c*) Special assessments on benefited property;
(*d*) Appropriations by the state;
(*e*) Voluntary contributions; and
(*f*) Revenues from service charges and loans secured by the revenues.

As the trend in financing has been toward service charges and revenue bonds, the discussion in this part of the paper will be limited to that method.

There are relatively few court decisions and rulings by regulatory commissions on charges for sewage disposal service. From the standpoint of general theory and the computation of rate structures, the application to sewage disposal projects is relatively undeveloped. Among early rate structures are those at Brockton, Massachusetts, and Spokane, Washington, which were established between 1890 and 1900. At the end of 1938 there were some 600 municipalities in 35 states using revenue bonds and the income from sewage disposal charges for financing such projects. In some cases the revenue is sufficient to meet operating charges only, while in others rates produce sufficient revenue for the entire annual cost of the project, including operation and debt service and, in some cases, a reserve fund for current extensions and replacements.

The various acts grant different powers as to the amount and use of revenue from sewage disposal charges. The Ohio law provides that the revenue shall be used for the payment of cost of management, maintenance, operation, and repair of the project. Any surplus in such fund may be used for enlarging or replacing parts of the project and for the creation of a sinking fund for the payment of any debt incurred for the construction. Revenue cannot be used for expansion into unsewered areas.

It is of interest to note that about 104 municipalities in Canada are reported as having established sewage disposal charges. Some 200 municipalities in Texas receive sewage disposal service from projects financed by revenue bonds. There are about 26 in Illinois, and a number in Massachusetts and New Jersey.

There are three principal kinds of sewage for which service is rendered:

Sanitary or domestic sewage;
Storm water, usually comprising the first part of the runoff; and
Industrial sewage or trade waste.

The structures to provide the service will include combined sewers or separate sewers, and the service charge may be limited to a sewage disposal project for sanitary or domestic sewage only, or for combined sewage. This is an important consideration. In some cases, industrial sewage may be excluded, but, in general, much industrial sewage is discharged into the system. In considering revenues and rates, the kind of sewage disposal project must be stated. The elements of use or service are:

(*a*) Treatment and disposal of sanitary or domestic sewage;
(*b*) Handling and disposal of storm water; and
(*c*) Treatment and disposal of industrial sewage.

The collection of these kinds of sewage may or may not be part of the project, but a consideration and comparison of rate structures should take the element of its cost into consideration. Also, the municipality must make some provision for future growth. A quite general practice in evaluating the quality of the service is to consider that sanitary sewage is reasonably measured by the quality of water used in the dwelling, exclusive perhaps, of water used for lawn sprinkling, and discharged to the sewage disposal project.

Industrial sewages may affect the cost of providing sewage disposal service because of their greater strength. They may have high oxygen or chlorine demand, or they may contain large quantities of solids or grease, difficult to handle. Fortunately, in many municipalities the amount of annual cost of handling such wastes is not a large proportion of the total cost. Frequently adjustments can be made by special rates or agreement with the industry, in some cases providing pretreatment.

If the collecting sewers are combined, some of the storm water reaches the sewage disposal project. Capacity for this storm water must be provided and part of the total annual cost is required for storm-water disposal. This service is more a function of the tributary area than of the use of water. Thus, area is indicated as a possible yardstick for measuring this service. The evaluation of this yardstick so far has been computed from the assessed valuation, which gives some weight to the extent, area, use and value of the property. A charge on the basis of value and area appears to be reasonable and expedient.

Additional expenditures and annual costs for provision of future capacity for growth of the city are made for the benefit and use of presently vacant property and for increased development of presently occupied property. Property is served by the sewage disposal project because its use and value are protected. This element of service may also be related to area, perhaps through the assessed valuation.

Thus, for combined systems in which the financial structure covers both storm and sanitary sewers, a two-part rate is indicated. One part of the rate might be based on the use of water and the other on the assessed valuation of the property within the area served, or to be served, by the project. Such a two-part rate has been used at Buffalo for more than three years.

There are many types of rate schedules for sewage disposal service, among which are the following:

(*a*) A charge related to the water bill, which may be a percentage of the bill or may be a separate graduated or uniform scale, related to the quantity of water.

(*b*) A flat rate per connection, according to the class or kind of property.

(*c*) A charge based on the number and kind of fixtures connected to the project.

The trend seems to be toward rates or charges related to the water consumption, with consideration being given to a two-part rate.

Experience in the percentage collection of bills for sewage disposal service appears to have been favorable. At Battle Creek, Michigan, current arrears do not, in general, exceed five per cent of the bills. At Lima, Ohio, during the years 1934–1938, inclusive, receipts were over 99 per cent of the total bills. Experience at Buffalo has also been satisfactory. The actual cash collections have been in excess of 93 per cent of the current bills. Some proportion of the arrears has been in deferred payments by adjoining tributary municipalities, with whom contract adjustments were pending.

General Summary

There has been a marked trend toward the use of revenue bonds and charges for financing sewage disposal projects. Experience in selling revenue bonds and collecting revenue has been satisfactory. It seems likely that this method of financing will continue and expand. There is need for a further clarification of the structure of rate schedules for sewage disposal service and a classification of present experience in the light of fundamental considerations.

T. L. Herrick

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# WASTE DISPOSAL PROBLEMS IN WARTIME

By F. W. Mohlman

*Chemical and Metallurgical Engineering*, 50, 78–81, 127–131 (1943)

## Sewage

The need for meeting war production requirements has forced the problem of industrial waste treatment and disposal into the background where it will probably remain for the duration of the war. Stream sanitation programs may have to be partially sacrificed during the emergency. Health standards, however, must be maintained.

There is a lack of appreciation on the part of many industrial chemists of the mechanism of the natural purification of streams, and the best managed industries only rarely make any attempt to study the relationship between their wastes and receiving water bodies. Excuses usually offered for failure to provide suitable disposal methods are lack of methods for treating their particular wastes or lack of funds. A more sensible basis of procedure would be for the industries to face their waste disposal problems squarely and undertake careful studies of them in coöperation with consultants familiar with pollution problems. A waste prevention and pollution abatement organization in each industry faced with a disposal problem would be of much assistance. It is unwise to approach the industrial waste problem solely on the basis of demonstrating the value of by-product recovery from the wastes. A better approach would be to consider the objectives of industrial waste salvage on the basis that such salvage would merely reduce the cost of the inevitable burden of proper industrial waste disposal.

A certain amount of salvage from ordinary sewage has proven practicable. Sludge from various treatment processes can be utilized as fertilizer. It is unwise to attempt to sell digested sludge as commercial fertilizer. However, farmers should be urged to use air dried, digested sludge and it should be made available to them at the plant site free of charge. Properly heat-digested sludge is substantially free from pathogenic organisms and can be used on all vegetables that are to be cooked or on tomatoes, corn, beans or squash. Possibly esthetic considerations ban its use on radishes, lettuce, and celery. Dried activated sludge is now well established as a commercial fertilizer. It has little phosphoric acid and no potash but the available nitrogen is valuable for green crops, cotton, and tobacco.

A second source of salvage from sewage and sewage treatment is contained in the gas produced by sludge digestion. Sludge gas contains about 70 per cent methane, the chief constituent of natural gas, and has a net heat value of 600 B.t.u. per cubic foot. The gas can be used for heating sludge digestion tanks, buildings and running gas engines. It is used for motor vehicle fuel in Germany and Britain.

Grease recovery from sewage and sewage sludge is not as a rule an economical undertaking. Grease separation processes in sewage treatment plants are installed to avoid operating difficulties in biological treatment units. An important exception is at Bradford, England, where grease recovery from wool washing process wastes has been demonstrated to be economically sound.

Fish culture using diluted sewage effluents has been practiced for years in Munich, Germany. Sewage plant effluents suitably diluted promote the growth of plankton which serve as fish food. Munich reports the production of about 500 lb. of carp per year per acre of fish culture ponds. It is unlikely that this practice will ever prove popular in the United States, however.

Sewage and sewage sludge are known to contain plant growth stimulating hormones such as indole, skatole, indole-acetic acid and naphthalene-acetic acid. Their value remains questionable, but some of the stimulating effect of sewage and sludge on plant growth has been ascribed to these hormones. Sewage may also contain other valuable extracts but this possibility remains to be demonstrated.

### Industrial Wastes

Industrial waste salvage work offers far greater rewards than does corresponding work in the field of ordinary sewage treatment. This is due to the greater value of materials present in many industrial wastes and to their higher concentration. Industrial wastes may contain as much as 5 per cent solids while domestic sewage never contains over 0.1 per cent. The National Resources Committee has reported that the cost of treatment of industrial wastes throughout the United States would be of the order of $700,000,000. A recent survey by the U. S. Public Health Service of the Ohio River Basin showed that industrial wastes reaching that river have a population equivalent of nearly 10,000,000. An extensive industrial waste survey of the Sanitary District of Chicago covering a seven year period indicated a total industrial waste population equivalent for the District of 2,700,000, with a daily flow of 93 million gallons, and a daily suspended solids contribution of 172 tons. Data relating to the cost of treatment works, population equivalents in the Ohio River Basin, and the results of the Sanitary District survey are summarized in three tables according to type of industry.

