SEWAGE WORKS JOURNAL

VOL. XV NOVEMBER, 1943 No. 6

Special Features

Chicago Convention — Page 1228

OFFICIAL PUBLICATION OF THE
FEDERATION OF SEWAGE WORKS ASSOCIATIONS

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

SEWAGE WORKS JOURNAL

REG. U. S. PAT. OFF.

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

Publication Office: Prince and Lemon Sts., Lancaster, Pa.

Subscription Price:

Members of Local Sewage Works Associations affiliated with the Federation, $3.00 per year.

Non-members: U. S. and Canada, $5.00 per year; other countries, $6.00.

Foreign Subscriptions must be accompanied by International Money Order.

Single copies: United States, $1.00 each; Foreign, $1.25 each.

Manuscript may be sent to the Editor, F. W. Mohlman, 910 So. Michigan Ave., Chicago, Ill., for acceptance or rejection subject to the provisions of the Federation Constitution.

Advertising copy should be sent to Arthur A. Clay, Advertising Manager, Lancaster, Pa., or 40 Wall St., New York, N. Y.

Subscriptions and address changes should be sent to W. H. Wisely, Executive Secretary, Lancaster, Pa., or Box 18, Urbana, Illinois.

No claims will be allowed for copies of Journals lost in the mails unless such claims are received within sixty (60) days of the date of issue and no claims will be allowed for issues lost as a result of insufficient notice of change of address. " Missing from files " cannot be accepted as the reason for honoring a claim.

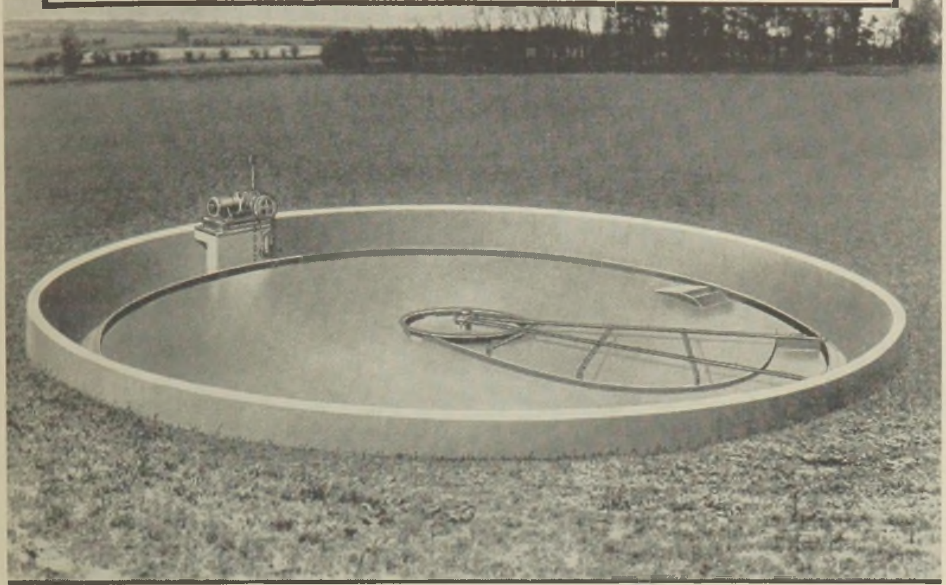
Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879.

★ *ANNOUNCING* ★

YEOMANS "RIM-DRIVE" CLARIFIER MECHANISM

Simpler, better, costs much less

Torque Demand Reduced More Than 95%



You'll recognize instantly the many advantages of the new Yeomans "Rim-Drive" Clarifier Drive for circular settling tanks

- **Motor and drive unit mounted on the rim of the tank.** Does away with costly bridges and walk-ways. Easy to get at.
- **Power applied at the rim.** Full effective use of the lever arm principle—positive engagement on full periphery of plow-blade assembly—cuts torque demand over 95%.
- **No complicated and costly high-torque, high-reduction gears**—A simple worm gear eliminates vertical shafting and bearings.
- **Automatic overload release**—simple, positive, audible or visual alarm—or both.
- **Automatic scum removal,** if specified, with Yeomans "Auto-Skimmer" and "Auto-Flusher."
- **Simple installation, reduced maintenance.** A minimum of working parts gives ample assurance of long life. All parts are easily adjustable for wear.

Keep your data file on clarifiers complete and up-to-the-minute by getting full information on Yeomans "Rim-Drive."

YEOMANS BROTHERS COMPANY

1411 NORTH DAYTON STREET • CHICAGO 22, ILLINOIS

SEND THE COUPON . . . *There's No Obligation . . .*

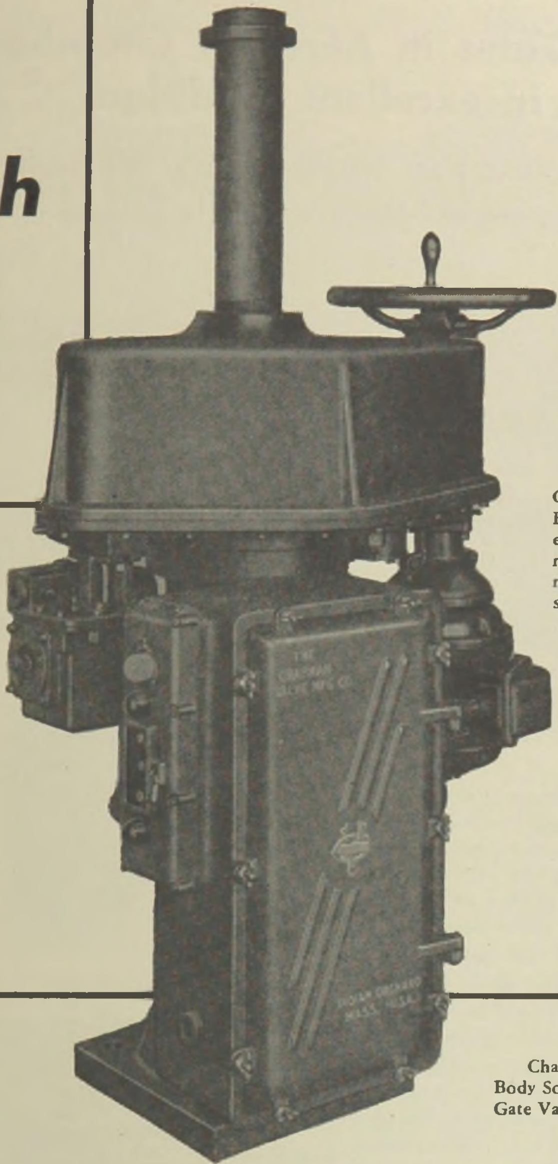
YEOMANS BROTHERS COMPANY
1411 North Dayton Street • Chicago 22, Illinois

Please send us detail drawings and literature on Yeomans "Rim-Drive" Clarifier mechanism.

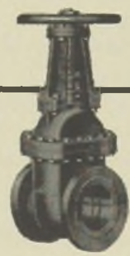
Name____________________

Address____________________

City____________ State____________



Chapman Motor-Operated Floorstands may be equipped with electric motors or with air-driven motors and air-limit switches.



Chapman Iron Body Solid Wedge Gate Valves.

Sewage Works Journal

Published by

Federation of Sewage Works Associations

Lancaster, Pa.

Vol. XV November, 1943 No. 6

Plant Operation

SYMPOSIUM: POST–WAR PROBLEMS

THE TEN YEAR PLAN OF SEWAGE AND WASTE TREATMENT *

By Morris M. Cohn

Editor, Sewage Works Engineering; Sanitary Engineer, City of Schenectady, N. Y.

As sanitary engineers, we foresee a post-war era which will finish the unfinished business of sanitation—particularly sewage treatment. To that end, we are beginning to energize post-war programs. Last January, *Sewage Works Engineering* conducted a conference on post-war sanitation needs which brought together leaders in public health, government, industry, economics and education. Out of that conference came perhaps the first lucid expression of the hopes of the profession that the post-war period will bring opportunities for improving the nation's sanitation facilities. Out of that conference came, also, the creation of the Committee for Joint Action on Post-War Sanitation, with representatives of some two dozen organizations. This Committee has already offered its assistance to other groups; urged state sewage works associations to talk and think and work for post-war planning and construction; and urged 45 State Municipal Leagues to recognize the importance of sanitation in all post-war construction programs.

Of outstanding significance is the creation of the new Committee on Water and Sewage Works Development, representing the Manufacturers Association, two great water works associations and the Sewage Works Federation. This group has established a practical and strong policy and is energetically championing the cause of "Blueprint Now" for post-war construction of water and sewage utilities.

Given, then, that there is need for public works construction in the post-war period and that sewage treatment and sewerage must play an important role in this construction program, but for what are we striving in sewage treatment? What is our goal? Do we propose a program of sufficient scope to leave an impress on the national post-war employment scene as well as on national sanitation? We have too long viewed sewage treatment as the dream of the sanitary engineering profession and as the aspiration of sportsmen. Insufficient stress has been placed upon the economic aspects of stream degradation. Now we have in our hands a double-barreled weapon for public health and

* Introducing the Post-War Symposium, Fourth Annual Convention of the Federation of Sewage Works Associations, Chicago, Oct. 22, 1943.

national economic stability. I, therefore, propose Sewage Treatment for Sanitation and Post-War Employment.

Despite the existence of nearly six thousand civilian sewage treatment plants in the United States, we are faced with demanding unfinished business in both sewage and industrial waste treatment. The USPHS survey, as of 1940, reported that only 58 per cent of the sewered population was provided with treatment facilities. In addition, many of the existing plants are antiquated and in need of modernization, replacement and enlargement, especially since the construction limitations of the war period have produced a serious backlog of needed work which looks to the post-war period for completion. *It is not far-fetched to set a goal of six thousand treatment plants to be built or reconstructed in the post-war period;* the industrial waste treatment works construction program will greatly increase this goal.

Since we have been talking dollars as well as B.O.D., it is sensible to ask how much money must be spent on sewage treatment. What part of the 5 billion dollar yearly public works program should be devoted to the construction of treatment plants? How long should it take to make good on the ideal of "treatment for every gallon of sewage and industrial waste," in a measure commensurate with the needs of the stream?

I urge the adoption of THE TEN-YEAR PLAN OF SEWAGE AND WASTE TREATMENT—that we aim for the completion of our unfinished business by ten years after Victory.

Can the Ten Year Plan be accomplished? Can we build six thousand works and thousands of waste treatment plants in a decade, without taking an excessive share of national income? We must look to the past for the answer to the problems of the future.

In 1939, according to the annual census conducted by *Sewage Works Engineering,* 850 plants were under construction at an estimated cost of $101,000,000, catalyzed by federal funds. In 1940, 600 plants were being built or rebuilt at a cost of $100,000,000. With some 6,000 plants to be built and with industry willing to construct waste plants to handle at the back door the wastes of the products that go out the front door, it is apparent that we can readily build these plants in ten years at a cost of approximately two billion dollars.

Here then is the goal: Solution of the sewage and waste problem on the Ten Year Plan at a cost of two billion dollars out of a national decade income of twelve hundred and fifty billion dollars.

Not only will sewage treatment take up its share of the five billion dollars worth of public works needed yearly to maintain a balanced national economy, but this construction will serve to energize the basic industries which were left unaided by the pump-priming program of previous years. Construction of sewage plants will set up immediate demands for the materials of construction and for the equipment which will pour forth from factories which themselves will create constructive employment to meet this demand. No other phase of public works construction, unless it be water works construction, can draw so heavily upon the basic industries whose activities spell full employment for the nation's workers.

Wishful thinking will not produce the construction program. We must plan before we can build. It is necessary to have "plants on paper" before we can put "plants on ground." Fortunately, consulting engineering staffs are available for planning right now, since the rush of military camp construction has ceased. Fortunately also the art and science of sewage treatment has reached a stage of assured performance that makes it possible, yes, even desirable, to follow the plea of the Committee for Water and Sewage Development, "Blueprint Now."

It is time for each association of the Federation, each state health department, each individual to become a strong voice demanding that cities plan now for sewage treatment as an instrument for post-war sanitation and employment. The method of financing sewerage projects must be worked out by the community itself, without waiting in line for federal "handouts" which indirectly come from the pockets of the community.

THE CONSULTING ENGINEER AND POST-WAR PLANNING *

By Charles A. Emerson

Consulting Engineer, New York City

The function of the consulting engineer in post-war planning programs is precisely the same in principle as it was in pre-war planning programs, namely, furnishing expert engineering service in the particular branch or branches of the general field of engineering in which he specializes and for which he has been qualified by adequate training and broad experience.

The consulting engineer must keep informed of new developments in his particular field and must maintain an independent position so that he can serve his clients impartially, in accordance with the codes of ethics and fair practice of various national engineering societies, of which he should be a member, and in conformity with the regulations of the state or states in which he is licensed to practice his profession.

The foregoing terse statements as to the functions of the consulting engineer will be easier of application if we adopt the term "Advance Planning" instead of "Post-War Planning" and confine our thoughts to our particular field—sewage and industrial wastes treatment.

Advance planning is not a new venture for the consulting engineer. Every sizable sewage and industrial wastes treatment plant constructed in pre-war years involved considerable advance planning because of

* Presented at the Fourth Annual Convention of the Federation of Sewage Works Associations, Chicago, Oct. 22, 1943.

the months, and frequently the years, which intervened between the date of the preliminary report, or even the start of design, and the date on which construction was completed and the plant was placed in service.

In view of certainty that the immediate future would bring improvements in the art of sewage treatment, the designing engineer has long been accustomed to prepare his plans and specifications to permit their ready adaptation to new models of equipment or innovations in methods of plant operation. This not only involved careful planning and foresight on the part of the engineer, but also necessitated a very considerable measure of confidence on the part of the client.

That the procedure was widely prevalent in past years is amply attested by the 6,000 or more functioning sewage treatment plants in this country which would not have been built if public officials of the last three or four decades had lacked confidence in their consulting engineers, and withheld authorization for designs on the plea that some new and marvelous, but still unannounced and unproven, development in the art might be available in a year or two, or three.

That the confidence manifested by the clients was not misplaced is evidenced by the fact that sewage treatment plants designed by experienced engineers, in accordance with best information prevalent at the time, were not declared to be obsolete on completion and replaced shortly thereafter but continued to function at satisfactory efficiency for many years. These circumstances did not apply merely to isolated instances or to short periods of quiescence in progress but obtained throughout the whole range of development of modern sewage treatment.

Some of the men present here today were engaged in sewage treatment plant design when the Cameron septic tank, followed by contact beds or intermittent sand filters, constituted the approved method for complete treatment. If these veterans in design, with the co-operation of public officials then in office, were able to so adequately safeguard public funds invested in sewage treatment throughout the monumental progress of the past 35 or 40 years, it does not require an extraordinary degree of faith to believe that these same men, together with the younger specialists of today, are fully competent to span whatever gulf may lie between present advanced procedure and that which may obtain during the early years of the post-war era.

Numerous conversations during the past few months have fully convinced the speaker that this belief is shared by the well informed, experienced consulting engineers and that they have neither apprehension nor foreboding that advance planning under present conditions will involve unwarranted risk on their part nor result in wasteful expenditure by the client.

If these designing engineers are correct, and as yet no persuasive arguments to the contrary have been forthcoming, would not a valiant service be rendered the broad cause of advance planning if their convictions could be imparted to public officials generally? If those in charge of municipal programs could be brought to realization that present sewage treatment problems are subject to painstaking analysis and reasonable solution, just as they were in past decades, the apathy still remaining in some quarters should disappear and many more needed sewage treatment projects would be placed under detailed design.

It may be helpful to mention three of the many questions put to the speaker during recent months which were causing grave concern to honest intentioned municipal officials. These are:

(1) Can funds for needed sewage treatment plant construction be made available after the war?
(2) Is there not real danger that some of the revolutionary discoveries and developments by scientists in connection with the war effort may completely and promptly change the entire trend in sewage treatment, even though there are no indications at present that such will occur?
(3) How can any reasonable forecast be made at this time of the probable post-war needs of a municipality for sewage treatment?

Finances

First as to finances: Our leading political economists are seemingly in general agreement that the United States can emerge from this war with its financial structure intact and its credit unimpaired if precautions are taken which will place a brake on indiscriminate Federal spending. Even now powerful committees of Congress are carefully scrutinizing and seriously questioning various proposals for increasing our tax burdens and existing machinery designed to curb inflation is being carefully studied to determine its adequacy. These are encouraging signs.

It is freely admitted that taxes will have to be continued at high levels to provide for debt service, maintenance of the military establishment, foreign relief, rehabilitation and a multitude of other purposes, but at the same time it is maintained that national income will also continue at high levels which will be sufficient to meet such current expenditures and leave a balance available to finance carefully planned, long life, public works which will conserve the public health or contribute to the public welfare.

The men responsible for these views have been dealing in finance for many years and undoubtedly will have much to do with direction of our financial policy after the war. They are wholly familiar with the attempts of the early thirties to cure unemployment and are determined that similar mistakes must not recur. The claim is simply that construction of justifiable, carefully planned public works will be of material assistance in providing jobs during the immediate post-war period. It is not asserted that such construction will furnish jobs to all the millions who will require assistance during the reconversion period and until normal peacetime activities are fully resumed—but merely that it will assist greatly.

It seems reasonable to believe that the benefits of advance planning will be materially increased if the program also includes local financing. Such procedure would further our American ideals of personal freedom and private enterprise. If, through individual and locally sponsored efforts, honest jobs can be provided for the major percentage of those who are able and willing to work, we can preserve our true democracy, but if the mass unemployment of the early thirties is permitted to return because of our complacency and inaction, we may be sure that Government will again take a hand and create jobs with all the attendant evils of concentrated political power, regimentation and stifling of free enterprise.

Unless we are honestly of the opinion that we know more about national and international finances than do the leading economists and, likewise, have something better to offer, it seems mandatory that we accept their conclusions and do our best to comply with pleas for immediate planning of public works.

It is not intended to imply by the foregoing that all sewage treatment projects should go forward immediately on declaration of peace, nor that designs should be approved which contemplate adoption of partially developed or scantily proven processes of treatment. It must be appreciated that in our advance planning more than ordinary attention should be given to selection of the process of treatment and that the design should provide for stretching the construction dollar as tightly as consistent with sound engineering judgment and experience in order that public funds may not be wasted.

Unexpected Developments

In these days when we frequently hear radio announcers orate mysteriously about a post-war Elysium which will be created by the magic of electronics, plastics, super power or other marvels as yet unrevealed, it is not surprising that some municipal officials should look askance at a mere engineer who tries to tell them that advance planning can be undertaken at this time with little risk that the works will be obsolete and have to be wholly abandoned or changed at great expense before completion of construction or shortly thereafter.

One of the other speakers on this program will doubtless go into this matter in detail. It is merely noted here that the major activities of most research workers and manufacturers of sewage treatment equipment have been directed to the war effort so that they have had little opportunity during the past two years for consideration of possible improvement in processes of treatment or the development of new equipment.

Undoubtedly some of the scientific discoveries and improvements which have been fostered by the war effort can be advantageously adapted to the field of sewage treatment and we may expect that this will be accomplished in due course. However, adaptation and development of a new product to the marketing stage takes time, and opportunity can readily be afforded the designing engineer to make needed minor changes in prepared plans, either before or during the construction period.

It is true that various modifications of older methods of sewage treatment have been incorporated in several plants constructed for cantonments or war housing, but these modifications were largely conceived before the war and their inclusion in these treatment plants has really constituted fortunate opportunity for their thorough test.

Determination of Future Sewage Treatment Needs

The determination of the sewage treatment needs of a municipality for the post-war era may readily require more extensive study than would have been necessary for a similar determination in normal peace times.

The engineer must estimate what proportion of the migrant war workers, who have flocked into an industrial center, will continue as permanent citizens of the community and must also estimate the probable nature and volume of industrial wastes which will be discharged into the sewers after reconversion of the industries to peace time pursuits or to such modifications of former activities as are being planned by the management. Plainly, such determinations will involve procurement of opinion from municipal officials, bankers and industrialists, as well as advice of the state health department, but with knowledge at hand as to the pre-war conditions and the departures caused by the combined war activities of the district, an estimate of the post-war sewage treatment needs should be possible to the degree of accuracy required for purposes of design.

Conclusion

It is sincerely hoped that this presentation of some of the problems facing the consulting engineer in advance planning of sewage treatment works and recital of possible methods for approach may lead to wider appreciation that the basic conditions underlying the present situation appear to be analogous to those of the past and should be susceptible of solution by application of the same type of reasoning and skill which has so materially assisted in the rapid advance of the art of sewage treatment from its simple beginnings to its present state of perfection.

It is not to be considered as laudation of the consulting engineer nor an invitation for his employment.

THE CANADIAN POINT OF VIEW ON POST-WAR PROBLEMS *

By A. E. Berry

Director, Sanitary Engineering Division, Ontario Department of Health

Post-war planning in Canada has been attracting energetic inquiry for an appreciable length of time. It has now reached a more conclusive stage, with action replacing the study period. Many committees, governmental and private, have studied various aspects of this problem. The public have participated in these discussions and have followed closely the views of the different groups. Municipalities have compiled lists of works which might form a part of this programme. These actions might be regarded as preliminary planning of a general nature, and this step was necessary until that time when it was felt that a more favorable turn in the progress of the war was at hand, and when there was a concomitant realization that post-war work requires advance planning.

Recent months have brought a transformation in viewpoint and in activity. There is now a general desire to proceed with the preparation of plans and to complete those details necessary for an immediate start at the appropriate time. Municipalities are engaging engineers to prepare plans and estimates. They are deciding on how these projects are to be financed and how endorsation of the voters will be secured. In all these projected activities sewerage construction occupies a prominent position.

Development of the Program

In order to indicate the scope of post-war planning in Canada it is desirable to review briefly some of the developments that have taken place. These are to be seen in the work of some of the more prominent committees.

Early in 1941 the Dominion Government appointed a "Committee on Reconstruction," with Principal F. C. James of McGill University as Chairman, and associated with him were five prominent citizens, selected in order that their wide knowledge and experience might enable them to look at these problems from the broad angle of Canada's needs rather than the views of specialists in different fields of knowledge. This committee functioned under terms of reference which read as follows: "to examine and discuss the general question of post-war reconstruction, and to make recommendations as to what government facilities should be established to deal with this question."

The work of the James Committee was allocated to a number of subcommittees, including the following: (*a*) post-war employment opportunities, (*b*) conservation and development of natural resources, (*c*)

* Presented at the Fourth Annual Convention of the Federation of Sewage Works Associations, Chicago, Oct. 22, 1943.

publicly financed construction projects, (*d*) agricultural policy. Industrial rehabilitation was to be studied by various committees in the major industries of Canada.

One of these committee activities, namely that of publicly financed construction projects, is of more direct interest to those engaged in the sanitary field. In this, the committee from the outset has stressed the need for close co-operation between Dominion, Provincial and municipal organizations, and likewise for the need of early and careful planning of these works.

It is understood that the work of the James Committee, which is purely advisory to the government, has been pretty well completed and its report submitted.

Three other committees of Federal Government origin have been functioning: one an advisory committee on economic policy; one, a special committee of the House of Commons on reconstruction and re-establishment and as the name emplies embracing a wide field of re-adjustment from wartime to peace; and finally an interdepartmental committee from the Dominion Civil Service.

The main purpose of these different committees has been fact finding and advisory to the Federal Government. Their appointments and their subsequent activities have indicated an aggressive interest on the part of the government to prepare to meet post-war situations.

In addition to these there have been, of course, many committees functioning in more limited fields. Reference might be made here to a committee of the Engineering Institute of Canada. This is an attempt to determine the part that the engineer can play in the post-war reconstruction field.

The Present Situation

All these studies, made by government-appointed committees as well as by many other groups, have done much to secure for administrative bodies facts which are essential to an intelligent approach to the problem. They have likewise created a favorable public attitude towards the future of the country. It is now generally accepted that pre-war conditions, including public facilities and services, will not be satisfactory in the future. There must be a concerted effort to create required improvements, and if governmental action is necessary the public will expect this to be forthcoming just as impetus has been given in the conduct of the war.

Two reasons for post-war planning are now in evidence. The first concerns the prevention of unemployment, and it is now an accepted view that widespread unemployment, as occurred in the past, cannot be tolerated. The second reason is that adequate public services, such as water works and sewerage, are imperative in the new standard of living which is envisioned for the future. It is believed that sewerage programs will occupy a major position in these activities in Canada.

The Need for Sewerage

If our attention be focused on the sewerage field the need for post-war planning in this will be apparent by a survey of present-day conditions. In Canada, there has been a substantial development in the installation of water works systems and water purification plants. There are now in operation nearly 1,300 public systems, which serve nearly 60 per cent of the entire population, and, of course, a much higher proportion of the urban dwellers.

Good progress has been made in water treatment in the past, and while there is a wide program yet to be carried out, involving filtration, softening and taste control, this is not so great as in the sewerage field. Only a relatively small number of municipalities in Canada with populations in excess of 600 are now without public water works.

A comparison between the numerical development in water works and sewerage systems emphasizes further the need for sewerage. In comparison with the 1,300 water works systems there are but 500 sewered municipalities, and many of these are sewered in part only. For the treatment of sewage only 115 municipalities are yet supplied, and 60 per cent of these are in the Province of Ontario. The reason for this wide divergence between water works and sewerage may be attributed to a number of factors. In addition to the usual procedure of water works first the method of financing water has been a definite asset. Water accounts are less onerous than tax bills. In Ontario a good proportion of water works are administered by Public Utilities Commissions, and the rates are quite moderate.

Need for Sewerage

Sewerage systems should be as necessary as water works, and there is now a desire that these be provided in the post-war reconstruction period. Not only are public sewers demanded for these urban centers, but it is anticipated that pollution of water must be checked by the construction of sewage treatment works.

Planning Now Under Way

To meet this need considerable activity is now taking place. Progress may be said to be on the verge of the blueprint stage. Municipal councils are becoming impressed with the need for further preparation and it is encouraging to observe that many of these are now instructing their engineers to furnish the plans and estimates. It is anticipated that this trend will increase as time goes on. The Ontario Department of Health is urging municipalities to take this action, and to be prepared for immediate construction when the time arrives.

Objectives in Sewage Treatment

In the post-war sewerage programs certain objectives are being kept in mind. Not only is it desirable to provide widespread facilities for carrying away sewage and similar wastes, but there must be an end to undue pollution of surface waters. Treatment plants must give adequate purification. Protection of natural waterways and the resources of the country are essential both to ensure public health and to maintain their natural purity for the use and enjoyment of all.

Kind of Equipment

It is expected that in the sewage treatment plants to be built, full use will be made of modern methods, and mechanical equipment. The trend in mechanization will, it is hoped, be continued, with better control over the processes and less manual work for the operators.

In these future plants and their equipment, Canada looks to the United States for assistance and co-operation. The large number of plants in your country in comparison with ours makes possible the accumulation of extensive knowledge and invaluable experience. Canada feels fortunate in being able to take advantage of this experience because of her proximity and similarity in local conditions.

In the plants that are to be constructed we look to the inclusion of the most modern ideas which will improve efficiency, and reduce costs, operating difficulties and nuisances.

Requirements in Ontario

A recent survey has been made in the Province of Ontario by the Provincial Department of Health to ascertain the needs of the municipalities in respect to water works and sewerage. The expenditure required has been estimated at $40,000,000, of which the major portion is for sewers and disposal works. This amount is chiefly for new works rather than for the replacements, repairs and extensions which must be anticipated after a war period in which most of this maintenance has had to be postponed. This expenditure is aimed to give these public facilities to all urban centers of a size capable of their support, and to provide water treatment and sewage disposal to meet every reasonable standard. By this our natural waters will be protected against unwarranted pollution, and made useful for domestic and recreational purposes.

Financing of Projects

The exact mechanism by which these projects will be financed is not yet clear as to detail. To what extent the Dominion Government and the Provinces will contribute and assist the municipalities is not clear. It is apparent, however, that the financial situation in our municipalities has improved materially in recent years, and much of the debenture debt of former years is now expiring. These communities will then be in a favored position to embark on new and essential projects.

Recent legislation has been passed which will assist municipal governments to carry forward their own works independent, if need be, of outside aid. One measure which has recently been passed enables municipal councils to set aside during the war period amounts of money for use on post-war projects. This will enable advantage to be taken of the more prosperous conditions of the present, and to store this up for the future rather than returning it to the citizen in the form of reduced taxes.

Measures have also been adopted to permit financing of these works in as painless a fashion as possible. The sewer rental plan, whereby the rates will be paid similarly to water bills instead of in taxes, is one method designed for this purpose.

Conclusion

In conclusion it may be stated that in Canada there is a strong belief in a major post-war program of public works which will aid in the elimination of unemployment, but which will also provide needed utilities for the citizens. The blueprint stage has now been reached to put this into effect.

POST-WAR PROJECTS OF SEWAGE WORKS EQUIPMENT MANUFACTURERS *

By W. B. Marshall

Chain-Belt Company, Milwaukee, Wis.

After being asked to participate in this post-war planning program, as the representative of the manufacturers, I talked to quite a number of people and asked for suggestions as to what might be pertinent and interesting for a brief talk of this kind.

Among others this point was raised, "Are engineers or municipal officials hesitating to 'Blueprint Now' because they fear that radical improvements in equipment designs, materials or processes will make such plans obsolete in the post-war period?"

It seemed very doubtful that this feeling could be widespread. Most of us believe that changes and improvements in the future will be as in the past, gradual and evolutionary rather than radical, dramatic or revolutionary. However, so much publicity has been given to fantastic developments predicted for post-war use in certain other fields that it would not be surprising if there was some misunderstanding on this point in the sewage field.

Rather than depending on a personal appraisal, a questionnaire was sent out to all members of the Water and Sewage Works Manufacturers Association and a remarkably complete and representative response was received. Several questions were asked. The first and most important was this: "Generally speaking, could an engineer

* Presented at the Fourth Annual Convention of the Federation of Sewage Works Associations, Chicago, Oct. 22, 1943.

specify your product in accordance with the latest pre-war issue of your catalogs and specifications with reasonable certainty that immediate post-war improvements would be no more upsetting than ordinary pre-war product improvements which you have customarily made from time to time?'' Notice particularly that the question recognizes, and does not preclude, the refinements and improvements that manufacturers are accustomed to make from time to time. This work has been done in the past, and it will be done in the future, but it has never been a justification for holding back or postponing the planning and designing of sewage works projects.

What answers did the questionnaire obtain to this question? Unanimously ''Yes,'' not one single exception. Certainly this should remove any doubt on this point. But to carry this one step further, the direct question was asked—''Do you intend to market any radically new product for immediate post-war use?'' This produced two exceptions out of a total of 52 replies. So this again was a further confirmation. But what about those two exceptions? How would they effect an engineer's plans for a post-war project? Well, the third question was intended to get that answered—''If your answer is ''Yes,'' how can an engineer know immediately about these radically new products so that they can be specified *now* on projects being planned for construction during the immediate post-war period?'' These two manufacturers state that adequate data are already in engineers' hands (or is right now being placed in engineers' hands), so that no delaying is justified on that account.

So summarizing these answers I believe we can all agree that hesitation for fear of quick obsolescence in sewage works plans made now, for future construction, is an excuse rather than a reason, as one reply aptly expressed it. These questionnaire replies show a definite lack of radical changes in the immediate future. But what of the more distant future? Is the industry at a point of stagnation, and without vision or initiative for the future? Definitely not—although on this point it is more difficult to get a definite answer. Over one-third said ''Yes'' to this last question—''Do you have definite intentions of marketing any radically new product at some time in the post-war period after adequate time for development, testing and marketing plans?'' Here in fairness to many of those who said ''No,'' I believe it should be recognized that this is a very difficult ''Yes'' or ''No'' question. As some responses pointed out, it is a very indefinite question in many respects; therefore, it is hard to give a definite answer. I do not believe there is any manufacturer that does not hope and want to get out improved products, but I cannot justify taking the time to enlarge upon this by quoting or even giving excerpts from the many detailed explanatory responses.

It boils down to this: There is a general desire and intention on the part of manufacturers to improve and enlarge the usefulness of their products for the sewage field. Conditions at present make it difficult if not impossible to carry on much of this work without conflicting with their war effort. As soon as these restrictions are released they will resume their work on new developments and perhaps even radical improvements.

Sewage equipment manufacturers generally have been in a rather fortunate position because their products have had direct application to the war effort. Also this has provided a sufficient volume of orders to require little or much less than complete conversion to other products to utilize fully their manufacturing facilities. This means that they can quite readily resume their handling of post-war municipal sewage requirements.

And it is more than just a question of manufacturing facilities. The cumulative experience of past years, resulting primarily from the PWA and WPB programs, produced processes, equipment designs, etc., that were tried and proven over the great range of service and capacity requirements both for municipal and industrial sewages. To this experience has now been added the peculiar and severe requirements of military camps and war industries, and in some ways these have proved to be a more severe test than any previous experiences. This is cited to indicate the importance of years of experience as well as design; a point which we cannot afford to overlook in considering the practical aspects of improvements for the future.

While thus considering the future by examining the past, perhaps there are certain points that should be mentioned to guide our forward planning in continuing and expanding the good things that have been done, as well as searching for new improvements. In this, we, as manufacturers, will urgently need the co-operation and support of operators, engineers, and municipal officials. I am thinking of such experience-taught details as:

Easier operation.	Lower operating cost.
Easier to keep clean.	Better appearance.
Longer life.	Easier installation.
Lower maintenance.	Prompt repair parts service.
Lower first cost.	Well prepared operation and instruction books.

Helpful preliminary engineering data.

These are fundamental requirements, but how many come from radical improvements? Very few, I think. Most of them are refinements and gradual (not radical) improvements learned from experience in actual design and operation. They come through the development of more sizes and capacities of equipment, and also of supplies, to meet better capacity and sewage requirements. They come through the use of standardized units wherever they are practical and available. Yet as we compare what is available today with what was available ten years ago, we see changes and improvements that might well be called radical. I believe the manufacturers of materials, equipment, and supplies for sewage works have, generally speaking, done a good job in the past that can and should be utilized to "Blueprint Now" for the post-war future.

And so I would like to deflate and de-emphasize at this time the thought and influence of radical improvements on post-war projects, and instead point out with enthusiasm the very excellent and comprehensive lines of modern, time-tested materials, equipment and supplies available now for you as planning engineers, officials and operators on your post-war projects. As manufacturers we believe we are prepared and qualified, and I am sure we are ready, and willing to co-operate with you in "BLUEPRINTING NOW."

"BLUEPRINT NOW"—AIMS AND METHODS OF OPERATION OF THE COMMITTEE ON WATER AND SEWAGE WORKS DEVELOPMENT

By E. L. Filby

Field Director

(See *This Journal,* 15, 970, September, 1943)

A MUNICIPAL POST-WAR PROJECT FOR SEWERAGE DEVELOPMENT *

By Clyde L. Palmer

Dept. of Public Works, Detroit, Mich.

It is assumed by many that a post-war period of depression will develop after the close of the present hostilities. There is some divergence of thought on the subject but in general the preponderance of opinion favors the planning of a program designed to absorb the unemployment that is expected to develop with the collapse of war industry and the return of the armed forces to civilian life. Municipal governments will be expected to assume an important part in the post-war program and are for the most part undertaking the preparation of plans to that end. Municipal sanitation, particularly sewerage and sewage disposal, as a function of community interest, should anticipate a promising opportunity to participate in these plans for the future.

Detroit, acting on the report of the Mayor's Capital Improvement Program Committee, has established and implemented an organization for the purpose of planning for the post-war period. The effort has been designated as advance planning, inasmuch as the activities are to be more inclusive and embrace all planning for the future, irrespective of what may eventually become post-war.

* Presented at the Fourth Annual Convention of the Federation of Sewage Works Associations, Chicago, Oct. 22, 1943.

The advance planning program is to include the preparation of plans and specifications for those needed capital improvements that normally would have been annually provided but because of war created shortages have been deferred, in addition to desirable expansion of public service facilities as a program to provide a cushion for the expected post-war unemployment.

The committee has studied the needs of various branches of municipal service and has prepared a program of advanced planning which was subsequently adopted and in which the City Engineer has been designated as responsible for matters of design.

In order to avoid the ordinary detail activities of the City Engineer's office it was deemed advisable to establish a separate and distinct organization devoted exclusively to the problems of advanced planning and in accordance with this decision the Civil-Sanitary Division of the Advanced Plan organization was established. This division is headed by an associate civil engineer with an assistant and a complement of junior engineers and draftsmen to make the division complete within itself to handle all problems of design pertaining to sewerage.