Studies by the author on the problem of reducing the pollution power of wastes from the production of organic chemicals such as dyes, pigments, intermediates and detergents have indicated that it is of importance to concentrate on those processes that produce wastes of greatest population equivalent from the standpoint of B.O.D. or suspended solids. The B.O.D. of organic chemical wastes, many of which are germicidal, is difficult to determine, but these wastes may exert a considerable B.O.D. in dilute solution when seeded with bacteria.

The principle of recirculation is important in the entire field of industrial waste disposal and its value has been demonstrated in many industries. Changing from "once through" to recirculation processes involves considerable study but once the problems attendant to this change have been worked out and recirculation is adopted valuable by-products may be recovered and a substantial decrease in pollution effected.

TNT wastes present an important problem intimately related to war economy. These wastes are of two main types, the acid or yellow wastes and the alkaline or red wastes. These wastes have no B.O.D. but both have intense colors which persist even at high dilution. All usual treatment methods applied to these wastes fail and only chlorination, evaporation, or dilution are available as possible means of treatment and disposal. Chlorine will greatly reduce the color of the mixed wastes or the red waste alone but is now difficult to obtain. Evaporation is an expensive process and requires critical equipment such as multiple effect evaporators and kiln dryers in addition to large quantities of caustic soda. Investigations have shown that the degree of dilution required to reduce the color to an insignificant value can be accurately determined. Where dilution water is available, the maximum color that can be tolerated in the streams should be determined and the flow required to dilute the wastes to this value calculated. When stream flows are less than the minimum required, the wastes must be stored until higher stream flows are available. Disposal by dilution has been shown to be a satisfactory method of handling TNT wastes and has resulted in the elimination of several evaporation units.

The 1943 quota for alcohol production is 530,000,000 gallons of which 465,000,000 gallons are to be derived from fermentation processes. This introduces the problem of disposal of the still slop since the enormous amount of slop produced would tax the natural purification powers of the largest streams. The population equivalent of the still slop derived from 465,000,000 gallons of alcohol is estimated to be 28,800,000. The total sewered population of the United States is 70,506,000.

Studies by the Chicago Sanitary District of brewing industry wastes indicated a loss of suspended solids to the brewery sewers of 1.7 lb. of suspended solids per barrel of beer produced. The population equivalent was 18.6 per barrel of beer. Pro-rated for all breweries in the U. S. these figures give a daily suspended solids load of 120 tons, and a population equivalent of 26,000,000. Improved methods of recovery of yeast, spent grains and possibly dissolved solids should be inaugurated by the industry.

The "bottling up" practice of the corn products industry is cited as an example of salvage from industrial wastes. The "bottling up" process was put into effect in 1926 at the Argo, Illinois, plant of the Corn Products Refining Company. Recoveries were quite profitable and the construction of a $3,000,000 waste treatment plant was made unnecessary.

Food products including glutamic acid and betaine are being manufactured from beet-sugar Steffens waste at an Ohio plant.

Yeast wastes at one plant in Illinois are partially treated by digestion and the gas produced is utilized for heating, etc.

The problem of the disposal of wastes from the sulfite pulp process remains unsolved although hundreds of patents have been granted in this field. Consideration is now being given to the production of alcohol from waste sufite liquor. Its use for alcohol production would have little effect insofar as pollution abatement is concerned, however.

The author indicates that the wastes from the manufacture of synthetic rubber may have a significant B.O.D. and create a waste disposal problem. However, the urgency of production may make necessary the allowance of a moderate degree of stream pollution.

The salvage of phenol from ammonia-still wastes produced in by-product coke plant wastes is especially important at present because of the use of phenol in plastics and explosives manufacture. Two processes for recovery of phenol are in use, the benzol extraction process and the Koppers vapor recirculation process.

The disposal of waste pickle liquor from steel mills presents a large and difficult problem. This is now receiving careful study at the Mellon Institute. Considerable attention has been directed to the Ferron process which involves the manufacture of building material from ferric hydroxide and calcium sulfate precipitated from the pickle liquor. An interesting, large-scale process involving the manufacture of iron oxide and sulfur dioxide from pickle liquor has been developed by the Chemical Construction Company.

If chromium and chromium salts become scarce and expensive it may prove economically feasible to recover chromium salts from tannery wastes.

Grease can be profitably recovered from packinghouse wastes by means of properly designed and supervised recovery equipment.

The necessity for treatment of industrial wastes is much more urgent than the need for demonstrating profitable by-product recovery. Expansion of basic industries and establishment of many new types of chemical industries have increased the industrial waste load imposed on streams and lakes to a point where the latter will no longer be able to assimilate the pollution by natural purification processes unless the wastes are adequately treated. Industrial authorities are urged to establish within their organizations, divisions charged with the responsibility of investigating waste disposal problems.

Paul D. Haney

## ACID WASTE TREATMENT WITH LIME

By Willem Rudolfs

*Industrial and Engineering Chemistry*, 35, 227 (Feb., 1943)

The expansion of the chemical industries because of the war has increased the volume and variety of chemical wastes. These wastes consist chiefly of acids and alkalies with or without small amounts of salts, solvents and poisons present. The problems created by discharge of these wastes to the sewerage system pertain mostly to corrosion of sewers and equipment, their effect on biological processes of sewage treatment and their interference with fish life and self purification of streams.

The wastes of five chemical plants were studied with regard to chemical characteristics, variations in strength and fluctuations in flow. Laboratory experiments were conducted on the treatment of these wastes by neutralization and on the effect of various neutralizing agents.

Table I shows the variations in character and flow of the wastes studied:

Table I

| Waste No. | Principal Ingredients | pH | Acidity P.p.m. | Alkalinity P.p.m. | Types of Acids | Flow, gal. per day | |
|---|---|---|---|---|---|---|---|
| | | | | | | Min. | Max. |
| 1 | Acids, Alkalies | 2.0–8.6 | 0–900 | 0–85 | $H_2SO_4$, HCl, $HNO_3$ | 14,400 | 35,000 |
| 2 | Acids, Alkalies, Solvents, Poisons, Salts | 1.7–10.5 | 0–1,180 | 0–1,140 | $H_2SO_4$, HCl | 865,000 | 1,800,000 |
| 3 | Acids, Alkalies | 0.9–1.4 | 9,000–11,800 | 0 | $H_2SO_4$, $HNO_3$ | 3,400,000 | 7,800,000 |
| 4 | Acids, Alkalies, Solvents | 1.0–3.2 | 250–4,000 | — | $H_2SO_4$, HCl | 325,000 | 365,000 |
| 5 | Acids, Alkalies | 1.8–4.3 | 0–3,000 | 0–5,000 | $H_2SO_4$, HCl | 90,000 | 160,000 |

Some of the wastes varied widely in pH due to the intermittent discharge of acids and alkalies. For the most part they consisted mainly of mixtures of acids as indicated. All contained cooling and wash waters. Wastes 2, 4 and 5 contained small amounts of domestic sewage.

Considerable experiment established that the most effective method of treatment for these wastes are:

1. Neutralization by filtering through a calcium limestone bed with a 5 minute contact time.
2. Equalization of flow and neutralization to pH 6.0 with high calcium hydrate.
3. Neutralization with high magnesium hydrate and soda ash.
4. Equalization and neutralization with high magnesium hydrate.
5. Neutralization with dolomitic limestone and aeration.

It is evident that the method of neutralization is influenced by the ingredients other than acid or alkali in the waste.

During the course of the experiments the behavior of various neutralizing agents on the waste from a nitrocellulose plant was studied. The waste chosen had a total acidity of 11,810 p.p.m. with 3,660 p.p.m. nitric and 8,150 p.p.m. sulfuric acid. It also contained some solvent and a small amount of nitrocellulose floc.

The general procedure consisted in treating the waste in beakers fitted with a rapid stirring devise and an instrument to measure pH.

Keeping the contact period constant at 30 minutes, the quantities of neutralizing agent were determined. Table II gives the theoretical quantities required, the actual amounts used and the resultant pH.