The Civil-Sanitary Division has approached the problems of advanced planning from the fundamental idea that for the good of all concerned any planning for the future should be founded on a sound basis of orderly and purposeful development toward a definite goal. It is hoped that the implied urgency of the present demand for a post-war program will not foster a tendency toward haphazard planning. To eliminate this danger, as far as possible, it was felt the ultimate needs of the community should be evaluated as accurately as possible and a master plan established to accomplish this end. It was recognized that although the order of development within a district may not be evaluated accurately, nevertheless the ultimate condition is more subject to analysis and forecast, and a master plan to provide for the ultimate needs could be designed with sufficient flexibility to allow adjustment for unequal rates of development toward ultimate conditions.

The development of sewerage and sewage disposal is basically one of advanced planning and by nature inherently committed to master planning. From its inception sewerage has its master plan in the natural land drainage. In reality the so-called master plan of the engineer is for the most part a program for artificial improvement of natural drainage. As a practical matter, however, the development of a master plan is not simplicity itself but involved in many complications.

The economy of sewerage and drainage in a growing community is by necessity one of piecemeal construction, advancing the service life not for all time but for some arbitrary time in the future, and the unpredictable shifts of population and development impart to sewerage plans the element of gradual growth up to ultimate maturity. Usually the need for a master plan is not considered important until extensive development has already taken place under the guide of the then present necessity but lacking provision for future expansion, and all metropolitan areas have remnants of the sewers constructed during the early years of the community incorporated in their sewerage systems to complicate the master planning picture.

Records would probably show that the need for a master plan for sewerage was first realized by a community about the time when the original sewers became overtaxed by subsequent development and a comparatively large program of construction was in prospect. Unfortunately, in too many cases, although the need for a master plan might have been recognized, only the correction of the local trouble would be authorized on the grounds of economy and the overall plans for ultimate need postponed.

A common result of the evolution of sewerage systems is that a comprehensive master plan for ultimate needs of a community is not ordinarily attempted until the sewer system is more or less completed with structures of various service life remaining and many with their capacities already overtaxed.

Detroit has experienced all the trials and problems of a rapidly expanding community and has developed a sewerage system partly by expediency and partly by plan on a background of the natural drainage. Detroit's sewerage system, exclusive of the sewage disposal system, for the most part is in need of storm relief. The rapid urban development has so increased the storm water run-off that the capacity of parts of the existing system is often overtaxed.

The demand for a post-war program and the existing need for storm relief have combined to create the necessity for a master plan for storm relief sewerage and accordingly the Civil-Sanitary Division is preparing such a master plan to provide for the ultimate needs of the city itself and adjacent areas that by virtue of topography are tributary to the Detroit system. With a master plan as a basis for a post-war program all effort can be directed toward its accomplishment, with the result that the needs of progress will be served on a sound engineering background at the same time that the requirements of economy and necessity are satisfied. The fundamental soundness of such an approach to a post-war program seems well beyond the realm of serious criticism.

Preliminary to the development of a master plan for Detroit's storm water relief sewers, a number of engineering studies were made to evaluate the most recent data available on natural and economic phenomena.

As would be expected in any storm relief problem, rainfall data were the first to be investigated. The U. S. Weather Bureau station at Detroit provided the source of the data for a 47-year record of rainfall, 1896 to 1943, which was then re-studied using probability methods of statistical analysis, and rainfall frequency curves computed. The adjusted rainfall frequency curves have been adopted and provide the basis of all run-off computations using the well-known rational method.

During the year 1943, the Detroit River level has reached to within a few tenths of the maximum recorded stage of 1929. This experience prompted the re-study of river level data to check the hydraulic gradient inasmuch as all of the relief sewers would have their outlet to the Detroit River. The river level data obtained from the U. S. Lake Survey were analyzed by probability methods and using a basin lag of one day, for local phenomena, a design hydraulic gradient was established which would be equalled or exceeded .3 per cent of time or 30 days in 30 years.

The basis of any master plan is an evaluation of ultimate conditions to be designed for, and in the case of storm water sewerage the controlling feature is urban development. In addition to the evaluation of ultimate conditions it is also important for economic considerations, to be discussed later, that the present degree of urban development be determined in relation to ultimate. The Detroit area for purpose of this study was divided into three districts and analyzed separately. The results of the urban development study provided information as to the ultimate and present density of population, the date at which ultimate conditions of urban development could be expected, the present urban development in per cent of the ultimate, and the per cent of impervious surface that could be expected at ultimate development.

The economy of deferred construction is a very important consideration in the design of master plan details. The determination of ultimate needs establishes the final requirements but economy may dictate the intermediate steps to attain that end. An analytical study of costs indicated that the most economical procedure in providing sewerage for any given period would be to install 75 per cent of the ultimate requirements and defer the remaining 25 per cent. To make practical use of the study, the application of the 75–25 principle had to be adapted to a heterogeneous set of circumstances where, except in areas having no sewerage, the existing structures had in each case various amounts of service life remaining, and in many cases the sewers were already overtaxed. As a matter of judgment it was assumed that all construction should provide for not less than 20 years in advance of the present needs, thus if ultimate conditions would be reached within that time the construction should be for ultimate requirements. If ultimate development was expected more than 30 years in the future, the 75–25 rule could safely be applied. For the period between 20 and 30 years the most expedient plan could be chosen considering the limits set forth as approximate rather than definite values.

Numerous other studies were made to implement the design work that would be necessary to develop the master plan. Cost data for various types of construction were studied and curves prepared for estimating purposes, engineering cost indices were prepared in forms useable in design, and a library research was made of most recent publications covering methods of computing storm water run-off. As a result of the engineering investigations made preliminary to and in conjunction with the development of a master plan, the details could be approached with quite complete and up-to-date information in a form most applicable to the problem.

Since the establishment of the Civil-Sanitary Division the preliminary work has been completed on the detail computations supporting the development of a master plan for storm water relief sewers in the Detroit area, providing for the ultimate needs of the community. On the basis of the master plan engineering drawings are now being prepared for those portions that have been authorized. To date, plans and specifications have been completed for $2,500,000 of the authorized $20,000,000 project for sewerage development, and the planned progress for the Civil-Sanitary Division is expected to result in completed plans and specifications for an additional $2,000,000 of the project per month.

HIGH RATE BIOLOGICAL SEWAGE TREATMENT *

By Samuel A. Greeley

Greeley and Hansen, Engineers, Chicago and New York

General Statement

The title "High Rate Biological Sewage Treatment" brings to mind more particularly high rate trickling filters and various aeration methods designed to shorten or speed up the aeration process. During the past decade much effort has been given to the study and development of such methods of sewage treatment and many plants of various arrangements and details have been built. Their accomplishments and costs and their place in the field of sewage disposal merit appraisal. The broad objective of the high rate processes is to accomplish the needed degree of sewage treatment at lower over-all costs and within smaller sites. It should be noted as important that the same degree of treatment is not everywhere required and that this greatly affects the proper application of various high rate biological processes.

It has been difficult in the past to evaluate the various methods of high rate biological treatment on comparable bases, due chiefly to a lack of sufficiently extended and reliable operating data. Some such data are now available. The present paper sets forth a suggested procedure for rating and comparing different types of high rate sewage treatment plants for a given set of sewage characteristics and required degree of treatment. Possibilities for further studies and analyses are indicated.

Meaning of "High Rate"

Experiment and operation have indicated a meaning for the term "High Rate." A conventional or standard trickling filter is often operated at a rate of 2.0 more or less million gallons per acre per 24 hours depending upon the strength and character of the raw sewage and the amount of preliminary sedimentation. This is equivalent to an average load of some 300 to 400 pounds per day of applied B.O.D. per acre foot of filter. Some of the older filters such as those at Decatur and Fort Worth have been dosed at rates of 800 or more pounds of B.O.D. applied to the filter per acre foot per 24 hours.

In contrast to these so-called standard rates, high rate trickling filters are in operation under applied loads as high as 15,000 to 20,000 pounds of B.O.D. per acre foot per day. These very high rates do not accomplish high percentage removals but are useful for reducing the load on other treatment plant structures such as a standard filter. Loads of around 3,000 pounds of B.O.D. per acre foot per day, however,

* Presented at the Fourth Annual Convention of the Federation of Sewage Works Associations, Chicago, Ill., Oct. 22, 1943.

are often applied to high rate filters of various kinds with removals of upwards of 75 per cent.

The progression of loads and efficiencies from those on standard filters to those on high rate filters may be uniform, although some experience indicates an intermediate range of loads where pooling occurs. The more or less regular relationship may, however, apply, provided the filter is kept clean by recirculation, backwash, or otherwise. At the present time, the common understanding of the term "high rate filter" is one operating under a load of 3,000 pounds or more per acre foot per 24 hours, which, with normal sewages, results in a dosing rate materially in excess of the rate on a conventional filter.

Filters operating under applied loads, say from 5,000 to 20,000 pounds of B.O.D. per acre foot, may be thought of as roughing filters. The effluents which they produce are not generally acceptable for discharge into many waterways. Filters of this kind are in operation at Austin, Minnesota and Springfield, Missouri.

If a conventional activated sludge plant provides a displacement period in the aeration tanks of 6 hours for the sewage treated, a short period or high rate aeration process might have a similar displacement period of some 2 to 3 hours. Successful operation at these short periods of aeration has been accomplished at the Bowery Bay plant in New York City and the North Side plant at Chicago.

Current High Rate Terms

Through research, development, and promotion, a number of terms have come to be associated with high rates of sewage treatment, as follows:

(*a*) Trickling Filters
- Aero
- Accelo
- Bio
- Back-wash
- Roughing

(*b*) Aeration and Activated Sludge
- Short period
- Distributed load
- Step
- Recirculation
- Contact
- Stream flow

Several names are associated with high rate terms, including Jenks, Ward, Levine, Halvorson, Fischer, Hays, Gould, and Fair and special studies have been reported by Mohlman, Rudolfs, Keefer, Imhoff, Edwards, and others. Results of operation have been reported by Kessler, Walton, Warrick, and others. A considerable amount of pertinent comment and information appears in the British technical journals.

Two-stage processes are included, some with and some without intermediate sedimentation. Mohlman operated two-stage aeration as early as 1929 and bio-aeration ahead of trickling filters was installed by Whitehead at Birmingham, England in 1927. Two-stage treatment has long been considered applicable to a strong sewage, as for instance beet sugar plant wastes.

Description of High Rate Plants

The several kinds of treatment plant associated with high rates of operation are briefly described in the following paragraphs. Operation may be with or without recirculation and in one or two stages. When operation is limited to a single stage at high rates without recirculation, the filter is more of a roughing filter, to be followed by some further treatment as on a standard filter.

The Biofiltration system (H. N. Jenks) is described as "the combination of a clarifier and a trickling filter wherein filter discharge material is recycled back to the clarifier which also receives incoming feed to the system."

The Aero-filter (H. O. Halvorson) is described as, "A process for treating sewage in a trickling filter open to atmosphere to purify the same, which comprises applying filter influent to the filter at a daily average rate of more than ten m.g.a.d. and at a distribution ratio of less than substantially ten to one." In this system it is understood that the effluent from a final sedimentation tank is recirculated to the filter if necessary to maintain a dose on the filter at a rate of some 10.0 m.g.a.d. or more.

The Accelo-filter is described as "accelerated biological treatment . . . by direct recirculation of large quantities of material to a rotary distributor and thence to a biological filter." Flow diagrams indicate that the effluent from the filter is recirculated directly back to the filter influent.

A method of step or distributed-load aeration is in use at the Bowery Bay plant in New York City. The aeration tanks have four passes. A favorable operating routine includes the delivery of the return sludge at a rate of about 45 per cent of the sewage into the first pass. The sewage from the preliminary sedimentation tanks is then discharged in about equal quantities into the other three passes of the aeration tanks. Various applications of recirculation and distributed load have also been studied on an experimental basis under Fair at Harvard and by Setter at the Wards Island plant in New York City.

Two-stage contact aeration (C. C. Hays) is another recent development.

In brief, a Hays process plant comprises preliminary sedimentation, first stage contact aeration, intermediate sedimentation, second stage contact aeration, and final sedimentation. The aeration tanks are shallower than conventional aeration tanks as used, for instance, in the North Side and Bowery Bay plants. The contact plates extend over the entire tank area and for most of the depth, and are made up of $\frac{3}{16}$ inch thick asbestos-cement sheets set vertical across the tank and about $1\frac{1}{2}$ inches apart. Air is blown into the tank under the plates through orifices in a pipe grid. These orifices have tended to clog or corrode and the maintenance of efficient distribution of air has been difficult.

Operating Data

Results of operation on a plant scale, where the laboratory work is competent, are the best bases of appraisal. Notable contributions in this field appear in the recent report by Graham Walton entitled "High Daily Rate Trickling Filter Performance" and in the papers presented by Lewis H. Kessler and John T. Norgaard on the operation of army sewage treatment plants. While these records of operation throw some light on the relations between loads and resulting efficiencies for various kinds of high rate biological treatment processes, they are not sufficiently comparable to permit very definite conclusions. The best method of relating the operation of various methods of sewage treatment is to study parallel operation with the same sewage, which is certainly difficult on a plant scale and not frequently done on a testing station scale. Many local factors influence the performance of sewage treatment plants. Although these cannot be reviewed at length, they should be noted so that their effect in particular cases will not be overlooked. Among them are the following:

(*a*) The character of the sewage.
(*b*) The extent and efficiency of preliminary treatment.
(*c*) The character and method of disposal of sludge liquor from digestion tanks.

The character of the sewage is a very important item. If there is a low per capita rate of flow, say 50 g.c.d. or less, and the climate is warm, the sewage may reach the high rate process stale, devoid of oxygen and with a high immediate oxygen demand. This condition is accentuated if sulphur is present. The percentage of volatile matter in the suspended solids and the ratio of B.O.D. to the suspended solids are factors that differ from place to place. Some plants are subjected to more sudden changes in the strength of the sewage than others and this affects the relative overall efficiency.

The effectiveness of preliminary sedimentation is an important factor which varies in different installations. At some of the Army plants studied, high removals of B.O.D. were observed in the preliminary sedimentation tanks as shown in Table I. This high average of 48 per cent compares with 25 to 35 per cent in many municipal treatment plants.

The use and interpretation of operating data is thus limited and must be applied with caution and judgment so far as descriptive or comparative yardsticks are concerned. Overall removals of B.O.D. from less than 50 up to 90 per cent are of record, depending on the load and other conditions of operation.

Although the operating records are not sufficiently extensive or comparable, they provide a basis for describing a procedure for the study of high rate processes along comparative lines. Such a study, outlined in following sections, is illustrative only but may be a framework into which further data will fit.

TABLE I.—*High Rate Biological Sewage Treatment*

B.O.D. Removals by Preliminary Sedimentation Tanks at Army Posts

Post	Period Covered	B.O.D.—P.P.M.		Per Cent Removal	Displacement Period—Hours
		Raw Sewage	Prelim. Effluent		
A	6 mo.	138	72	48	2.5
B	3 mo.	437	236	46	2.5
C	3 mo.	334	168	50	3.0
D	8 mo.	411	249	39	3.4
E	6 mo.	280	163	42	3.5
F	1 mo.	150	53	65	1.8
Average				48	

Sewage disposal problems do not lend themselves to simple solutions because they are inherently complicated and difficult.

During the last eighteen to twenty months, the Army and Navy have put into operation several hundred sewage treatment plants, the majority being of the high rate type. The operating results, however, are not as yet available for general use. The importance of sewage disposal to the whole country would appear to justify the appointment by the Government of a Commission to review the operation of sewage treatment plants during the war years and to record results and conclusions for the use of the general public, as well as for the Army and Navy.

Short Period Aeration Processes

Operating records to illustrate short period or high rate aeration processes have been studied for the North Side Treatment Plant in Chicago, the Bowery Bay Treatment Plant in New York, and a Hays Process treatment plant in Texas. All of them had relatively fresh, dilute sewage, the average rate of sewage flow being as follows:

Plant	Gallons per Capita per 24 Hours
North Side	205
Bowery Bay	121
Hays Plant	150

Other operating data for the three plants are summarized in Table II. Each of these plants was operated at a relatively high load of B.O.D.

North Side Plant.—This plant receives a relatively dilute sewage with an average B.O.D. of 109 p.p.m. During the years 1936 and 1937, two of the batteries were operated with a displacement period, based on mixed liquor, of 3.0 hours. During the year summarized in Table II, there was no preliminary sedimentation, as the raw sewage contained only about 100 p.p.m. of suspended solids. The results for the year 1937 were practically the same as those for 1936. There was no sludge supernatant return from digestion tanks.

Bowery Bay.—This plant receives a sewage somewhat less dilute than the sewage treated in the North Side plant with an average B.O.D.

TABLE II.—*High Rate Biological Sewage Treatment*

Summary of Operating Data for High Rate Aeration Plants

Item	Chicago North Side Plant	New York Bowery Bay Plant	Hays Process Plant
Displacement period in aeration tanks—hours	3.0	2.6	1.6
Return sludge—per cent of sewage flow	21.7	46.0	0.0
5-Day B.O.D.—p.p.m.			
Raw sewage	109	156	138
Prelim. sedimen. tank effluent	—	110	72
Final effluent	10	16	15
Per cent removal of B.O.D. by aeration and final sedimentation tanks	91	85	82
B.O.D. load applied to aeration tanks—lb. per day per 1,000 cu. ft. of aer. tanks	44.8	47.5	66.4
Air—cu. ft. per gal. of sewage	0.37	0.59	1.29
B.O.D. in raw sewage—lb. per capita per day	0.19	0.16	0.17
Period covered	Year 1936	May, 1942–1943	Mar.–Aug. 1943

of 156 p.p.m. Beginning with May, 1942, the plant has operated at an average displacement period of 2.6 hours. During this period, the preliminary sedimentation tanks removed an average of 30 per cent of the B.O.D. The operating routine is to return activated sludge to the first pass of the aeration tanks and settled sewage in about equal quantities to each of the other three passes.

Hays Plants.—Thirty or forty sewage treatment plants of the Hays type have been built for army establishments, mainly in the south and southwest. Operating data regarding these have been published by Kessler and Norgaard and we have had an opportunity of further studying their operation. One of the contact aeration plants in Texas, treating a fairly fresh, dilute sewage which has been producing a satisfactory effluent, has been used to illustrate favorable results with this type of plant. This plant receives a sewage with an average B.O.D. of 138 p.p.m. Operating records are available for six months in 1943 during which time the average displacement period in the two aeration tanks was 1.6 hours. These data are as favorable as any we have observed for Hays process plants. Aeration periods have been computed on the basis of net tank volumes, after deduction of the volume of the plates themselves and the space below the bottoms of the plates which is used for sludge removal apparatus. During this period of operation the removal of B.O.D. by the preliminary sedimentation tanks was high, averaging 48 per cent.

The contact aeration plants observed in operation and reported by Kessler and Norgaard have developed a number of recurring operating and mechanical difficulties, among which are the following:

Plugging of holes in aeration piping.
Uneven air distribution.
Black septic growths on contact plates.
Thin sludge.
Breaking of blades on sludge removal mechanisms.

Warping and breaking of contact plates.
Incomplete removal of sludge from contact plates and tank bottoms.
Uneven distribution of sewage through spaces between contact plates.

Some of these operating troubles are not inherent in the process but the operation of the plants as a whole has been difficult and has occasioned numerous investigations to find methods of improvement. In general, the results of operation have been better and the difficulties with maintenance have been less with smaller plants and more dilute sewages than with larger plants and strong sewages. This was stated by Kessler and Norgaard about a year ago, as follows:

"Observations to date indicate that the smaller plants have good possibilities of producing results equal to high-grade intermediate type of treatment. Perhaps the Hays process plant can continuously produce a highly purified effluent but when such is the case it will be accomplished at a cost that is relatively high, and the needs in most Army camps where the plants are now in operation could be met more economically by other methods."

The treatment plant of this type for which operating data are given receives the sewage from about 3,500 population and is thus a relatively small plant treating a relatively fresh and dilute sewage.

Operating data for the three aeration plants are brought together as follows:

Plant	Sewage Flow G.C.D.	Air, Cu. Ft. per Gal. of Sewage	Aeration Period Hours	B.O.D. Appl'd P.P.M.	Per Cent Removal of Applied B.O.D. in Aeration and Final Tanks
North Side	205	.37	3.0	109	91
Bowery Bay	121	.59	2.6	110	85
Hays Plant	150	1.29	1.6	72	82

Unit Quantity of Air.—Most of the Hays plants observed and for which operating records are included in the publications by Kessler and Norgaard have used relatively high unit quantities of air, the range being from 1.25 to 4.0 cubic feet per gallon of sewage, with an average of about 2.5 cubic feet per gallon.

It should be noted that the air pressure in the Hays plants is considerably less than in the North Side and Bowery Bay plants, being 5.0 pounds per square inch for the Hays plants and 7.25 pounds per square inch for the others. Thus, the cost of air per million gallons of sewage in the Hays plants has been over twice that in the others.

The foregoing figures are, of course, not directly comparable because the strength of the applied sewage was different in each case. Relating the air use to the pounds of B.O.D. applied in each case results in the following:

Plant	Lb. B.O.D. Applied per 1000 Cu. Ft. of Air
North Side	2.46
Bowery Bay	1.55
Hays Plant	0.47

The present indications are that the Hays plants require at least twice as much air as the high rate activated sludge plants described above. Even with these high air rates, the contact aeration plants seem to have labored when the tributary sewage was concentrated, particularly in the larger installations.

At many sewage treatment plants in Texas, it has been observed that relatively high temperatures and sulfur compounds accentuate the operating difficulties.

Computation of Aeration Tank Performance.—As a means of expressing the performance of a high rate aeration plant, we have com-

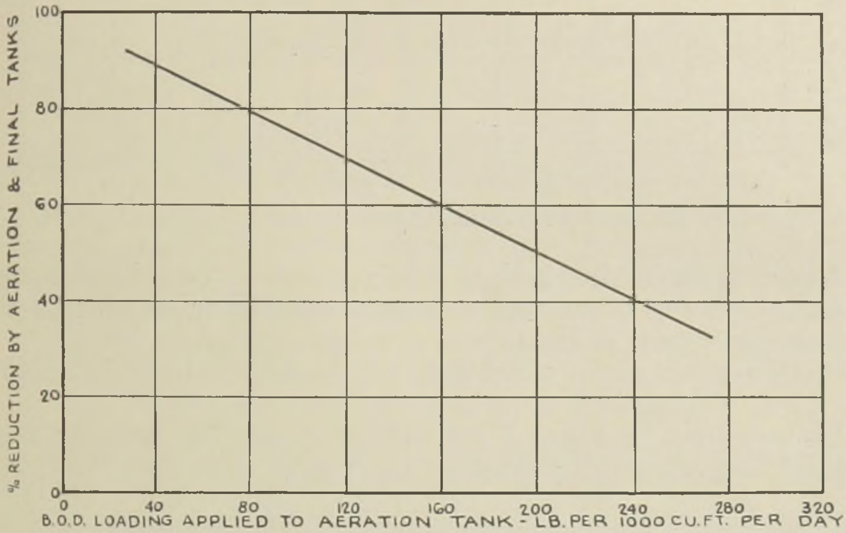


Fig. 1.—B.O.D. removals by hight rate aeration.

puted the percentage of removal of B.O.D. by the aeration and final sedimentation tanks, including for the Hays process the first and second stage aeration tanks and the intermediate and final sedimentation tanks, as related to the applied load in pounds of B.O.D. per 1,000 cubic feet of aeration tank capacity. In the Hays process, the aeration tank capacity is taken as the net capacity above the air grids, excluding the volume occupied by the contact plates. The results are shown on Figure 1 and correspond to the following average relationships:

Plant	Lb. B.O.D. Applied per 1,000 Cu. Ft. of Aer. Tank	Per Cent Removal of B.O.D. by Aeration and Final Tanks
North Side	44.8	91
Bowery Bay	47.5	85
Hays Plant	66.4	82

An application of this relationship to an activated sludge plant accomplishing 90 per cent overall removal of B.O.D. indicates a load of some 52 lb. B.O.D. per 1,000 cu. ft. of aeration tank volume, if an allowance of 30 per cent is made for removal of B.O.D. by preliminary sedimentation.

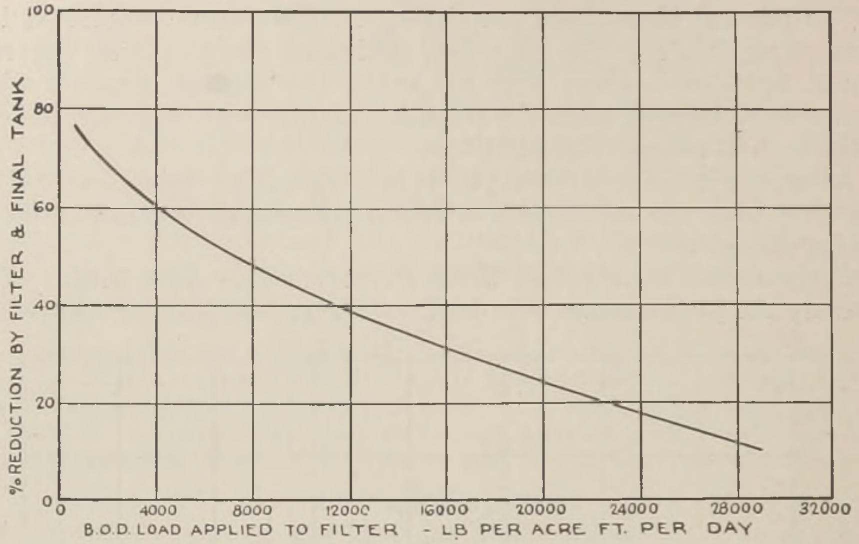


Fig. 2.—B.O.D. removals by high rate trickling filters.

A performance rating such as this is a necessary and helpful step in computing the cost of a sewage treatment plant in terms of the desired or necessary degree of treatment.

Operating records on which Fig. 1 is based are shown in Appendix A.

Computations of Filter Plant Performance.—The curve in Fig. 2, showing the relationship between percentage removal of B.O.D. by

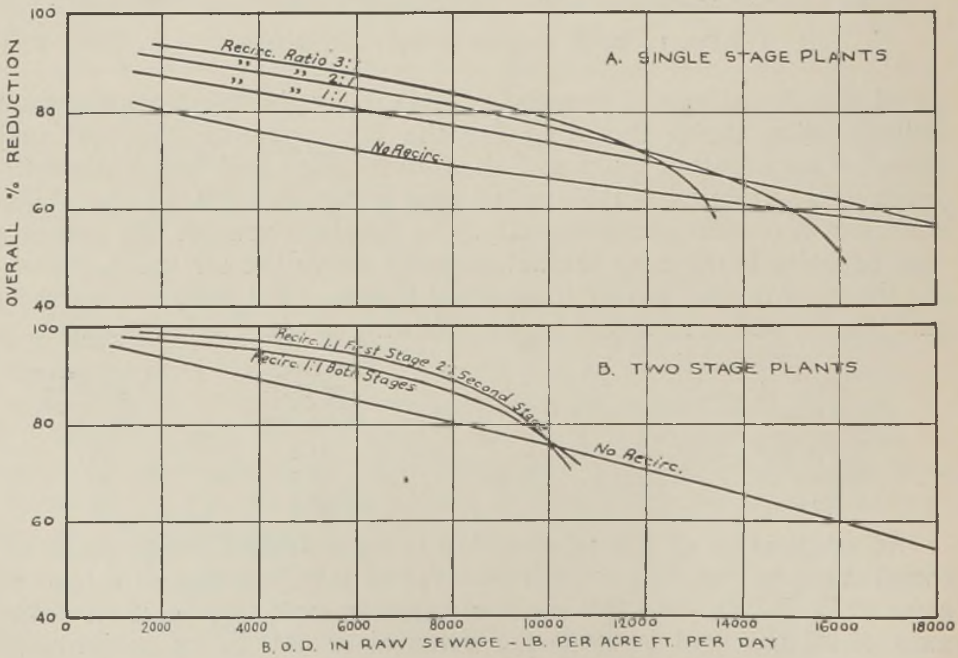


Fig. 3.—Computed B.O.D. removals of high rate filter plants.

filters and final tanks and the loading on the filters per unit of volume, was developed from consideration of operating data at a number of treatment plants, including those published under date of March, 1943, by the Board of State Health Commissioners Upper Mississippi River Basin Sanitation Agreement. The loadings were computed from the B.O.D. content of the sewage applied to the filters, including recirculated liquor, if any. Data for both first stage and second stage filters are included. No differentiation is made between sewages of different strengths, nor between filters of different depths. From this curve, the data for the curves of overall removals shown on Fig. 3 were computed, using the following basic assumptions:

1. 30 per cent removal of B.O.D. by preliminary sedimentation tanks.
2. Recirculated liquor of the same B.O.D. content as the effluent from the filter sedimentation tank combination under consideration.
3. First and second stage filters of equal volume.

Computations may also be made with other assumptions, as for instance first stage roughing filters loaded up to perhaps 15,000 lb. B.O.D. per acre foot per day, with second stage filters of sufficient size to provide the required overall reductions in B.O.D.

Operating records on which Fig. 2 is based are given in Appendix B.

Typical Costs of High Rate Treatment

The foregoing sections give a broad picture of high rate biological sewage treatment processes. The outline can be extended with some consistency to computations of typical costs. The costs of certain parts of high rate biological sewage treatment plants are closely related to the permissible applied load, which is in turn a function of the degree of treatment or per cent removal to be accomplished. These parts are the sedimentation tank, the filters or aeration tank, the blower buildings and the return sludge or recirculating pumping equipment. Sludge disposal structures may also be somewhat different for varying loads and for different methods of sewage treatment, depending on the characteristics of the sludge, chiefly its density.

The selection of a sewage treatment method for a given degree of treatment and set of local conditions will also depend on a number of factors other than the construction cost, many of which it is possible to evaluate in terms either of first cost or of operating costs. The various items entering into such a comparison are briefly as follows:

Area of site
Operating cost
Uniformity of performance
Life of structures and equipment
Difficulties in maintenance and repair
Simplicity of operating control
Head required for operation

A number of other considerations, moreover, might result in departures from the typical computation. These are dependent to some extent on local conditions and largely on some uncertainties arising from the interpretation and the incompleteness of the available data. It is desirable, therefore, to list some of the more important of such considerations with brief comments:

(*a*) The loadings and per cent removals from which the study is developed do not allow for the possible effect of any differences in the depths of trickling filters, the strength of the applied sewage, or its temperature, or the effect of supernatant liquor from sludge tanks. Some experience has been interpreted to indicate that the loads and the percentages of removal are affected by these factors but the data are not sufficiently complete to permit a close appraisal. Perhaps some coefficients or series of load-removal curves will be found to apply. I have the feeling, however, that the differences caused by such factors as the foregoing may not be found to have sufficient magnitude, for the biological treatment and the final sedimentation together, to result in great modifications.

(*b*) Certain factors relating to the efficiency may have a bearing. For trickling filters the dosing rate, the efficiency of distribution and the ventilation of the filter will affect the removal under a given load; and for an aeration tank the efficiency of air distribution is important, as brought out by Kessler and Norgaard in connection with the Hays plants. Differences in the effectiveness of preliminary sedimentation should not be overlooked.

(*c*) It is apparent that differences in several items will affect the relative final costs, including operating head, land areas, quantity and character of sludge to be disposed of, and relative costs of construction throughout the country and under varying competitive conditions. The degree of treatment to be accomplished also has a bearing on the relative cost.

Computations under several assumed conditions and unit costs, indicate, in general, that the contact aeration type of treatment plant is the more expensive. This appears to result mainly from the intermediate sedimentation tank, the larger quantity of air, and the cost of contact plates. This is in accord with the comment by Kessler and Norgaard quoted on page 11.

Summary Statement

The subject of high rate biological sewage treatment is extensive and it has not been possible in a paper of this kind to do more than sketch the outlines of the problem as viewed by the writer and to indicate the direction in which further effort should be made. A scrutiny and appraisal of presently available information shows that useful degrees of sewage treatment can be accomplished by high rate biological processes. Certain accomplishments support this statement. The overall efficiency as reported depends somewhat upon the laboratory data and its interpretation. The large scale operation of the aeration process at the Bowery Bay plant of New York City and the North Side plant of the Sanitary District of Chicago with relatively low quantities of air are noteworthy. Trickling filters under very high loads at Austin, Minnesota, and Springfield, Missouri, each of the roughing filter type, have been successful in operation over a term of years. A number of trickling filter plants providing recirculation, with one or with two stages, and of various filter depths have given satisfactory results in operation. Plants of the contact aeration type have given satisfactory effluents with fairly dilute and relatively fresh sewages and where the load is not too high but under such conditions it seems likely that the results will be accomplished at a fairly high cost and that the necessary degree of treatment can be accomplished more economically by other methods of high rate biological sewage treatment.