Table II

| Type of Lime | Theoretical P.p.m. | Actual P.p.m. | Final pH |
|---|---|---|---|
| High calcium-hydrate | 9,200 | 9,250 | 8.6 |
| Dolomitic hydrate | 7,020 | 7,750 | 8.5 |
| High calcium limestone | 12,240 | 13,000 | 4.7 |
| Dolomitic limestone | 10,930 | 15,000 | 1.4 |
| High calcium quickline | 6,900 | 9,000 | 3.4 |
| Dolomitic limestone | 6,000 | 8,000 | 3.3 |

Calcium and dolomitic quicklime were unsuitable because of balling caused by coating of the lime particles with sulfate before hydration could take place. Dolomitic limestone required quantities far in excess of the theoretical amounts to produce satisfactory results. Calcium limestone formed $CO_2$ most of which could be removed by aeration. Less dolomitic hydrate is required than calcium hydrate.

The effects of concentration, the time of contact and the weight and volume of sludge formed were studied for each neutralizing agent. It was concluded that for this type of waste, dolomitic hydrate was best for neutralization although it produced somewhat larger amounts of sludge.

Studies using caustic soda and soda ash indicated that soda ash was preferable because it did not produce the intense colors caused by caustic soda. However even this was undesirable because of intense foam formation.

Mixtures of soda ash and lime were next studied. Experimentation showed that unless the lime was added first, carbonization of the lime particles by the $CO_2$ produced occurred. The weight of sludge formed by this treatment increases with the amount of dolomitic hydrate used. With lower amounts of soda ash, however, the sludge becomes more voluminous and more difficult to dewater. The smallest volume and lowest dry weight was produced when the acids were neutralized with 80 per cent dolomitic hydrate and 20 per cent soda ash. This sludge did not settle as well as that produced by the lime alone.

The time of contact required for neutralization also increased with increasing amounts of soda ash. With 10 per cent soda ash the contact time was half that required when 50 per cent was used. This is probably due to the formation of large volumes of $CO_2$ which are not released even with vigorous stirring fast enough to prevent carbonization of the lime.

Similar studies were made for the other wastes mentioned and the most suitable type of treatment determined as indicated previously.

E. Hurwitz

## PENNSYLVANIA ANTHRACITE AS A FILTER MEDIUM

By H. G. Turner

*Industrial and Engineering Chemistry*, 35, 145 (Feb., 1943)

In the preparation of anthracite coal for filter use, care is given in the selection of the material to obtain a low ash material of the correct shape and to control the particle size to fit the specific use for which the filter is designed.

Unlike sand, which is chiefly silica, anthracite is essentially carbon and is therefore inert to acids, alkalies and other chemicals. Its particle shape is conchoidal and its particle charge is negative and much stronger than the charge on sand.

In the removal of solids from liquids on filter beds, the filter media serve as entrapping agents rather than as strainers. Since the degree of entrapment is directly proportional to the surface area, the sharp angular particles of "anthrafilt" are more efficient than the same size sand. It has been found that "anthrafilt" having an effective size of 0.70 mm. and uniformity coefficient of less than 1.60 removes the same amount of solids as rounded sand with an effective size of 0.45 and a uniformity coefficient of 1.60.

"Anthrafilt" weighs about 50 lb. per cu. ft. compared with 100 lb. for sand. Because of its light weight, the 50 per cent expansion desirable in filters is easily obtained without increasing backwash velocities. Also since coarser "anthrafilt" can be used to obtain efficient removal, longer runs between backwash periods are possible.

The first mention of the use of anthracite for sewage work was made in a report of the Lawrence Experiment Station for 1910. The report describes a filter in which anthracite was used and which was operated at a rate of 800,000 gal. per acre per day from 1901 through 1910. During this time the filter removed "large percentages of suspended matter from the sewage and by some biological process not fully understood appears to destroy this matter with great rapidity." "Anthrafilt" has since been used successfully for sewage filtration, filtration of chemical wastes and filtration of cannery wastes.

From the standpoint of degradation "anthrafilt" and sand have about the same life. "Anthrafilt" resists incrustations on its surface and from this standpoint, it will last twice as long as sand.

The cost of anthrafilt per ton is greater than sand but since it has only half the weight per cu. ft., it is no more expensive volume for volume.

E. Hurwitz

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## ILLINOIS WATER LITIGATION, 1940–1941

By Langdon Pearse

*Proc., American Society of Civil Engineers,* 68, 1689–1713 (December, 1942)

The State of Illinois, in a petition dated January 11, 1940, requested a temporary relaxation in the order restricting the flow of water from Lake Michigan to relieve conditions in the upper Illinois Waterway, particularly at Joliet. The diversion has been restricted to an annual average of 1,500 c.f.s. in addition to domestic pumpage since January 1, 1939, by an order of the United States Supreme Court dated April 21, 1930.

A War Department permit dated March 3, 1925, limited the diversion to 8,500 c.f.s. This permit expired on December 31, 1929. A new permit was then issued authorizing an annual average diversion of 7,250 c.f.s., or such lesser annual average diversion as would restrict the average annual flow at Lockport to 8,500 c.f.s., until July 1, 1930.

The Supreme Court decree provided that the diversion should be reduced to 6,500 c.f.s. on July 1, 1930; to 5,000 c.f.s. on December 31, 1935, and to 1,500 c.f.s. on December 31, 1938. A controlling works was also to be built at the mouth of the Chicago River. The reductions were made on schedule and the controlling works were built. The decree does not specify the type of sewage treatment works to be built by the Sanitary District of Chicago or when they shall be completed.

The depression retarded tax collections in 1931, 1932, and 1933 and stopped the Sanitary District from selling bonds because of the technical default of its then outstanding issues. Hence the schedule of the completion of the sewage treatment works of the Sanitary District was upset. Treatment provided was sufficient to show some improvement in the condition of the upper Illinois Waterway until the final reduction at the end of 1938, when the flow was reduced so greatly that conditions were created that were worse than at any other time in the preceding 30 years.

The Special Master had been instructed to determine the diversion required for the Port of Chicago. This was interpreted to include the Main Channel at Lockport. Thus conditions below Lockport were ignored in preparing the 1930 decree because the Des Plaines-Illinois River system between Lockport and Utica was not then a navigable water of the United States. By the River and Harbor Act of July 3, 1930, the entire waterway from the Chicago River to Utica became a navigable waterway of the United States.

This paper is concerned principally with the happenings in the upper pool, known as Brandon Pool. It extends from Lockport to the Brandon Road Dam, a distance of 4.84 miles, through the heart of Joliet. The pool varies in width from 200 ft. to 1,400 ft., with a maximum depth of 27 ft. Before the closing of the Brandon Road Dam, in 1933, flow in the section through Joliet was very rapid, resulting in a high rate of re-aeration. To the end of 1938 little was heard of conditions in the pool, though sludge was accumulating in it.

With the reduced diversion conditions changed rapidly for the worse. The 5-day B.O.D. at Lockport rose rapidly. The dissolved oxygen disappeared not only at Lockport but upstream for 30 miles into the Chicago River at Damen Avenue. In the summer of 1939 the outcry from Joliet became so great that the State of Illinois applied for a permit to increase the diversion to 5,000 c.f.s. in addition to domestic pumpage, until December 31, 1942. On April 30, 1940, the Court ordered that the petition and the return of the Complainant States be referred to Monte M. Lemann as a Special Master. He was directed to

". . . make summary inquiry and to report to this Court with all convenient speed with respect to the actual condition of the Illinois Waterway by reason of the introduction of untreated sewage, and whether, and to what extent, if any, that condition constitutes an actual menace to the health of the inhabitants of the Complaining Communities, and also with respect to the feasibility of remedial or ameliorating measures available to the State of Illinois without an increase in the diversion of water from Lake Michigan."

The hearings were held in Chicago, and the case was argued in New Orleans, La., in February, 1941. The Master rendered a report to the Court on March 31, 1941. On May 26, 1941, the Court denied the petition.

After the completion of the hearings the petition was modified. In the revised petition Illinois requested a temporary increased diversion during the warmer months of 1941 and 1942 sufficient to maintain a minimum of 1 p.p.m. of dissolved oxygen in the Brandon Pool. The increased flows requested in this petition amounted to annual averages of 2,000 c.f.s. and 1,250 c.f.s. in 1941 and 1942, respectively.

### Minimum Dissolved Oxygen

Witnesses for Illinois testified that in the absence of sludge deposits at least 1 p.p.m. of dissolved oxygen is necessary to prevent nuisance. In New York vs. New Jersey, 256 U. S. 296,311, decided in 1921, the Master expressed his belief that the weight of opinion is that the presence of any dissolved oxygen is sufficient. In that case, however, the Court held that 25 per cent to 50 per cent of saturation is necessary to prevent offensive odors from decomposing organic matter deposited in the body of water under consideration. On that basis, 2 to 4 p.p.m. dissolved oxygen would be required in the warmer months in Brandon Pool.

The evidence shows that the most important factor responsible for the foul conditions of the Main Channel and Brandon Pool is undoubtedly the deposits of putrefactive sludge that formed since the diversion was reduced. In the Brandon Pool these deposits have formed since 1933, from residual solids in the effluents of the various treatment works of the Sanitary District, from raw solids, the discharge of sludge at the West and Southwest works of the District, and from storm-water solids. Witnesses for both sides agreed that these sludge deposits have a high demand for oxygen, and are the most important factor in the production of the foul conditions noted. They agreed that the discharge of settling solids, whether in partly treated sewage or as sludge, should be stopped as soon as possible. This is what the Sanitary District program contemplates doing.

The sludge deposits require a long time to lose their putrefactive character. Dr. Mohlman testified that a test of the oxygen demand of sewage sludge overlaid by Illinois River water showed consumption of oxygen for more than 1,100 days. For the first 400 days this was confirmed in other tests by Dr. W. Rudolfs. Results show that during the first summer the loss of oxygen may range from 50 per cent to 55 per cent. The following summer possibly 20 to 25 per cent more of the oxygen demand may be destroyed.

### The Health Problem

The proceedings before the Master were clearly divided into three parts:

1. Complaints and the health conditions along the Waterway;
2. Status of sewage treatment by the Sanitary District and the outlook for the summers of 1941 and 1942; and
3. Available remedial or ameliorating measures.

Illinois contended that the present condition of the Illinois Waterway in the Joilet-Lockport area constitutes not only an actual menace to health but also a definite injury to health. The evidence shows a two-fold health problem:

(*a*) The actual detriment to health caused by the inhalation of gaseous odors emanating from the Waterway; and

(*b*) The potential hazard, danger, or menace to health occasioned by the present highly polluted and foul conditions of the Waterway.

The Opposing States contended

"... that the phrase 'actual menace to health' as used in the order of the United States Supreme Court means the effects on the health of the people residing near the Waterway must be real and exist in fact, as opposed to any potential, speculative, hypothetical views on what might happen, unsupported by any real cases or actual happenings."

They maintain that at most the evidence shows only annoyance, discomfort, and inconvenience suffered by some people.

*Complaints of Lay Witnesses at Joliet.*—Complaints as to the Waterway came chiefly from people residing near the pool in Joliet. All complaints were based on the offensive odors from the pool, and the effects ascribed to them. No water from the Waterway is used for drinking purposes, and there is no swimming in it.

A total of 127 witnesses testified at Joliet. Of these, 15 were physicians and 24 were nurses and employees of a Joilet hospital. The complaints were generally that in the hot months of 1939 the pool gave off extremely offensive odors, which in many cases caused nausea, lack of appetite, or inability to sleep.

The Health Commissioner of Joliet received hundreds of complaints in June, July, and August, 1939. He stated that there was danger of an epidemic from flies and mosquitoes alighting on the scum; that the stench was nerve-racking; and that the odorous gases irritated the mucous membrane of the nose, throat, and sinus. The other fourteen Joliet physicians considered the pool a menace to health for similar reasons.

Statistics on reportable diseases in Illinois show that the case rate in 1939 was less in Will County (in which Joliet is located) than the average for the state except for poliomyelitis, malaria, and influenza. The typhoid rate in Will County was 0.9 per 100,000 as compared with an average of 1.8 for the years 1930 to 1938, and a rate of 1.4 for the state.

The Master concluded that no cases of specific illness clearly attributable to the Waterway were cited by the physicians.

*Testimony by Opposing States on Health Conditions.*—Casual tests on August 3, 1940, disclosed no trace of hydrogen sulfide in the air over the pool. Bacterial tests on July 16, 1940, showed only the usual bacteria found in air to be present. Samples of water from the pool on September 28, 1940, showed hydrogen sulfide from 0.1 to 0.2 p.p.m. Various experts testified that there was no possibility of an epidemic in the adjoining community due to the transmission of germs or bacteria by air from the Waterway.

A toxicologist testified that hydrogen sulfide in the air, concentrated as low as 50 p.p.m., may cause nausea. A concentration of 100 p.p.m. may cause local irritations and depression of the nervous system, but doubted if such a concentration could occur in the air over the pool.

All the physicians, health authorities, and sanitary experts who appeared for the Opposing States agreed that the Waterway did not constitute a menace to the health of persons living along it.

*Testimony for Illinois on Health Conditions.*—A toxicologist for Illinois testified that complaints of nausea, headaches, insomnia, and loss of appetite "may have been caused by hydrogen sulfide." He could not refer to any record in medical literature where an individual was overcome in the open air from a polluted Waterway. Upon exposure to more than 20 p.p.m. but less than 50 p.p.m., the average person would complain of irritation of the mucous surfaces of the eyes, nose, and throat. He considered the condition of the waterway a very definite menace to health. Any contamination of the air is a menace if a sound state of health is upset.

A physiologist for Illinois regarded the pool as a menace even if the water is not used for drinking or bathing. His conception of a menace to health was typified by conditions which, through accidents or any ordinary course of human events, can lead to injury to health. He used the words "menace to health" in a scientific sense as a theoretical danger which cannot be measured in any statistics or in any outward observation by a physician. In his opinion the fact that the communicable disease rate in Joliet is no higher than in other places is no factor in determining whether the pool is a menace to health. Another physiologist corroborated, holding that the disturbances reported due to odor showed an unhygenic condition working to a detriment to the health of the people.

### General Authorities on Sewage Odors

Reference was made to a report of the American Public Health Association which stated:

" A long prevalent theory that sewage odors are directly responsible for disease has been definitely refuted. It is now realized that the physiological effect, if any, is indirect. Odors, by causing worry, loss of sleep, loss of appetite, etc., may be a contributory cause of ill health, and certainly cause discomfort. The courts, in general, have held that the creators of an odor nuisance are responsible therefor, and as far as municipal sewage disposal is concerned, the odor hazard appears to have been shifted from the public health to the public pocketbook."

M. J. Rosenau, M.D., was quoted:

" While odors may be unpleasant, they are not known to seriously influence health. Contrary to common opinion, they are by no means a reliable sign of danger."

" The effect of odors upon health is not well understood. Odors influence the nervous system in various ways; some stimulate, others depress."

### Conclusions as to Health Conditions

For many years there have been odors from the Des Plaines River at Lockport and through Joliet. In 1925 when the river flowed over rapids at Joliet, the odors were offensive. From 1930 to 1938 conditions at Joliet improved, notwithstanding the reductions in the flow from Lake Michigan because of the added treatment which the Chicago sewage gradually received. When the flow was reduced at the end of 1938, conditions retrogressed and complaints ensued from the residents. They compared the 1939 conditions with those prevailing in 1938 and those immediately prior to 1938. They had forgotten the conditions prevailing prior to 1930, or felt that the improvement should continue.

The Master concluded that the Court did not use the expression " menace to health " in the sense which physiologists for Illinois ascribed to it. With that definition the stream would continue a menace as long as any untreated sewage is discharged into it, and an increase of the flow to 5,000 c.f.s. would not eliminate the menace. He then stated that

" It is obvious that the presence of untreated sewage in an open stream is not in accordance with proper standards of sanitation and should be abated.

" The record leaves no reasonable doubt as to the safety of the water supply of Joliet and Lockport. Nor can the effect of odors upon invalids and persons of less than average health be accepted as any test of health menace; even in cases of private nuisance the test is the effect of the acts complained of upon persons of ordinary sensibilities and in normal health. In the present case it is Illinois itself which is creating the nuisance of which it complains and of which it seeks to be relieved by water which has in effect been adjudged by the Court to belong to the opposing States.

"My conclusion is that the facts proven do not establish any menace to the health of the inhabitants of Joliet and Lockport or elsewhere along the Waterway requiring an increase in diversion in water from Lake Michigan."

### Present Status of Sewage Treatment by the Sanitary District

The Sanitary District comprises 442 sq. mi., including Chicago and 59 other municipalities. The area is divided into four main projects with sewage treatment facilities as follows:

| Treatment Works | Design Capacity M.g.d. | Type | Date in Service | Sludge Disposal |
|---|---|---|---|---|
| North Side | 250 | Act. Sludge | Oct. 3, 1928 | Pumped to the Southwest Works |
| Calumet | 136 | Act. Sludge | Dec. 3, 1935 | Dewatered, and dried for burning or sale as fertilizer. |
| West Side | 472 | Imhoff Tank | June 2, 1930 | Drying on sand beds. |
| Southwest | 400 | Act. Sludge | June 27, 1939 (First battery of aeration tanks) | Dewatered, and dried for burning or sale as fertilizer. |

The Racine Avenue Pumping Station was placed in service on March 20, 1940, completing the pickup of sewage except for some minor sewers with a flow of about 70 m.g.d. By September 26, 1940, all but about 35 m.g.d. was connected.

The equivalent population of the Sanitary District is as follows (exclusive of the Corn Products Refining Company):

| Population | 1930 | 1940 | 1941 |
|---|---|---|---|
| Human (U. S. Census) | [a]3,901,569 | 3,962,514 | 3,962,514 |
| Industrial Equiv. | 1,486,000 | [b]2,237,000 | 2,549,300 |
| Total | 5,387,569 | 6,199,514 | 6,511,814 |

[a] Estimated. [b] April to December, incl.