APPENDIX A.—*High Rate Biological Sewage Treatment*

Data on Removal of B.O.D. by Aeration at High Rates

Place	Period Covered	B.O.D. P.P.M. Aera. Tank Influent	Air Cu. Ft./Gal.	Lb. B.O.D./1000 Cu. Ft. Aeration Tank/Day	Per Cent Removal of B.O.D. by Aeration and Final Tanks
Army Camp	1 mo.	92	1.22	87.0	77
	1 mo.	83	1.26	79.0	81
	1 mo.	67	1.33	60.5	80
	1 mo.	78	1.34	70.0	87
	1 mo.	58	1.25	55.7	84
	1 mo.	52	1.34	46.4	85
New York—Bowery Bay	1 mo.	95	0.50	38.5	82
	1 mo.	73	0.58	26.0	82
	1 mo.	83	0.50	34.6	75
	1 mo.	131	0.49	57.4	87
	1 mo.	106	0.54	43.7	91
	1 mo.	123	0.64	52.7	94
	1 mo.	132	0.72	51.7	89
	1 mo.	116	0.73	48.3	86
	1 mo.	118	0.58	50.8	87
	1 mo.	129	0.58	56.5	78
	1 mo.	112	0.61	51.8	85
Chicago—No. Side Plant Battery "B"	1 mo.	94	0.29	41.7	87
	1 mo.	115	0.36	45.0	90
	1 mo.	119	0.39	50.5	90
	1 mo.	102	0.30	51.6	92
	1 mo.	103	0.34	49.4	92
	1 mo.	97	0.38	41.0	91
	1 mo.	98	0.38	37.8	93
	1 mo.	83	0.38	36.0	92
	1 mo.	96	0.37	39.6	91
	1 mo.	103	0.33	43.1	93
	1 mo.	125	0.34	47.4	92
	1 mo.	145	0.36	41.1	91
Army Camp	1 mo.	230	1.70	153.0	58
	1 mo.	258	1.81	164.0	64
	1 mo.	279	1.67	129.0	56
	1 mo.	273	2.96	106.0	49
	1 mo.	311	2.71	132.0	72
	1 mo.	307	2.86	124.0	83
	1 mo.	396	2.84	159.0	74
	1 mo.	478	3.08	176.0	76
	18 days	219	5.52	45.8	85

Appendix A.—*High Rate Biological Sewage Treatment—Continued*

Place	Period Covered	B.O.D. P.P.M. Aera. Tank Influent	Air Cu. Ft./Gal.	Lb. B.O.D./ 1000 Cu. Ft. Aeration Tank/Day	Per Cent Removal of B.O.D. by Aeration and Final Tanks
Chicago—Calumet Plant Experimental Unit	1 mo.	79		126.8	52
	1 mo.	79		118.8	72
	1 mo.	89		135.0	74
	1 mo.	71	.58	108.8	65
	1 mo.	78	.47	123.5	59
	1 mo.	88	.34	144.0	59
	1 mo.	76	.31	122.5	53
	1 mo.	94	.30	152.2	63
	1 mo.	93	.29	150.0	58
	1 mo.	84	.30	135.0	56
	1 mo.	71	.30	117.3	69
Chicago—West Side Plant Experimental Unit	1 mo.	80	.45	46.4	82
	1 mo.	73	.15	48.8	82
	1 mo.	56	.15	38.0	82
	1 mo.	51	.18	45.2	85
	1 mo.	46	.20	42.0	76
	1 mo.	33	.17	30.0	74
	1 mo.	36	.17	31.4	71
	1 mo.	38	.23	37.0	68
	1 mo.	31	.26	27.3	67
	17 days	46	.23	45.0	74
	20 days	44	.19	26.5	85
	7 days	94	.42	38.3	95
	7 days	114	.38	58.0	95
	10 days	119	.38	74.6	93
	1 mo.	112	.33	75.5	86
New York—Wards Island Pilot Plant	68 days	117		251.0	50
	66 days	128		131.0	72
	43 days	117		85.0	80
	83 days	120		61.6	85
	21 days	109		29.5	86

Appendix B.—*High Rate Biological Sewage Treatment*

Data on Removal of B.O.D. by High Rate Trickling Filters

Plant	Period Covered	Recirc. Ratio	Dosing Rate m.g.a.d.	B.O.D. Applied to Filters Lb. per ac. ft. per day	Per Cent Removal of B.O.D. by Filters and Final Tanks
Austin, Minn.	1 mo.	0.0	18.4	8,700	56
	1 mo.	0.0	18.9	7,750	54
	1 mo.	0.0	18.6	9,850	51
	1 mo.	0.0	19.6	9,650	46
	1 mo.	0.0	18.9	14,600	38
	1 mo.	0.0	19.0	13,100	36
	1 mo.	0.0	19.4	13,800	34
	1 mo.	0.0	19.8	14,600	33
	1 mo.	0.0	19.8	10,200	36
	1 mo.	0.0	18.3	9,700	47
	1 mo.	0.0	18.3	10,500	33
	1 mo.	0.0	21.1	10,000	38
	1 mo.	0.0	20.4	11,000	44
	1 mo.	0.0	21.5	12,800	44
	1 mo.	0.0	21.3	12,200	31
	1 mo.	0.0	20.4	12,100	42
	1 mo.	0.0	21.8	13,100	40
	1 mo.	0.0	21.9	16,400	33
	1 mo.	0.0	20.5	14,800	27
	1 mo.	0.0	20.1	19,200	25
	1 mo.	0.0	18.2	14,100	30
	1 mo.	0.0	19.7	13,500	28
	1 mo.	0.0	20.3	13,100	38
	1 mo.	0.0	21.3	14,400	38
	1 mo.	0.0	22.0	16,900	30
	1 mo.	0.0	21.6	15,600	24
	1 mo.	0.0	20.4	11,600	42
	1 mo.	0.0	19.7	12,600	39
	1 mo.	0.0	19.7	14,400	31
	1 mo.	0.0	19.4	17,100	30
	1 mo.	0.0	20.1	22,600	25
	1 mo.	0.0	19.3	11,500	32
	1 mo.	0.0	20.6	12,500	32
	1 mo.	0.0	20.7	8,700	23
	1 mo.	0.0	21.9	10,100	42
	1 mo.	0.0	21.7	14,700	34
	1 mo.	0.0	22.1	13,900	39

Appendix B.—*High Rate Biological Sewage Treatment—Continued*

Plant	Period Covered	Recirc. Ratio	Dosing Rate m.g.a.d.	B.O.D. Applied to Filters Lb. per ac. ft. per day	Per Cent Removal of B.O.D. by Filters and Final Tanks
Springfield, Mo.	1 mo.	0.0	22.9	15,200	44
	1 mo.	0.0	20.4	10,400	33
	1 mo.	0.0	20.0	7,900	13
	1 mo.	0.0	21.6	5,550	52
	1 mo.	0.0	21.0	6,200	37
Army Camp—(First Stage)	1 mo.	1.1	34.5	15,600	37
	22 days	1.2	35.6	17,800	22
	1 mo.	1.2	34.5	18,800	39
	1 mo.	1.2	38.5	22,300	22
	1 mo.	1.1	37.0	21,400	23
	1 mo.	1.0	39.0	24,300	3
	1 mo.	1.1	36.2	20,000	25
	1 mo.	1.0	35.4	17,200	41
	7 days	1.2	37.0	20,600	40
	7 days	1.7	50.8	20,600	56
	7 days	2.6	29.3	14,700	53
	23 days	1.3	35.5	30,700	16
	1 mo.	1.7	25.7	12,600	46
(Second Stage)	1 mo.	1.1	34.5	6,800	38
	22 days	1.2	35.6	10,000	30
	1 mo.	0.9	30.3	8,900	55
	1 mo.	1.2	38.5	13,000	33
	1 mo.	1.0	35.4	11,800	33
	1 mo.	1.0	37.5	15,900	45
	1 mo.	1.2	37.2	10,900	34
	1 mo.	0.8	32.1	8,400	12
	7 days	1.0	34.6	9,400	30
	23 days	1.3	36.5	22,300	32
South St. Paul—Backwash Filters	1 mo.	0.0	6.6	7,200	72
	1 mo.	0.0	6.6	7,400	69
	1 mo.	0.0	7.4	6,500	49
	1 mo.	0.0	7.3	7,300	60
	1 mo.	0.0	6.9	5,000	61
	1 mo.	0.0	7.0	5,700	52
	1 mo.	0.0	6.5	6,700	58
	1 mo.	0.0	6.7	6,800	64
	1 mo.	0.0	6.4	7,900	62
	1 mo.	0.0	6.2	5,900	66
	1 mo.	0.0	5.5	5,000	68
	1 mo.	0.0	6.0	4,200	57
Army Camp	1 mo.	0.6	14.4	2,280	58
	1 mo.	0.6	15.3	3,570	61
	1 mo.	1.3	19.4	4,620	47
	21 days	1.4	12.9	2,580	67
	15 days	1.8	16.2	2,620	62

APPENDIX B.—*High Rate Biological Sewage Treatment—Continued*

Data Published by Board of State Health Commissioners Upper Mississippi River Basin Sanitation Agreement

Plant	Period Covered	Recirc. Ratio	Dosing Rate m.g.a.d.	B.O.D. Applied to Filters Lb. per ac. ft. per day	Per Cent Removal of B.O.D. by Filters and Final Tanks
Glenwood City, Wis.	24 hrs.	2.41	14.4	2,920	49.7
	24 hrs.	1.59	14.3	2,870	51.2
	24 hrs.	1.85	14.2	2,820	55.1
	24 hrs.	2.33	15.9	1,860	62.3
	24 hrs.	3.55	15.9	2,540	70.4
	24 hrs.	2.85	16.0	2,130	64.3
	24 hrs.	2.32	13.2	2,230	64.1
	24 hrs.	2.24	13.0	2,080	63.0
	24 hrs.	1.67	12.7	1,840	61.5
	24 hrs.	1.49	10.5	1,880	50.3
	24 hrs.	1.85	10.6	1,670	54.5
	24 hrs.	1.55	10.6	1,610	45.7
	24 hrs.	0.0	4.0	1,260	54.9
	24 hrs.	0.0	4.0	1,260	54.8
	24 hrs.	0.0	4.2	1,200	58.2
River Falls, Wis.	24 hrs.	0.0	18.2	4,660	71.5
	24 hrs.	0.0	17.0	4,880	73.9
	24 hrs.	0.0	16.8	4,580	75.3
Owatonna, Minn.	24 hrs.	0.77	16.9	2,280	82.3
	24 hrs.	0.85	17.5	1,480	64.8
	24 hrs.	0.91	15.9	2,890	77.1
	24 hrs.	0.66	21.0	26,200	20.4
	24 hrs.	0.81	17.3	6,190	57.0
	24 hrs.	0.66	19.3	8,320	56.1
	24 hrs.	0.67	18.2	3,200	65.5
	24 hrs.	0.60	18.7	3,260	65.3
	24 hrs.	0.50	20.7	3,500	47.8
	24 hrs.	0.0	6.8	1,640	77.4
	24 hrs.	0.0	6.8	1,530	81.1
	24 hrs.	0.0	6.6	1,190	73.0
	24 hrs.	0.0	18.8	6,190	52.3
	24 hrs.	0.0	18.5	3,760	57.9
	24 hrs.	0.0	18.2	3,500	66.7
	24 hrs.	0.0	7.2	2,050	56.4
	24 hrs.	0.0	7.2	1,890	66.8
	24 hrs.	0.0	7.0	1,470	55.2
	24 hrs.	0.0	15.9	6,140	40.8
	24 hrs.	0.0	15.3	3,620	47.9
	24 hrs.	0.0	15.0	3,350	57.4
Lakefield, Minn.	24 hrs.	0.29	6.8	2,610	78.8
	24 hrs.	0.31	7.1	1,970	77.3
	24 hrs.	0.18	7.5	2,440	75.1
Austin, Minn.	24 hrs.	0.0	21.0	11,250	46.2
	24 hrs.	0.0	21.7	11,900	43.5
	24 hrs.	0.0	21.5	12,500	40.8

APPENDIX B.—*High Rate Biological Sewage Treatment—Continued*

Plant	Period Covered	Recirc. Ratio	Dosing Rate m.g.a.d.	B.O.D. Applied to Filters Lb. per ac. ft. per day	Per Cent Removal of B.O.D. by Filters and Final Tanks
Lake Mills, Iowa	24 hrs.	0.21	14.2	1,460	60.5
		0.18	12.2	1,300	52.2
		0.12	11.8	1,610	77.2
Webster City, Iowa	24 hrs.	0.83	17.3	3,490	48.4
	24 hrs.	0.05	20.4	2,680	62.7
	24 hrs.	1.08	15.2	2,000	58.5
	24 hrs.	1.53	16.8	1,340	79.2
	24 hrs.	1.38	16.8	2,140	57.0
	24 hrs.	0.74	18.6	1,290	51.7
	24 hrs.	0.0	10.3	580	54.9
	24 hrs.	0.92	16.5	620	38.2
	24 hrs.	1.08	15.2	2,000	45.0
	24 hrs.	1.53	16.8	1,340	52.8
	24 hrs.	1.38	16.8	2,140	68.4
	24 hrs.	0.74	18.6	1,290	50.0
	24 hrs.	0.0	10.3	580	47.1
	24 hrs.	0.92	16.5	620	55.9
Carlyle, Ill.	24 hrs.	0.24	29.1	5,700	60.8
	24 hrs.	0.15	23.7	6,180	58.6
	24 hrs.	0.41	29.9	6.750	57.2
Paris, Ill.	24 hrs.	0.21	15.1	510	44.0
	24 hrs.	0.28	15.1	1,290	62.6
	24 hrs.	0.31	15.1	990	51.0

Discussion *

By R. M. Dixon

Captain, Corps of Engineers, Dallas, Texas

In examining the subject of sewage treatment from the Army's point of view, we collide with some very practical considerations that should determine the selection of a treatment process:

1. Necessity and degree of treatment required, based on the plant location and requirements of the receiving watercourse or drainage course.
2. Duration for which the treatment works will be needed.
3. Construction materials available.
4. Manpower available for operation.
5. Operating costs vs. first costs.
6. Other considerations, not the least of which is the actual arrangement of the facilities to be served and the use that will be made of those facilities. This is important because the rate at which the waste ar-

* Presented at Fourth Annual Convention of the Federation of Sewage Works Associations, Chicago, Oct. 21, 1943.

rives at a treatment plant has a decided effect on the success of the high rate plant.

A plant might take a peak flow of 50 per cent above average flow for several hours and do a satisfactory job, but when that load increases from a minimum of 20 per cent of the average flow to 250 per cent of the average flow in a period of 15 minutes, the effects will be felt. All plants at Army posts do not so operate but a large number of them do. Housing is generally concentrated and training routines make for simultaneous use of waste collection facilities by the greatest number of men. One to ten to one to fifteen flow ratios, from minimum to maximum, are not uncommon and the peak organic load arrives with the heavy flow. A high rate treatment works designed to treat an average flow with what would be regarded as a normal peak will not satisfactorily handle such heavy peak loadings. A hydraulic study of the camp and a knowledge of the training routine to be employed would be helpful as a part of the basis for the design. In the design the degree of treatment provided should have taken into account the conditions to be met in the receiving watercourse and not have been based entirely upon a per cent B.O.D. reduction. We have a lot of camps in the Southwest, but very few of them are located on large watercourses. This means that we have to have positive treatment or, in lieu of that, reduction after removal. In many instances, the waste is relatively strong, for water is not a surplus commodity at some of the posts and water conservation is a very important matter. In the instance of the Hays plant discussed in the foregoing paper, an excessive use of water has been permitted in order to gather data on treating a dilute sewage by the Hays process.

At this point, attention is invited to per cent reduction as a basis for rating sewage treatment works. If the water consumption at the subject camp were reduced to 70 gallons per capita—the amount set up as normal requirements by the Army design manual—we would be getting 50 gallons of sewage per capita instead of 150 and the concentration would be about 350 p.p.m. B.O.D. instead of 135 to 150. Based on the same per cent reduction as is now being obtained, we would wind up with an effluent of around 40 p.p.m. B.O.D. and a nuisance, instead of 13 p.p.m. B.O.D. and a sparkling clear effluent in the outfall ditch. Yet the pounds of B.O.D. removed per day might be the same. Per cent removal is a phrase that might well be used with discretion in interpreting sewage treatment records for actual plant performance. It may serve to compare processes but it doesn't tell the whole story. On the same basis, the amount of 5-day B.O.D. in p.p.m. alone, taken as a criterion, is not enough, if treatment is to be carried through the nitrogen cycle. Short period aeration and high rate filters usually carry treatment through the carbon cycle but from there on the work done is more costly. It doesn't offer a satisfactory yardstick in determining when a yard of rock is a yard of rock. Yet, in terms of B.O.D. loadings, there seems to be an analogy between high rate and standard rate trickling filters. In making this comparison, recirculation, which can be regarded as multiple filtration in one sense of the word, must be disregarded because it tends to cloud the loading picture. As Fischer has pointed out (*Water Works and Sewerage,* October 1942), it is practically impossible to get any consistent figure for B.O.D. loading in terms of settled sewage for bio-filter plants due to primary recirculation and unpredictable performance by filters and primary clarifiers considered as a unit. By comparison it can be said that, based on Army experiences the quality of high rate plant effluents is more variable in character than those produced by standard filters.

We normally think of high rate filters as units operating above 10 m.g.a.d. and loaded above 3,000 lb. per acre foot based on settled sewage, and standard rate filters as units dosed with settled sewage at around 2 to 3 m.g.a.d. and loaded at 600 lb. per acre foot. Between the two rates there exists a range that has been designated as dangerous ground where many unfavorable operating conditions, mainly ponding, supposedly are to be encountered. Experience does not always bear this out. Records are available at an army camp located in Kentucky where the dosing rate on a fixed nozzle installation is around 8.5 to 9 m.g.a.d., approximately 50 per cent of which is recirculated filter effluent to primary influent. The B.O.D. loading per acre ft., based on primary effluent has varied from 1,500 to 2,500 lb. per acre foot. B.O.D. removals average 90 per cent overall and satisfactory operation has been reported. Raw B.O.D. was 314. An Oklahoma army camp standard filter, following a high rate, is operating on an average B.O.D. load that has varied from 600 to 1,000 lb. per acre foot and is dosed at a rate of from 4.2 to 6.2 m.g.a.d. The B.O.D. of the effluent from the final tank, in parts per million has for the past five months been as follows: May, 20, June, 18, July, 18, August, 19, and September, 21. Ponding has not occurred.

For the past six months at the Dallas municipal plant the loading, on a basis of settled sewage, has been 4 to 5 m.g.a.d. and 940 lb. B.O.D. per acre foot. The average plant effluent B.O.D. has been 32 p.p.m. and no ponding has occurred. Filters are 7.5 ft. deep. The plant has been operating under this loading since January, 1943. Dissolved oxygen and nitrates in the effluent average 4 p.p.m. This nitrification is strikingly similar to that obtained at a Texas army camp aerofilter plant that produced 2.6 p.p.m. nitrates at a loading of 938 lb. per acre ft., 1.5 parts at 1,131 lb., 0.5 at 1,760 lb. and ceased to produce nitrates at 1,825 lb. per acre ft., using 7 ft. filters. Flows varied from 14 to 18 m.g.a.d.

The author operated the Dallas plant in 1941 under 1,200 lb. per acre ft. loadings for about 30 days but due to increased odors during the summer months, the run was suspended and the load distributed to additional units. Removals of 1,050 pounds per acre ft. in the filter and final tank were obtained and no ponding was noticed. Nitrates in effluent averaged 3.5 p.p.m. A recirculation ratio averaging 1 to 1 was used at Dallas several months during 1941 but the recirculation was discontinued because the results obtained were not appreciably better than when raw settled sewage was applied directly to the filters, with only enough tank effluent returned to the filters at night to maintain rotation and keep the exposed surface of the rock wet. No ponding difficulties were encountered when recirculation was used. The recirculation treatment produced a dosing rate of about 6 m.g.a.d. and there was nothing to indicate that recirculation had any appreciable effect in keeping the filter clean.

TABLE I.—*Camp A*

Single Stage Bio.—Complete
Recirc.—Filter Effluent to Raw
Final Effluent to Filter Influent
Sec. Sludge to Raw
1 103 Ft. Diam. by 3 Ft. Deep Filter
Area = 8,330 Sq. Ft. = 0.1913 Acre
Volume = 25,000 Cu. Ft. = 0.574 Acre Ft.

Month	B.O.D. in Raw Sewage			B.O.D. in Applied Filter Inf.			Dosage Rate M.G.A.D.	Recirc. Ratio.
	Lb./A′/D	Lb./Cu. Yd.	Overall Per Cent Reduction	Lb./A′/D	Lb./Cu. Yd.	Per Cent Reduction Filter Sec.		
1943								
March	7,600	4.71	81.4	7,190	4.45	48.6	27.6	1.62
April	8,250	5.11	80.4	7,870	7.88	50.3	28.3	1.42
*May	10,840	6.72	85.5	8,420	5.22	60.5	26.4	1.11
*June	9,700	6.01	85.8	7,050	4.37	56.3	25.6	1.24
July	5,520	3.42	91.4	3,785	2.35	60.5	26.9	2.17
Aug.	7,600	4.71	83.7	5,660	3.51	48.4	28.6	1.38
Sept.	9,890	6.12	76.2	7,950	4.93	53.5	26.0	.845

* Recirculation same as at Camp B.
Average B.O.D.—Raw Sewage—236 p.p.m.
Average B.O.D.—Final Settling Tank Effluent—44 p.p.m.

Camp B

Single Stage Bio.—Complete (Original Design)
Recirc.—Final Effluent to Raw
Final Effluent to Filter Influent
Sec. Sludge to Raw
1 103 Ft. Diam. by 3 Ft. Deep Filter
Area = 8,330 Sq. Ft. = 0.1913 Acre
Volume = 25,000 Cu. Ft. = 0.574 Acre Ft.

Month	B.O.D. in Raw Sewage			B.O.D. in Applied Filter Inf.			Dosage Rate M.G.A.D.	Recirc. Ratio.
	Lb./A′/D	Lb./Cu. Yd.	Overall Per Cent Reduction	Lb./A′/D	Lb./Cu. Yd.	Per Cent Reduction Filter Sec.		
1943								
May	4,230	2.62	92.6	5,270	3.27	68.8	27.9	4.15
June	4,670	2.89	93.1	4,850	3.01	67.1	30.2	3.92
July	3,600	2.23	87.3	4,780	2.96	50.7	29.4	4.16

Average B.O.D.—Raw Sewage—244 p.p.m.
Average B.O.D.—Final Settling Tank Effluent—29 p.p.m.

Camp C

Two Stage Bio.—Complete
Recirc.—1st Stage Filter Effluent to Raw
Final Effluent to 2nd Stage Filter Influent
Sec. Sludge to Raw
2 45 Ft. Diam. by 4 Ft. Deep Filters
Area: Each—1,590 Sq. Ft.; 0.0365 Acre. Total—3,182 Sq. Ft.; 0.073 Acre
Volume: Each—236 Cu. Yd.; 0.1460 Acre Ft. Total—471 Cu. Yd.; 0.292 Acre Ft.

Month	B.O.D. in Raw Sewage			1st Stage Filter	B.O.D. in 2nd Stage Applied Filter Inf.			2nd Stage Filter	
	Lb./A'/D	Lb./Cu. Yd.	Per Cent Reduction Overall	Recirc. Ratio.	Lb./A'/D	Lb./Cu. Yd.	Per Cent Reduction Filter Sec.	Dosage Rate M.G.A.D.	Recirc. Ratio.
1943									
April	7,780	4.82	78.2	0.96	9,640	5.97	32.8	37.5	.9
May	8,510	5.28	76.4	0.89	10,570	6.54	29.1	42.4	.87
June	7,780	4.82	75.6	0.87	9,830	6.09	26.2	42.4	.85
July	8,760	5.43	73.0	0.73	10,530	6.53	31.3	41.1	.53
Aug.	10,150	6.29	80.6	0.76	10,000	6.20	27.6	44.4	.64
Sept.	9,930	6.15	83.0	0.81	8,470	5.25	29.5	41.4	.76

Average B.O.D.—Raw Sewage—359 p.p.m.
Average B.O.D.—Final Settling Tank Effluent—79 p.p.m.

Camp D

Single Stage Aero-Filter
Recirc.—Final Effluent to Filter Influent
2 70 Ft. Diam. by 7 Ft. Deep Filters
Area: Each—3,850 Sq. Ft.; 0.0884 Acre. Total—0.1768 Acre
Volume: Each—0.619 Acre Ft. Total—1.238 Acre Ft.

Month	B.O.D. in Raw Sewage				Per Cent Reduction Filter—Secondary on Basis of Applied Settled B.O.D.
	Lb./A'/D	Lb./Cu. Yd.	Per Cent Reduction		
			Overall	Primary Settling	
1942					
Jan.	4,090	2.53	71.0	36.7	54.2
Feb.	4,040	2.50	71.5	26.2	61.4
May	4,040	2.50	70.3	29.1	58.1
June	4,780	2.96	73.8	37.0	58.4
July	3,400	2.11	74.7	44.2	54.6
Aug.	2,110	1.31	87.6	56.2	71.6
Sept.	2,650	1.64	80.9	57.3	55.2
Oct.	3,110	1.93	75.2	46.6	53.6
Nov.	4,070	2.52	75.6	41.0	58.5
Dec.	5,440	3.37	71.7	38.8	53.7
1943					
Jan.	6,570	4.08	68.0	38.2	48.3
Feb.	5,660	3.51	58.7	26.4	43.9
Mar.	4,260	2.64	64.2	31.2	47.9
Apr.	4,660	2.89	83.7	57.0	62.1
June	3,990	2.47	81.6	51.7	61.9

Average B.O.D.—Raw Sewage—214 p.p.m.
Average B.O.D.—Final Settling Tank Effluent—57 p.p.m.

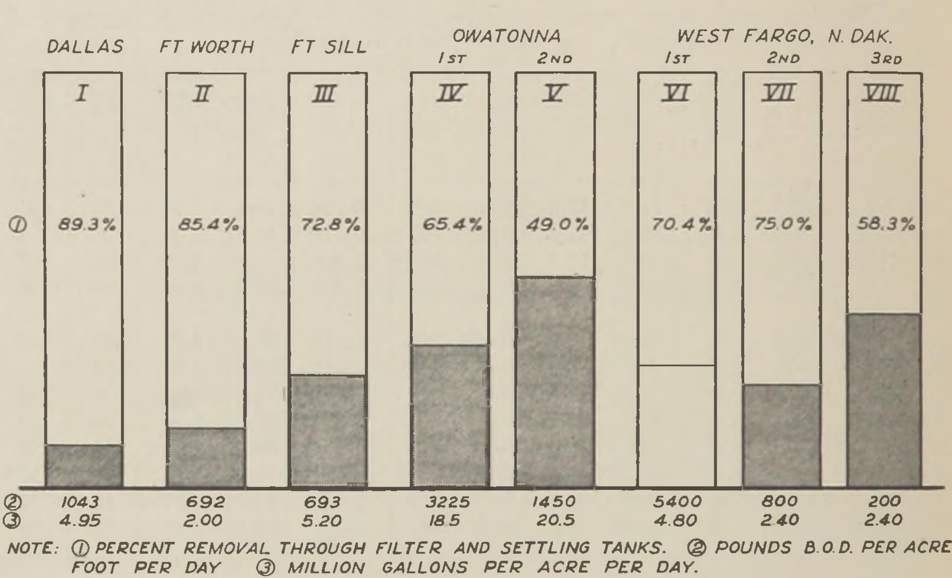
Camp E

Two Stage Filtration: High Rate Filters, Intermediate Settling, Low Rate Filters.
Recirculation: Bottom of Intermediate to Raw
Final Settling Tank Sludge to Raw.
Primary Filters—2 85 Ft. Diam. by 3 Ft. Deep
Total Area—0.25 Acre
Total Volume—0.75 Acre Ft.
Secondary Filters—2 130 Ft. Diam. by 5 Ft. 6 In. Deep
Total Area—0.61 Acre
Total Volume—3.35 Acre Ft.

Month	Primary Filter—Intermediate Settling					Secondary Filter—Final Settling					Int. Set. Tank
	B.O.D. in Filter Influent			Ave. Dosage Rate M.G.A.D.	Recirculation Ratio	B.O.D. in Filter Influent			Ave. Dosage Rate M.G.A.D.	B.O.D. Final Effl. p.p.m.	B.O.D. Final Effl. p.p.m.
	Lb./A'/D	Lb./Cu. Yd.	Per Cent Reduction			Lb./A'/D	Lb./Cu. Yd.	Per Cent Reduction			
June '42	7,460	4.63	74.1	17.0	0.53	300	0.186	46.4	4.84	22	41
Sept. '42	8,780	5.44	59.4	17.4	0.60	527	0.327	68.9	4.85	23	74
Oct. '42	10,400	6.44	50.0	17.4	0.76	684	0.424	71.7	4.24	30	106
Nov. '42	9,880	6.13	40.5	16.6	0.70	820	0.508	70.3	4.23	38	128
Feb. '43	11,610	7.19	42.2	17.0	0.61	996	0.618	68.5	4.56	45	143
Mar. '43	12,250	7.59	40.8	16.9	0.55	1100	0.682	69.5	4.70	47	154
Apr. '43	9,350	5.79	41.6	17.7	0.53	857	0.531	74.8	5.08	28	111
May '43	7,060	4.38	57.2	17.5	0.51	1158	0.717	67.7	5.24	20	62
June '43	6,175	3.83	62.1	17.9	0.40	407	0.252	61.7	5.71	18	47
July '43	7,100	4.40	47.7	20.0	0.42	634	0.393	73.1	6.23	18	67
Aug. '43	7,815	4.85	48.9	20.0	0.43	670	0.415	73.6	6.21	19	72
Sept. '43	8,660	5.37	64.9	19.2	0.65	453	0.281	63.1	5.22	21	57

Filters operating under these conditions are not generally recognized as high rate, and by the same standard of measurement, short period aeration activated sludge or Hays plants operating on weak sewages should not be classed as high rate. On a basis of B.O.D. per volume of aeration tank or lb. B.O.D. removed per cu. ft. of air, we find little difference between short-period aeration plants referred to by Mr. Greeley, and the standard activated sludge plants. It is indicated that short period aeration can be successfully applied only to weak sewages. Such sewages are not common in the United States, because the average per capita water consumption in the majority of towns is too low to produce wastes of such character.

Our experience with high rate filters indicates that satisfactory treatment, in terms of B.O.D., can be obtained if the loadings and/or recirculation ratios are correctly maintained, but our treatment experience is not always in keeping with the claims made by the manufacturers. A typical two-stage biofilter at Army Camp C operating with one-to-one recirculation ratio for each stage has obtained a reduction of about 78 per cent overall, with loadings varying from 7,000 to 10,000 lb. per acre ft. raw sewage basis. A single stage biofilter at Army Camp B operating under a raw sewage load of approximately 4,000 lb. per acre ft., and with a final-effluent-to-raw recirculation of 4 to 1, has obtained reduction from 87 to 93 per cent. At nearby Camp A, a single stage biofilter was operating under approximately twice the B.O.D. raw sewage loading as Camp B was receiving, and the recirculation ratio varied from .85 to 1.62, and the overall removals varied from 76 to 85 per cent. Loading at 5,520 lb. per acre ft. and using a recirculation ratio of 2.17, the overall removal increased to 91.4 per cent. At Camp D, a single stage aerofilter with approximately 20 per cent return of final effluent to filter influent and operating under an



Filter Performance

I. Settled sewage to std. rate filter. II. Settled sewage to std. rate filter. III. Settled roughing filter effluent to std. rate filter. IV. Settled sewage to high rate filter. V. Settled high rate filter effluent to high rate filter. VI. Settled sewage to high rate filter. VII. Settled high rate filter effluent to high rate filter—2 stage. VIII. Settled 2nd stage filter effluent to high rate filter.

average B.O.D. loading of 4,000 lb. per acre ft. had overall B.O.D. removals varying from 58.7 per cent (5,660 lb. B.O.D. per acre ft.) to 87.6 per cent (2,110 lb. B.O.D. per acre ft.) with the average at 78 per cent. Methylene blue stabilities of high rate army camp plant unchlorinated effluents are seldom over 20 per cent and are often lower. Dissolved oxygen in these high rate effluents is usually low and nitrification does not generally occur.

If we study the loadings for high rate filters and standard rate filters the difference is not as great as what first meets the eye. At West Fargo, N. D., we find two standard units operating in series on a high rate effluent. From the Chart we note that the B.O.D. remaining from the roughing filter may be more difficult to remove than that which has been taken out by the high rate unit. The standard filter following the first standard filter apparently has still a harder job to perform in per cent removal. A similar condition is shown on the chart for Camp E where a standard filter follows a high rate unit. The difference in percentage reductions between standard rate filters operating on settled sewage and the standard rate filters operating on roughing filter or standard filter effluents is quite evident.

In terms of B.O.D. alone, a yard of rock is apparently not a yard of rock, and the standard filter is retained as a good work horse to accomplish the more difficult work but there are indications that its operation can be modified by the simple process of recycling the sediments from the final tank to the settled sewage and applying them to the filter. This routine was tried out on a plant scale by the author and the results were quite surprising. It required about 60 days to stabilize the plant after this scheme was put into effect but when the filters and sludge were stabilized the plant operated without the characteristic filter fly nuisance, was relatively free of filter odors, and reductions through the filters increased. Plant overall removals averaged slightly over 94 per cent for 3 consecutive months, with loadings of 1,100 lb. per acre ft. of rock. B.O.D. in raw sewage averaged 341 in the final effluent 20 p.p.m. Particular attention is invited to the 60 day period required to stabilize the plant.

Nitrates in the plant effluent dropped from about 9 p.p.m., under normal operation, to an average of 2.5 p.p.m.; dissolved oxygen remained at around 5 p.p.m.; and ammonia was reduced from 25 parts to 10 p.p.m. through the filters. The filters unloaded constantly—suspended matter in the filter influent averaged about 500 p.p.m. and was reduced only about 20 p.p.m. through the filter. Settling in the final tank was rapid. No sludge was wasted from March 15, 1942 to late in the Fall of that year and yet the suspended matter did not increase above 600 p.p.m. when returned at a rate of 150 g.p.m.

In reviewing the operating picture as given for the Hays plant in Mr. Greeley's paper, it might be added that the short period Hays contact aeration plant does not accomplish nitrification, but some of the other Hays plants that have longer detention periods in the aerators are producing effluents with a low B.O.D. concentration and show a conversion of part of the nitrogen compounds present. Hays plants are relatively new to sewage treatment, and construction cost estimates will be subject to modification through experiences encountered in operating them. It is evident that developments will occur as the process continues to be used. Even at this time the intermediate tank is not a proven necessity, and it is entirely possible that additional savings can be made in the size of the final tank. Air is usually supplied through perforated pipe and this is not generally accepted as the most efficient way to apply air in a process where oxygenation is desired. An extensive experimental study is now under way at an army camp covering loadings and oxygen utilization with different types of diffusers, treating both fresh and stale sewages. Mechanical difficulties have occurred

TABLE II.—*Operating Data. Dallas, Texas, Sewage Treatment Plant*

Month	Total Flow M.G.D.	B.O.D.—P.P.M.					NH_3 p.p.m.			NO_3 p.p.m. Raw	Dosing Rate M.G.A.D.	B.O.D.—Lbs.					
												*Applied		Removed		Per Cent Removed	
		Raw	Fri. Eff.	Filt. Inf.	Filt. Eff.	Fin. Eff.	Raw	Filt. Inf.	Fin.			A.	A. Ft.	A.	A. Ft.	In Filt.	Overall
1941																	
Aug. 25.....																	
Sep. 25.....	26.6	347	208	208	53	38	21	21	13	4.3	5.96	10,350	1,380	7,720	1,030	74.5	89.1
1942																	
Jan.........	25.4	381	231	167	74	45	29	21	8	12	3.79	5,280	704	2,940	392	55.5	88.2
Feb.........	24.7	374	229	204	89	44	30	25	10	10	3.68	6,290	836	3,540	472	56.4	88.2
Mar.........	24.5	366	223	223	112	30	28	26	10	10	3.65	6,880	915	3,370	450	50.0	91.8
Apr.........	24.8	221	122	171	93	14	16	16	4	7	3.70	5,270	702	2,420	320	45.6	93.6
May........	21.3	256	145	185	84	15	18	16	5	6	3.18	4,900	654	2,680	356	55.5	94.1
June........	27.8	321	182	234	101	19	20	20	7	4	4.15	8,120	1,079	4,620	615	56.8	94.1
July........	27.2	335	191	243	92	18	24	24	11	3.5	4.06	8,190	1,092	5,110	680	62.2	94.4
Aug.........	26.0	367	215	267	113	22	25	25	12	2.5	3.88	8,600	1,145	4,960	660	57.7	94.0
Sept........	24.4	355	208	246	114	29	27	26	14	2.4	3.64	7,520	1,000	4,020	535	53.7	91.9
Oct.........	21.9	318	194	214	76	29	26	26	15	2.5	3.27	5,550	740	3,620	482	64.5	90.5
Nov.........	23.5	332	193	242	128	36	26	25	16	2.7	3.50	6,740	896	3,180	424	47.2	89.1
Dec.........	24.8	372	216	305	172	49	18	27	19	1.8	3.70	9,440	1,255	4,120	549	43.6	86.8
1943																	
Jan.........	26.3	308	221	247	149	52	28	27	17	4.0	3.92	7,940	1,056	3,210	428	39.6	83.1
Feb.........	20.4	381	230	219	88	58	29	29	19	6.5	3.04	5,570	742	3,330	443	59.6	84.8
Mar.........	20.0	385	229	208	83	53	29	29	18	8.7	2.98	5,150	686	3,090	412	60.5	86.2
Apr.........	18.8	341	188	187	61	42	25	25	15	5.0	4.22	6,580	880	4,450	594	67.4	87.7
May........	18.8	340	193	178	67	40	46	26	16	5.8	4.22	6,260	834	3,910	522	62.4	88.2
June........	21.7	320	184	181	54	38	25	25	14	5.6	4.87	7,380	986	5,175	690	70.2	88.2
July........	21.7	330	195	191	31	26	25	26	15	6.1	4.87	7,760	1,038	6,520	870	83.7	92.1
Aug.........	22.4	289	180	187	32	20	26	27	18	3.2	5.03	7,860	1,047	6,520	870	82.9	93.1

Note: During 1942 the plant was operated with final settling tank sludge returned directly to the filter influent at a rate of approximately 150 g.p.m.
* Filter loadings are based on B.O.D. in filter influent.

at some of the Hays plants but these are not all inherent to this process. And these, too, are being investigated.

The Army construction program was a rush program and with no plant designers completely acquainted with the Hays process, the results were inevitable.

The plants were placed in operation with operators not experienced in operating Hays plants, and a good looking plant effluent was their immediate ambition. While it is definitely true that Hays plants at Army posts have used excessive amounts of air, economical operation is difficult to accomplish if operators are convinced that additional air will improve the plant effluent, and most of them think that it does. Air requirements as recorded for Hays plant have been determined from blower capacity as rated by the manufacturer. In the majority of cases, these ratings have never been checked. Plant operating data, so compiled, should be interpreted in that light. Air requirements for Hays plants are still a matter of experimental consideration and may remain so for sometime to come. It is partly so with activated sludge; this process has had the advantage of many years of operating experience that the Hays plants must yet accomplish.

Operating costs, like construction costs, are modified by local conditions and are difficult to compare except insofar as they can be expressed in power units and man hours required per million gallons. In this case we find large plants in a favorable light because economies that can be applied to their operation are not always transferable to small plants. The grade of supervision provided for the larger plants cannot be afforded in small plants and good supervision is part of good operation. High rate filters operating costs will vary in proportion to the recirculation ratio and the dynamic head on the pumps. Hays process plants and activated sludge plants will find a high proportion of the operating costs allocated to air compression, and this will vary in proportion to the kind and concentration of the waste and its amenability to treatment (the degree of treatment required being fixed) but always keeping in mind that the cost of a pound of B.O.D. removed will increase as the percentage removal approaches complete treatment as a limit.

OPERATING EXPERIENCES AT ARMY SEWAGE TREATMENT PLANTS *

By John T. Franks and Chester A. Obma

Sanitary Engineer and Captain, R. & U. Division, 7th Service Command, Omaha, Nebr.

On account of the physiography of this, the Seventh Service Command, most of the stations, unless the sewage is disposed of through adjoining or surrounding municipalities, have complete sewage treatment; however we do have a few posts which discharge their sewage directly into receiving streams without treatment. With one exception, no trouble is being experienced from this practice; nevertheless a close watch of the streams is being maintained. The settling plants have nearly all been of the Imhoff type: they are circular, square, and rectangular, all concrete, all wood, and a mixture of the two materials. Those tanks using wooden flowing-through compartments appear to be standing up very well, but the all-wood types are giving some trouble structurally. These Imhoff tanks are followed in most cases by some form of secondary treatment, for example, leaching fields; aeration lagoons; sand filters—trench type, rapid, slow and underground; and rock filters.

Where this secondary treatment is a rock filter, the effluent is uniformly good. Other forms are giving trouble, for a number of reasons, among them the location of leaching fields in impervious soil and so-called aeration lagoons, and even the Imhoff tanks themselves, too near populous points. Inasmuch as it was never the intention of the Office of the Chief of Engineers to include complete laboratory facilities with the Imhoff tank plants, only the simplest tests are being run, and as a result no laboratory data are available. Suffice to say that these plants are doing as good a job as would be expected. We have two major objections to Imhoff tanks: poor digestion and the fact that they are too easily neglected.

The following table gives the anticipated sewage flows from the various classes of stations:

Type of Unit	Gallons per Capita per Day		
	Permanent Posts	Mobilization Type	T. of O. Type
Airfields, Camps, Cantonments and Troop Facilities	100	70	50
Hospital Units	100	100	85
Plants, Post and Storage Projects (Civilian War Workers)	30 per 8 hour shift 100 for resident personnel		

* Presented at the Annual Meeting of the Rocky Mountain Sewage Works Association, Denver, Colorado, Sept. 15, 1943.

At the outset the foregoing figures seemed too conservative, but a water conservation program has brought the present actual flows into very close agreement, for the most part.

Sewage Characteristics

	Design Basis
Suspended Solids	0.27 lb. per capita per day
B.O.D. (5 day)	0.20 lb. per capita per day
Ether-Soluble Matter	0.09 lb. per capita per day

Actual results would seem to indicate that the suspended solids are somewhat lower than expected and are running nearer to .18 lb. per capita per day. The B.O.D.s are in very close agreement. The actual amount of ether-soluble matter is not known on account of lack of equipment and the difficulties involved in making this determination. But we believe that the figure given above is not in serious error in most cases. Grease has been a major problem at our plants. The installation of grease interceptors, mess scoring systems, salvage drives, and general policing has helped greatly, but there is still room for improvement, and grease still remains a major operating problem at most of the plants. One of the outstanding features of Army sewage is its uniformity from station to station. With the exception of laundry wastes it is almost straight domestic sewage; nevertheless, it is substantially different from ordinary municipal sewage in that it is stronger both on a per capita and parts per million bases. It is high in colloids and pseudo-colloids, and relatively high in dissolved B.O.D. This accounts to a great extent for changing the basis of design from a 40 per cent anticipated primary B.O.D. removal to 35 per cent, which is approximately what the plants in this Service Command are averaging, after allowing for recirculation through the primary tank where practiced.

There are only five primary plants in this Service Command; and of these, two serve different portions of the same station. Of the remaining plants one has not been in service very long, but is located at a point where secondary treatment of some sort was indicated and a nuisance is already resulting. Another plant which was followed by an absorption field located in a soil heavy in bentonite or some similar substance is now served by a three-mile outfall sewer from tank to nearest flowing stream. Finally, at one station we have the equivalent of double sedimentation with an intermediate chamber for the addition of ferric chloride. No laboratory data are as yet available but it has been found necessary to build an outfall sewer 7,500 ft. to a flowing stream in order to prevent the formation of sludge beds in the ditch near the station.

At this point it may be well to mention the capacity factor which was intended to be applied to the plant as a whole and was introduced into the design basis to provide for the following:

(1) Reasonable increase in population.
(2) Variations in sewage flows and uncertainties as to actual sewage quantities for projects of the same type.
(3) Unusual peak flows the magnitude of which cannot be accurately estimated in advance.

This factor varies from 1 for large stations 50,000 or over to 2 for stations of less than 10,000. This factor was well considered, and in most cases has been applied, but in a majority of these the succeeding paragraph in the Engineering Manual was either overlooked or ignored. We quote: "ARRANGEMENT OF UNITS: Plants serving populations greater than 5,000 should be flexible enough to permit operation and treatment with any individual plant unit out of service. This can be accomplished by providing the required capacity for primary settling, filters, final settling and other plant elements in at least two units each and arranging the piping so that any individual unit can be taken out of service. The arrangement of plant units should be such as to permit future enlargement of the plant capacity at a minimum cost and minimum interference with plant operation."

The Manual now calls for a displacement period in hours, based upon the 24-hour average rate of flow, of 2.5, with the exception of activated sludge, which is 1.5. In some of the older plants 3 hours was used. Now these displacement periods, together with the items mentioned in the preceding two paragraphs, have led to some overlong detention in the primary sedimentation tanks, especially at periods of low flows. This condition has caused no particularly difficult operating problems in the plants where sedimentation only is practiced, but has been the cause of some difficulties where secondary treatment is used.

Activated Sludge

We have only one relatively small activated sludge plant in this Command and it is of the mechanical aerator type. Laboratory facilities are rather sketchy and analytical data are meager. It has been underloaded until recently, when it was heavily overloaded overnight. This shock was too much for the half-starved sludge and as a result the effluent changed from drinking water appearance to something less desirable. The plant is making a recovery but it is apparent that it will have to be expanded if the overload continues. This type plant, when loaded to near design, does not stand the daily peak flow very well, and requires considerable well-planned operation.

High Rate Filters

There are only five high rate filter plants in this Service Command and for various reasons they cannot be considered really typical installations. While conceding that considerable differences of opinion exist as to what constitutes a high rate filter, for purpose of discussion, we shall differentiate between the shallow, high instantaneous rate filter and the so-called high capacity, low rate filter. Of the former type we have two, and they are turning out a high grade effluent (15 p.p.m. 5-day B.O.D.); but neither is loaded to over 60 per cent of the designed capacities, the actual load being 1.3 lb. B.O.D. per cubic yard of media, on a settled sewage basis. What they would do if loaded, we do not know. The first plant of this type constructed in this Command never had a chance. It was overloaded from the beginning and has since been supplemented with a standard rate filter, the original filters acting as roughers. So this installation is not considered a high rate filter plant. It is, however, doing a good job, operating with a substantial overload, and reducing the B.O.D. about 90 per cent.

We are in somewhat the same predicament with the latter type that we were with the former. At one of these plants it was intended that all of the sewage be pumped to the filters from the primary sedimentation tank, but due to a slip-up in pump design or installation it is impossible to pump all the sewage or to maintain the recommended dosing rate; and as the plant is rapidly approaching, if not exceeding, the design basis the results are not so good as was originally expected. The effluent averages 80 p.p.m. B.O.D. At another, while considerable laboratory data are available, on account of a number of plant breakdowns and finally an enlargement program, it is not of such a nature as to make it satisfactory for the basis of a statement regarding this type of filter. The plant at the present time is underloaded and is turning out a nice effluent with an average B.O.D. of 45 p.p.m. At the remaining plant the flow is not large enough, even with constant recirculation, to maintain the recommended dosing rate. No laboratory results are available from this plant at this time. The effluent is only fair, but on account of the nature of the country onto which it is discharged, it is deemed satisfactory. From the foregoing it should be readily understandable why we do not feel justified in making other than a broad, general statement of findings: better results are obtained with a high rate filter when recirculation is practiced. They remove more and more B.O.D. as the loading and treatment rate are increased but the percentage of removal decreases. For this reason we feel that they can be used advantageously as roughing filters. Finally, when they are used for secondary treatment the effluent is generally not of as good quality as that from a standard rate filter.

Hays Process

Any real evaluation of the Hays Process is hard to make and for that reason we are only setting forth the facts as we see them. There are six plants of this type in this Service Command. Five were designed for approximately the same population—that is, 6,000, the other for 35,000. They have all given us considerable trouble both from an operating and reduction standpoint. The troubles are common to all the plants. They are, for the most part, mechanical failures, stoppage of holes in the air grids, collapse of the transite plates, heavy anaerobic sewage growths between the plates, and odor. While two of the plants are discharging a very clear effluent, the loading is only about 60 per cent of design, and the peculiar odor that seems inherent to the process is still very much in evidence.

We have tried a great many things to overcome these troubles, but so far we have nothing definite to report. Some improvement has been noted where recirculation was tried. Various means of eliminating hole stoppage have been tried with no continued success. It is our belief that long detention periods in the primary sedimentation tanks, together with the supernatant from unheated digesters are responsible for part of the troubles. So far scrupulous cleanliness around the plant has seemed to do the most good. On account of necessary plant enlargement at two of these plants, high rate filters have been or are being added as roughing filters to take care of the additional load. One of these filters was put into operation about three weeks ago. The results have been very satisfactory, but the station population is below normal and it is too early to make any predictions. We regret that we cannot make a more satisfactory report on this interesting process. We can say that we believe that some progress is being made and a more comprehensive report will be forthcoming.

Standard Rate Filters

We have had very little trouble with standard rate filters. In fact, on the whole, we feel that for all-round performance, insofar as Army sewage is concerned, this type of filter is very hard to beat. They plug along day after day under wide variations of loading and dosing with a minimum of operating requirements. Our biggest difficulty has been in maintaining a proper dosing rate, but we are overcoming this, together with the problem of oversize sedimentation tanks, by recirculation. In every case where we have started recirculating the overall performance of the plants has increased. The dosing rate varies from ½ million to 4 million gallons per acre per day, the B.O.D. loading varies from 300 lb. to 800 lb. 5-day B.O.D. per acre foot per day and the overall plant reduction averages better than 90 per cent. We also recognize the limitations and operating problems of the standard rate filter. To mention a few—in large installations they become unwieldy; they are not always adaptable to the terrain, the cost of rock may become excessive; they freeze up easily; and unless they are closely attended, are the source of filter fly trouble.

Digesters

The subject of digesters has been left for the last because regardless of the remainder of the plant the digesters are pretty much the same. We feel that they are the heart of the plant, but that too many designers are more interested in other details. The Engineering Manual sets forth the following capacities in cubic feet per capita:

	Heated	Unheated
Plain Sedimentation	2.0	3.0
Activated Sludge	4.0	6.0
All other types	3.0	4.5

We have found these capacities ample, but not excessive, especially with the unheated type. In fact, we have found that in this area because of temperature conditions, regardless of size, unheated digesters will not give satisfactory results. For example, an unheated digester located in southern Kansas and another in southern Missouri have never been above 60° F. Another one in Iowa with a capacity of approximately 6 cu. ft. per capita showed no indication of digestion until after heating coils were installed. We had originally 10 unheated digesters, but we have installed, or are in the progress of installing, heating coils in seven of these. In every instance where heat was not available either no digestion or very poor digestion occurred. In cases where digestion did occur even in a small way, the gas was very erratic; and where the gas was wasted unburned to the air, it was accompanied by foul odors. Also when it was necessary to draw sludge the attending odors were extremely obnoxious and in every case official cognizance was taken by the Commanding Officer and Post Surgeon.

We have had our problems with heated digesters; for example, some digesters which were started at the same time and under similar conditions reacted in entirely different ways, some of them going along without trouble and others being the continual source of troubles. Two that we have in mind particularly were started at the same time, following identical procedures. They were both heated to and maintained at 95° F. One has never given any trouble and has acted normal in every way. No lime was ever added. The other refused to start, the pH remained very low; finally, after the addition of 15 tons of lime in 1,000 pound batches, digestion began. The foaming was not so bad as was expected. No further trouble was experienced. Scum is the cause of considerable trouble, especially where grease is bad, and this is the case at most camps. However, where temperature of the digester is maintained at or above 90° F. this trouble is minimized. The most serious scum trouble has occurred with unheated or undersized digesters.

One outstanding difference between municipal and Army sewage is that the raw sludge from Army sewage is higher in volatile material. It varies from 75 to 90 per cent except in camps where grit is causing trouble. This is one reason why ample digester capacity is essential. We feel that all plants should have as large a digester as is compatible with cost and heating requirements. It may be well at this point to mention that we have found that the centrifugal type sludge pump is not particularly satisfactory where the sludge is pumped directly from the primary sedimentation tank to the digester. This is not the case when a sludge well is used or the sludge is being pumped to the primary for resettling.

Supernatant still is a major operating problem and some work is being done to minimize its effect. In this respect we have found that the supernatant from a two-stage digester is nearly always of much better quality than that discharged from the single-stage type, and that from an unheated digester is always a potent source of trouble. We feel that the disposal of the supernatant liquor should be made a ''must'' on the research list.

We are aware of the fact that we have wandered rather far afield from the subject of this paper; but really the operating experiences and problems at an Army plant are not much, if any, different from those at any other plant—maybe more of them but not very different; besides we are not the best ones to tell of these experiences. It is the men who actually operate the plants—the ones who skim the grease, fight the foaming digesters, and freezing filters, clean clogged pumps and keep 'em running—that should do the telling. These men must have the truly objective viewpoint; and they must be loyal and conscientious. We have been fortunate in obtaining this class of men. Most of our larger plants and those having complete treatment are adequately staffed with men familiar with sewage treatment; but those stations which have been recently constructed, especially those having Imhoff tanks, are not so well situated. The manpower shortage is, believe it or not, affecting the Army—at least the civilian personnel. This brings us back to one of our objections to Imhoff tanks; they are too easily neglected—and the fact that they do operate with a minimum of supervision makes it hard to get proper personnel assigned to them, when personnel is scarce. Still if the draft boards and army economics do not become too drastic, we will get by—somehow.

Conclusion

It is realized that this paper leaves much to be desired and that there are some glaring omissions. This is due to several factors: probably the greatest is our own deficiency. Aside from this there are several legitimate reasons: they are the need for military censorship; the inability to evaluate all that we have seen—this will probably come when the world is more peaceful and we have time for deliberate cogitation; and finally, the lack of reliable laboratory information—this is being minimized as time goes by. We can summarize our findings and beliefs as follows:

That Imhoff tanks, even with their inherent limitations, are indicated under certain conditions.

That plants with separate, heated digesters are much better.

That if secondary treatment is deemed desirable the standard rate filter with minor modifications is the most foolproof method and delivers a uniformly good effluent over wide variations of loading.

That the various types of high rate filters have many advantages, but require more operating and do not always deliver a high quality effluent, especially when loaded; however, we do feel that they have a definite place in sewage treatment.

That it is unfortunate that the Hayes Process was adopted to such a large extent, before some of the more outstanding "bugs" had been eliminated or minimized; and that its possibilities have not been exhausted.

That in this Service Command we have some of the equipment manufactured or produced by every company or individual furnishing sewage works equipment in the United States; and that in every case where the equipment is doing the job for which it was intended, is not seriously overloaded, and is given ordinarily good care, good to excellent performance is being obtained.

That the simplification of sewage plants in the interest of conservation of critical materials can be accomplished up to a certain point, but beyond that point it is not desirable either from a standpoint of economy or results.

That the sewage treatment plants in this Service Command, with certain exceptions, are as well designed, constructed, and operated, as equal municipal installations; and the sewage disposal situation is good after due consideration has been given to the honest mistakes which were made in design and construction, the speed with which the plants were constructed, the lack of what would normally be considered minimum essentials, the scarcity of well-trained personnel, and the comparative shortness of time since the inception of the present program.

And finally, that when the time is available for a study of all the data on Army sewage treatment that is being accumulated, the findings of such a study will be of incalculable value to the post-war builders and operators.

NOTES ON AN ACCIDENT AT A SMALL SEWAGE TREATMENT PLANT RESULTING IN THE DEATHS OF THREE WORKERS

By Allen D. Brandt

Sanitary Engineer, U. S. Public Health Service, Chicago, Ill.

On August 14, 1943, a sewage treatment plant operator was overcome by an oxygen deficiency in the air of the plant house while cleaning a check valve on the discharge side of the pump employed to pump the sewage sludge from the settling tank to the digestion chamber. Two other workers were overcome and died while attempting rescue operations. This accident should never have happened, but it did and, therefore, the necessary precautions and safeguards should be observed at other plants to prevent the recurrence of similar accidents.

Description of Plant

The sewage treatment plant at which this accident occurred was not unusual. It was designed to provide primary treatment of the sanitary sewage from an industrial population of 4,500. The bases of design were: a maximum population of 2,250 on any one shift; an average flow of 120 g.p.m. and maximum of 500 g.p.m.; a settling period of 3 hours for average flow and 1 hour for maximum flow; a digestion capacity of 3 cu. ft. per capita (2,250 population); and a sludge bed area of 2 sq. ft. per capita. A plain settling tank with two sludge hoppers was used in preference to a tank equipped with mechanism for the sake of simplicity in construction and operation, and to conform with the policy of minimum use of critical material.

The flow diagram for the sewage treatment plant is shown in Fig. 1 which is self-explanatory. Ball-type check valves are located on the upstream and downstream sides of the sludge pump. The plant was so operated that the operators (one per shift) were not in constant attendance but performed the required duties at the treatment plant in conjunction with other duties at other stations within the industry. The time required to pump the sludge from the settling tank to the digestion chamber was only about 5 or 10 minutes daily and this duty was assigned to the "graveyard" or 12 midnight to 8 A.M. shift. Owing to the nature of the sludge, one of the check valves would occasionally become fouled by a piece of solid material, requiring a cleaning operation, which was no great task since the valves were constructed accordingly. It was the cleaning of these valves, as described later, that caused the accident.

The sewage treatment plant house was of concrete and frame construction and was of the one-story and basement variety. The valves, pump, and other mechanical equipment were housed in the basement

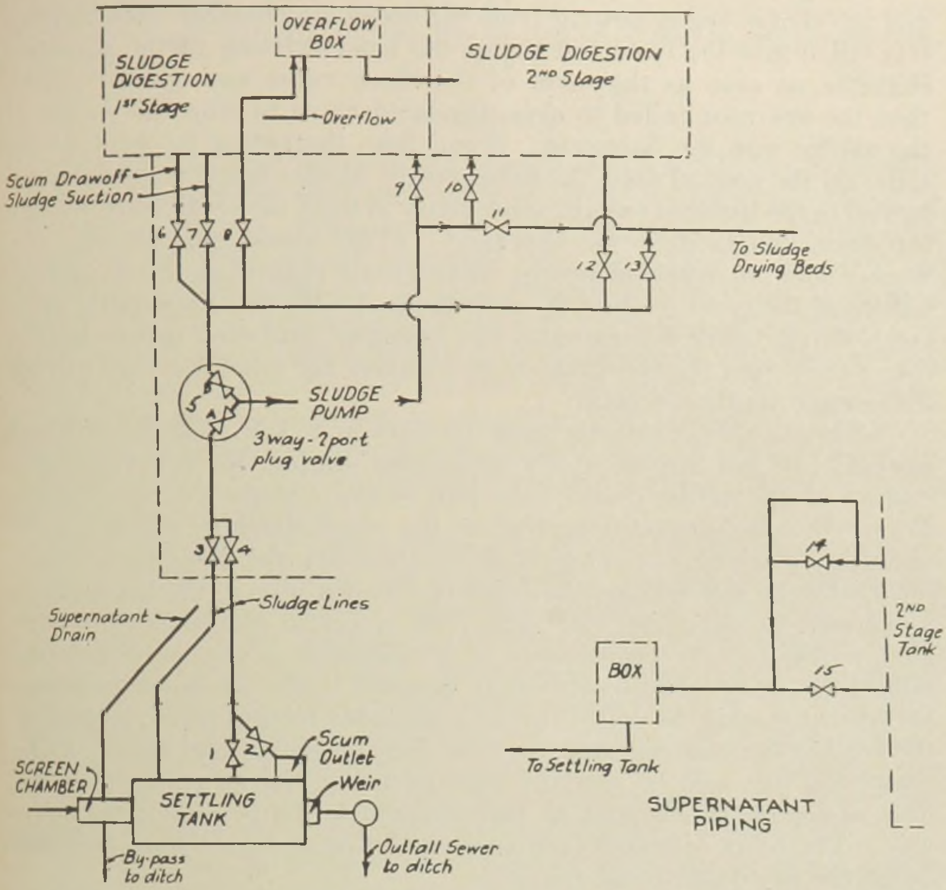


Fig. 1.

which was of solid concrete construction having only one opening, the stairway to the ground floor. The ground floor structure was of frame and had a door, four windows, and a small diameter roof stack.

Description of Accident

The notes in the operator's log book and other information available make possible the reconstruction of the events in connection with the accident. Apparently the windows of the plant house, which are normally open in warm weather, were closed some time after 12 midnight as a result of a rainstorm. During this or a subsequent trip to the plant house, and while pumping the sludge from the settling tank to the digestion chamber, one or both check valves fouled. It is believed that the operator first opened the check valve upstream of the pump (since it would be the more likely to foul) but apparently found that the trouble was in the check valve located downstream of the pump. He failed to close the hand valve between the check valve and the digestion chamber (valve No. 9, Fig. 1) before opening the check valve and the sludge began flowing from the digestion chamber back through this valve into the basement under the head existing in the digestion chamber, as soon as the cover of the check valve was opened. Even then the operator failed to close the hand valve to stop the escape of the sludge into the basement. Some time thereafter he went to the toilet on the ground floor (as indicated by sludge tracks) and later returned to the basement again, apparently to flush the sludge out through the drain and to clean the basement. (This would indicate that this worker had not received proper instructions regarding the dangerous nature of the gases evolved by such sludge.) He was apparently overcome shortly after returning to the basement and died before he was discovered since there is little or no occasion for other workers to visit the sewage treatment plant.

When the relief operator came on duty at 8 A.M. and the previous operator did not appear at his designated station, the relief operator had a transportation driver take him to the sewage treatment plant. When the relief operator arrived at the plant house he called for the operator, received no answer, and started down the steps to the basement when he saw the operator slumped over a pipe in the basement in a partially kneeling position. The relief operator suspected illness but gave no thought to the presence of a hazardous atmosphere and permitted the transportation driver to proceed to the basement to rescue the operator while he called for an ambulance from a phone located at the head of the stairway and near the door on the ground floor. As he completed this call, he saw the transportation driver slump over the body of the operator which he had dragged to the bottom of the stairway. The relief operator then suspected a hazardous atmosphere and called the fire department for help.

The ambulance arrived with two guards and two universal type canister gas masks which the guards donned, apparently in considerable confusion, and proceeded to the bottom of the stairway where they lifted the transportation driver in an effort to rescue him. One guard then let his hold slip and grasped his mask as if to remove it. The other guard then sensed difficulty in his breathing and ascended the stairs after having attempted to assist his partner who was slumping to the floor. The guard who escaped collapsed outside the building. Considerable confusion followed and several other workers were temporarily overcome before the rescue work was completed.

A careful investigation into all the circumstances attending the accident revealed that the cause of the three deaths was an oxygen deficiency in the basement atmosphere owing to the displacement of the air by the gases liberated by the sludge which, at one time, covered the entire basement floor to a depth of 16 inches. The deaths were believed by the rescue workers and the plant medical department to have been caused by hydrogen sulfide. That such was not the case is indicated by (1) the failure of canister type gas masks to provide protection, (2) lack of hydrogen sulfide odor reported by the majority of the rescue workers, (3) the small amount of hydrogen sulfide usually found in sludge digestion gases, and (4) the low concentration of hydrogen sulfide in the gas remaining in the sludge digestion chamber after the accident.

Conclusions

It is obvious that this accident should not have happened and after it had happened, two additional workers should not have lost their lives in rescue attempts. Fundamentally, it indicates inadequate education and training of the sewage treatment plant operators, of the industrial guards, and of the firemen. Yet at a somewhat similar plant in a small municipality in an adjoining state, a similar accident occurred the week following the one reported herein. In this instance, also, two workers died in an attempted rescue of the first victim, resulting in three deaths. In addition to the occasional occurrences of such accidents which present a warning for the properly instructed operators, there are those resulting from a leak of the gases into enclosed spaces without adequate warning to the operators.

Of interest and of some concern also is the fact that the oxygen deficiency hazard is usually not recognized at sewage treatment plants and the standard respiratory protective device for emergency work at such plants in many instances is the Bureau of Mines approved Universal type canister gas mask. Such masks protect the wearer against all known toxic gases in concentrations in the order of 2 or 3 per cent by volume, but provide no protection against an oxygen deficient atmosphere. When the oxygen concentration in the atmosphere at or near sea level is reduced to about 10 to 13 per cent, it is no longer adequate to sustain life and is rapidly fatal at lower concentrations.

To prevent the occurrence of similar accidents at other sewage treatment plants, the following precautions and safeguards should be instituted:

1. Emphasize the education and training of the plant operators in the proper performance of their duties and in the nature of the gases which may escape into the rooms of treatment plant buildings. Also, the guards or police, and firemen should be informed of the nature of the gases present in accidents at sewage treatment plants and the proper respiratory protective devices for such conditions.

2. Provide the proper types of respiratory protective devices only—namely, oxygen breathing apparatus or hose masks. These devices separate the wearer from his atmosphere as regards respiration and assure an adequate supply of oxygen. This may present some difficulty where the plant contains a chlorination room, since the proper type canister gas mask affords adequate protection against chlorine and is the usual device found in such rooms. In the confusion following an accident of this nature, little attention is usually paid to the limitations of a gas mask, and it is highly probable that the gas mask in or near the chlorination room would be appropriated by some uninstructed rescue worker with serious results. This can probably be prevented by means

of an appropriate warning sign at the chlorine mask and by proper instruction of the various workers in the hazards involved, as indicated in 1 above.

3. Both foregoing suggestions assume that there is some warning of the presence of gas to the operator or would-be rescuers. Such will not always be the case, as indicated previously, since leakage of the sludge gas may take place directly into the building without adequate warning. Such conditions may be determined by the use of combustible gas indicators, explosive meters, or safety lamps. However, the only way to guard against them satisfactorily is (*a*) to provide a positive and well distributed supply of air to such buildings so that the possibility of an oxygen deficiency occurring is very remote, or (*b*) to provide an oxygen recorder which rings an alarm when the oxygen is reduced to a predetermined unsafe value (such instruments are not yet available commercially, but will be shortly after the close of the war).

THE SIGNIFICANCE OF THE FINDING OF THE VIRUS OF INFANTILE PARALYSIS IN SEWAGE. A REVIEW *

By Kenneth F. Maxcy and Howard A. Howe

Poliomyelitis Research Center, Department of Epidemiology, Johns Hopkins University

It has now been demonstrated by a large number of investigators that the virus of infantile paralysis may be excreted in the feces of an infected individual. It has been repeatedly found in the second and third week of convalescence from a paralytic attack of the disease. In one instance it was isolated from the stool of a child who had been ill 123 days prior to the time when the test was made. Many studies (1, 2, 3, 4) have demonstrated that the virus may be present in the stools of persons suffering from non-paralytic, or abortive attacks, or subclinical infections. These greatly outnumber the paralytic and frank cases, and are generally undiagnosed. They are the equivalent of transient healthy carriers.

The volume or quantity of poliomyelitis virus which is discharged into the domestic sewage of a community is determined by the number of recognized cases and unrecognized carriers at any point in time. For present purposes, the incidence of paralytic cases may be regarded as a rough index of the amount of virus pollution. This incidence varies seasonally and periodically. The smaller communities may go for months or years without having a paralytic case. In the larger cities there may be one almost every month in the year with a tendency to increase during the summer and fall. Every few years the frequency builds up to a level regarded as epidemic. The pollution of domestic sewage with the virus of poliomyelitis in a community varies accordingly.

Paul and Trask (5) have reviewed the actual circumstances under which the virus of poliomyelitis has been recovered from sewage. In four instances it was from samples collected in close proximity to hospitals in which patients with infantile paralysis were being treated. When eleven samples of urban sewage were collected at random after epidemics in four large cities, a series of 22 tests were negative. When samples were collected routinely over a long period of time at intervals of about one week in New Haven and in New York, 85 were negative and from two, the virus of poliomyelitis was recovered.

The two positive samples came from the Manhattan Grit Chamber

* Presented at the Second Wartime Conference of the Federation of Sewage Works Associations, Chicago, Ill., Oct. 21, 1943.

Aided by a grant from The National Foundation for Infantile Paralysis.

located in the heart of New York City—one in September, 1940 and the other in October, 1941—at a time of year when the incidence of the disease is maximum. In neither year, however, was it regarded as epidemic. Thus it has been demonstrated that in domestic sewage the virus may remain stable, at least for a short time, and long enough to be transported for a distance of at least 1/8 mile.

In evaluating these results it must be borne in mind that methods available for the detection of poliomyelitis virus in sewage are relatively crude. Trask and Paul (6), for example, collected 4 liters, sedimented 3 to 6 hours in a refrigerator, and syphoned off 700 cc. from the middle layer. This was treated with 105 cc. of ether, corked, and refrigerated overnight. 200 to 400 cc. were concentrated to a volume of 30 to 50 cc. with $(NH_4)_2SO_4$ by Gard's method, and on the next day the concentrate was inoculated intra-abdominally into a rhesus monkey. The criteria for the identification of the virus of poliomyelitis consisted in (*a*) the reproduction of infectious myelitis in the monkey with (*b*) characteristic histological lesions in upper and lower levels of the spinal cord and (*c*) passage to another monkey. It is entirely possible that quantities of the virus in sewage sufficient to infect man when introduced into his body by the natural portal of entry are not detected by this procedure.

Laboratory observations made on the virus *in vitro* indicate a surprising degree of stability. Tests have been made of its survival in glycerinated monkey spinal cord suspensions under a variety of conditions. It may be kept for months or years with little loss of potency in the refrigerator at temperatures at or below 0° C. When heated to 45 or 50° C. for 30 minutes, or exposed to ultraviolet light for a few seconds, it is inactivated. Schultz and Robinson (7) have recently reviewed the resistance of such virus suspensions to a large number of chemical agents. They are remarkably tolerant to a varied array of compounds, and wide differences in hydrogen ion concentration. The virus may not be inactivated when exposed to 1.0 per cent phenol for several weeks, is unaffected by acetone or ether extraction, can be treated with normal acetic acid and precipitated by 50 per cent saturation with ammonium sulphate, or by solutions of tannic acid, or by aluminum hydroxide, without much loss of infectivity.

In view of this relative stability of the virus *in vitro,* it has been inferred that its survival in sewage polluted water might be much greater than is indicated by the crude methods available for its isolation and identification. It is notable, however, that early in their work Paul, Trask and Gard (8) pointed out that the duration of the interval between the collection of a specimen of sewage and its inoculation into monkeys was important, for the infectivity of poliomyelitis virus diminishes in a few hours on standing in sewage at ordinary temperatures. Even when the sewage sample was kept in the refrigerator it was difficult or impossible to demonstrate the presence of virus after 72 hours, although Kramer (9) and others have found *fecal* specimens active after six months at temperatures of 3–5° C. Sewage at ordinary temperatures is a tremendously active and rapidly changing biological universe since it contains a wide variety of animal and plant life. It is therefore to be expected that there is a complex system of metabolic exchange, advantageous to some forms and disadvantageous to others. Since poliomyelitis virus is a highly specialized intracellular parasite there is no reason to expect its multiplication in this milieu. On the other hand (10), it is well within the realm of possibility that there may be formed antagonistic or antibiotic substances, of the same class as penicillin, tyrothricin, and gramicidin, which would have a detrimental effect upon the infectivity of any surviving virus or actually destroy it.

Under natural conditions the virus must not only survive in sewage but in sewage polluted water during the hours and days when it is undergoing dilution and natural purification to reach a stage at which it is potable for drinking, or suitable for the intake of a water purification plant. The question has been raised as to whether the purification procedures ordinarily employed would remove the virus if it were present in the raw water supply. Carlson, Ridenour and McKhann (11) have recently attempted to answer this question. To samples of city water and raw untreated water were added relatively large quantities of virus emulsions. These were made from the brain and spinal cord of mice paralyzed after an intracerebral injection of an infective dose of the Lansing strain. The water samples thus heavily contaminated were treated by methods improvised in the laboratory to imitate standard purification processes. The treated water was then tested for the presence of the virus by the inoculation of mice. From these laboratory observations the authors concluded that the methods commonly employed in water purification plants, namely, coagulation and sedimentation, sand filtration, absorption on activated charcoal, aeration, adjustment of pH and storage at refrigerator temperatures for 100 days, *failed when tested individually* to remove completely poliomyelitis virus from artificially heavily contaminated water.

Obviously such experiments, no matter how carefully they are performed in the laboratory, do not answer the question propounded. These conclusions apply only to the improvised methods of water treatment experimentally set up in the laboratory, and not to methods actually employed in the purification of a large volume of water in a municipal plant.

These same authors make the statement that chlorination by present day methods is of little value in the destruction of the virus, referring to the work of Levaditi, Kling and Lepine (12), and to that of Kempf and Soule (13), and of Kempf, Pierce and Soule (14). The first named authors reported their work in 1931. In one experiment they made an emulsion of infected monkey cord in tap water. It contained so much nervous tissue in suspension that even after decantation and filtration through cotton the liquid was visibly turbid. To this was added a dose of 4 mgm. of chlorine per liter (4 p.p.m.). After agitation it was permitted to stand 24 hours at laboratory temperature in a dark place. A rhesus monkey inoculated intracerebrally with 1 cc. of the chlorinated emulsion survived and presented no evidence of being infected. In a second experiment the tap water containing monkey cord emulsion was sufficiently clarified by filtration and centrifugation to obtain a clear fluid, still, however, with a very high organic content. Chlorine was added in a dosage of 0.4 mgm. per liter (0.4 p.p.m.). After 18 hours contact in a dark place, 1 cc. was inoculated intracerebrally into a rhesus monkey which survived without presenting evidence of infection. The authors concluded that under normal conditions, the ordinary dosage of chlorine assures protection of water for drinking purposes.

Kempf and Soule reinvestigated this problem. The suspensions to be tested were prepared by making a 10 per cent emulsion of infected spinal cord in saline with subsequent centrifugation at 4,500 r.p.m. Two cc. of the supernatant containing a "minimum amount of organic matter" were added to 100 cc. of chlorinated water, at a temperature of 21–23° C., and a pH between 8.3 and 8.5. The final virus dilution was estimated as 1:1,650. Chlorine in a concentration of 0.55 p.p.m. did not inactivate the virus of poliomyelitis in 1.5 hours under those conditions, but was effective after a 4-hour period of contact with a residual chlorine of 0.35. Kempf, Pierce and Soule later carried out similar studies with calcium and sodium hypochlorites. In one test, a solution of $Ca\ (ClO)_2$ in tap water containing 1.0 p.p.m. chlorine, and acting for 25 minutes, had no apparent effect on the virus. At the end of 4 hours, by which time the chlorine had dropped to 0.2 p.p.m., the suspensions still proved infectious. Similar results were obtained with sodium hypochlorite. In a second test a solution of Na ClO in tap water containing 1.5 p.p.m. of chlorine sufficed to inactivate the virus in 20 minutes. A concentration of 0.55 p.p.m. in river water inactivated it in 1 hour, while a concentration of 0.2 p.p.m. in the same medium acting for one hour had no effect.

Paul and Trask have been carrying on experiments with the assistance of the chemical division of the Wallace and Tiernan Company of Newark, New Jersey. They have used suspensions of virus from infected spinal cord, and also suspensions of virus as it naturally occurs in the human stool from patients convalescent from human disease. The results were reported as being somewhat irregular, and the work was incomplete at the time of the death of the junior author.

On the basis of the published studies, there is no justification for the statement that present day methods of chlorination are of little value in the destruction of the virus. Before such a statement can be made at least two conditions must be fulfilled in the experimental trial. The source of the viruses must be human feces or domestic sewage, and not suspensions of nervous tissue from monkeys or mice. The addition of this virus suspension must be made in such a manner that the polluted water resulting shall have no higher organic content than is customary when chlorination is employed in water works practice. The technical difficulties of such a trial have as yet not been solved.

Nevertheless, until there is evidence to the contrary, it may be assumed that it is at least theoretically possible that the virus of poliomyelitis in domestic sewage may survive the natural purification process of polluted water and pass through a treatment process used in purification for drinking or for swimming pool purposes. Bacteriological standards of safety, using the density of *E. coli* as an index, and based upon experience with typhoid fever do not apply. A purification process which would be adequate to retain or destroy such bacteria as *E. coli* or *Eberthella typhosa* would not necessarily be equally effective in removing viruses. Thus, the fact that a community water supply was judged safe on the basis of Treasury Department Standards would not, by itself, exclude the possibility of its acting as a medium of dissemination of poliomyelitis.

Up to the present time no one has succeeded in recovering the virus of poliomyelitis directly from drinking water or bathing water suspected of being a medium of dissemination, with one possible exception. Carl Kling (15), in the State Bacteriological Institute in Sweden, has for several years tested samples of water from supplies which epidemiological observations suggested might be involved in transmission. Methods have gradually been improved. It is reported that during the period from July 1, 1938, to June 30, 1939, 27 such samples were tested by animal inoculation, and one of these was regarded as positive.