The District has spent about $166,300,000 for intercepting sewers, pumping stations, and treatment works to December 31, 1941. It was estimated that $11,756,900 was required to complete the program. The principal items to be built were aeration and settling tanks and extensions to the blower house and sludge handling plant at the West-Southwest works.

### Progress in Treatment

The flow of sewage treated increased from 67.9 m.g.d. in 1928 to 929.9 m.g.d. in 1940. A total of 53,970 tons of sludge (dry basis) were discharged to the Main Channel in 1939. In 1938 the figure was 44,198 tons. No sludge was discharged after September 16, 1940.

The volatile solids entering the Main Channel decreased from a total of 145,572 tons in 1936 to 76,472 tons in 1940. The Southwest Works lacks blowers and sludge handling equipment, and activated sludge treatment was given only to sufficient sewage to produce solids within the capacity of the dewatering and drying equipment. The remainder received preliminary treatment only.

### Available Remedial Measures

It was the contention of Illinois that an increased diversion was the only immediate, feasible, remedial measure available for relief of the critical situation at Brandon Pool. Expert witnesses for Illinois testified that a diversion of 5,000 c.f.s. would improve the conditions over those existing prior to 1939, and that no other temporary measures are available which can be quickly applied. Witnesses for the Opposing States were confident that chlorination would provide more certain relief at Brandon Pool than the diversion of an additional 3,500 c.f.s.

As the witnesses for both sides agreed that the critical period of nuisance occurs during the warmer months, budgeting of the diversion appeared logical. Since the end of 1938 the District has budgeted the water from Lake Michigan to best meet the needs of sanitation.

It is considered necessary to maintain a flow of not less than 2,400 c.f.s. at Lockport for the protection of the Chicago water supply. Domestic pumpage amounts to 1,650 c.f.s., which combined with storm-water runoff of 550 c.f.s. leaves only 300 c.f.s. to come from Lake Michigan. In the cooler months of 1939 and 1940 dry-weather flows of 2,400 to 2,600 c.f.s. were budgeted and attained.

Various remedial measures were proposed by the Opposing States. Illinois contended that these were unsound in principle, effective only to a limited degree, and available too late to serve the emergency in 1941 and 1942. The suggestions may be divided into temporary and permanent classes. They are shown below.

| No. | Program | Opposing States (temporary) | Illinois (permanent) |
|---|---|---|---|
| 1 | Chemical treatment at West Side Works | √ | .... |
| 2 | Activated sludge treatment for West Side Imhoff tank effluent | .... | √ |
| 3 | Eliminate by-passing of Southwest preliminary tank effluent | √ | √ |
| 4 | Keep all sludge out of Main Channel | √ | √ |
| 5 | Chlorinate the flow in Main Channel | √ | .... |
| 6 | Chlorinate the effluent of the West Side Works | √ | .... |
| 7 | Double the air used at the North Side Works; increase the aeration period from 5 to 7 hrs. to produce 5 p.p.m. nitrogen as nitrates | √ | .... |
| 8 | Build cascades at the controlling works at Lockport to aerate the flow above the Brandon Pool | √ | .... |
| 9 | Increase diversion in summer, in accordance with analyses, to provide a minimum of 1.0 p.p.m. of dissolved oxygen in Brandon Pool | .... | √ (temporary) |

*Dredging, Draining, or Flushing Brandon Road Pool.*—The original volume of the pool was approximately 151,000,000 cu. ft., which was reduced by 1939 to 120,000,000 cu. ft. It is estimated that there is about 1,250,000 to 1,500,000 cu. yd. of deposited material, from 2 to 10 ft. deep. The U. S. Engineer office estimated that the material could be removed by hydraulic dredging at a cost of between $500,000 and $700,000. This appears to be an impractical proposition as the denser material has largely lost its potency to cause nuisance.

Draining the pool was regarded as impractical by the U. S. Engineer office for many reasons. The Chief of Engineers declined to allow it. It was finally decided to increase the flow to 10,000 c.f.s in addition to domestic pumpage for 10 days starting December 2, 1940. To this both sides and the Court agreed.

During the test period the flow averaged 9,937 c.f.s. at Lockport. The level of the Brandon Pool was lowered 0.5 ft. at first and later an additional foot. The following table shows results of the test.

| Description | Total Suspended Matter | | Volatile Suspended Matter | |
|---|---|---|---|---|
| | Tons | % | Tons | % |
| Delivered to pool | 84,010 | — | 27,067 | — |
| Discharged from pool | 21,123 | 25.2 | 7,512 | 27.7 |
| Remainder deposited in pool | 62,887 | 74.8 | 19,555 | 72.3 |

Solids washed out of the pool were slightly higher in percentage organic matter than those entering. The incoming total solids contained 32.4 per cent volatile matter and the outgoing solids contained 35.6 per cent.

Velocities in the pool averaged from 0.47 to 0.55 ft. per sec. The maximum velocities were from 1.33 to 1.58 ft. per sec. All witnesses agreed that in the Main Channel and Brandon Pool a considerable benefit was accomplished by removing sludge from the Main Channel.

*Chlorination of the Waterway.*—The Opposing States urged the use of chlorine to eliminate the odors at Lockport and Joilet. It was suggested that the chlorine be applied at the Southwest Works and at Lockport. Assuming no new sludge came into the pool, a dosage of 3 p.p.m. at the Southwest Works and 6 p.p.m. at Lockport was stated as the probable requirements. If sludge continued to enter 12 p.p.m. would be necessary at Lockport; possibly 15 to 25 p.p.m. The cost was estimated at roughly $700 to $3,000 per day.

Another witness believed 2 to 3 p.p.m. at Lockport would be sufficient, with a boat in the pool to apply 1 p.p.m., if sludge were no longer discharged, and perhaps 5 p.p.m. if sludge continued to be discharged.

The Illinois experts conceded that, in many situations, chlorine is used effectively to prevent odors. However, in view of the sludge deposits, it was not thought that chlorine could be used effectively, even with large quantities at great expense. Three points of application were believed necessary; Damen Avenue, Summit, and Lockport. This might require 150 tons per day during the summer months at a cost of $6,000 to $7,000 per day.

Experiences at Indianapolis were cited, where, in 1930, an average of 10 p.p.m of chlorine was applied to the plant effluent. The reduction in B.O.D. was about 10 per cent or 2 p.p.m. per part per million of chlorine. On only one occasion was any residual chlorine found farther away than 2,000 ft.

*Cascades at Lockport.*—The flow of the Main Channel passes through the turbines at the power house below Lockport and generates power worth about $1,500 per day to the Sanitary District.

An expert witness for the Opposing States suggested passing the flow over a cascade instead of through the power house, thereby picking up 6.75 p.p.m. of dissolved oxygen, equivalent to that contained in 2,650 c.f.s. of lake water. The cost of a wooden structure was estimated at between $50,000 and $100,000. Another witness declined to express an opinion as to how long such pickup could be retained and doubted whether any dissolved oxygen would be carried through.

Witnesses for Illinois testified that conditions would be improved but slightly and that a local odor nuisance would be created. It was pointed out that the effect would be lost before the pool were reached because of the anerobic conditions.

*Supply of Additional Oxygen Through the Production of Nitrate by Increased Use of Air at North Side and Calumet Works.*—It was suggested that 40,500 pounds daily of additional oxygen might be developed in the effluents of the North Side and Calumet works by using more air in the activated sludge process. The cost was estimated at $89,000 for a 5-month period, or $216,000 for a 12-month period.

It was pointed out by witnesses for Illinois that the production of nitrates would require an increase in the present aeration period of 4.5 or 5 hr. to 7 hr. Tank capacity for this is not available at the North Side works. It was stated that algae and green plants would form in the North Shore Channel which would create a secondary source of B.O.D.

*Chemical Treatment at West Side Works.*—The installation of chemical treatment on the effluent of the West Side works Imhoff effluent was suggested. This would supplant the treatment by activated sludge which is part of the Sanitary District program. Such treatment would reduce the B.O.D. of the effluent by 21 p.p.m. An expert for the Opposing States estimated the operating cost at $200,000 for a 5-month period and $481,700 for 12 months.

Illinois held that chemical treatment would not be suitable as the B.O.D. would be reduced from 57 p.p.m. to only 36 p.p.m., whereas activated sludge treatment would reduce it to 10 p.p.m. The Sanitary District estimated construction costs of $1,300,500 and $3,662,000 for chemical treatment and activated sludge, respectively. The operating costs were estimated at $555,800 per year for chemical treatment and $320,600 for activated sludge.