This positive sample came from a well which was suspected of being the source of infection of a 6-year-old boy living on the same property. It was obtained the day *after* discovery of this case. The well was in a dilapidated condition with walls of rubble and obviously open to human pollution. A virus recovered by animal inoculation was classified as belonging to the poliomyelitis group, although the strain had a low virulence for monkeys (cynomolgus and rhesus macaques) and the histological changes were not altogether typical. This is a suggestive result and, so far as we are aware, the only report in the literature of a poliomyelitis-like virus recovered from water which was customarily used for drinking purposes. However, failure in this respect with the methods available does not prove the absence of virus in sufficient quantities to infect, any more than does failure to demonstrate typhoid bacilli prove the innocence of suspected water supply as a source of typhoid cases.

That water is a medium of transmission of *biological importance* can be accepted only if it can be shown that the behavior of the disease in nature can be satisfactorily explained on this basis. It is not sufficient merely to show that the causative parasite leaves the body of the human host in feces and survives a short time in sewage. If this were the only requirement, tuberculosis might have been classified as waterborne. More evidence than this is needed. *It must be convincingly shown that the behavior of a disease in human communities is such as would be expected if the causative parasitic micro-organism were dependent for continued dissemination, in part, or at times, upon the medium of contaminated water.*

Specifically, what is the behavior that would justify such an inference? The question can be best answered by reviewing certain observations which have been made with regard to the prevalence of cholera and typhoid fever, diseases generally accepted to be water-borne. In general, their prevalence has been correlated with a poor sanitary environment including, but not necessarily depending directly upon, water supplies subject to human fecal pollution. In communities with a common water supply subject to such pollution, the incidence has tended to be excessive and cases were scattered throughout the population in time, in place, and in persons (except as modified by immunity), as would be expected from a wide dissemination of the infective agent through the water distribution system. In some instances it has been possible to show that the incidence of one of these diseases was significantly greater in the group of people using the suspected water supply than in another or other groups using a different supply but *alike in all pertinent respects.* A classical example is John Snow's analysis of the mode of communication of cholera in South London (16).

In other instances it has been possible to show that an abrupt decline in incidence immediately followed the installation of a water purification plant although living conditions changed in no other important respect. Or, *per contra,* increased incidence has abruptly followed some breakdown in the treatment process or distribution system of a common water supply. Numerous examples of these contingencies can be found in the typhoid history of American cities and towns.

Perhaps most convincing of all are the explosive outbreaks in which groups of people were simultaneously infected, and it was conclusively shown that the only medium of common dissemination to which all or nearly all could have been exposed was a water supply subject to human pollution. Finally, it is to be pointed out that wherever sanitation has been improved, including the improvement in water supplies, these diseases have been unable to maintain their prevalence in human populations and have tended to decrease or disappear. This is the sort of evidence upon which it has been generally accepted that they are or may be water-borne.

Turning now to the extensive literature on poliomyelitis which has accumulated since the initial observations of Wickman (17), *epidemiological evidence of this character is conspicuous by its absence.* The incidence of this disease has not been highly correlated with sanitary environment. It has never been shown that either the epidemic or the endemic incidence of poliomyelitis is significantly associated with the quality and safety of drinking water supplies as determined either by a sanitary survey, or by bacteriological analysis, or by both. Assuming that filtration and chlorination are ineffective in removing the virus, then, for example, it would be expected that the incidence would have increased over a period of years in the cities which obtain their water from the Ohio River with its speedily increasing load of sewage pollution from domestic sources. On the other hand, it would be expected that small communities supplied with water, whether treated and chlorinated or not, but from watersheds or underground supplies which careful sanitary surveys have shown were protected from human fecal pollution, would have a conspicuously favorable experience with poliomyelitis, yet sharp outbreaks have occurred in such communities. When poliomyelitis has invaded large urban communities whose population is served simultaneously by a common water supply, the cases have not been scattered in time, in place, and persons in the sudden random fashion which is expected. The disease has characteristically manifested a slow radial or progressive spread from initial foci. When poliomyelitis has occurred in rural areas, it has moved at a strikingly constant speed from place to place in a wholly unpredictable manner, but unaffected by the character of the local private water supplies. Finally, and perhaps most important of all, there is on record at present not a single instance of an explosive outbreak of this disease which has been attributed to simultaneous exposure of a group of people to a common source of water.

Nor can the absence of epidemiological evidence incriminating water as a medium of transmission be attributed to insufficient investigation. There are now in the literature a large number of studies made by competent epidemiologists on the conditions under which poliomyelitis occurs and spreads. Many of these investigators have had extensive experience in tracing water-borne epidemics of typhoid. Even if it be true that the result of mass exposure might in part be masked by the presence of large numbers of immunes and inapparent infections, nevertheless recognized paralytic cases have been sufficiently numerous to call attention to several instances in which the infection was apparently milk-borne (18–20) and one where a lemonade stand was thought to have been a center of exposure (21).

Since there seems to be no crucial evidence to justify the hypothesis that drinking water is a common and important medium for the dissemination of poliomyelitis virus, other possible modes of transmission must be given careful consideration. The recent demonstration of virus in the bodies of flies trapped in epidemic areas brings up, from another angle, the potential importance of sewage and fecal material as a reservoir of virus (22–26). Carlson, Ridenour and McKhann (27) have investigated the effect of activated sludge upon aliquots of infective spinal cord emulsion seeded into it. They found that the infectivity of the mouse-adapted Lansing strain of poliomyelitis virus was greatly diminished when it was aerated for 6 hours in a concentration of .3 per cent with 1,100 p.p.m. of sludge. Here again this type of experiment can be considered only as a rough approximation of the conditions which would exist in an actual sewage disposal plant. The implication of their finding, however, is in conformity with the previously observed lability of poliomyelitis virus in sewage. This summer Melnick (28) has been able to demonstrate virus in the effluent from the West Side sewage disposal plant in Chicago. At this plant, however, the raw sewage from the mains is allowed to settle in open basins (Imhoff tanks) for only about 3 hours before the effluent is discharged into a nearby canal. A sample of this effluent, which had received virtually no treatment, was found to contain virus.

In most instances the flies from which virus has been isolated were trapped in areas where sanitation was very primitive and there was ready access to exposed feces, but in one case (22) they came from a good residential district where no privies were found. This, however, cannot be interpreted as evidence that sewage was the source of the virus. In modern sewage disposal plants there would be little opportunity for flies to gain access to raw sludge although a rapidly discharged, untreated supernatant should be given consideration from this point of view. Since the methods of treating sewage are not uniform even within a given community the most probable source of fly pollution would have to be determined locally in each instance. It would be of importance, however, to extend the virus studies which have been made on raw sewage to include treated sewage as it leaves various types of disposal plants.

Studies on the exposure of various species of flies to spinal cord emulsions infected with mouse encephalomyelitis and the Lansing strain of poliomyelitis (29), leave no doubt that virus in this form is incapable of multiplication in the fly. It is notable, however, that poliomyelitis virus has not been isolated from the bodies of flies more than 48 hours after the exposure of the insects (29, 30, 31), thus suggesting that the fly is a short term vector. In contrast to this, the closely related virus of mouse encephalomeylitis was demonstrable for 12 days. In these experiments house flies were found to be more efficient carriers of both viruses than filth flies, although the latter have been implicated in field tests. It is important to stress again the fact that survival experiments of virus on flies have not been conducted with stool virus and that its ability to resist drying in this form is completely unknown.

Quite apart from the known fact that virus can be obtained from house and filth flies is the question of its epidemiological importance. While the summer incidence of poliomyelitis suggests an analogy with dysentery, it must be remembered that even in this latter disease the fly has not been proven to be the principal vector, and that other forms of fecal contamination are an important factor in its high familial incidence.

There are fifty times as many recognized cases of poliomyelitis among young children as among young adults. Furthermore, a large percentage of the cases occurs in children under 5 years of age. This fact, plus the frequent occurrence of multiple cases in families, indicates that the virus is ubiquitous and present in many households where it is apparently spread from one person to another by some form of rather intimate contact. Nevertheless, poliomyelitis is not closely correlated with poor living conditions as is dysentery. While this does not rule out hand to mouth fecal contamination it renders gross fecal dissemination less reasonable as the principal mode of transmission. Many years ago Frost (32) discussed the question of fly transmission, although in those days biting flies were thought to be a possible vector. He called attention to the fact that diseases transmitted by insects were not primarily children's diseases when they occurred in a non-immune population. It must also be recognized that flies are not invariably associated with outbreaks of poliomyelitis. These considerations lead one to the conclusion that there may be still another possible means of disseminating virus. Such a one exists in reality—for the secretions and walls of the pharynx have been shown to contain virus in both poliomyelitis cases and in healthy persons (33–36). At present it is not possible to state the significance of this fact because it is not known which is relatively the more common source of virus, the stools or the pharyngeal secretions. Recent work has emphasized the former and more modern methods of virus assay have not been applied to the latter. Present knowledge, therefore, does not resolve the question as to whether poliomyelitis is spread by fecal contamination of objects, hands and food, or by transmission of the secretions of the pharynx, or by both.

Summary

Poliomyelitis virus has been repeatedly demonstrated in the stools of patients and healthy carriers. It has also been found on several occasions in urban sewage during the period of maximal incidence of the disease, but is thought to be quite unstable in this medium so that its survival is possibly only a matter of hours.

Various experiments designed to show the efficacy of chlorination in destroying poliomyelitis virus in water are inconclusive because they have neither employed virus in the form of sewage (which would be the natural contaminant) nor followed the complete procedure used in the average water purification plant.

From the epidemiological point of view poliomyelitis does not behave like a water-borne disease. It has never been correlated with poor drinking water supplies nor have explosive outbreaks of widely scattered cases appeared in cities with municipal water systems (as would be expected if virus were disseminated in the water mains). Furthermore, cities with water sources located in remote spots far from human habitation suffer from poliomyelitis as frequently as those which obtain their water from sewage polluted streams. In reality the disease usually spreads progressively from initial foci at a strikingly constant speed, quite without reference to water distribution systems.

While poliomyelitis virus has been demonstrated in flies trapped in epidemic areas their role in the dissemination of the disease is as yet unknown. Flies are not invariably associated with poliomyelitis, nor would the disease attack children preponderantly, as is the case, were it transmitted primarily by the fly or any other insect.

Not only is virus present in the stools of patients and certain healthy individuals, but it is also found in the walls and secretions of the pharynx. There thus exists the possibility that it may be passed from one person to another by means of droplets of pharyngeal mucous as well as by fecal contamination of food, drink, objects or hands. Present knowledge does not resolve the problem of the relative importance of these two routes.

Bibliography

1. J. D. Trask, A. J. Vignec, and J. R. Paul, "Poliomyelitis in Human Stools." *J. A. M. A.*, 111, 6 (1938).
2. P. Lepine, P. Sedallian, and V. Sautter, "Sur la presence du virus poliomyelitique dans les matieres fecales et longue duree d'elimination chez un porteur sain." *Bull. Acad. de Med. Paris*, 122, 141 (1939).
3. S. D. Kramer, A. G. Gilliam, and J. G. Molner, "Recovery of the Virus of Poliomyelitis from the Stools of Healthy Contacts in an Institutional Outbreak." *Pub. Health Rep.*, 54, 1914 (1939).
4. A. D. Langmuir, "Carriers and Abortive Cases in a Rural Poliomyelitis Outbreak." *Am. J. Pub. Health*, 32, 275 (1942).
5. J. R. Paul, and J. D. Trask, "Occurrence and Recovery of the Virus of Infantile Paralysis from Sewage." *Am. J. Pub. Health*, 32, 235 (1942).
6. J. D. Trask, and J. R. Paul, "Periodic Examination of Sewage for the Virus of Poliomyelitis." *J. Exp. Med.* 75, 1 (1942).
7. E. W. Schultz, and F. Robinson, "The *In Vitro* Resistance of Poliomyelitis Virus to Chemical Agents." *J. Inf. Dis.*, 70, 193 (1942).
8. J. R. Paul, J. D. Trask, and S. Gard, "Poliomyelitis Virus in Urban Sewage." *J. Exp. Med.*, 71, 765 (1940).
9. S. D. Kramer, "Virus of Poliomyelitis. Survival for Over Six Months in the Feces of a Contact." *J. Mich. State Med. Soc.*, 39, 766 (1940).
10. S. A. Waksman, "Antagonistic Relations of Microorganisms." *Bact. Rev.*, 5, 231 (1941).
11. H. J. Carlson, G. M. Ridenour, and C. F. McKhann, "Efficacy of Standard Purification Methods in Removing Poliomyelitis Virus from Water." *Am. J. Pub. Health* 32, 1256 (1942).
12. C. Levaditi, C. Kling, and P. Lepine, "Nouvelles recherches experimentales sur la transmission de la poliomyelite par la voie digestive. Action du chlore sur le virus poliomyelitique." *Bull. Acad. de Med. Paris*, 3rd series 105, 190 (1931).
13. J. E. Kempf, and M. H. Soule, "Effect of the Chlorination of City Water on Virus of Poliomyelitis." *Proc. Soc. Exper. Biol. & Med.*, 44, 431 (1940).
14. J. E. Kempf, M. E. Pierce, and M. H. Soule, "The Effect of Hypochlorites on the Virus of Poliomyelitis." *J. Bact.*, 41, 51 (1941).
15. C. Kling, "In Search of Poliomyelitis Virus in Drinking Water." Internat. Bull. Vol. A–40, Infantile Paralysis. Published in the U. S. by The National Foundation for Infantile Paralysis, Inc., New York, 1939–40.
16. J. Snow, "On Cholera." (Reprinted.) The Commonwealth Fund, New York, 1936.
17. I. Wickman, "Acute Poliomyelitis." Nervous and Mental Disease Monograph Series 16, New York, 1913.
18. W. L. Aycock, "A Milk-Borne Epidemic of Poliomyelitis." *Am. J. Hygiene*, 7, 791 (1927).
19. J. C. Dingman, "Report of a Possibly Milk-Borne Epidemic of Infantile Paralysis." *New York State J. Med.*, 16, 589 (1916).
20. A. C. Knap, E. S. Godfrey, and W. L. Aycock, "An Outbreak of Poliomyelitis Apparently Milk-Borne." *J. A. M. A.*, 87, 635 (1926).
21. E. A. Piszczek, H. J. Shaughnessy, J. Zichis, and S. O. Levinson, "Acute Anterior Poliomyelitis: Study of an Outbreak in West Suburban Cook County, Ill., Preliminary Report." *J. A. M. A.*, 117, 1962 (1941).
22. A. B. Sabin, and R. Ward, "Flies as Carriers of Poliomyelitis Virus in Urban Epidemics, 1941." *Science*, 94, 590 (1941).
23. J. R. Paul, J. D. Trask, M. B. Bishop, J. L. Melnick, and A. E. Casey, "The Detection of Poliomyelitis Virus in Flies." *Science*, 94, 395 (1941).
24. J. D. Trask, J. R. Paul, and J. L. Melnick, "The Detection of Poliomyelitis Virus in Flies Collected During Epidemics of Poliomyelitis. I. Methods, Results, and Types of Flies Involved." *J. Exper. Med.*, 77, 531 (1943).
25. J. D. Trask, and J. R. Paul, "The Detection of Poliomyelitis Virus in Flies Collected During Epidemics of Poliomyelitis. II. Clinical Circumstances Under Which Flies Were Collected." *J. Exper. Med.* 77, 545 (1943).

26. J. A. Toomey, W. S. Takacs, and L. A. Tischer, "Poliomyelitis Virus from Flies." *Proc. Soc. Exp. Biol. and Med.*, 48, 637 (1941).
27. H. J. Carlson, G. M. Ridenour, and C. F. McKhann, "Effect of the Activated Sludge Process of Sewage Treatment on Poliomyelitis Virus." *Am. J. Pub. Health*, 33, 1083 (1943).
28. J. L. Melnick, Personal communication.
29. F. B. Bang, and R. W. Glaser, "The Persistence of Poliomyelitis Virus in Flies." *Am. J. Hygiene*, 37, 320 (1943).
30. S. Flexner, and P. F. Clark, "Contamination of the Fly with Poliomyelitis Virus." *J. A. M. A.*, 56, 1717 (1911).
31. C. W. Howard, and P. F. Clark, "Experiments on Insect Transmission of the Virus of Poliomyelitis." *J. Exper. Med.*, 16, 850 (1912).
32. W. H. Frost, "Poliomyelitis in Iowa." Commonwealth Fund, 1941, Collected Papers, p. 256.
33. A. J. Vignec, J. R. Paul, and J. D. Trask, "Recovery of the Virus of Poliomyelitis from Extra-Neural Sources in Man, with a Survey of the Literature." *Yale J. Biol. and Med.*, 11, 15 (1938–39).
34. S. D. Kramer, B. Hoskwith, and L. H. Grossman, "Detection of the Virus of Poliomyelitis in the Nose and Throat and Gastro-Intestinal Tract of Human Beings and Monkeys." *J. Exp. Med.*, 69, 49 (1939).
35. A. B. Sabin, and R. Ward, "The Natural History of Human Poliomyelitis. I. Distribution of Virus in Nervous and Non-Nervous Tissues." *J. Exp. Med.*, 73, 771 (1941).
36. W. L. Aycock, and J. F. Kessel, "The Infectious Period of Poliomyelitis and Virus Detection." *Am. J. Med. Sciences*, 205, 454 (1943).

Discussion

By G. M. Ridenour and H. E. Miller

Department of Public Health Engineering, School of Public Health, University of Michigan

The interesting and comprehensive paper just presented before this association by Drs. Maxcy and Howe on the significance of finding virus in sewage is extremely illuminating in several respects. It constitutes an excellent review of the available knowledge and evidence that exists on the possibility of transmission of polio through sewage and water, and represents the studied opinion of the epidemiological significance of the information now available from laboratory research work and field study of polio occurrences. While the contents of the paper would seem to allay undue fears that polio may be water borne, the presence of the virus in sewage and the absence of data to prove the impossibility of such a mode of transmission indicate the water carriage route cannot be entirely disregarded at this time.

Since the sewage and water professions are noted for their zealous attitude in maintaining the highest quality of product from the plant, in the interest of safeguarding the health and welfare of the community, it is not only fitting that the paper just given should appear on this program, but the fact that the authors have been invited to present it is in itself a high tribute to the alertness of the sewage works profession. It clearly indicates that any form of disease that may even remotely be transmitted by water is not to be overlooked and the profession is "on the trigger," so to speak, to provide ways and means of eliminating any such hazards.

In view of the nature and theme of the manuscript, the writers feel that it does not call for any technical discussion of the topics or contents. It is evident that too little is yet known about techniques of isolation and transmission of the virus to warrant anything further than the expression of opinions. Any disagreement with the contents or interpretations of the data presented therein, which the writers feel is justified in certain parts, would likewise be in the nature of opinions.

It would seem though that one part of Drs. Maxcy and Howe's paper should have a little clarification in justice both to themselves and other research workers—that is with respect to laboratory investigations designed to indicate the efficiency of water purification and sewage treatment processes. It would be highly presumptuous on the part of any research worker with laboratory scale apparatus to offer final conclusions for the field based upon such work. It is justifiable, however, to offer the results of such labors and let the field judge as to whether they may be indicative of what may happen under plant scale conditions. This is particularly true when no information on the subject is available even in meager amount. Furthermore, laboratory investigations are entirely appropriate and justified, and should, and probably will, be continued by many workers along this same line for the reason that laboratory studies under carefully controlled circumstances very often yield information that cannot be obtained from more or less unwieldy and inflexible full scale plants where many uncontrollable variable factors are encountered.

However, there appears to be general agreement on one fact and that is the definite trend in recent years toward the thought that polio might be water borne. In some quarters this thought is reflected as a fear and in others as a greater belief in the possibility. The thought has obviously originated from repeated findings of the virus in sewage. Such a conclusion from this evidence only is, as Drs. Maxcy and Howe have pointed out, fallacious. The idea may have been further exaggerated by the work that has been done on the removal or inactivation of virus from water or sewage by standard water and sewage treatment devices. The latter possibility has been a particular concern of the writers in fearing that unjustified conclusions may be drawn from the reported work by inadequately informed persons and thus further contribute toward a lay belief in this same direction.

On the other hand, it does not seem to be appropriate for the water and sewage professions to fail to recognize the importance of any bit of knowledge they might contribute toward a better understanding of the route of transmission of this dreaded disease. Better understanding of the fate of polio in water and sewage and in treatment devices of those fields may very well add to this knowledge. Of even greater importance to both the profession and public is the fact that only by such work can the answers that are necessary for the protection of consumers of water supply be there when, and if, the epidemiologist decides polio is, or is not, water borne. If it should be found that the disease cannot be water borne, the most serious indictment of the public health engineering profession that can be made is that it has been too diligent in safeguarding the trust imposed upon it. Without the least intent of inference that polio may be water borne, it should be recalled that it took many years to establish the fact that water was one of the means of transmission of typhoid fever. There were many opponents and proponents of the theory during that time. Furthermore, it should be recalled that much confusion resulted from conflicting evidence obtained during that same period. This confusion was not cleared up until accumulated knowledge about the disease made it possible to understand the various routes involved. It is also to be recalled that only during recent years has it been shown, by engineering techniques, that one of the routes of transmission of amoebic dysentery may be by water carriage, whereas previous epidemiological evidence did not indicate this possibility. Whether justified or not, one of the first measures instituted at the present time by public health officers in polio epidemics is to close down public swimming pools. The prevalence of this practice at least indicates a popular suspicion of water as a potential hazard in the transmission of the disease. We still know marvelously little about it.

If the time should come when polio is established as water borne, then the problem of public protection, in so far as public recreational waters and supplies is concerned, will be, as in typhoid fever, an engineering problem. In such case, a considerable reorientation of viewpoint and methods may be required. This seems to be apparent by virtue of the admitted difference in nature of the contaminate and apparent resistance of the virus under many of the conditions where bacteria are removed or destroyed. Some of the changes in plant engineering and operation perspectives that may be necessary are indicated from a brief comparison of the accepted characteristics of viruses and bacteria.

Viruses are obligate parasites and will grow only in the presence of living cells. They cannot grow in artificial or lifeless media.

The size of viruses vary from 12 μ to 175 μ, the former being about the size thought for poliomyelitis virus. This contrasts to 200 μ to 5,000 μ for bacteria.

Viruses are heat labile at relatively low temperatures, 50° to 60° C., but may be preserved at lower temperatures for long periods of time.

They may resist drying, freezing, oxidizing agents, and the application of more or less stringent chemicals that ordinarily have either a bacteriostatic or lethal effect on bacteria. All of these characteristics are of significance to water and sewage plant design and operation.

On the basis of fundamental thinking only, they show obvious necessity for reconsideration of both treatment plant design and operation, if ever the public health engineer is confronted with the necessity for treating virus contaminated sewage.

Of first importance in this respect is the obvious need for quicker and more exact methods of detecting virus in dilute quantities. This is a prime necessity. Efficiency in control and operation of water and sewage treatment plants for bacterial removal has largely paralleled the ease and facility with which plant operators were provided with simplified bacteriological testing tools to gauge the performance of their plants and the results of their labors toward refinements in operations. The present standards of bacteriological quality as a guide to safety of virus-contaminated waters is insufficient in view of our present lack of knowledge of effective minimum doses.

A second point of reconsideration is the necessity of selecting and applying an effective sterilizing agent, always the last line of defense. This, contrary to the views of Drs. Maxcy and Howe, for the writers feel that while evidence up to the present time may not be conclusive enough to condemn the effectiveness of chlorine on inactivation of virus, yet the evidence is sufficient to cause distrust of the effectiveness of chlorine in this respect, especially in view of the relatively small residuals that are permitted in water supplies because of esthetic reasons. In completed work of Carlson, Ridenour and McKhann, yet unpublished, on the effect of both chlorine and chloramine, the virus survived residual chlorine doses way beyond those that could be tolerated in drinking water supplies. These were actual residuals over and above the chlorine required to satisfy the organic demand. This treatment was carried to the ''break point'' and performed upon material freed of gross suspended matter.

Also of importance may be the necessity of changing the type of coagulant to be used in water plants, a change in type of construction of filters, and perhaps new unvisualized treatment units to be added. More reliance may have to be placed on sewage treatment devices, which from all evidence available at the present time may be found to be an even more important factor in protection of public recreational waters and supplies. Much more detailed and instructive investigations will be needed along all of these lines.

Far be it from the public health engineering profession to foment a water and sewage borne phobia regarding polio, but also far be it from the workers of this profession to fail to recognize their responsibilities as long as there is any doubt as to whether virus disease may be transmitted through this medium. It is the epidemiologists' prerogative to ascertain the true route of transmission of communicable diseases. It is, likewise, the prerogative of the combined professions of engineer, chemist, and bacteriologist in the water and sewage fields to find ways and means of interrupting the chain of communication once the route is established. From past performances it is believed they won't fail in this respect.

PHOTOELECTRIC DETERMINATION OF DISSOLVED OXYGEN WITH AMIDOL

By M. M. Ellis and M. D. Ellis

Water Quality Laboratories, U. S. Fish and Wildlife Service, and the Department of Physiology and Pharmacology, University of Missouri, Columbia, Missouri

The amidol (diaminophenol hydrochloride) method for the visual colorimetric determination of dissolved oxygen, as introduced by Isaacs (1) and modified by Gilcreas (2), although having the advantages of simplicity and speed over the standard Winkler method, is limited in accuracy by the polychrome reactions of the amidol. If a water sample be buffered to approximately pH 5.1 and amidol added, two dominant colors develop, a red which is apparently proportional to the amount of dissolved oxygen present, and a variable yellow. Although Gilcreas (2), to compensate for the differences in the amounts of red and yellow produced by various quantities of dissolved oxygen, prepared for visual comparison workable artificial standards from mixtures of cobaltous chloride and potassium dichromate solutions, it seemed to the writers that the photoelectric measurement of properly filtered light transmitted through the oxidized amidol solutions might enhance the accuracy of the method without sacrificing its advantages.

Various solutions of oxidized amidol obtained by adding first 1 ml. of 75 per cent solution of sodium citrate and subsequently 250 mgs. of purified amidol to 70 ml. of water carrying a known quantity of dissolved oxygen (0.1 to 8.5 p.p.m.) were tested for light transmission with a spectrophotelometer through the gamut 3,200 to 7,000 Ångström Units. The minimal transmission (Fig. 1, A) was found consistently near 4,900 A.U., in a band of very low transmission extending from 4,400 to 5,200 A.U. for all of the amidol solutions studied. The low transmission in this band is due to the red component of the oxidized amidol color, the actual amount of light transmitted varying inversely with the quantity of dissolved oxygen in the sample. A second band of low transmission extended from 3,300 to 3,700 A.U. and was dependent upon the yellow component. The span of this band varied in different samples, in general the spread being greater for samples carrying the smaller amounts of dissolved oxygen.

The transmission curves for the artificial standards prepared according to Gilcreas (2) varied somewhat in minor details as would be expected in view of the differences in the ratios of cobaltous chloride to potassium dichromate for the various equivalent oxygen values, but the minimal transmission (Fig. 1, B) for all of the artificial standards equivalent to dissolved oxygen between 0.0 and 8.5 p.p.m. was found to be near 3,700 A.U. in a minimal transmission band extending from 3,400 to 3,900 A.U. A second low transmission zone was evident between 4,500 and 5,200 A.U. This band of low transmission for the artificial standards spans the minimal transmission zone of the oxidized amidol solutions. However as the minimal transmission through the oxidized amidol solutions varies with the red component and through the artificial standards with the yellow component (dichromate), these artificial standards are necessarily unreliable for fine determinations in either colorimeter or photelometer, unless correct light filters are used. The artificial standards were discarded accordingly in favor of the direct determination method using only the transmission through the oxidized amidol solutions.

These spectrophotelometric analyses collectively show therefore that for maximal efficiency in the direct photoelectric determination of the red component of the oxidized amidol solution a monochromatic light near 4,900 A.U. or a light filter having a maximal transmission

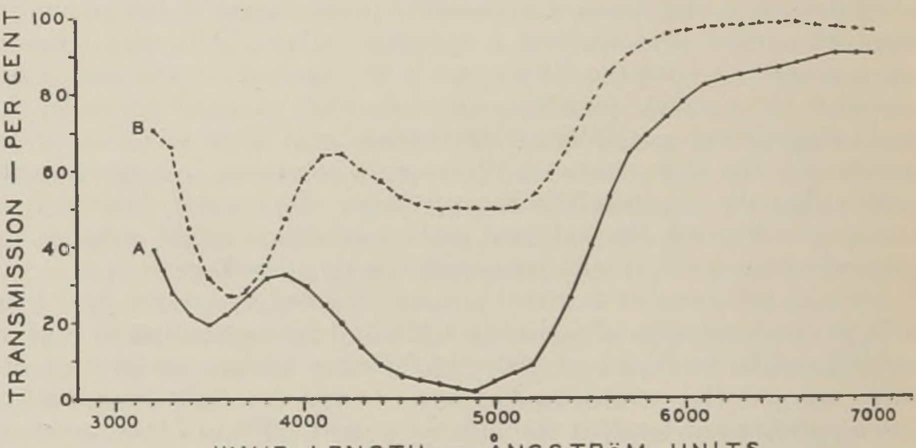


FIG. 1.—Light transmission curve of an amidol-treated water sample carrying 1.7 p.p.m. dissolved oxygen (*A*), and of a Gilcreas artificial standard equivalent to 2 p.p.m. dissolved oxygen (*B*).

band spanning the blue to yellow-green zone between 4,400 and 5,200 A.U. must be used.

Applying these findings standardized calibration curves were obtained readily from readings of oxidized amidol solutions developed from samples of known dissolved oxygen content, with a spectrophotelometer set at 4,900 A.U. or with a photelometer using a filter which transmitted very little light below 4,600 or above 6,000 A.U. and which had a maximal transmission near 4,900 A.U. These curves like most calibration curves for photoelectric determinations (Hoffman, 3) are most effective for laboratory or field use if plotted on semilogarithmic paper. With these curves differences of 0.1 p.p.m. in dissolved oxygen were noted easily in amidol treated samples. The method was very effective for dissolved oxygen determinations between 0.0 and 5.0 p.p.m., and particularly so between 0.2 and 2.5 p.p.m. over which range the curve had a good spread. For quantities of dissolved oxygen above

5.0 p.p.m. small cells must be used owing to the density of the color developed.

Gilcreas (2) noted that the color of the oxidized amidol was controlled best about pH 5.1, and stated that the maximal color was developed at that acidity in 30 minutes, the sample remaining usable for visual comparisons for about two hours. To ascertain the time limits for accurate light transmission through the oxidized amidol solutions at ordinary room temperatures a series of readings were taken at 30, 60, 90, 120, and 150 minutes after the reagents were added. Each sample was read successively in a photelometer without a light filter, with an amber yellow filter as suggested by Isaacs (1) as an aid to visual comparison, and with the green filter previously described, and also in a spectrophotelometer at 3,700, 3,900, 4,900, 5,200, and 6,600 A.U. Some of the samples were also read visually in a comparator block.

In terms of the 30-minute reading the apparent dissolved oxygen value fell, that is, the light transmission increased slightly, at 60 minutes for all readings except those made with the green filter or at 4,900 and 5,200 A.U. in the spectrophotelometer, which three readings showed no change at the end of 60 minutes. After 90 and 120 minutes increased transmission of light of all wave lengths excepting the three green lights was very evident, amounting to an indicated loss of 1.0 to 1.5 p.p.m. dissolved oxygen in samples actually carrying 3.5 to 5.0 p.p.m., and from 0.1 to 0.5 p.p.m. in samples containing less than 3.5 p.p.m. dissolved oxygen. After 90 minutes even the readings with the green filter and at 4,900 and 5,200 A.U. showed a slight increase in the amount of light transmitted. It is evident therefore that for analytical purposes the photoelectric readings on oxidized amidol solutions should be made with a green light between 30 and 60 minutes after the reagents are added.

In all determinations of dissolved oxygen with amidol care must be taken to prevent oxidation at the surface of the solution. If the sample be exposed to the air after the amidol has been introduced a deep color quickly develops in the surface layer, which color will be added to the reading. The extreme sensitivity of the reagent therefore becomes a hazard if the operations are carelessly performed. In the laboratory, where this method is particularly applicable to serial determinations of dissolved oxygen of polluted waters or oxygen consumption by aquatic animals or substances having oxygen demands, the use of glass gas sampling tubes with a two-way glass stopcock on each end is recommended. After collecting the sample in one of these gas sampling tubes, the sodium citrate solution and the amidol solution can be introduced into the bottom of the sampling tube from oxygen-free containers through the two-way stopcock, while the displaced fluid overflows via the top stopcock. When the color has developed the cell for the photoelectric reading is filled from the bottom stopcock of the sampling tube by flooding. The cell while overflowing is sealed quickly with its glass stopper.

For work requiring large numbers of serial determinations of dissolved oxygen a special cell with glass stopcocks is convenient. This cell may be made up in its own photoelectric unit and can be filled and emptied repeatedly without changing the apparatus. In this way 10 to 15 oxygen determinations per hour are easily possible.

In the field for streamside determinations the writers have carried a photelometer many thousands of miles in an auto truck, current for the operation of the photelometer being obtained by connecting the instrument to the battery of the automobile.

In summary, the red component of an oxidized amidol solution is readily measured photoelectrically if a green light near 4,900 A.U. be used, giving a method for the rapid determination of dissolved oxygen accurate to less than 0.1 p.p.m. in routine serial tests. This method is applicable to both laboratory and field work.

References

1. M. L. Isaacs, "A Colorimetric Method for the Determination of Dissolved Oxygen." *This Journal*, 7, 435–443 (1935).
2. F. W. Gilcreas, "A Colorimetric Method for the Determination of Dissolved Oxygen." *Journal American Water Works Association*, 27, 1166–1177 (1935).
3. W. S. Hoffman, "Photelometric Clinical Chemistry." Wm. Morrow and Co., New York, pp. 254 (1941).

THE EFFECT OF VARIOUS TREATMENT PROCESSES ON THE SURVIVAL OF HELMINTH OVA AND PROTOZOAN CYSTS IN SEWAGE *

By Eloise B. Cram

Senior Zoologist, Division of Zoology, National Institute of Health, U. S. Public Health Service

Introduction

An attempt has been made to evaluate under controlled conditions the effect on ova and cysts of human parasites of sewage treatment processes simulating those in common use today. The subject merited attention for several reasons. On the one hand there has been a dearth of information in this respect. Critical experimental work has been done previously with *Eberthella typhosus* (1, 2) but as regards the protozoan and worm parasites available information appeared to be confined to observations made under natural conditions of pollution. On the other hand the subject appeared to be one of increasing importance because of two factors operating at the present time.

First, there is to be expected an inevitable increase of parasitic infections in this and other countries because of the return of infected military personnel from areas where parasites are prevalent, especially the tropics and the Orient. Therefore there is a probability of an increase of certain parasitic infections already known here and the introduction of exotic infections not previously endemic here. In this connection, the writer (3) was impressed by critical studies published after the World War, principally in Germany and France, showing a greatly increased prevalence and severity of parasitic diseases not only in returning troops but in the civilian population. Crowding and other factors leading to the breakdown of sanitation, as well as impaired nutrition, offered favorable conditions for an easy spread of such infections. In France especially severe cases of ascariasis, like those usually seen only in the tropics, became prevalent in the civilian population; this was strikingly evident from observations made in the surgical department of a hospital in Havre where, in the two years following cessation of the war, one of every three persons operated on vomited ascarids during the two days following operation.

Secondly, there is to be expected an increased use of sewage sludge as fertilizer, here and abroad. Present day recommendations (4) are bringing to the attention not only of the farmer but also of the amateur "victory" gardener the fertilizer value of sludge.

Preliminary investigations on this problem (5) were initiated in the summer of 1941, at which time there were examined 26 samples of sludge

* The present study was made under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and the National Institute of Health. Presented at the Fourth Annual Convention of the Federation of Sewage Works Associations, Chicago, Ill., Oct. 21, 1943.

from sewage treatment plants in 16 municipalities and 2 national parks in California and 1 national park in Arizona, and 75 samples of sludge from 17 army camps in 8 southern states. With a single exception, no eggs of parasitic helminths were found in the sludge from municipalities and parks. However, from 27, or slightly over one-third of the samples from the army camps, eggs of parasitic helminths were isolated. Ova of *Ascaris lumbricoides* were encountered most frequently and were found in samples drawn at all stages of treatment from raw sewage to the final dried sludge. The viability of the eggs was demonstrated. A species of amoeba closely related to *Endamoeba histolytica* was found in sludge both of municipal and camp origin.

These preliminary observations emphasized the need of a critical investigation conducted under controlled conditions. The facilities of the Stream Pollution Investigations Station of the U. S. Public Health Service at Cincinnati, Ohio, were utilized. These facilities were made available originally by Medical Director H. E. Hasseltine and subsequently by his successor, Engineer Director H. W. Streeter. Mr. Donald O. Hicks, assistant scientific aide, worked with the writer in practically all phases of the investigation. The staff at the Station cooperated in ways too numerous to cite; the chemists, notably C. C. Ruchhoft, O. R. Placak and W. A. Moore, were responsible for chemical analyses, J. B. Lackey furnished biological material and data, C. T. Butterfield supplied cultures of bacteria, while S. R. Weibel designed and supervised construction and operation of much of the experimental equipment.

Methods

A small Imhoff tank served as a source of supply of partially digested and later of ripe sludge; it was fed by a constant flow of sewage which had been settled in a tank supplied by a sampling device with representative samples from continuous flow sewage from one of the municipal mains. Sewage and sludge were inoculated with eggs and cysts of intestinal parasites, and were subjected to treatment processes simulating in principle those of present day practice, as nearly as was possible under experimental conditions. It was necessary to conduct the tests on a miniature scale in order that the inoculated material could be recovered subsequently.

Eggs of various parasites and cysts of *Endamoeba* were used in the studies. The eggs of the large roundworm, *Ascaris lumbricoides,* were obtained by dissection of worms originating from man and from swine. The egg of this parasite is thick-shelled. The development of the embryo within the egg proceeds at a relatively slow rate, reaching the infective stage under favorable conditions in 12 to 15 days. Hatching does not occur in the external environment and the embryo remains within the egg until the latter is swallowed by a suitable host.

Eggs of the dog hookworm, *Ancylostoma caninum,* were used for the present tests. Eggs of the dog ascarid, *Toxascaris leonina,* and whipworm, *Trichuris vulpis,* were included incidentally.

Cysts of the protozoan parasite, *Endamoeba histolytica,* which is the cause of amoebic dysentery of man, were obtained from cultures of the amoebae grown in a modified Boeck and Drbolav egg-Locke media with rice starch.

Primary Settling

Observations were made in three tests on the degree of settling of *Endamoeba* cysts and of hookworm and ascarid eggs, thoroughly mixed and allowed to stand quiescent in sewage of different strengths. Two types of containers were used for comparative purposes; one was a glass cylinder with outlet at bottom only, the other a metal tank with outlets at bottom and at several levels on the side (Fig. 1). The verti-

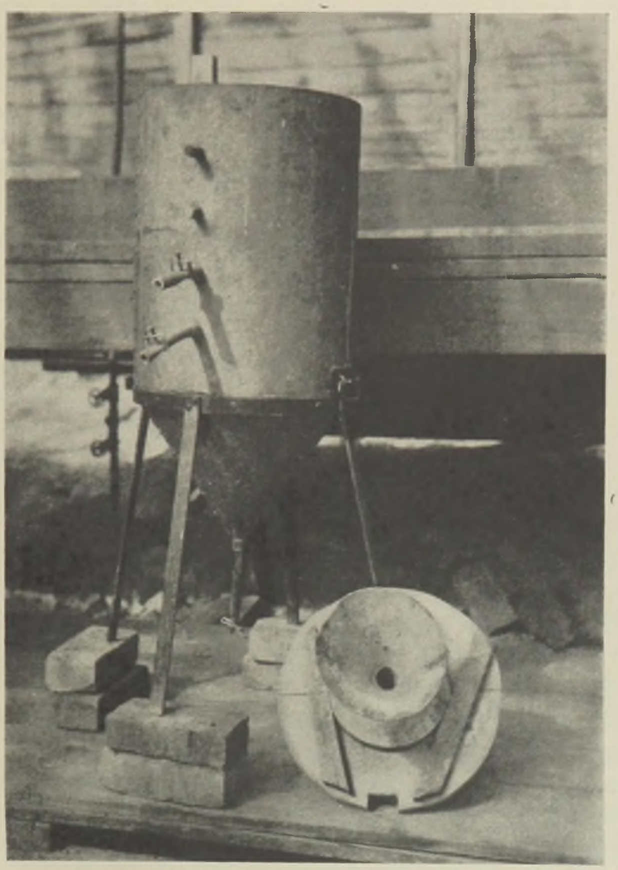


Fig. 1.—Metal tank, capacity 72 liters, used for primary settling experiments and subsequently, with floating cover, for sludge digestion.

cal depth of settling in all three tests was 26 inches. The room temperature was 23° to 27° C. The inoculum of cysts and/or eggs was thoroughly mixed with raw sewage. This mixture, standing quiescent except for such currents as were caused by sampling, was sampled by insertion of a capillary pipette just below the surface and in test No. 3 also to a depth ⅓ of the way down from the surface, and by draws made at the outlets. Samples were centrifuged, the liquid aspirated, and counts and cultures made from the sediment.

The findings are summarized in Tables I and II. The counts from the upper two levels show the presence of large numbers of cysts of *E. histolytica* at the surface and a short distance below the surface for a period of 3 hours, the extent of observation, evidence which indicates that the effluent from primary settling tanks would be of major importance as a site of amoeba cysts originally present in sewage. Hookworm eggs also were still present at the upper levels after 2½ hours of settling. On the other hand, no *Ascaris* eggs were found in samples from the upper third after a 15-minute period of settling; accordingly, it may be concluded, as regards the disposition of *Ascaris* ova, that the effluent would be of decidedly minor importance as compared with sludge.

Trickling Filters

Tests were run to determine whether standards of efficiency of purification by trickling filters, as now measured by 5-day B.O.D. reduction, were of significance as regards removal of protozoan cysts and eggs of intestinal parasites, and to determine whether differences in rate and intensity of application of infectious sewage and rate of flow of the filter influenced the relative numbers of cysts and eggs appearing in the effluent at various periods. For this purpose experimental pure culture growth was developed in a filter (Figs. 2, 3, and 4) 22 inches deep, or approximately ⅓ the depth of a full scale filter, comparable to that described by Butterfield and Wattie (6, 7). Three species of zoogleal bacteria, Numbers 87, 102, and 103, used by these authors, were employed in the present tests. The principal particulars of technique and the results of the five tests are summarized in Table III.

Prior to introduction of *E. histolytica* cysts and helminth eggs, when the flow was equivalent to 1 million gallons per acre per day, the filter showed a 63.2 per cent reduction in biological oxygen demand, a high efficiency for a filter ⅓ normal depth. This efficiency dropped as the tests proceeded. The efficiency as regards cyst removal ranged from approximately 88 to 99.9 per cent in a 24-hour run in the various tests, but there appeared to be no correlation between efficiency in B.O.D. removal and in cyst removal. In Test 1, when reduction of B.O.D. was highest, percentage removal of amoeba cysts was lowest, approximately 12 per cent appearing in the effluent in 24 hours. In this case the cysts were introduced in concentrated form in relatively large numbers, and this cyst load, that is, the number introduced and the rate of their introduction, appeared to be of significance. In Test 2, in which other factors were much the same as in Test 1 but in which the cysts were introduced in the influent in very dilute form over a considerable length of time, less than one-tenth of one per cent passed the filter. Comparable results were obtained with filters of lower efficiency in B.O.D. removal (Tests 3 and 4); with a heavier cyst load only about a 90 per cent removal of cysts was effected, as compared with a 99 per cent removal

TABLE I.—*Comparative Counts of Cysts of E. histolytica During Primary Settling*

Test	No. 1			No. 2			No. 3		
Container:	Tank			Tank			Cylinder		
Inoculum: No. cysts	1,000,000			1,500,000			400,000		
Amt. of sewage	36 liters			36 liters			1.2 liters		
Chemical analysis:	Susp. solids 392 p.p.m. Ash on solids 23.47% 5-day B.O.D. 740			572 p.p.m. 23.80% 610			1480* 22.43% —		
Amount of sample	25 ML.			25 ML.			5 ML.		
Counts: No. cysts	Top	1/4 down	Bottom	Top	1/4 down	Bottom	Top	1/3 down	Bottom
At start	472	348	425	300	432	230	—	—	—
After 15 min.	304	294		400	301	220	129		307
After 30 min.	402 (av. 365)	412 (av. 337)		245 (av. 369)	280		126		156
After 45 min.	—	430		360	450 (av. 395)	(av. 337)	64 (av. 99)		
After 1 hr.	282	202		539	511	560	77	40	
After 1¼ hrs.	248	262		—			76		
After 1½ hrs.	120	278	315	532	372	210	99		
After 1¾ hrs.	— (av. 235)	208 (av. 269)	330 (av. 268)	— (av. 321)	420 (av. 357)	128 (av. 169)	(av. 80)		
After 2 hrs.	336	330	160	110	279	168	66	95	
After 2¼ hrs.	—	426		—		169			
After 2½ hrs.	150	374		369 (av. 332)	259	28 (av. 83)	80	67	
After 2¾ hrs.	(av. 273)	348 (av. 397)		296	432 (av. 345)	44	(av. 100)		
After 3 hrs.	396	440					120	245	693
Average	301	335	307	361	374	195	93	112	385

* Due to addition of sedimented fecal material containing hookworm eggs (see Table II).

TABLE II.—*Comparative Counts of Helminth Ova During Primary Settling*

	Test No. 2 (see Table 1) Inoculum: No. ova: *Ascaris lumbricoides* 1,500,000				Test No. 3 (see Table I) Inoculum: No. ova: Hookworm 50,000 *Toxascaris* 35,000			
	Counts: No. ova:				Counts: No. ova:			
					Top	1/3 down	Bottom	
	Top	1/4 down	Bottom		Hookworm	Hookworm	Hookworm	Toxascaris
At start	300	208	220	10 min.	20		252	918
15 min.	10	0	1,261	20 min.	27		280	540
30 min.	0	0		30 min.	51		396	210
1 hr.	0	0	5,040	45 min.	8			
1½ hrs.	0	0	406	1 hr.	0	25		
1¾ hrs.	0	0	48	1¼ hrs.	2			
2 hrs.	0	0	24	1½ hrs.	3			
2¼ hrs.	0	0	104	2 hrs.	0	5		
2½ hrs.	0	0	0	2½ hrs.	3	3		
2¾ hrs.	0	0	22	3 hrs.	0	0	45	0

with a lighter cyst load. When operated as a contact filter (Test 5) approximately 96 per cent of the cysts were removed. That the viability of *E. histolytica* cysts was not affected by passage through the filter was demonstrated by cultures in three of the five tests.

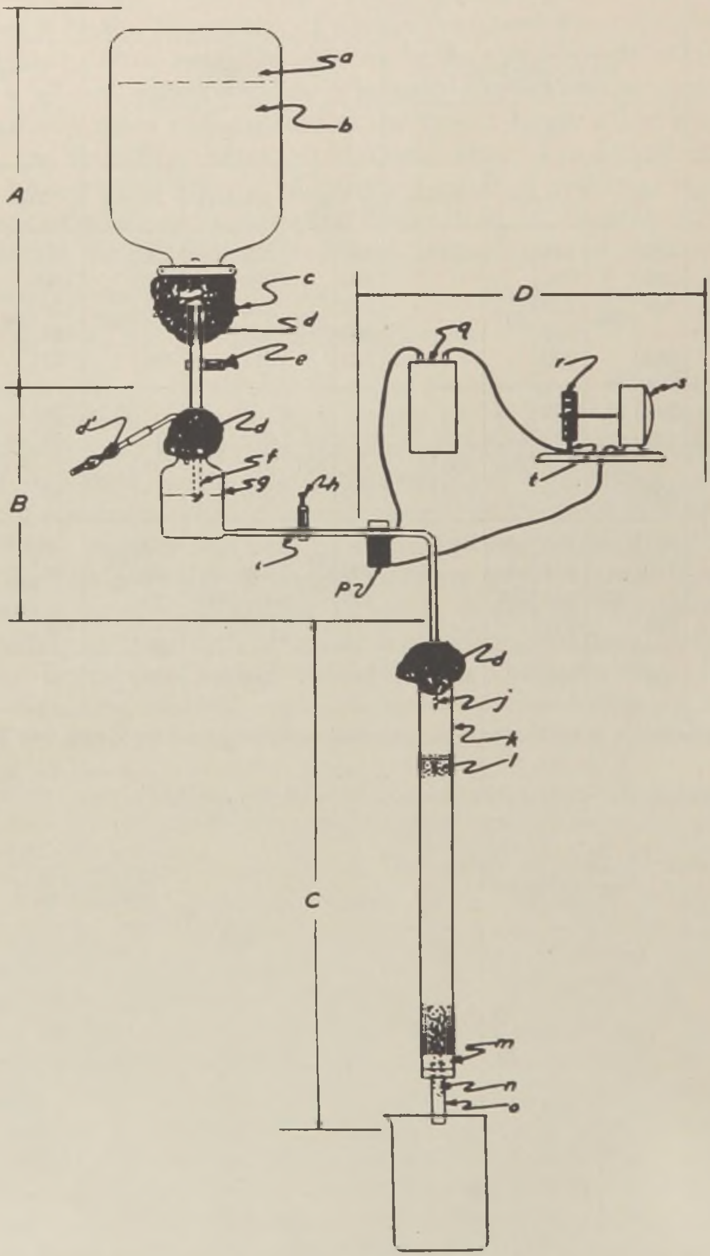


FIG. 2.—Sketch of pure culture trickling filter equipment. *A*, stock supply of sterile synthetic sewage; *B*, equalizing reservoir for maintaining approximately a constant pressure on the feed line; *C*, trickling filter with provision for inflow and outflow of liquid, and *D*, control device for intermittent flow. After Butterfield and Wattie (1941). For details of construction see original article.

Eggs of worm parasites (4 species) were removed much less efficiently (Tests 1 and 4) than were amoeba cysts under the same conditions. Eggs that remained in the filter continued their development and subsequent sloughing brought away live hookworm larvae and embryonated ascarid eggs.

In summary, therefore, the tests failed to show a correlation between efficiency of the filter as regards 5-day B.O.D. reduction and re-

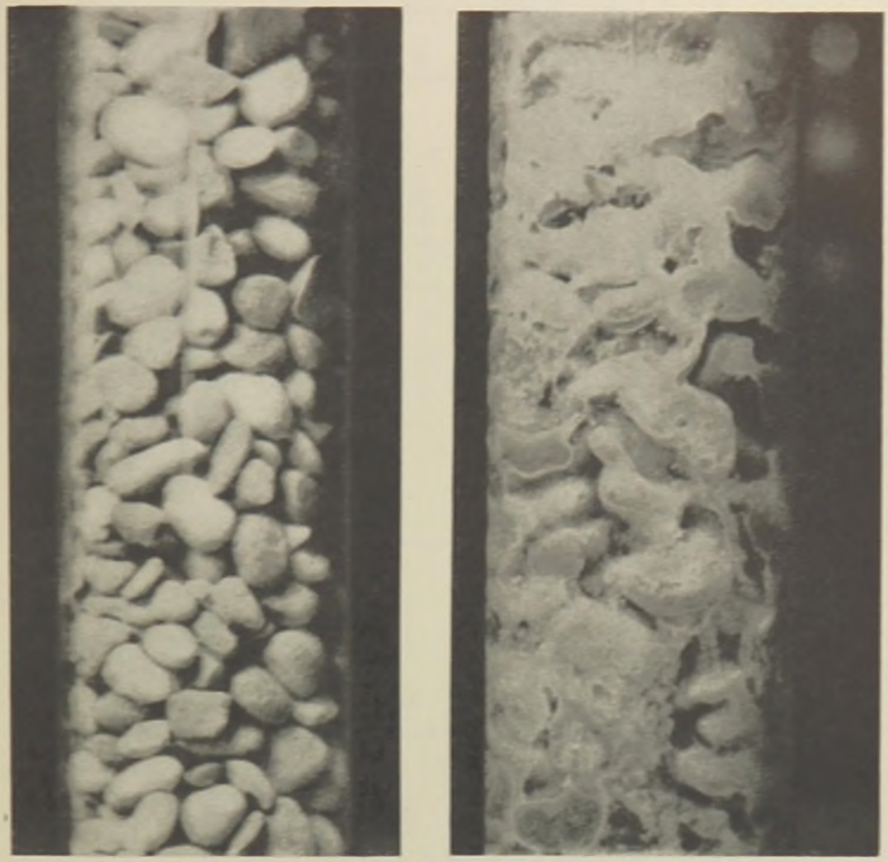


FIG. 3.—Unseeded sterile filter. After Butterfield and Wattie (1941).
FIG. 4.—Trickling filter 7 days after seeding. After Butterfield and Wattie (1941).

moval of cysts and ova. Although the filter was ⅓ normal depth and the conclusions to be drawn are limited by this fact, nevertheless the evidence to date throws doubt on the efficacy of trickling filter treatment in the removal of infectious parasitic material from sewage.

Activated Sludge

Technical difficulties were encountered in connection with critical testing of the effect of activated sludge treatment, especially as regards *E. histolytica* cysts. The biota of the sludge, especially organisms producing rapid digestion of starch, prevented normal reproduction of the

TABLE III.—*Trickling Filter*

Flow	Efficiency; reduction in 5-day B.O.D.	Inoculum	How applied	Present in filtrate in								Viability
				5 min.	1 hr.	2 hrs.	3 hrs.	4 hrs.	7 hrs.	24 hrs.	48 hrs.	
					Per cent							
1. Slow (approx. one million gals. per acre per day)	63.2% before, 54.3% during test	Cysts 500,000; *A. l.* eggs 1,500,000	Sprayed on surface in concentrated form	Cysts 8% Eggs 16%	9.7 22.4	9.8 22.5	9.8 22.5	11.3 22.5	11.5 22.6	11.6 22.8	13.3 23.3	Cysts; positive to 24 hrs. (17×); negative 30–46 hrs. Eggs: positive. Dev. continued in filter
2. Slow (approx. one million gals. per acre per day)	42.8%	Cysts 300,000	In influent, in very dilute form	Cysts 0	.001	.002	.06	.06	.06	.06	.06	?
3. Fast (approx. three million gals. per acre per day)	19.3%	Cysts 345,000	In influent, in very dilute form	.82%	9.3	10.6	10.6	10.7	10.7	10.7	—	Positive to 7 hrs. (13 of 14×)

TABLE III.—*Continued*

Flow	Efficiency; reduction in 5-day B.O.D.	Inoculum	How applied	Present in filtrate in								Viability
				5 min.	1 hr.	2 hrs.	3 hrs.	4 hrs.	7 hrs.	24 hrs.	48 hrs.	
					Per cent							
4. Fast (approx. three million gals. per acre per day)	12.6%	Cysts 140,000;	In influent, in very dilute form	—	.23	.49	.79	.92	—	1.3	1.5	
		hookworm eggs 50,000;		—	3.3	8.2	12.8	14.5	—	27.3	29.8	
		Toxasc. eggs 25,000;		—	3.9	12.3	18.3	19.6	—	26.0	27.7	
		whipworm eggs (small nos.)		—	*	*	*	*	—	*	*	
				Cysts in consecutive one-fourth portions								
5. As contact filter (slow filling; closed 1/2 hr. Slow draining) Total 6 hrs. (Run between 1 and 2)	45–50%	Cysts 60,000	Sprayed on surface in concentrated form (as in no. 1)	(1) 1.0%	(2) 0	(3) 0.3%	(4) 3.8%					Positive in 1, 3, 4

* Whipworm eggs present in samples drawn at these intervals.

amoebae in the media used for cultures. Furthermore, the presence of numerous free-living amoebae in some lots of sludge complicated identification of atypical specimens of *E. histolytica.* There was also the possibility of the presence of larval roundworms of free-living species complicating the identification of hookworm larvae. Accordingly there was developed an experimental activated sludge of limited biota and a double series of tests was run with experimental and with natural activated sludge. To develop an activated sludge of mixed known pure culture organisms, sterilized sewage in an 8-liter serum bottle with aerator attachment was inoculated with fungi (10 species of *Phycomycetes*) of trickling filter and activated sludge origin, algae (*Euglena viridis* and *Chlorogonium euchlora*), 1 species of ciliate (*Glaucoma pyriformis*) and 1 species of filamentous bacterium (*Sphaerotilus natans*), both of activated sludge origin, and 3 species of zoogleal bacteria (Butterfield and Wattie Nos. 87, 102, and 103) of trickling filter origin. After 7 weeks development the experimental sludge contained 1120 p.p.m. suspended solids and effected a 92.38 per cent purification, as measured by 5-day B.O.D., during a 24-hour period of aeration.

Endamoeba Histolytica

Experimental Activated Sludge.—A 3-liter portion of sludge (2,688 p.p.m. suspended solids; 95.52 per cent reduction in 5-day B.O.D. during 24 hours aeration) was inoculated with approximately 500,000 cysts. Viability of the cysts was demonstrated at half-hour intervals up to 3 hours and at the end of 24 hours and of 48 hours of activated sludge treatment; cultures made 72 hours after inoculation of the sludge were negative.

Natural Activated Sludge.—Conclusive results were obtained which confirmed those secured with experimental activated sludge. There was growth of *E. histolytica* in cultures made both from samples of the mixed sludge and settled sludge, at 4 hours and 24 hours after inoculation, and from the supernatant when it was withdrawn by siphon and settled by centrifugation after 4 and 24 hours, and after 2, 3, and 5 days of activated sludge treatment.

The results with both lots of sludge indicated that the criteria of efficiency of purification by activated sludge are not of significance as regards the effect on *E. histolytica* cysts.

Hookworm

Inoculation of hookworm eggs secured from dog feces by zinc sulfate flotation followed by repeated washing and settling in water was made into two lots of experimental activated sludge (one lot with suspended solids about 2,400 p.p.m., the other about 3,400 p.p.m.) and one lot of natural activated sludge (2,400 p.p.m.), held at room temperature. Results were essentially similar in all lots. Eggs in advanced stages of development were present in the settled sludge for 2 days; many active larvae and in one case some eggs were found in the supernatant drawn after 20 hours aeration. With daily renewal of liquor, live larvae continued to be present in considerable numbers in the supernatant on the 3rd to 5th days but only dead larvae were recovered between the 6th and 10th days. Thereafter the search failed to reveal any eggs or larvae. It was apparent therefore that development and hatching of hookworm eggs proceeded at a normal rate in activated sludge; that larvae, alive and active up to 5 days but dead thereafter, remained principally in the supernatant and were drawn off with it daily, until all had been removed or, if remaining, had disintegrated by the end of 10 days.

Ascaris Lumbricoides

Two lots of natural activated sludge were inoculated with eggs of *A. lumbricoides;* lot No. 1 was held for 35 days, No. 2 for 14 days at room temperature, then both at 20° C. Development in the eggs proceeded through the normal stages to active embryos. The eggs apparently settled sufficiently rapidly so that their numbers were not greatly depleted when the supernatant was withdrawn daily after 30 minutes settling. In one lot of sludge, eggs containing active embryos were found at intervals up to 151 days. At 192 and 222 days, respectively, a single egg with nonactive embryo was isolated but thereafter the search failed to reveal eggs. In the second lot of sludge there was evidence of disintegration in eggs 82 days after inoculation, and no eggs could be found at later periods.

The evidence indicates therefore that activated sludge treatment does not affect the viability of *E. histolytica* cysts or of hookworm or ascarid eggs.

Secondary Settling After Activated Sludge Treatment

As noted previously, *Endamoeba histolytica* cysts were found to be present in the supernatant drawn off by siphon from activated sludge after 15 to 30 minutes settling of the sludge.

Observations were made as to the effectiveness of further settling of the supernatant from three lots of cyst-inoculated sludge; *E. histolytica* cysts were still present in the upper portions of the liquor for periods up to 16 hours.

Chemical Precipitation During Secondary Settling

The effectiveness of alum floc as an aid in the settling of cysts of *E. histolytica* was tested with two lots of supernatant drawn respectively after 4 hours and 24 hours of activated sludge treatment. In both cases approximately ⅖ of the liquor was left untreated to serve as a control, and the remainder treated with aluminum sulfate and concentrated ammonium hydroxide at a rate of 10 ml. of a 10 per cent solution of the sulfate and 1 ml. of the hydroxide per liter of liquor. The floc was allowed to settle for 15 minutes. The results indicated effective removal of the protozoan cysts by the chemical precipitation. Cultures made from the untreated liquor and from the alum floc of the treated liquor gave positive growth of *E. histolytica* but those from the clear supernatant drawn off after chemical precipitation were negative.

Intermittent Sand Filtration

Tests were run to determine the effectiveness of intermittent sand filtration in the removal from sewage of cysts and eggs of intestinal parasites. The construction of the filter and method of dosing are shown in Fig. 5. Raw settled sewage was used. The sand had an ef-

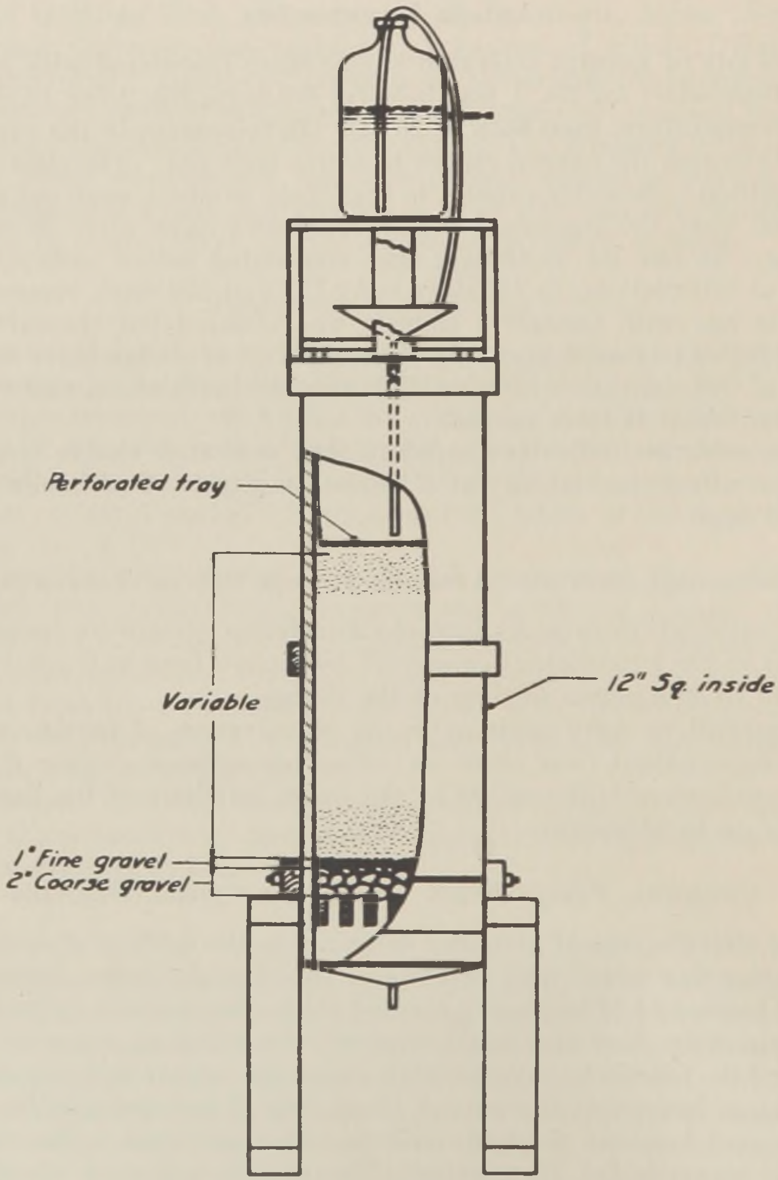


Fig. 5.—Experimental intermittent sand filter.

fective size of 0.53 and a uniformity coefficient of 1.47. The results are shown in Table IV. With the sewage fed at a rate of 100,000 g./a./d. in the initial test with a 12-inch sand layer *Ascaris* eggs were found to

TABLE IV.—*Intermittent Sand Filtration for Removal of Ascaris and Hookworm Eggs and E. histolytica Cysts*

Fresh settled sewage — Sand, effective size 0.53. Uniformity coefficient 1.47

Test No. 1

Temperature: Max. 80° F. Min. 68° F. — Sand depth 12″ — Gravel depth 3″ — Inoculation: 8 million *Ascaris* eggs in Dose 1 — Dose: At 24 hr. intervals 7,192 ml. in 7 to 21 min., equivalent to 100,000 gal./acre/day

Dose; day No.	Dosing time, minutes	Filtrate lag, minutes	Duration of filtrate flow, minutes	Result found in filtrate		
				1st half *Ascaris* eggs	2nd half *Ascaris* eggs	Total Eggs
1	21	7	33	27	2	29
2	19	6	29	3,320	60	3,380
3	18	6	34	70	0	70
4	17	6	28	6	1	7
5	7	4	21	0	0	0

Test No. 2

Sand depth 24″; otherwise the same as test No. 1

1	17	12	55	0	0	0
2	14	12	50	0	0	0

Test No. 3

Sand depth and dose: Same as Test No. 2. Inoculation: 30,000 hookworm eggs in Dose 1

			Minutes	Hookworm eggs or larvae		
1	14	10	60	0	0	0
2	10	8	60	0	0	0
3	8	7	60	0	0	0
4	19	12	70	0	0	0
7	17	12	65	0	0	0

Test No. 4

Sand depth 24″ — Dose: 142 ml. in 14–15 min.

Inoculation: 1 million cysts in Dose 1. — equivalent to 100,000 gal./acre/day

			Drip, hrs.	Cysts	Cysts	Cysts
1	15	10	4	0*	0*	0
2	14	12	4	0	0	0

* Cultures negative.

pass through the filter. A 24-inch sand layer was subsequently used and the results indicated effective removal of *Ascaris* and hookworm eggs and, in a smaller filter, of amoeba cysts. Later the dosing was speeded up to 125,000 and then 173,000 g./a./d. and, although these tests did not include amoeba cysts, no *Ascaris* or hookworm eggs were found in the filtrate, even with these high dosings.

Sludge Digestion

In 18 lots of sludge held for varying lengths of time eggs of *Ascaris lumbricoides* were found to be extremely resistant to digestion. Eggs obtained by dissection of specimens of the worms were inoculated into raw or partially digested sludge from the Imhoff tank or into a mixture of ripe sludge, 1 part, with fresh settled sewage, 4 parts in 4 or 8 liter serum bottles. For three larger lots of sludge a miniature digestion tank with floating cover (Fig. 1) was used and to 10 parts of ripe Imhoff sludge was added daily for 30 to 60 days 1 part of fresh settled sewage, with a final yield of 60 to 72 liters of sludge. Under the anaerobic conditions, development of the eggs was suspended; only in eggs which were brought to the surface, probably with gas bubbles, did embryonation occur. Graph 1 correlates the length of stay of the eggs in the sludge with the average viability. For the first 3 months of digestion, the viability of the eggs appeared to be little affected; after 6 months an average of 10 per cent was still viable. After a year in sludge eggs were still found which were capable of development. The temperature during digestion of the sludge did not appear to affect the results to any practical extent, as seen in Table V, which assembles data as to the original composition of the mixtures, the final analyses at the end of the observation period, at different temperatures, and the proportion of eggs which were still viable after various periods of time. Not only were the eggs still viable after long periods at the constant temperatures of 20° and 30° C., but also there was high percentage viability at the end of 3 and 4 months at higher temperatures of the greenhouse and of the laboratory.

The development of hookworm eggs also was suspended while they were in digesting sludge. They survived for shorter periods of time than did ascarid eggs, as was to be expected; however, development and hatching of hookworm larvae were demonstrated after sludge digestion for periods up to 64 days at 20° C., 41 days at 30° C., and 36 days at room temperature.

These results indicate that the eggs of these two intestinal parasites will withstand sludge digestion for periods sufficiently long for ripening of the sludge. By comparison, cysts of *Endamoeba histolytica* appeared to be much less resistant. From observations on 17 lots of sludge, cysts were still viable after 12 days at 20° C., 10 days at 30° C., and 4 days at outdoor winter temperatures ranging from —12° to 19° C., but cultures made at later times failed to show growth of this amoeba. More extensive studies are desirable, especially in view of the limitations of technique. However, the evidence to date indicates that there would be a considerable safety factor in the difference in length of viability of cysts of *E. histolytica* and the usual length of the period of sludge digestion.

Sludge Drying

For testing the resistance to drying of ascarid and hookworm eggs which had previously undergone sludge digestion, the sludge was poured into two types of drying units. In the one type (Fig. 6), non-adjustable as to depth, the sludge sank below the surface during drying; in the other type (Fig. 7) the upper sections of the unit were removable so that the surface of the sludge could be exposed to direct sun and air currents during the entire drying period. Observations were made on *Ascaris lumbricoides* eggs in 26 cakes of drying sludge. The effect of

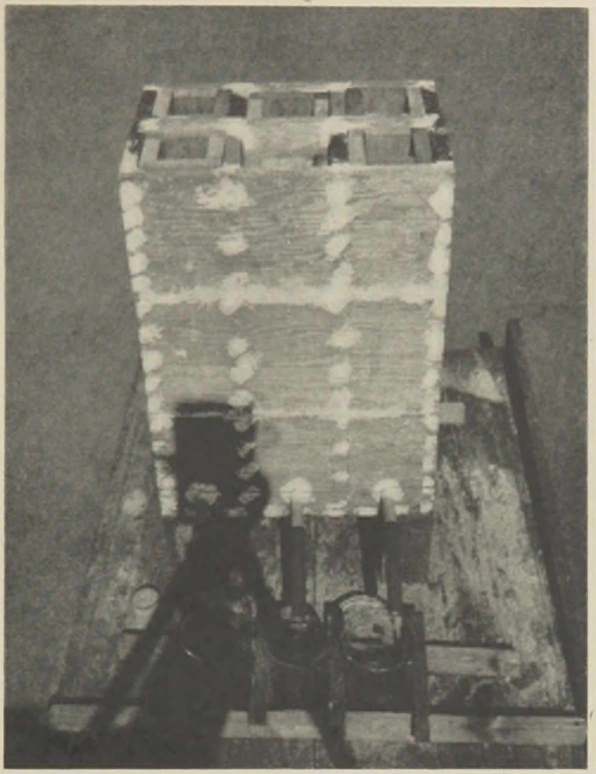


Fig. 6.—Non-adjustable units used for sludge drying.

variations in depth of gravel, sand and sludge layers was investigated, as was also the effect of indoor drying, in greenhouse and laboratory, where direct sunlight was lacking and air motion was limited but where drying progressed consistently, and of outdoor drying, where direct sunlight and air currents were present but where the degree of drying varied with the weather. Space does not permit a detailed analysis of the findings here. Ascarid eggs survived long periods of sludge drying; they were viable for as long as 118 days of indoor (greenhouse) drying and for 170 days of outdoor drying. They were very resistant to loss of moisture; viable eggs were found in several cakes with moisture content below 10 per cent. In one lot of sludge the cake still

TABLE V.—*Sludge Digestion (Anaerobic); Effect on Eggs of Ascaris lumbricoides*

Lot No.	Digestive mix	Original Per cent		Date Inoc.	Temp.	Days obs.	Final analysis Per cent		Age (days) and average per cent viable								
		Solids	Ash				Solids	Ash	1–40 avg. 22 days	40–60 avg. 43 days	60–80 avg. 70 days	80–100 avg. 92 days	100–120 avg. 109 days	120–140 avg. 128 days	140–160 avg. 146 days	160–180 avg. 168 days	180–200 avg. 189 days
1	Imhoff	6.38	26.47	3/26	20° C.	371	3.14	49.8						8	+	23	9
8	Imhoff	6.36	32.45	5/14	20° C.	321	3.42	51.7				2	8	44	20	13	8
M 12	Imhoff 1 pt. Sewage 4 pts.	—	—	7/8	20° C.	139	0.97	62.37		41	43	27	27	38			
2	Imhoff	7.13	26.14	4/9	30° C.		—	—				+					
M 3	Imhoff	6.23	30.15	4/16	30° C.	205	3.47	55.71						9	5	0	
4	Imhoff	6.23	30.15	4/17	30° C.		7.92	25.75						+			
5	Imhoff	4.12	32.85	5/7	30° C.		2.87	46.48				+					
6	Imhoff	1.95	39.92	5/7	30° C.		1.46	49.92				+					
7	Imhoff	5.96	36.50	5/14	30° C.		1.81	54.13		+							
M 11	Imhoff 1 pt. Sewage 4 pts.	4.51	42.00	6/26	30° C.	216	—	—			42	12	2	4	0		
25	Imhoff 10 pts. Sewage 1 pt. 33 days	—	—	10/7	30° C.	39	2.72	53.38	39								

TABLE V.—*Continued*

Lot No.	Digestive mix	Original Per cent		Date Inoc.	Temp.	Days obs.	Final analysis Per cent		Age (days) and average per cent viable								
		Solids	Ash				Solids	Ash	1–40 avg. 22 days	40–60 avg. 43 days	60–80 avg. 70 days	80–100 avg. 92 days	100–120 avg. 109 days	120–140 avg. 128 days	140–160 avg. 146 days	160–180 avg. 168 days	180–200 avg. 189 days
9	Imhoff	9.85	37.15	5/21	R. T.	135	3.92	57.51				67	51	44			
10	Imhoff	4.85	43.53	6/21	R. T.	113	3.18	60.10			94	75	73				
13	Imhoff 1 pt. Sewage 4 pts.	3.56	42.30	6/26	G. H.	90	2.63	65.62			68	68					
15	Imhoff 1 pt. Sewage 4 pts.	—	—	7/9	G. H.	85	—	—		94	95	97					
16	Imhoff 1 pt. Sewage 4 pts.	—	—	7/9	G. H.	85	—	—		97	83	83					
17	Imhoff 1 pt. Sewage 4 pts.	—	—	6/30	G. H.	76	8.13	58.25		78	43						
26	Imhoff 10 pts. Sewage 1 pt. 31 days	—	—	10/7	G. H.	61	11.92	52.62	40	8							

contained viable eggs when its moisture content was 5.84 per cent after 81 days of drying with summer temperatures which frequently reached 115° F. in the greenhouse. However, in cakes with 3 and with 4 per cent moisture, only disintegrated ascarid eggs were found. In general, therefore, although there appeared to be variations in the resistance of *Ascaris* eggs in different sludge lots, there was a preponderance of evidence that the survival periods were such that sludge drying would not ordinarily destroy the viability of the eggs of this parasite.