The Master saw no reason to accept the suggestion of chemical treatment to care for the summer of 1942 when it would be almost immediately superseded by activated sludge.

*Chlorination of West Side Imhoff Tank Effluent.*—Chlorination of the West Side effluent was suggested as an alternative to chemical treatment. It was estimated that chlorination would reduce the B.O.D. by 50,000 lb. instead of 76,000 lb. by chemical treatment. Illinois witnesses did not consider this a practical measure to ameliorate conditions in Brandon Pool.

*Planned Use of Water.*—The 1930 decree permits variations in the diversion, which the District has utilized to provide more flow in the summer. It was suggested that the present arrangement be adjusted to provide 4,200 c.f.s. flow at Lockport during four summer months. Illinois conceded the merit of this suggestion. However, it was pointed out that the District must carry a reserve at all times for use in event of storm to prevent reversals in the Calumet River and flooding of basements in the Loop area. Hence, application of the scheme is limited.

### The Comments of the Special Master

The Master commented that

"The record indicates that the Sanitary District has been influenced not so much by the desire to make speed as by the purpose ultimately to complete an efficient system at as little expense as possible to its taxpayers. These are praiseworthy motives when considered from the standpoint of the Sanitary District alone, but they may not place the emphasis upon expedition to which the legitimate protection of the interests of the Opposing States entitles them."

The Master recommended that a decree be entered dismissing the petition and the modified petition of the State of Illinois for a modification of the decree of April 21, 1930, and taxing the costs of the litigation against the State of Illinois. The Court dismissed the petition without comment on May 26, 1941.

T. L. Herrick

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## THE OCCURRENCE AND CAUSE OF POLLUTION OF GRAYS HARBOR

By Arne Eriksen and Lawrence D. Townsend

State of Washington, State Pollution Commission, Pollution Series—*Bulletin* 2, 100 pages (June, 1940)

Grays Harbor forms one of two breaks in the coast line of the State of Washington south of Cape Flattery. For several summers serious fish mortalities were noted in the upper region of the harbor and a comprehensive study of the problem was undertaken by the State Pollution Commission. Part of the results of the study have been reported previously in a publication issued by the Commission. However, this report includes all material presented in the previous publication. Sources of pollution in Grays Harbor were waste sulfite liquor from a pulp mill, domestic sewage, paper mill wastes, pilchard reduction plant wastes, brewery wastes and harbor dredging operations. Studies of all these sources of pollution indicated that the waste sulfite liquor discharged from the pulp mill was responsible for more than 90 per cent of the total oxygen demand.

The average daily flow of pulp mill wastes was 4.6 m.g. One 8-hour composite sample was used for estimating the characteristics of this waste. This sample had a pH of 1.90, a specific gravity of 1.0062 and contained 1.65 per cent total solids. B.O.D. determinations were made using dilution waters from Grays Harbor proper, sea water, and river water. Corrections were made for the observed B.O.D. of the various dilution waters. B.O.D. values were generally lower where sea water (approximately 17,710 p.p.m. $Cl^-$) and river water (less than 40 p.p.m. $Cl^-$) were employed for the dilutions. The average 5-day 20° C. B.O.D. of the waste sulfite liquor using Grays Harbor water (approximately 9,570 p.p.m. $Cl^-$) was found to be 4,600 p.p.m. The average 20-day B.O.D. was 6,600 p.p.m. Based on the latter value and the average flow the daily contribution of oxygen demand was 254,000 lb. Average B.O.D. values for other time periods based on dilutions ranging from 1–1,000 to 1–10,000 and the use of Grays Harbor dilution water are given as follows: 8 days, 4,900 p.p.m.; 10 days, 5,900 p.p.m.; 13 days 5,300 p.p.m.; 15 days, 6,700 p.p.m. The population equivalent of the pulp mill wastes was estimated to be 1,400,000. This was calculated from the 20-day B.O.D. and average flow using a per capita oxygen demand value of 0.18 lb. per day.

Extensive fish kills were observed in 1937–38, 39 and reports of fish mortality in previous years appear to be well authenticated. The aquatic life distress reactions were those which are known to characterize oxygen depletion; *i.e.*, fish swim to surface and expose heads at the same time exhibiting a characteristic gasping reaction. When water samples were taken in the vicinity of distressed fish, these samples were found to be extremely low in dissolved oxygen.

In general the plankton was always at a low level of abundance. The authors believe this condition may have been due to the pollution of the harbor or more likely to lack of water of suitable chloride concentration for optimum diatom growth. Data available did not confirm or refute either of these explanations, however. There was no indication that oysters were affected by the harbor pollution.

The mixing of fresh water, mainly from the Chehalis River system, and sea water in the upper portions of the harbor produces a chloride concentration gradient which rises from east to west through the harbor. Only about 1.2 per cent of the 16,500,000,000 cu. ft. of mixed sea water and fresh water in Grays Harbor are replaced with each cycle of the tide. The average concentration of waste sulfite liquor in the upper part of the harbor, calculated from data on water interchange was 1,570 p.p.m. Early in the investigation it was found that two factors influenced the minimum dissolved oxygen concentrations found on particular days. These were the amount of fresh water entering the harbor from the rivers and the amount of waste sulfite liquor discharged from the pulp mill. Low dissolved oxygen concentrations found during the summer time were definitely correlated with pulp mill operations and the greatest reduction in the dissolved oxygen concentration occurred in the portion of the harbor nearest the pulp mill. In the winter only minor reduction in the dissolved oxygen in the harbor water was noted because of the greater quantities of dilution water available from the rivers and consequent increased intercharge of the harbor water. Atmospheric reaeration was found to play an important rôle in preventing complete oxygen depletion. During low river flow periods the oxygen demand of the waste sulfite liquor was about 50 per cent greater than the amount of dissolved oxygen available. The average minimum dissolved oxygen concentration during low flow periods was approximately 15 per cent of saturation.

The average 5-day 20° C. B.O.D. of samples of the harbor water collected at 14 sampling points during pulp mill operation ranged from 0.56 to 3.67 p.p.m. depending on tide and river stage conditions. During pulp mill shutdowns the variation was from 0.10 to 0.75 p.p.m. Dilution water for these B.O.D. determinations consisted of a 1:1 mixture of harbor and Chehalis River water.

Large areas of mud which are exposed in Grays Harbor at low tide contained organic matter derived from sawmill wastes, sewage, etc., but as a result of oxygen demand studies on numerous samples the authors conclude that the mud has no appreciable responsibility for the low dissolved oxygen content of the harbor water. Harbor dredging operations had no significant effect.

A careful study of the pH of the water in Grays Harbor indicated that the pH varies with the chloride concentration, seasons, river discharge, and pulp mill operations. The pH of the water in the upper Harbor was significantly decreased when the pulp mill was operating. The primary source of the acid material was the waste sulfite liquor from the pulp mill which had a pH of 1.9 and exhibited a strong buffer action.

The maximum and minimum water temperatures recorded were 21.4° C. (70.5° F.) and 2.9° C. (37.2° F.), respectively. The greatest difference in temperature on any one day was about 6° C. (10.8° F.).

The effects of waste sulfite liquor in a dilution of 1:1,000 and low dissolved oxygen (range 1.25–1.99 p.p.m.) on silver salmon fingerlings were studied. The results indicated that waste sulfite liquor in the concentration tested markedly affected the ability of the fingerlings to withstand low dissolved oxygen concentrations. From a consideration of laboratory data and field observations the authors conclude that continued pollution will largely eliminate the chinook salmon runs to the Chehalis River and possibly affect the silver salmon runs to a marked extent leaving only the chum salmon remaining as fish of commercial importance.

The bulletin is concluded with recommendations together with brief discussions on the growth of the wood pulp industry in Washington in general and in the Grays Harbor area in particular. Methods available for treatment of waste sulfite liquor are also reviewed. It is noted that, while progress in the disposal of waste sulfite liquor has been made in certain instances, no general solution to this disposal problem has been found. The authors recommend that the discharge of waste sulfite liquor into Grays Harbor be so regulated that the dissolved oxygen concentration never falls below 5 p.p.m. and that any proposed method of treatment or disposal of waste sulfite liquor be subject to the approval of state agencies. They further recommend that adequate records of the degree of treatment necessary to maintain the minimum dissolved oxygen concentration of 5 p.p.m. be made available to the State Pollution Commission so that this information can be used for the allocation of responsibility for additional treatment or disposal measures in the event of the establishment of new sulfite pulp mills at Grays Harbor.

It is also recommended that all mills be required to dispose of the same percentage of wastes but their combined wastes should be such that the minimum dissolved oxygen concentration of 5 p.p.m. is always maintained. Thirty-five maps and charts, 48 tables, 77 references.

Paul D. Haney

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## RED RIVER OF THE NORTH RESEARCH INVESTIGATION

Prepared by The North Dakota State Department of Health covering the Joint Investigation by the North Dakota State Department of Health and the Minnesota State Board of Health in collaboration with the U. S. Public Health Service.

Issued by North Dakota State Department of Health, Division of Sanitary Engineering, 158 pages (1938–1941).

Prior to the investigation covered in this report two studies had been made on Red River pollution problems. As a result of the first study conducted during the period 1931–33 it was concluded that in order to improve water conditions in Red River it would be necessary to provide for the treatment of sewage and all major industrial wastes from Breckenridge to Grand Forks. The second study conducted in 1938 confirmed the original conclusion and recommended that further investigation of the river be made in order to determine the full effects of ice coverage on oxygen relationships. The purpose of the investigation covered by this report was to obtain data which would serve (1) To determine the oxygen relationships in the stream before and during ice coverage. (2) To determine the rate of oxygen depletion in the stream during ice coverage. (3) To determine the suitability of relatively unpolluted streams for dilution purposes. (4) To determine the characteristics and quantities of the various wastes entering the river. During the investigation considerable data were obtained on the low temperature B.O.D. of flour mill, packing plant, and beet sugar plant wastes. These data are not presented in this report, however.

The Red River of the North flows practically due north. It starts at Wahpeton, North Dakota, and discharges into Lake Winnipeg in Manitoba, Canada. The river distance from Wahpeton to the Canadian border is 394 miles. The slope in general is slight and diminishes toward the north. The drainage area south of the border is 35,895 square miles. Serious floods have occurred. Serious drouth conditions began in 1930 and stream flows decreased steadily. From 1929–1935 there were 5 periods aggregating 14 months when the flow at Fargo was zero. The climate of the basin is characterized by long cold winters and short warm summers. The yearly temperature variation may be as great as —50° F. to +110° F. The 1930 population of the basin was 489,000 and the primary industry is agriculture. Industrial development is confined largely to service industries and those necessary to the processing of various agricultural products. In 1930 there were 150 creameries serving the growing dairy industry.

Until recent years practically all sewered cities on the river and tributaries discharged raw sewage. Now, however, most of the major cities have provided some type of sewage treatment. The treatment of many important industrial wastes still remains to be accomplished. Serious pollution conditions have existed for the past several years during low flow periods and as a result the usefulness of the river to municipal and rural riparian owners has been impaired. The bacterial and organic loadings upon water treatment plants have at times been excessive. All but one of the larger cities along the river depend upon it as the source of public water supply.

Several water storage projects have been proposed, but no additional storage reservoirs are recommended for the Red River proper since evaporation losses are likely to more than offset storage benefits. One of the important problems to be solved is that of securing a practical balance between the cost of constructing or improving and operating sewage treatment works and the cost of constructing and operating storage or diversion works to supply dilution water. The degree of stream cleanliness to be achieved influences this economic balance. During recent years considerable attention has been directed to the diversion of water from the Missouri River to the Red River Basin and other watersheds. From the standpoint of stream pollution the proposal has great merit. The cost of the project would be approximately $39,000,000 and would provide for the diversion of 600 c.f.s. Benefits are calculated to be of the order of $38,000,000 exclusive of recreation, water power and general increase in land values. A 996,000 acre foot storage reservoir would be constructed on the head-waters of the Sheyenne River with about one-third of its capacity available for diversion. A portion of the flow would be diverted to the Red River above Fargo.

During this investigation twelve sampling stations were maintained on the Red River proper. Eleven stations were maintained at the mouths of tributaries and one station was maintained at the East Grand Forks beet sugar factory. Samples were collected weekly on Red River stations south of the International Boundary. Samples collected from tributaries were obtained regularly during periods of perceptible flow. Chemical and bacteriological samples were taken in a sampler so designed that a bacteriological, dissolved oxygen and B.O.D. sample could be taken at one time. The B.O.D. sample (2 liters) was large enough to provide samples for other tests. Samples, in most cases, were taken from bridges and were obtained from the channel at mid-depth. During winter holes were cut into the ice and the sampler lowered into the stream from the ice. All samples were analyzed on the same day they were collected. Routine analytical examination consisted of nitrite, turbidity, pH, dissolved oxygen, 5-day 20° C. B.O.D. and bacteriological determinations. Several long-time B.O.D. determinations were made on Red River samples at both 0° and 20° C. Bicarbonate dilution water was used in all B.O.D. determinations, except those made on sugar beet wastes. For these Formula "C" (*Public Health Reports,* 48, 24, p. 683) phosphate dilution water was employed. Mineral analyses and organic nitrogen determinations were made on representative river and tributary samples during ice coverage in 1939.

Compilation and analysis of laboratory and field data collected during this investigation and information obtained from studies previously reported led to the following conclusions: (1) Under ice coverage the dissolved oxygen content of the Red River was depleted to zero in a few weeks except where aeration provided by dams exerted appreciable influence; (2) With flows of 200 c.f.s. very unsatisfactory conditions prevailed below Grand Forks during the winter critical period; (3) The quantity and nature of the wastes entering the river are such that without additional treatment the amount of dilution water which could be reasonably provided would not solve the pollution problem; (4) High stream flows were accompanied by less septic conditions than were low flows. The less septic condition resulted not only from increased dilution, but also from increased stream velocity; (5) During the winter and summer critical periods flows from tributaries with the exception of Red Lake, Ottertail, Sheyenne, Buffalo and Minnesota Wild Rice Rivers were insignificant from the standpoint of pollution contributed and dilution provided; (6) Overflow dams (less than 12 ft. high) appear capable of providing sufficient aeration to increase the D.O. content of low temperature oxygen-deficient water to approximately 6 p.p.m. The effectiveness of such dams as aerating devices could probably be improved if they were designed with this end in view; (7) Due to natural pollution alone (barnyard drainage, dumped manure, refuse) the oxygen content of waters stored in reservoirs or river channels is likely to be diminished or entirely depleted. Therefore, to be of greatest value for dilution purposes impounded waters should be aerated upon release from reservoirs; (8) Sludge deposits exert an appreciable effect on the river. During periods of high flow organic material deposited at low flows is dislodged and increases the pollution loading on the stream. At flows less than those required to dislodge sludge particles the pollution load also may be increased. This latter effect is attributed to the direct solution of deposited organic matter and of the products of anaerobic digestion occurring in the sludge banks. Entrainment of material floated by gas from digestion processes was observed; (9) Relatively unpolluted streams may, due to natural pollution alone, become completely devoid of dissolved oxygen during the ice coverage period; (10) Data obtained on industrial wastes indicates that the rate and extent of oxygen utilization by such wastes is dependent upon several variables which include the nature of the waste, temperature, extent of dilution and type of dilution water. It is essential to determine in addition to the basic behavior of the waste its behavior in combination with other wastes under special stream conditions. The behavior of an industrial waste may be quite different from that of domestic sewage and the fallacy of forecasting the effect of industrial wastes on the basis of the behavior of domestic sewage is evident.

Following the main body of the report is a 57-page section in which are presented by means of graphs, tables and pictures all supporting chemical and biological data. Hydrometric data, pollution sources, theoretical B.O.D. calculations, stream flow requirements, population data and dilution water sources are presented in six appendices. Results and discussion pertaining to the 1938 sanitary survey of the Red River conducted by the North Dakota and Minnesota Health Departments are presented in the last 15 pages of the bulletin.

Paul D. Haney

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## SOME RECENT DEVELOPMENTS IN THE BIOLOGICAL TREATMENT OF SETTLED SEWAGE

By M. Lovett

*The Surveyor*, 101, 371–73 (Oct. 30, 1942); 101, 381–83 (Nov. 6, 1942)

In considering biological devices for the aerobic purification of sewage, the author suggests a classification of contact processes into three types according to the size of the contact medium provided for the bacteria. Under large contact material he lists contact beds and contact aerators and the various filters, such as conventional (low-rate), simple high-rate, double, enclosed aerated, bio-, accelo- and aero-. Land irrigation and intermittent sand filtration utilize sand and soil particles as the contact medium. Under small contact material he includes activated sludge, bio-aeration, surface aeration, diffused air and the Guggenheim Process.

Contact beds are largely of historic interest. They are suited only for treatment of weak sewage, are subject to clogging, require large units to provide necessary resting periods, and may be costly to maintain.

Conventional filters have performed so satisfactorily that careful attention to detailed design and improvements to design have been somewhat neglected. An excellent discussion is given by the author of early experimental work with high-rate filters. The author concludes that single-stage simple high-rate filtration will not provide an effluent complying with Royal Commission standards.

Double filtration, alternating the sequence of the filters, is believed to be promising.

Experiments with enclosed aerated filters are discussed at some length. A filter at Wolverhampton 20 feet in diameter and 13 ft. 6 in. deep has been in operation since October, 1937, treating a fairly strong sewage and producing a well nitrified effluent under a loading of 200 gallons per cubic yard per day. A second unit 6 feet deep and dosed at 1,050 gal. per cu. yd. per day shows about 56 per cent reduction of oxygen absorbed and 73 per cent reduction of 5-day B.O.D.