As regards hookworm eggs, development was resumed as aerobic conditions were established in drying sludge. Active larvae hatched, continued development to the sheathed infective stage, and remained alive for periods up to 62 days and until the moisture content of the

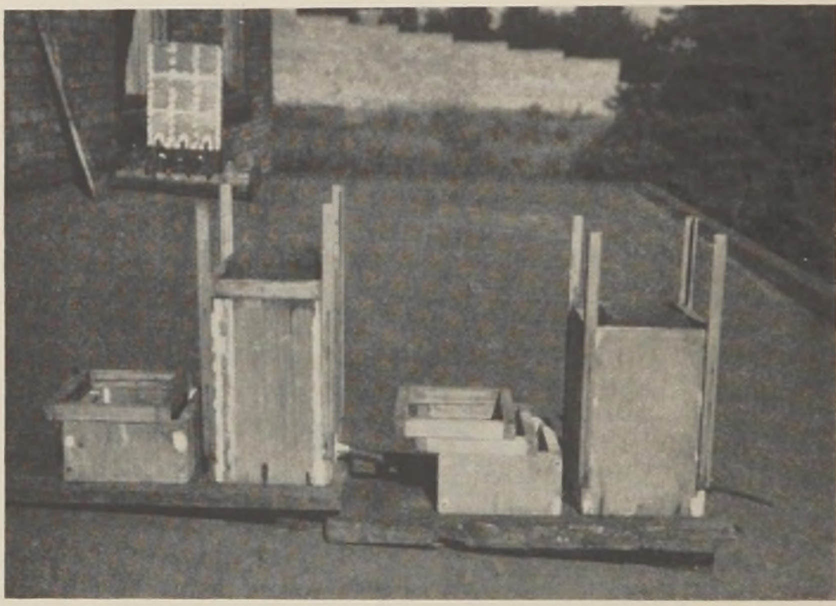


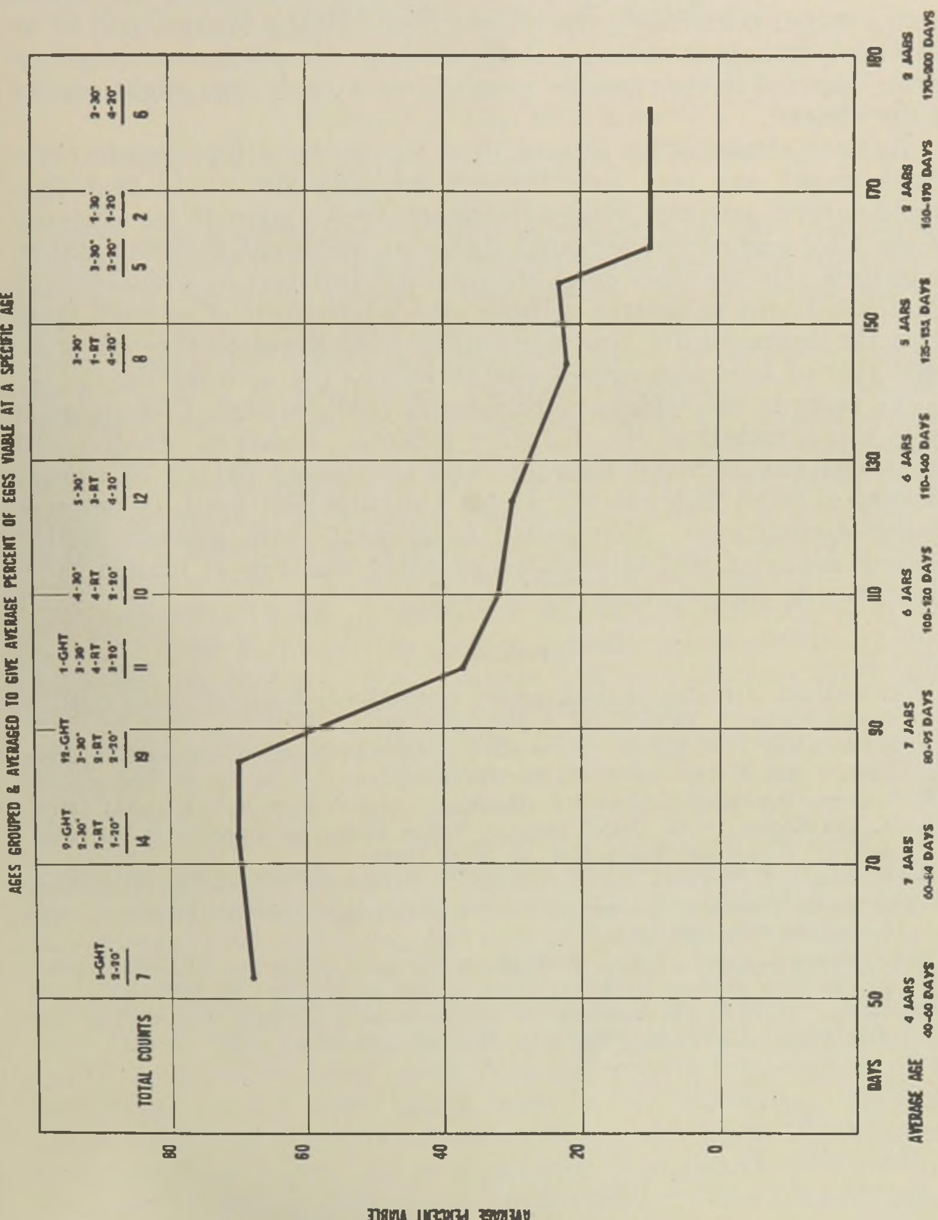
Fig. 7.—Adjustable units used for sludge drying.

sludge had dropped to as low as 9.87 per cent. The evidence indicates therefore that the usual drying of sludge could not be relied upon to kill hookworm larvae.

In tests of supplementary measures of possible value in the destruction of eggs of intestinal parasites, heating of pulverized sludge to 103° C. (217° F.) for 3 minutes destroyed 100 per cent of the *Ascaris* eggs. Fumigation of sludge cakes and of sand with gaseous methyl bromide for 24 hours appeared of limited value since it only destroyed *Ascaris* eggs which had not started development and had little effect on partially or completely developed eggs.

Summary

Under experimental conditions simulating sewage treatment processes in common use today, with inoculation of known quantities of



GRAPH 1.—Per cent viability of eggs of Ascaris lumbricoides in digesting sludge.

helminth ova and protozoan cysts representative of species of parasites of pathogenic importance to man, critical observations were made as to the survival of the ova and cysts.

Primary settling did not remove cysts of *Endamoeba histolytica* from sewage; accordingly the effluent from settling tanks would be of major importance in subsequent disposition. To a lesser extent hookworm eggs and in even smaller proportions *Ascaris* eggs might remain in the effluent.

As to treatment of the effluent, there was evidence that amoeba cysts and helminth ova may pass through trickling filters and that they would survive activated sludge treatment, irrespective of the efficiency of the filter and of the activated sludge as measured by 5-day B.O.D. reduction. On the other hand, chemical precipitation by production of alum floc during secondary settling effected removal of amoeba cysts from the liquor, as did also intermittent sand filtration through a 24-inch layer of sand at a rate of 100,000 gallons per acre per day.

As regards the sludge, there was no evidence that *E. histolytica* cysts could withstand the digestive process. However, *Ascaris* and hookworm ova survived digestion and subsequent drying of sludge. Heating of dried sludge to 103° C. for 3 minutes destroyed 100 per cent of the *Ascaris* eggs. Fumigation experiments with gaseous methyl bromide indicated that this method probably would be of limited value in destroying parasite material in sludge.

References

1. C. C. Ruchhoft. ''Studies on the Longevity of *Bacillus typhosus* (*Eberthella typhi*) in Sewage Sludge.'' *This Journal*, 6, 1054–1076 (1934).
2. C. E. Green, and P. J. Beard. ''Survival of *E. typhi* in Sewage Treatment Plant Processes.'' *Am. J. Pub. Health*, 28, 762–770 (1938).
3. E. B. Cram. ''Ascariasis in Preventive Medicine.'' *Am. J. Trop. Med.*, 6, 91–114 (1926).
4. L. W. Van Kleeck. ''The Use of Digested Sewage Sludge for Fertilizer in War Emergency.'' *Connecticut Health Bull.*, 57, 37–40 (1943).
5. W. H. Wright, E. B. Cram, and M. O. Nolan. ''Preliminary Observations on the Effect of Sewage Treatment Processes on the Ova and Cysts of Intestinal Parasites.'' *This Journal*, 14, 1274–1280 (1942).
6. C. T. Butterfield, and E. Wattie. ''Studies of Sewage Purification. XV. Effective Bacteria in Purification by Trickling Filters.'' *Pub. Health Rep.*, 56, 2445–2464 (1941).
7. E. Wattie. ''Cultural Characteristics of Zooglea-Forming Bacteria Isolated from Activated Sludge and Trickling Filters.'' *Ibid.*, 57, 1519–1534 (1942).

SOME BIOLOGICAL ASPECTS OF THE HAYS PROCESS OF SEWAGE TREATMENT

By James B. Lackey and R. M. Dixon

Senior Biologist, U. S. Public Health Service, Cincinnati, Ohio,

and

Captain, U. S. Army, Dallas, Texas

Introduction

Since 1938 a considerable number of sewage treatment plants have been constructed in the lower south central states, under the patents covered by the Hays process. This process was developed between 1930 and 1938 by Clyde Hays, City Chemist of Waco, Texas, who carried out experimental work in a small pilot plant on the grounds of the Waco activated sludge plant. The first municipal plant was constructed at Elgin, Texas, in 1939, and the number of installations has increased rapidly until now there are over seventy plants in operation, including those in Army and Navy camps. For a description of the structural details of such plants, the reader is referred to an article by Griffith (1), which also gives details of operation, and some of the difficulties encountered. An article by Kessler and Norgaard (2), deals with operation of some of the Army plants, and Hurley (3), in *The Surveyor,* looks at the process from an outside, detached point of view, and points out that the "Hays process will need to prove itself much superior to previous ventures in contact aerators."

Contact aerators have long been tried experimentally. Hurley's article lists some of the earlier trials and shows that so far, such treatment (exclusive of the Hays process) has not found wide use. One will review the literature in vain, however, for an accurate description of the biological forms and phenomena involved, and it is perhaps a lack of such knowledge plus economic considerations which is partly responsible for failure of successful application of contact aeration.

The organisms present in most types of sewage treatment plants are fairly well known, and seem to be substantially alike in similar plants. Thus Imhoff and anaerobic digesting sludge generally contains a restricted group comprising (aside from bacteria) a few small amoebas, some flagellates and about half a dozen species of ciliates. Activated sludge frequently contains branching fungi, and filamentous bacteria as *Sphaerotilus natans.* Protozoan fauna is abundant and is usually dominated by solitary, or colonial Vorticellidae. Other ciliates such as *Aspidisca, Chilodonella, Lionotus* and *Trochiliopsis* may occur in large numbers. There are few flagellate species but *Anthophysa, Monas* and *Oicomonas* sometimes abound. Amoeboid protozoa, except for the very small forms are less numerous, although the naked genera *Amoeba* and *Cochliopodium* and the shelled genera, *Arcella, Centropyxis,* *Trinema* and *Euglypha* sometimes reach high numbers. Rotifers, nematode worms and three genera of annelid worms, may likewise become very important. Trickling filters have a much greater diversity than activated sludge, and there are many members of each species. Green organisms are not found in any of these as a rule, except at the top, and on the upper part of the retaining walls.

Operation and Organisms Present

Recently an opportunity arose for detailed biological studies, correlated with some operational and performance data, on eleven Hays plants. Some of these were functioning excellently; others not so well. Fresh samples were secured at all of the plants and direct microscopic examination was carried out immediately. A compound binocular microscope was used and the material was examined at 125 and 537.5 diameters. Samples were collected from all parts of the plants visited, and film was obtained from both the upper and lower parts of the contact plates (or rock, at Elgin) by pulling up a plate, or by dewatering the aeration chamber and scraping material from the plates. It is felt that a comprehensive survey of all types of biological growths in these plants was obtained by these methods. The work was qualitative, there being insufficient time for counting the number of organisms in the film per unit area of plate surface, but an excellent relative comparison of numbers per ml. of activated sludge, Imhoff tank liquid, or standard trickling filter film was obtained.

Table I gives a summary of the organisms found at the eleven plants studied for the primary and second aerators. Some operational data are also included. There is little virtue in enumerating the organisms of incoming raw sewage, for they are few in number and act largely as seeding organisms. Furthermore, they fluctuate widely with time, surface water drainage, etc. The same is true of the organisms in the sedimentation chambers. The biological work is largely accomplished in the aerators and in the digesters, these latter to be subsequently mentioned. Therefore, it is the population of the aerators which should be immediately considered. The free liquid between the plates, at least in the secondary aerators, might be expected to have a biota comparable to that of an activated sludge plant. Actually this liquid contained very few organisms, other than bacteria; wherever flocs appeared in the effluent, such flocs were partly made up of organisms other than bacteria but there were very few free floating or swimming forms. Hence, the population listed in Table I refers almost wholly to those in the film on the plates or other parts of the aerators.

Griffith (*loc. cit.*) states that "more than thirty groups" of sewage organisms have been found. No list of these organisms has been published, hence it is not apparent whether the reference is to species of bacteria, algae, protozoa, or other organisms. However, Table I lists 69 groups, genera or species found in the eleven plants studied. For the bacteria and fungi, generic and species determinations were necessarily limited, and it is probable that a fairly large number of species could have been identified by the usual technique.

These organisms will be briefly discussed below, but it may clarify the discussion if the efficiency of the eleven plants is briefly commented upon. Plants IV, VI, VII and X were probably the best of the group. Plant X was producing an especially clear and sparkling effluent. At the time of our visit there was a small amount of suspended floc in the effluent, but the flocs were composed of zooglea and protozoa. There was an abundance of dissolved oxygen in its effluent.

Plant III was overloaded and some raw sewage was being passed directly into the second stage aerator. Plants I and V were overloaded, but doing the best work possible under the circumstances. Plants II, VIII, IX and XI were also carrying some overload and one of them was having experimental work done on it; the other some reconstruction. Figures on D.O. and B.O.D. were not immediately available for all of the plants.

The groups listed in Table I are included for a variety of reasons. *Beggiatoa alba,* the red and possibly the green bacteria, *Chromatium* and *Spirillum,* are intimately concerned with the sulfur cycle. In these particular plants, however, they are present in quantities far in excess of numbers found in other treatment plants examined by the writers. In most of the plants there was a slight green topmost zone, at or just under the water line, on all exposed surfaces. Below this for a few inches was a pink to purple zone usually completely covering woodwork, pipes, and cement. So complete was this coverage in some plants, that the color has been mistaken for paint. This red material can be pulled off in large flakes and broken into pieces resembling very stiff, dark red agar, ⅛ inch thick.

Below the pink or red zone is the zone of green bacteria; dark green to brown. These are green by reflected light; brown by transmitted light. These bacterial zones are not necessarily permanent—it remains to be seen whether they are seasonal or not. There is a possibility the bacteria of these zones are not concerned with the sulfur cycle, but in this brown zone are frequently found some of the larger colorless sulfur bacteria, especially *Chromatium.* This group rarely extends more than 6 to 8 inches down on the plates; for both the red and the green forms, light seems to be a limiting factor, but there is a lesser second possibility that more oxygen is available near the top of the aerators. *Beggiatoa* is found anywhere in the aerators, frequently forming large white patches almost at the bottom of the plates. The spirilli were common to only three plates.

Just why these plants should have such a large flora of sulfur bacteria is a puzzling question. Water supplies at some of the plants examined contain large quantities of sulfates, but at others the amounts are low. Plant VIII for example, treated water containing but 16 p.p.m. sulfates. The sewage treated is often a strong sewage, water consumption sometimes being 50 to 70 gallons per person daily. *Proteus vulgaris* and *Bacillus vulgaris,* which are putrefactive bacteria, are

TABLE I.—*Operational and Biologic Data Pertaining to 11 Hays Process Sewage Treatment Plants*

Chemical Data	I	II	III Municipal Plant	IV	V	VI Municipal Plant	VII Municipal Plant	VIII	IX	X	XI
Population (includes civilian population)	40,000	3,600		3,492	44,000			2,250	4,700	2,950	3,300
Gals. p.c.	63	48		107	75			75	41	130	52
5-day B.O.D.											
Influent	441	220		229	391			250	220	202	370
Effluent	45	62		11	93			50		4	62
Dissolved Oxygen											
Influent	0	0	0	1.86	0			0	0	0.0	0
Effluent	0	0	0	5.60	0			1.5	0	5.0	0
Suspended Solids											
Influent	312	165		65.0	478						312
Effluent	22	30		49.0	44						22

Biological Data	I P.	I S.	II P.	II S.	III P.	III S.	IV P.	IV S.	V P.	V S.	VI P.	VI S.	VII P.	VII S.	VIII P.	VIII S.	IX P.	IX S.	X P.	X S.	XI P.	XI S.
Bacteria and Fungi																						
Beggiatoa alba	f	a	f	a	c	a	a	c		c		f	a	a	c	a	c	a	a	c	a	c
Red bacteria	a	a	a	c	a	c	c	c	c	c			a	a	a	a	a		a	c	a	a
Green bacteria	c		f		f	c	c	c	c	c			a	a	a	a	a	a	a	c	a	a
Chromatium sp.	c		f	c	f	c			c				a	c					c	c	a	
Sarcina spp.	c	c											a	c								
Spirillum spp.	c										a	c					a	c				
Zooglea ramigera	c	c	a	a	a	a	a	c		c	a	a	f	c	a	a	a	a	a	a	a	a
Sphaerotilus natans			f		f	a	c		c		a	c	f	a	a	a	c	a	c	c	c	c
Fungi, unid.						f					c	c			c	a					c	

TABLE I.—*Continued*

	I		II		III		IV		V		VI		VII		VIII		IX		X		XI	
	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.
Blue Green Algae																						
Lyngbya sp.				c		c	c								c			c	a	c		
Oscillatoria sp.							c					c	f	f				a	c	c		
Phormidium sp.																		a		c	a	c
Green Algae																						
Navicula sp.				c		c	c					c			c			a	a	a	a	a
Chlorella vulgaris		a	c	c		c	c								a	c	c	c		c	a	c
Pleurococcus viridis																			c	c		c
Ulothrix zonata												c										
Carteria sp.										f												
Chlamydomonas sp.	c	c		c									f		c		a	f	c	c	a	a
Chlorogonium euchlorum															c							
Pyramidomonas sp.				c																		
Euglena agilis											a	c										
Euglena sp.															c	a						
Flagellate Protozoa																						
Bodo agilis							c														a	
Bodo caudatus	c					c	c														c	
Bodo globosus							c															
Bodo sp.													c			c						a
Hexamitus inflatus			c			c			c	c			c									
Menoidium incurvum																		c				
Monas sp.						c															c	a
Oicomonas sp.		c																				a
Physomonas vestita													c									
Polytoma uvella						c																
Spirochaeta sp.							c						c		c		a					
Tetramitus decissus	f			c			c			c											c	
Tetramitus pyriformis	f		c	c			c		c	c			a		c	f	f	c	a		c	f
Trepomonas rotans	f		c	c		c			c	c			c		c	f	f	c	a		c	f
Trigonomonas compressa			c						c	c			c		c				c		c	
Flagellates, unid.											c	c										

TABLE I.—*Continued*

	I		II		III		IV		V		VI		VII		VIII		IX		X		XI	
	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.
Amoeboid Protozoa																						
Amoeba vespertilio							c					c		c						c		
Cochliopodium bilimbosum								f				c										
Nuclearia simplex											c		c									
Hartmanella hyalina											c	c						c			a	c
Vahlkampfia albida			c		c	c	c	a					c		f			c				
Vahlkampfia guttula																	f	c				
Vahlkampfia limax							c															
Ciliate Protozoa																						
Acineta sp.												c										
Aspidisca costata											c			a						c		
Blepharisma undulans											c											
Chilodonella cucullulus												c		c								
Chilodonella uncinatus				c		c	c	a				c		c				c				
Colpoda inflata							c															
Cyclidium ecaudatum					f	f	c			a			c		c				c		c	c
Cyclidium glaucoma					f	f					c	c										
Enchelys vermicularis			c		c					c			c								c	
Epistylis sp.														a		a	f	a	a	a		
Glaucoma scintillans												c										
Hemiophrys sp.												c		c								
Lionotus fasciola												c		c						c		
Loxocephalus granulosus											c											
Metopus sp.			c		c	f			c									a		c	a	
Microthorax sulcatus							c															
Opercularia sp.					f	f					c	c			f	f			c	c		
Oxytricha sp.														c						c		c

TABLE I.—*Continued*

	I		II		III		IV		V		VI		VII		VIII		IX		X		XI	
	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	S.
Ciliate Protozoa (*Continued*)																						
Paramecium caudatum							c	a			a	a		a				a				
Paramecium putrinum																		c				
Trimyema compressa				c		c	c			c									c	c		
Vorticella sp.	f	f					a	a			a	c		c				c	c	a	a	a
Ciliates unid.						f	c	c				c								c		
Rotifers																						
Rotifera, various						f	a	a				c		c				a	c	c	c	
Nematode worms																						
Nematoda								c			c	c		c								
Annelid worms																						
Dero sp.								a				c										

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
No. species in primary aerator	13	13	12	27	9	16	20	19	13	21	24
No. species in secondary aerator	8	14	24	13	13	27	20	31	24	25	20
No. species in both	15	20	25	29	16	31	32	21	26	29	29

Symbols P and S refer to the primary and secondary aerators.
Small a means abundant or numerous.
Small c means less abundant, but still common.
Small f means few.

aerobes and reduce sulfur in the presence of oxygen; but whether there was a pronounced odor of H_2S at a plant or not, the sulfur bacteria were common to all but one of the eleven plants. Ellis (4) considers this group capable of utilizing organic compounds but states that they are facultative and not obligate autotrophs. Regardless of whether they themselves utilize the organic compounds in the sewage, or whether they utilize CO_2 and H_2S produced by such forms as the putrefactive bacteria mentioned above, there is no doubt that these treatment plants represent a favorable environment for them, and that they deposit considerable amorphous sulfur, clearly recognizable, in the film on the plates.

Recognizable colonies of zooglea were found at all of the plants. In general, where they are listed as abundant at the plants giving poor results their greatest numbers were in the upper 8 inches of the aerators. The very large size of the colonies was noteworthy in some cases. *Sphaerotilus* was erratic in distribution and likewise the single unidentified fungus which was encountered several times.

These findings relative to the bacterial flora (no other fungi were found in any quantity) are not in accord with the statement of Griffith, nor with the statement of Hays (5) that nitrification proceeds in the plants. There is no doubt that putrefaction occurs; that elemental sulfur is produced, as well as H_2S. But in view of the actual increase of ammonia in some of the plants, it is doubtful if the carbon and nitrogen cycles are carried to completion. A recent report by Fix (6) indicates that nitrification does not occur in Plant IV.

Blue green algae were surprisingly scarce; it was expected that the upper surfaces would be coated, but instead, only a few patches, usually toward the effluent end, were found. The only diatoms seen were a small *Navicula,* present in the upper green-brown area. A few filaments of the green alga *Ulothrix* were found in one plant; *Pleurococcus* was rare, but *Chlorella* occurred with some constancy, occasionally in abundance, in the upper zones. Only four green Volvocales were found, even *Chlamydomonas* being present only half the time. The Euglenophyceae were very few. Altogether the green algae and flagellates were decidedly a minor part of the population.

The protozoa were much more abundant than algae. For example, 16 species of colorless flagellates (*Mastigophora*) were found. Figure 1 shows the four most abundant species. These are species which are tolerant of an oxygen-poor, H_2S containing, organic medium. They have been characterized as Imhoff tank flagellates, and are able to live in the absence of all dissolved oxygen. But whereas they are relatively few in numbers in most Imhoff tanks, in some of the Hays plants examined they were present in vast numbers. These flagellates, with a few other organisms, formed thin grey coatings on the plates in the primary aerator in Plant II.

Why these flagellates should be so abundant is not understood at present. Very little is known of their food habits. Sandon (7) con-

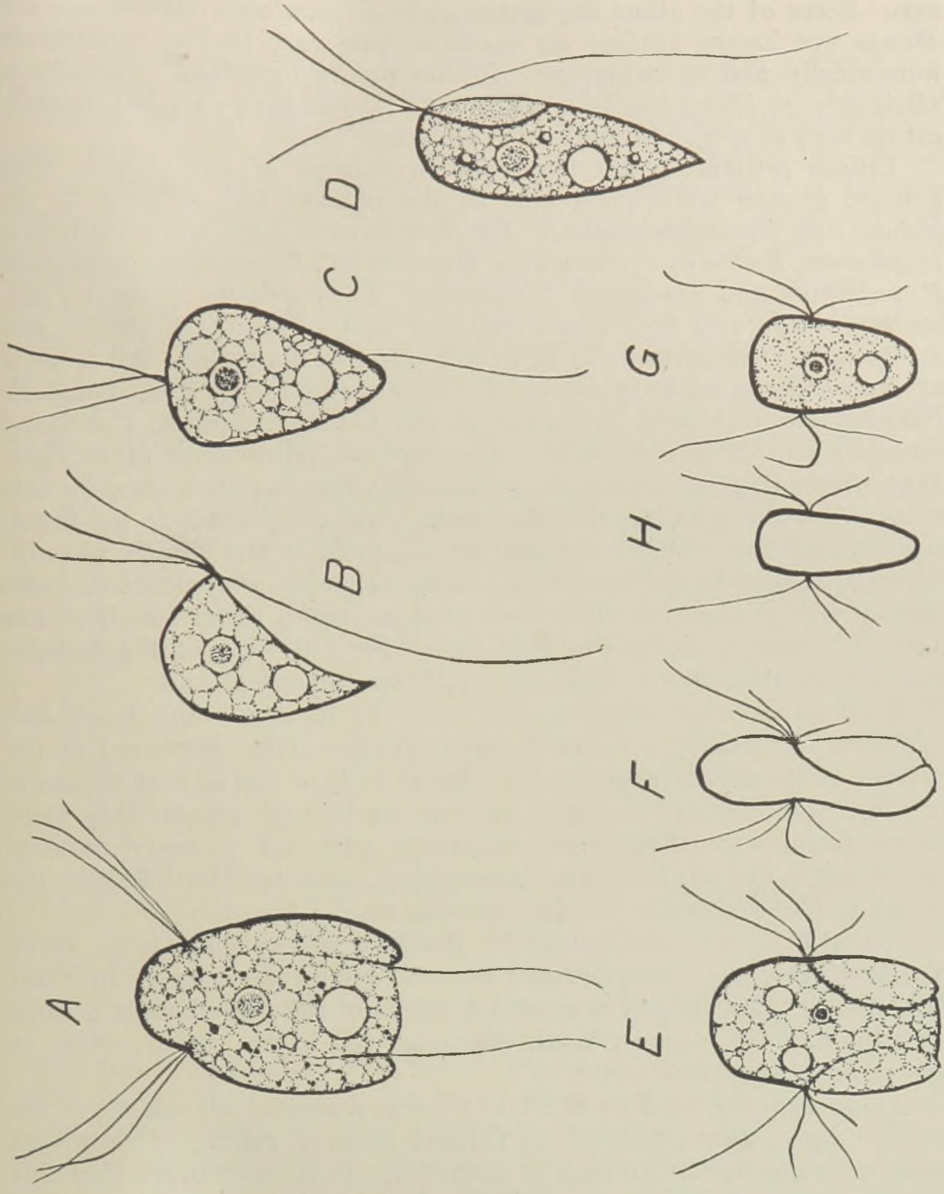


FIG. 1.—A. *Hexamitus inflatus.*
B. *Tetramitus pyriformis,* lateral view.
C. *Tetramitus pyriformis,* front view.
D. *Tetramitus decissus.*
E. *Trepomonas agilis,* front view.
F. *Trepomonas agilis,* side view.
G. *Trigonomonas compressa,* face view.
H. *Trigonomonas compressa,* side view.

siders that this group eats bacteria, but says that Hegner considers one of them (*Hexamitus*) saprophytic. There should be an abundance of dissolved organic matter available in such an environment, and their abundance indicates they function to some extent in purifying the sewage. Some of the other flagellates as *Bodo caudatus, Oicomonas* and *Monas* are known feeders on bacteria, but were of less importance numerically and in occurrence, in the plants examined. *Oicomonas* (*Oikomonas*) *termo* has been shown (8) also to thrive on rich organic media such as might be available in sewage.

Ciliate protozoa were abundant in several of the plants. Two general groups were observed. In the influent end of most of the plants, and throughout others, the dominant ciliates were *Cyclidium ecaudatum, Enchelys vermicularis, Metopus* sp., *Paramecium caudatum, P. putrinum* and *Trimyema compressa.* These ciliates (except *Paramecium caudatum*) are characteristic of foul, oxygen-free waters, and are generally recognized (9) in Imhoff tanks or digesters. All of them are known to be bacteria eaters, and they rarely attain great numbers. *Paramecium* was most abundant in the plants examined, *Cyclidium ecaudatum* next, then *Metopus. Paramecium,* however, is often abundant where there is dissolved oxygen, being unlike the others in this respect. Although their size may make them comparable to the flagellates in numbers, it appeared as if both flagellates and ciliates were ineffective in keeping down bacterial numbers, unless they decimated certain species of bacteria which they used as food. Other functions are difficult to ascribe to the protozoa, but Jager (10) claimed the flocculation of colloids as one function, certainly an important one.

Most of the other ciliates, dominated by *Epistylis* and *Vorticella,* might be termed the activated sludge group. They appeared at the surface of the aerators, and at the effluent ends of one or both aerators. If there was dissolved oxygen present, as in four plants, they were found throughout the plants, beginning with the primary aerator. Often they appeared in enormous numbers, and served both to keep the bacteria in check and to clarify the effluent.

Nematoda were unimportant. Rotifera were common in seven plants, in the same situations as the last group of ciliates. In Plant IV, however, they helped to cover the plates of the second stage aerator with the densest animal growth ever observed by the senior author in any sewage treatment plant.

Along with the rotifers in Plant IV was a similar abundance of the annelid worm *Dero,* which here formed balls of entangled worms as much as a quarter of an inch in diameter. It is noteworthy that this plant was satisfactory in operation. It is quite evident that unless there is a good population of oxygen-consuming, bacteria-eating animals at least toward the effluent end of these installations, they will not produce a satisfactory effluent.

Sludge from the digesters invariably showed an abundance of free-living bacteria, but visually not the types present on the plates; anaerobic flagellates dominated by the species discussed above but with an occasional unidentified type; and the anaerobic ciliates also discussed above. *Paramecium,* however, was not found in any of the digesters. Either it does not tolerate H_2S, or it requires some free oxygen.

Discussion

One of the claims of the Hays process is that it makes use of organisms tolerant of very foul water at the influent end and that there is a transition through the plant until at the end organisms tolerant of only clean water thrive and work. Such a gradient has indeed been found, but it appears to be different from the one visualized. In the first place, sharply limited flora and fauna has been found, falling far short in number of species from what would be found traveling down a stream from a point of gross pollution to one where the stream is clean. This difference, however, is not necessarily an adverse one, for a biological cycle can be carried out by large numbers of a few species possibly as well as by small numbers of many species.

The organisms do not seem, however, to be those postulated for the various stages in Hays plants. The only filamentous organisms en-

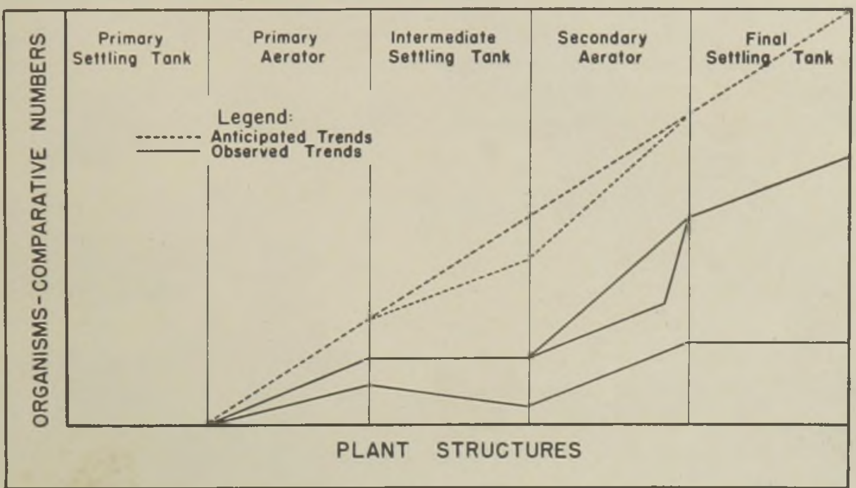


Fig. 2.—Trends of aerobic organisms.

countered were two bacteria, one of which (*Beggiatoa alba*) is apparently rather restricted in its metabolism to the sulfur cycle. The other, *Sphaerotilus natans,* is likewise restricted as far as research shows, to the carbon cycle, and furthermore is one of which most sewage men speak unkindly if not obnoxiously. Some of the remaining bacteria are, of course, putrefactive, but many others are likewise concerned with the sulfur cycle. *Zooglea,* that oxidizing genus so prominent in other types of sewage treatment works, was found abundantly in only a few of these plants and then only in the second stage aerators. The nitrifying bacteria, if one may judge from the usual lack of oxygen in the environment and from the figures on ammonia, were not likely to be very active, if present. The report by Fix (*loc. cit.*) bears this out.

Chlorophyll-bearing plants were negligible, being confined, when present, to a very narrow zone at the very top of the aerators. Finally, the animals showed a very peculiar distribution as a whole. A few species were abundant. As shown above, anaerobic forms were dominant at the influent end, being present to some extent in the raw sewage, the primary settler, and the first stage aerator. With successful utilization of the air, these forms should have been replaced by the aerobic animals, beginning in the primary aerator.

Such a replacement was not found in its entirety. In all of the plants examined, anaerobic animals were recoverable from the second stage aerator and from the final settling tank. It is true that they were not found in the free liquid of the final aerators of three plants, but they were found in the final settling tank and flocs secured from these

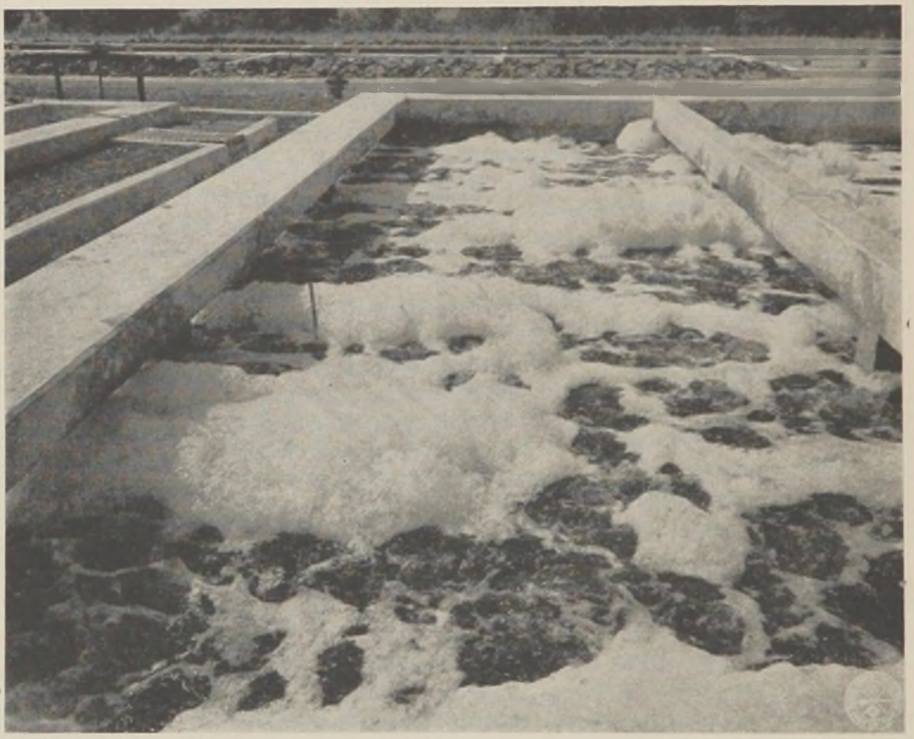


FIG. 3.—Surface of an aeration tank at an Army plant showing the distribution of air and the frequently characteristic foam.

last tanks frequently contained great numbers, especially of *Tetramitus* and *Trepomonas* in their interior. Had the material comprising these flocs been well oxidized, this should not have been the case. It has been found that the B.O.D. of the sludge at Plant V is high, indicating that the flocs are *not* well oxidized.