Land irrigation and intermittent sand filtration, the author believes, occupy a position between percolating filters and activated sludge processes.

Activated sludge differs from all kinds of filters in that the sewage itself supplies the contact material and a great deal more of it. Using Buswell's estimate of 500 square feet of surface area (of floc) per cubic foot of tank volume, it is concluded that this is perhaps 20 times greater than the surface area in a filter of 1 to 2 inch medium.

Many workers have experimented with contact aerators utilizing many different media and their claims are enumerated.

*The Surveyor*, 101, 401–403 (November 20, 1942)

The following excerpts are taken from discussions by various men of the paper on the above subject.

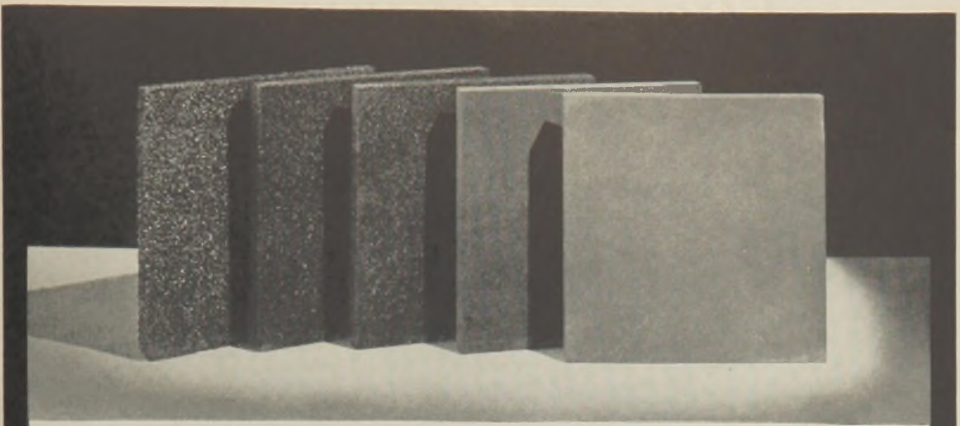
Mr. C. Lumb commenting on Mr. Lovett's remarks concerning the use of a layer of coarser medium at the top of filters said that after this measure was taken at the Halifax sewage works the filters had been free of ponding for several years. He was glad to note that Mr. Lumb agreed with his opinion of high rate filters, namely that they were only a partial treatment process, the ultimate value of which depended upon the ease with which such secondary treatment as was required could be achieved. Mr. Lumb cited the success he had had with an enclosed aerated filter in treating liquor derived from the heat treatment of sludge at Halifax. This unit could purify at least three times the volume handled by ordinary open filters.

Mr. L. F. Mountfort in commenting upon the property of high rate filters to act as decolloiders pointed out the increased quantity of secondary sludge produced and the effect this additional sludge might have upon sludge disposal facilities. He further called attention to the fact that the transfer of work from aerobic to anaerobic processes (by a more complete preliminary separation of potential sludge material) might change the value of sewage strength expressed in terms of oxidizable impurity as a basis of design of sewage treatment plants. Mr. Lovett, in pointing out the fundamental difference between filter plants and activated sludge plants, had stated that the contact surface per unit of tank volume in the case of an activated sludge plant was perhaps twenty times as great as the corresponding figure per unit of volume of filter bed composed of 1 to 2 inch medium. Mr. Mountfort thought that in a well ripened filter this ratio would not be more than 5 to 1. As far as relative reaction velocities were concerned (ratio of contact surface to volume of liquid in contact with it) the filter had a ratio from 3 to 5 times greater than the aeration tank.

K. V. Hill

## LOCAL ASSOCIATION MEETINGS

| *Association* | *Place* | *Date* |
|---|---|---|
| California | Fresno, California (Hotel Californian) | June 10–13, 1943 |
| Canadian Institute on Sewage and Sanitation | Niagara Falls, Ontario | Oct. 28–29, 1943 |
| Central States | Chicago, Illinois (Sherman Hotel) | Oct. 21–23, 1943 |
| Federation of Sewage Works Associations | Chicago, Illinois (Sherman Hotel) | Oct. 21–23, 1943 |
| Florida | West Palm Beach | June 9–12, 1943 |
| Maryland-Delaware | Baltimore, Maryland (Lord Baltimore Hotel) | May 13–14, 1943 |
| Michigan | East Lansing, Michigan | May 5–6, 1943 |
| New England | New Haven, Connecticut (Hotel Garde) | May 26, 1943 |
| New York State | Rochester, New York (Hotel Seneca) | June 4–5, 1943 |
| North Carolina | (Not selected) | Nov. 1–3, 1943 |
| North Dakota | Grand Forks, N. D. | Sept. or Oct., 1943 |
| Ohio Conference | Mansfield, Ohio (Mansfield-Leland Hotel) | June 23, 1943 |
| Pacific Northwest | Bellingham, Washington (Hotel Leopold) | May 6, 1943 |
| Pennsylvania | Harrisburg, Pennsylvania (Penn Harris Hotel) | June 9, 1943 |
| Rocky Mountain | Denver, Colorado | Sept. 16–17, 1943 |



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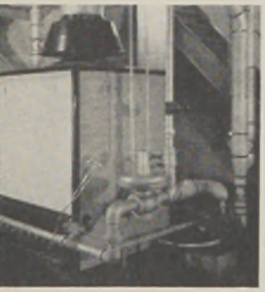

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low—Sludge inlet and supernatant
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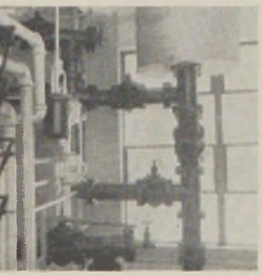

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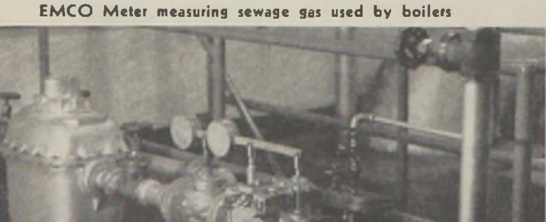

Nordstrom Valves on sludge lines in lower operating gallery between primary and secondary digestion tanks

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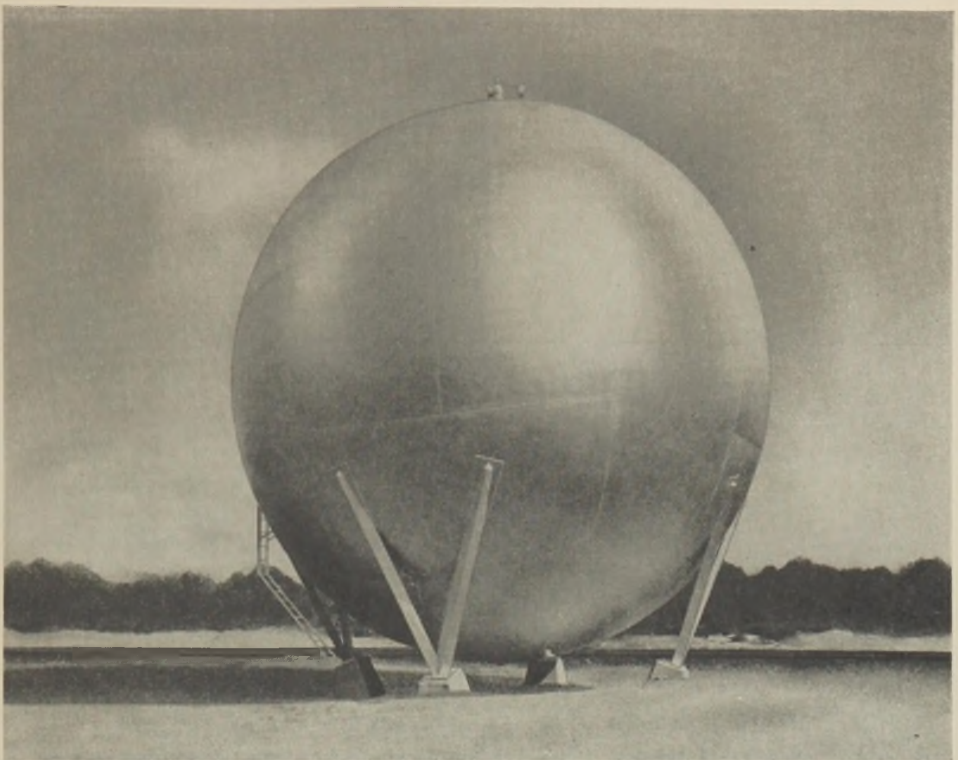


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