In those cases where replacement of anaerobic forms started in the primary aerator, there was invariably no increase or even a decline in the second settling tank. Figure 2 shows the trends expected and encountered with regard to the aerobic animals. The dotted lines represent the expected trends for aerobic animals in the five sections of the plant, the upper course being followed if aeration is completely successful. The solid lines represent three conditions actually found. The upper course was true for two plants; the middle course for two; and the lower course for six. For one plant, V, practically no aerobic animals were found, hence the solid line would be lacking.

There seemed to be two reasons for the conditions encountered; overloading and poor utilization of air. Relative to overloading, some of the incoming sewages showed 5-day B.O.D. figures as high as 449 p.p.m. for a 24-hour composite sample and 684 p.p.m. for peak strength. Without an increased detention period, it is apparent that overloading must result. How much the detention time should be increased appears to be an experimental matter.

The air seemed to be sufficiently abundant, and usually fairly well distributed, although here and there dead areas were to be seen. Figure 3 shows a section of the primary aerator at Plant V, bearing out this statement. The air was admitted to the tanks, however, through orifices ⅛ inch in diameter and there was an immediate rush to the top in large bubbles; both the size of the bubbles and their upward speed cut down the surface area and time for absorption. The result was oxygen starvation in the midst of plenty.

Summary

1. Detailed biologic examination correlated with an examination of construction and operational data was made for eleven Hays process sewage treatment plants.

2. All organisms found, exclusive of some bacteria, were identified and relative abundance noted. Seventy-one species, genera or distinct groups of microscopic organisms were found.

3. Four of the plants examined were producing an effluent which contained dissolved oxygen, was clear, contained few suspended solids, and had a relatively low five day biochemical oxygen demand.

4. In these four plants protozoa, rotifers, worms (in two of the four plants) characteristic of good activated sludge, or standard trickling filters, were found in abundance, in a film on the vertical plates or other contact surfaces.

5. Seven of the plants showed either no dissolved oxygen or a trace. The one showing a trace contained it at the effluent end of the secondary aerator.

6. In these seven plants the dominant protozoa consisted of five genera of ciliates and four genera of flagellates. Practically no amoeboid protozoa, rotifers or worms were present. All of these are characteristic of Imhoff tanks or foul waters of low oxygen tension and usually some hydrogen sulfide.

7. This same group, except *Paramecium,* was abundant in the digesters.

8. The biologic composition of the film in seven plants indicated insufficient utilization of, or access to, air despite the large quantities being bubbled up between the contact plates.

9. No biologic growths from plate to plate were found. The only filamentous organisms found in any abundance were sulfur bacteria of the genus *Beggiatoa,* and *Sphaerotilus natans.* Tufts of these were invariably free at one end.

10. Great quantities of sulfur bacteria, both pigmented and colorless, were characteristic of all eleven plants, but the significance of their abundance was not determined.

References

1. ''Contact Aeration for Sewage Treatment.'' Llewellyn B. Griffith. *Eng. News Record,* 130 (4), 138–142 (1943).
2. ''Operation of Army Sewage Treatment Plants.'' Lewis H. Kessler and John T. Norgaard. *This Journal,* 14 (6), 1228–1263 (1942).
3. ''Contact Aeration for Sewage Treatment.'' John Hurley. *The Surveyor,* 102, 183–185 (1943).
4. ''Sulphur Bacteria.'' A Monograph. David Ellis. Longmans, Green & Co., New York, N. Y. (1932).
5. ''Tentative Operation Instructions for Hays Submerged Biological Contact Filter Sewage Treatment Plants.'' Clyde C. Hays. Mimeographed. (1941.)
6. Privately prepared report for the Texas State Department of Health. Robert W. Fix.
7. ''The Food of Protozoa.'' H. Sandon. *Pub. Faculty Science,* The Egyptian Univ., I, 1–187 (1932), Misr-Sokkar Press, Cairo, Egypt.
8. ''An Investigation of the Physiological Requirements of a Pure Culture of the Heterotrophic Flagellate Oikomonas termo Kent.'' Garrett Hardin. *Physiological Zoology,* 15 (4) 466–475 (1942).
9. ''Die Ciliatenfauna der Emscherbrunnen.'' Hans Liebmann. *Zeits. Hyg. u. Inf.-Krankh.,* 118, 555–573 (1936).
10. ''Purifying Action of Pure Cultures of Protozoa on Domestic Sewage.'' C. Jager. *Zeits. Hyg. u. Inf.-Krankh.,* 120, 620–625 (1938).

REDUCTION OF MOISTURE IN ACTIVATED SLUDGE FILTER CAKE BY ELECTRO-OSMOSIS

By Robert E. Beaudoin

Senior Sanitary Chemist, Sanitary District of Chicago

In the disposal of activated sludge at the Southwest Treatment Works of the Sanitary District of Chicago, the sludge is treated with ferric chloride and filtered on rotary filters to a moisture content of from 80 to 85 per cent. This filter cake is mixed with dry sludge to give it better drying properties and is dried in a flash dryer. Table I shows that a filter cake of 85 per cent moisture contains nearly six tons of water per ton of dry solids; nearly a ton of coal is required to evaporate this water, not to mention the mechanical power necessary to handle such a large bulk of material. An excellent discussion of the arithmetic involved in producing one ton of dry solids from raw sewage is given by Genter (1). The present study was undertaken to find out whether the moisture content of the filter cake produced with ferric chloride could be further reduced by application of an electric current.

Table I

Solids Per Cent	Water Per Cent	Sludge to Make One Ton of Dry Solids	Tons of Water Removed for Each 1 Per Cent Drop	Required Coal, in Tons [a]	Cost, in Cents [b]
10	90	20,000 lb.			
11	89	18,181	.9095	.1516	53.06
12	88	16,666	.7575	.1262	44.17
13	87	15,385	.6405	.1067	37.35
14	86	14,285	.5520	.0917	32.09
15	85	13,333	.4760	.0793	27.76
16	84	12,500	.4165	.0694	24.29
17	83	11,764	.3680	.0613	21.42
18	82	11,111	.3265	.0544	19.04
19	81	10,526	.2925	.0487	17.05
20	80	10,000	.2630	.0438	15.33
21	79	9,524	.2380	.0397	13.90
22	78	9,090	.2170	.0362	12.67
23	77	8,696	.1970	.0328	11.48
24	76	8,333	.1815	.0302	10.57

[a] These figures assume that one ton of coal will evaporate six tons of water.

[b] Also assumes cost of coal is $3.50 a ton.

The coagulation of activated sludge by means of electric current has interested a number of investigators. A recent work by Slagle and Roberts (2) showed some measure of success, but despite its many drawbacks ferric chloride as a coagulant is still the best available.

Theory

The exact mechanism of the coagulation of activated sludge is not entirely clear. From work in colloid chemistry in other fields certain things about activated sludge coagulation have been assumed by analogy, but so far as the author knows, actual work on the theory of the mechanism involved is limited. Some of the fundamentals of colloid chemistry are here reviewed so that the work of this experiment may be clearer. The material given here is sufficient to explain the experimental part of this paper, but it is not intended as a complete explanation of the coagulation of activated sludge by ferric chloride. A more complete discussion of adsorption phenomena is given by Genter (3) in his paper on the elutriation of sludge. Two sentences from his paper might well be quoted here. First, "Flocculation is akin to chemical precipitation, however it is only a boundary relationship." Second, "Neither the reaction or the floc produced can be explained by any stoichiometric formulae."

Wilson (4) presents four points about ferric chloride coagulation which must be remembered. Wilson says, "Ferric chloride exerts a beneficial oxidizing action, it acts as a tanning agent, the chloride ion acts on the sludge increasing its capacity to take up iron, and the ferric chloride hydrolyses, furnishing hydrochloric acid to reduce the sludge to its iso-electric point." These quotations from the work of Genter and of Wilson are brought in at this point as a reminder that sludge coagulation is not entirely an electrical process, as might be inferred from the following paragraphs, but is a combination of chemical, electrical and other forces not yet clearly understood.

The particles of a colloidal solution may adsorb ions of electrolytes present in a dispersion medium and become electrically charged. The colloid solution may possess a higher conductance than the dispersion medium alone and the particles will behave like ions and will migrate through the solution under an impressed e.m.f. This electrical migration is called cataphoresis and has been observed with activated sludge under a microscope. If the particles are closely packed so that they cannot move, as in a plastic clay, then an applied e.m.f. will cause the liquid to move through the porous mass. This is called electrical endosmosis. The principle is the same in both cases so they are classed together as electro-osmosis.

When a suspensoid is treated with an electrolyte the two ions of the electrolyte will be adsorbed by the suspended particles, but both ions will not be adsorbed to the same extent. Proof of this is fairly well established. An explanation of this phenomenon can be found in modern colloidal chemistry textbooks under discussions of the Helmholtz (5) double layer theory and the further work of Gouy (6) and Freundlich (7) on the diffuse double layer. As the concentration of the electrolyte is increased a range will be reached where the original charge on the colloid will be neutralized by the adsorption of the oppositely charged ions of the added electrolyte and coagulation takes place.

Applying this principle in the case of activated sludge, which is negatively charged, and ferric chloride consisting of Fe^{+++} and Cl^{-}, both ions are adsorbed, but the Fe ion is adsorbed to a greater extent. Within a certain range of concentration, the positively charged Fe^{+++} ions neutralize the negative charge on the colloid, and coagulation takes place. Schulze's Law (8) states that the coagulating powers of electrolytes increase as a rule with increased valence of the active ion. Hence ferric chloride having Fe^{+++} of valence 3 is a better coagulant than NaCl, for example, with Na^{+} of valence only 1.

If more than the optimum amount of electrolyte is added the colloid is again stabilized, but its particles have charges of the opposite sign. The coagulation of suspensoids by electrolytes is reversible, so that when the adsorbed electrolyte is washed out the suspensoid re-disperses. Coagulation of a suspensoid does not take place at any particular point, but rather over a range of concentration of electrolyte. Coagulation over a range of concentration is characteristic of activated sludge.

At the Sanitary District Southwest Plant, daily tests are made to determine which of several concentrations of ferric chloride produces the best coagulation. This neutralizing or decreasing of the potential difference (charge on the particle) between the particle and the liquid by means of an electrolyte can be graphically illustrated as in Fig. 1. The actual measurement of the potential difference between the liquid and the particle is a problem for the colloidal chemist and was not attempted here.

Experimental

Before a number of experiments were made to determine whether electro-osmosis might be practical in removing water from filter cake, certain preliminary tests were made to see if the facts fit the theory. A sample of activated sludge was coagulated with ferric chloride and the pH at which coagulation took place was noted as about 3.5. More ferric chloride was added and the sludge re-dispersed. At this point the pH was about 2.7. Sodium hydroxide was added and as the pH increased to 3.5 coagulation again took place. Further addition of sodium hydroxide to bring the pH to 5.0 caused re-dispersion. Apparently as long as an excess of iron is present the coagulation of sludge is dependent on pH. In the above case a delicate balance between Fe, Na, Cl, and H ions and the negative colloid seems to exist.

To fit the theory to the above action we must take it step by step. To a negative colloid ferric chloride is added. The Fe^{+++} and Cl^{-} ions are adsorbed, more Fe^{+++} being adsorbed than Cl^{-}. At the coagulation point the Fe^{+++} charges neutralize the colloid charges. This coagulation point is not sharply defined but is over a range of ferric chloride concentration. Further addition of $FeCl_3$ causes more Fe^{+++} and Cl^{-} ions to be adsorbed as before, but since the adsorbed layer becomes thicker the charge on the particle becomes positive, which is the charge on the predominating ion. When NaOH is added, part of the HCl from the hydrolysed $FeCl_3$ is neutralized, permitting some of the adsorbed outer layer of $FeCl_3$ to be washed out thus reducing the positive charge on the particle and a range is reached where coagulation again takes place. Further addition of NaOH removes more of the adsorbed $FeCl_3$ layer until the particles are again re-dispersed and become negatively charged. This coagulation, re-dispersion, coagulation, re-dispersion cycle was actually produced as stated above.

The question of change of the charge on the particle still remains to be proven. The phenomenon of cataphoresis or migration of the particles of activated sludge under an impressed e.m.f. must be observed

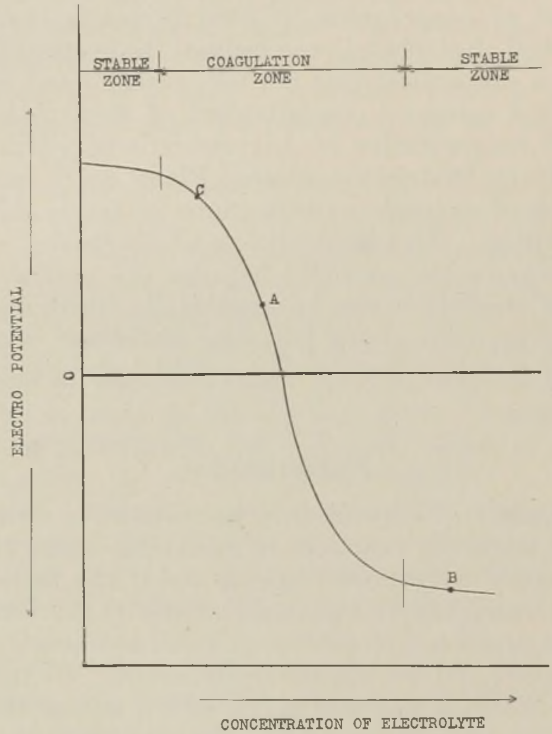


Fig. 1.

under a microscope, or by a method requiring a long period of time. However, it was found that the counterpart of cataphoresis, namely electro-osmosis, is more readily demonstrated. When sludge is coagulated with ferric chloride and filtered the charge on the particle remains negative up to a certain concentration, as stated above (see Fig. 1). A sample of sludge was coagulated with $FeCl_3$ (pH 3.5) and filtered and when a direct current was passed through the filter cake, water, in noticeable amount, appeared at the negative pole and the cake dried at the positive pole. This would indicate a condition corresponding to point A in Fig. 1. This cake was then mixed with considerably more ferric chloride (to pH 1.9) and re-dispersed, then filtered again. It filtered more slowly this time. A direct current was again passed through the cake and this time the water appeared at the positive pole. This would indicate that a point at the right end of the curve, point B in Fig. 1, was reached. This cake was again mixed with tap water (to pH 4.5) to wash out the excess $FeCl_3$, and filtered. Again a direct current was passed through the cake and water appeared at the negative pole as in the first cake. This would indicate a return to point C. Thus we find the coagulation of activated sludge by $FeCl_3$ obeying all the laws of coagulation as discovered in other fields of colloid chemistry, at least as far as electric charges are concerned.

Laboratory Application of Electro-endosmosis

Before describing the laboratory experiments, a brief reference to a similar use of electro-osmosis on a commercial scale will be made. At least five German patents (9), the earliest in 1903, have been issued covering a process for removing water from kaolin and from peat. The kaolin paste is placed between two electrodes and the solid kaolin particles act as a stationary membrane, while the water in the capillaries migrates to the negative pole when current is applied.

In the present experiments, a sample of filter cake from the rotary filters was laid over a filter paper in a perforated aluminum dish. A wire screen just large enough to cover nearly all of the cake, but small enough so as not to touch the sides of the dish, was laid on top of the cake. This was placed in a Buchner funnel and suction applied. The positive pole of a d.c. circuit was touched to the wire screen and the negative pole to the aluminum dish. In a short time enough water was released to thoroughly soak the filter paper and wet the under side of the dish, but not enough to be drawn away by the suction. As soon as the current was shut off the water was re-absorbed into the cake. The Buchner funnel apparatus was too slow and there were too many leaks, so a better arrangement was made by using a tinned paint can cover, which was perforated and fastened over the top of a glass funnel with shellac. This was used in place of the Buchner funnel. A bronze plate 3¼ inches in diameter was used as the positive electrode. The perforations in the tinned filter plate covered about the same circular area as the bronze electrode. A small bolt was soldered to the bronze plate so that electrical clips could be used to insure better contact. Some of the first tests were made by touch contact using carbon poles, but these results were not consistent and are not shown in the table. The diagram in Fig. 2 shows a carbon electrode 2½ inches in diameter in place of the bronze electrode, but the other items are as shown. Filter cake from the rotary filters was cut into circular pieces the size of the bronze plate. The cake varied in thickness from ¼ to ⅜ inch. After weighing, the cake was placed over a damp filter paper on the perforated funnel, the bronze plate was placed over this and connections made as shown in the diagram (Fig. 2). Current and suction was applied for a definite period of time measured by a stopwatch. After treatment the cake was again weighed, then dried and weighed again.

Data were recorded as shown in Items 1 to 4, 8, 14, 15 in Table II. The remaining items can be calculated from these data. Item 9, the watt minutes, is the product of time, volts and average amperes. Theoretically as the water is removed the resistance of the cake in-

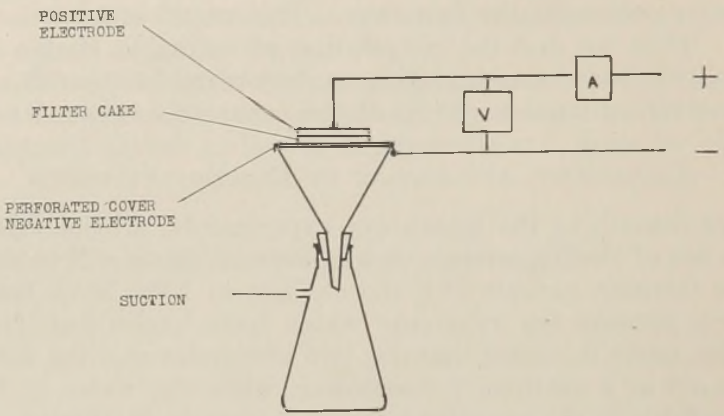


Fig. 2.

creases and the current drops. Since a larger amount of water is removed in going from 85.3 to 84.3 per cent moisture than is removed in going from 82.1 to 81.7 per cent moisture the current drop between the lower percentages is less than that occuring while the first water is being removed. In the actual experiments this was noticed, and in

Table II

1. Plate with sludge before	202.14 grams
2. Plate with sludge after	194.49
3. Plate with sludge dry	169.48
4. Plate alone	163.87
5. Grams of solids (*G*)	5.61
6. Per cent moisture in original cake	85.3
7. Per cent moisture in cake after treatment	81.7
8. Current in amperes	1.1–0.7
9. Watt minutes (*W*)	18
10. Kilowatt hours per ton of dry solids	48
11. Tons of water removed per ton of D. S.	1.33
12. Tons of coal required to evaporate water	.22
13. Cost of coal at $3.50 per ton, dollars	.77
14. Voltage	20
15. Time current applied in minutes	1

several cases a note of the current flow at the half period was recorded. In one example the initial current was 1.40 amperes at the start, 1.15 amperes after one-half minute and 0.95 amperes at the end of one minute. The drop during the first half minute was 0.25 ampere and during the second half only 0.20 ampere. Since this refinement is greater than the accuracy of the experiment it was decided to use the average amperage. Item 10, the k.w.h. per ton of dry solids, is calculated from the following formula:

$$\frac{W \text{ (watt minutes)} \times 2{,}000}{G \times .002205 \times 60 \times 1{,}000}$$

(.002205 is the factor for converting grams to pounds)

The above formula simplifies to $15.11W$ divided by G.

Item 11, the tons of water removed per ton of dry solids, is calculated from the moisture content before and after treatment. Thus in the example given in Table II, one ton of dry solids can be produced from 2,000 divided by (1 — .853) lb. of cake and likewise a ton of dry solids can be produced from 2,000 divided by (1.00 — .817) lb. of treated cake. The difference between these figures divided by 2,000 gives the tons of water removed per ton of dry solids.

It is estimated that under good operation in our plant one ton of coal will evaporate six tons of water. Item 12 then is one-sixth of item 11, and since the cost of coal is around $3.50 a ton, item 13 is 3.5 times item 12.

Current density is obtained by dividing the current in amperes by the area of the positive electrode, which in the case of the bronze electrode (tests 1 to 10) was 8.29 square inches. The carbon electrode (tests 11 to 39) had an area of 4.91 square inches.

Table III shows the results obtained by varying the voltage and time periods. For simplification the weights of the plate and sludge are omitted and only the average amperage is shown. In no case was the drop in amperage more than a few tenths during the time allotted.

When using a bronze plate for an electrode, the electrode lost a little weight during each test. In order to be sure that it was not further chemical coagulation caused by copper ions which released the water, the later tests, numbers 11 to 39, were made with a carbon electrode.

The possibility that heating effects produced by the electric current might have caused the release of water was also considered. Since it was not practical with the apparatus available to measure the temperature rise in the cake, a sample of cake was placed on the funnel over suction and heated in a 100° C. oven. No water was released except that which evaporated. A similar test using an electric hot plate placed on the filter cake (in place of the positive electrode) as a source of heat was tried. The cake dried, but no water was released.

Discussion

Since in this experiment the first common denominator, between k.w.h. per ton of dry solids and water evaporated per ton of dry solids, is dollars and cents, it was necessary to make all the above calculations in order to form a basis for comparisons. If we assume that one k.w.h. will cost one cent, which is a convenient and reasonable figure,

TABLE III

	Test No.	5 Grams of Solids, G	6 Moist. Before Treatment, Per Cent	7 Moist. After Treatment, Per Cent	8 Current in Amperes	9 Watt Minutes, W	10 K. W. H. Per Ton of Dry Solids	11 Tons of Water Removed Per Ton of Dry Solids	12 Tons of Coal Required	13 Cost of Coal at $3.50 Per Ton	14 Voltage	15 Time in Minutes	16 Current Density, Amperes Per Sq. In.
Bronze Electrode	1	5.55	86.0	83.9	1.15	23	63	0.93	0.15	0.53	20	1	0.139
	2	4.98	85.3	83.6	0.40	8	24	0.70	0.12	0.42	20	1	0.048
	3	5.61	85.3	81.7	0.90	18	48	1.33	0.22	0.77	20	2	0.109
	4	4.64	83.5	81.3	0.35	7	22	0.70	0.12	0.42	20	2	0.042
	5	4.63	83.4	79.8	0.60	24	78	1.00	0.16	0.56	20	2	0.072
	6	4.71	83.4	79.6	0.60	24	77	1.10	0.18	0.63	20	2	0.072
	7	5.34	83.2	77.0	0.70	28	79	1.60	0.27	0.94	20	2	0.084
	8	5.35	83.0	78.0	0.70	28	79	1.30	0.22	0.77	20	2	0.084
	9	5.34	82.3	80.3	0.80	32	90	0.50	0.08	0.28	20	2	0.096
	10	5.40	82.1	77.3	0.90	45	126	1.10	0.18	0.63	25	2	0.109
Carbon Electrode	11	3.37	83.0	75.3	0.60	30	135	1.83	0.31	1.08	25	2	0.122
	12	3.48	83.3	76.3	0.60	30	130	1.77	0.33	1.05	25	2	0.122
	13	3.33	82.6	75.4	0.60	30	136	1.68	0.28	0.98	25	2	0.122
	14	3.48	82.7	75.4	0.60	30	130	1.71	0.29	1.02	25	2	0.122
	15	3.38	82.5	74.0	0.80	40	179	1.86	0.31	1.08	25	2	0.163
	16	3.74	84.2	78.9	0.60	30	121	1.59	0.26	0.91	25	2	0.122
	17	3.57	85.6	77.9	0.90	45	119	2.42	0.40	1.40	25	2	0.183
	18	3.55	83.2	76.6	0.80	40	170	1.68	0.28	0.98	25	2	0.163
	19	4.22	82.4	79.4	0.80	40	143	1.25	0.21	0.74	25	2	0.163
	20	4.71	82.6	76.7	0.90	45	144	1.45	0.24	0.84	25	2	0.183
	21	4.36	84.1	79.9	1.28	32	111	1.31	0.22	0.77	25	1	0.261

TABLE III.—*Continued*

	Item No.												
		5	6	7	8	9	10	11	12	13	14	15	16
	Test No.	Grams of Solids, *G*	Moist. Before Treatment, Per Cent	Moist. After Treatment, Per Cent	Current in Amperes	Watt Minutes, *W*	K. W. H. Per Ton of Dry Solids	Tons of Water Removed Per Ton of Dry Solids	Tons of Coal Required	Cost of Coal at $3.50 Per Ton	Voltage	Time in Minutes	Current Density, Amperes Per Sq. In.
Carbon Electrode	22	3.97	84.3	80.2	1.12	28	107	1.32	0.22	0.77	25	1	0.228
	23	3.98	84.8	81.7	0.98	25	95	1.11	0.18	0.63	25	1	0.200
	24	3.21	84.7	81.8	0.88	22	104	1.09	0.18	0.63	25	1	0.179
	25	4.46	84.2	81.5	0.83	21	71	0.92	0.15	0.52	25	1	0.169
	26	4.46	84.1	80.0	0.92	23	78	0.98	0.28	0.98	25	1	0.187
	27	3.67	82.9	78.7	0.80	20	82	0.67	0.19	0.67	25	1	0.163
	28	5.27	82.6	77.6	0.90	72	207	1.20	0.20	0.70	40	2	0.183
	29	5.27	81.8	74.4	1.00	80	229	1.50	0.25	0.88	40	2	0.204
	30	4.16	86.6	76.9	2.20	100	400	3.18	0.53	1.85	50	1	0.448
	31	4.16	84.8	77.7	1.80	90	327	2.09	0.35	1.23	50	1	0.367
	32	4.18	85.0	76.7	2.20	110	398	2.38	0.40	1.40	50	1	0.448
	33	4.06	85.3	75.4	2.30	115	428	2.74	0.46	1.61	50	1	0.469
	34	4.42	85.2	75.6	2.50	125	427	2.66	0.44	1.54	50	1	0.509
Digested Sludge	35	5.96	79.4	73.4	0.90	45	114	1.09	0.18	0.63	25	2	
	36	7.41	80.8	74.4	0.90	45	92	1.30	0.22	0.77	25	2	
	37	7.51	80.6	75.4	0.90	45	91	1.05	0.17	0.60	25	2	
	38	8.34	81.1	77.8	0.60	30	54	0.79	0.13	0.46	25	2	
	39	9.84	84.5	82.3	0.90	45	69	0.80	0.13	0.46	25	2	

then the k.w.h. per ton of dry and the coal cost in cents per ton are on common ground.

At first there seems to be no connection between the various facts found, but it must be remembered that a large number of uncontrollable factors entered into the experiment. The amount of ferric chloride in each piece of cake varied, which, as can be seen from Fig. 1, changed the divergence from the isoelectric point. The amount of surface in contact with the electrode varied due to the uneven cake. Some of the filter cakes had cracks in them and were not continuous and others had large pieces of foreign matter such as small pebbles. A difference in the amount of pressure put on the cake caused a variation in the current flow. Only by a larger scale experiment can the actual cost of water removal be more accurately measured. A larger installation would probably do a better job of water removal with less current than used in the laboratory tests. Because of the large number of uncontrollable factors in the experiment, it is futile to make comparisons between the groups of results using different voltages and different periods of time. In general it seems that using 25 volts for 2 minutes produced the best results.

However, a better understanding of how impractical electro-endosmosis would be on a plant scale can be obtained by applying a little simple arithmetic. Table I is roughly calculated to show the cost of removing one per cent of water from filter cakes of different moisture content by means of evaporation. As the moisture decreases the cost of removing an additional one per cent of moisture decreases. On the other hand, the cost of removing water electrically increases with decrease in water content, the curve probably ascending at the same rate that the evaporation cost curve decreases. The curves must cross somewhere and the point at which they cross appears from the data of this experiment to be between 80 and 85 per cent moisture. Since filter cakes usually run between these figures the electro-osmosis process does not appear feasible on the basis of one cent per k.w.h.

No method of applying a positive electrode to the filter cake surface is suggested. If we assume that at least one-third of the surface area of the filter (570 sq. ft.) should be under the positive electrode, then the current density per sq. in. ($144 \times 570 \times .333$) would give an idea of the amperes required. The filter would have to revolve once in six minutes under these conditions. Selecting Test 12 at random the result of the above calculation would be ($.122 \times 144 \times 570 \times .333$) or 3,338 amperes. Equipment to supply such current at 25 volts would have to be of the type used in anodizing.

The use of high voltage from a Ford spark coil was tried as well as the use of a thicker filter cake, but these tests did not work so well. The use of higher voltages from the generator (50 volts as shown in the table) caused heating of the cake and no particular improvement in water removal.

Five tests using digested sludge were made, tests numbers 35, 36, and 37 using suction to remove the released water. The water in number 38 was absorbed on a filter paper. In test 39 the water drained from the perforated plate by gravity only. These tests are included to show what can be done. No conclusions are drawn from them.

Conclusion

The use of electro-endosmosis in the manner suggested here, while in the realm of possibility, does not appear economically feasible.

References

1. A. L. Genter, *This Jour.*, 13, 1164 (1941).
2. E. A. Slagle and L. M. Roberts, *This Jour.*, 14, 1021 (1942).
3. A. L. Genter, *This Jour.*, 6, 689 (1934).
4. J. A. Wilson, *Ind. Eng. Chem.*, 23, 437 (1931).
5. H. von Helmholtz, Wiedmann's *Annalen der Physik*, 7, 337 (1879).
6. G. Gouy, *Le Jour. de Physique et le Radium*, 9 (4), 457 (1910).
7. H. Freundlich, "Kapillarchemie," Vol. 1, Fourth Ed., pp. 365, *Akad. Verlage Ges.*, Leipzig (1930).
8. H. Schulze, *Jour. Prakt. Chem.*, 25, 431 (1882); 27, 320 (1883).
9. Electro Osmose, A. G. German Patent No. 179,806 (1903), 181,841 (1906), 252,370 (1911), 263,454 (1912), 272,383 (1913).

Industrial Wastes

INDUSTRIAL WASTES IN WARTIME *

By F. W. Mohlman

Director of Laboratories, The Sanitary District of Chicago

The war has resulted in the introduction of many new industrial waste problems, some of which are directly connected with armament and munitions, others with new products developed for war needs, and still others with the expansion of established industries to new maximum levels of production. Enormous plants have been built for manufacture of explosives, shells, bombs, airplanes and arms; entire new industries have been developed, including synthetic rubber, alcohol, vegetable dehydration, organic chemicals and high octane gasoline; and food industries, meat packing and metal-working industries have been expanded far beyond peacetime capacities.

In the manufacture of explosives and military supplies, and especially in the development of the new synthetic rubber industry and expansion of the organic chemical industries, the chemical engineer has been called upon to exert the utmost skill and ingenuity to design and build plants that will reach required production goals in the shortest possible time. The disposal of wastes has been given consideration in most cases, but the need for adequate provision for waste disposal has been far less urgent than the need for production and consequently the treatment or proper disposal of wastes has been slighted in some cases, in others the equipment installed may have been too elaborate or expensive for the requirements.

This discussion will deal with some of the aspects of the industrial waste problem in relation to the war effort, first with reference to the manufacture of explosives and munitions, second the development of new industries, mostly chemical, and third the effect of expanded industries on sewage treatment works operation and the sanitary condition of streams.

The war industries may be specifically listed under the following three classes:

Explosives and Munitions	New Industries	Increased Production
Trinitrotoluol (TNT)	Synthetic Rubber	Meat Packing
Trinitrophenol (Picrates)	Alcohol	Steel Industry
Smokeless Powder	High Octane Gasoline	
Shell Casings	Food Dehydration	
Airplane Motors and Parts (Aluminum and Magnesium)	Organic Chemicals	

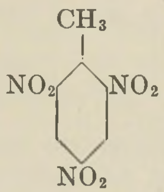
* Presented at the Fourth Annual Convention of the Federation of Sewage Works Associations, Chicago, Ill., Oct. 21, 1943.

Discussion of the detailed industries and their waste problems follows.

Explosives and Munitions

The industries most closely associated with war requirements are the manufacture of TNT, ammonium picrate, smokeless powder, copper and steel shell casings, and airplane motors and parts.

TNT.—Trinitrotoluene is made from toluene and a mixture of nitric and sulfuric acids. Toluene formerly was obtained almost entirely from by-products coke plants, but now greatly increased quantities are available from petroleum refining. Toluene is $C_6H_5CH_3$ and the three nitro groups must be attached symmetrically in the 2-4-6 positions, as follows:



There are no wastes from the nitration process, as the spent mixed acids (nitric and sulfuric) are separated, concentrated and re-used. Large volumes of cooling water are used, however, in the "acid area" and this dilution greatly reduces the concentration of the wastes from the TNT lines. Each line is a complete manufacturing process that is duplicated some six or twelve times in a TNT plant.

The wastes are produced in the wash house, in each line, wherein the "tri-oil" is purified and the TNT crystallized. The "tri-oil" is a mixture of various trinitrotoluenes, of which only the 2-4-6 is desired. The nitration is completed in batches and the liquid tri-oil is run into a wash tank, where it is washed with water; the water is drawn off above the melted impure TNT and run to catch boxes, in which entrained or dissolved TNT crystallizes and settles out and is recovered. A second wash follows, and passes through the catch boxes. The volume of water used in these washes averages 35 gallons per 100 lb. of TNT (based on 35 measurements at three plants) and the wastes are quite acid, with an acidity of about 25,000 p.p.m. in the first wash and 7,000 in the second. The wastes are bright yellow in color and odorless.

After the acid has been largely removed by these washes, the TNT is crystallized and washed with a solution of about 5 per cent of sodium sulfite ("sellite") which has the property of combining with the unsymmetrical isomers, such as 2-3-4 (beta), 2-4-5 (gamma) and other trinitro compounds, to form soluble sulfonates, whereas the pure 2-4-6 (alpha) TNT does not react with the sulfite and remains practically insoluble (2). The waste sulfite solution is usually run directly to the sewer, separate from the acid wastes. It is deep red in color and is alkaline to methyl orange with a pH of 9.2 and an alkalinity of approximately 900 p.p.m. The volume averages 38 gallons per 100 lb. TNT, based on 33 measurements at three plants.

Typical analyses of these wastes, based on a number of analyses from four plants, follow:

	TNT Wastes from Wash House Parts per Million						
	pH	Acidity	Alk.	Ox. Cons.	Total Solids	Vol. Solids	Color, 1 : 500
Yellow Wastes							
First Wash	1.0	25,700	—	780	—	—	24
Second Wash	1.7	7,300	—	720	—	—	40
Red Waste							
Sellite Wash	9.2	—	860	8,600	58,000	26,000	570
Composite	1.4	4,500	—	3,300	35,000	—	125

These results show that the yellow wastes are highly acid, have a comparatively low color, and are low in organic matter. The red wastes are alkaline, have a very high color even in 1:500 dilution, and contain nearly 6 per cent total solids, of which about 45 per cent is volatile. The composite wastes are quite acid, contain about 3.5 per cent solids and have a high color even in 1:500 dilution.

It is essential to know the volume and analyses of wastes per batch in order to relate the problem of disposal to the receiving stream. Numerous analyses of "TNT wastes" have been made, but the results of analyses depend entirely upon the production and the amount of cooling water mixed with the actual organic wastes, and unless the results are related to the production at the time the samples were collected, computations of necessary dilution, or experiments on the biological effect of the wastes on fish, on taste, on color, etc., are unrelated to the output of the plant.

The wastes have no odor and no appreciable B.O.D. (3). They are very stable and resistant to biological oxidation. All of the available methods of sewage or waste treatment are ineffective for removal of organic matter and color, except, as was found in laboratory tests when the problem was approached in March, 1942, the use of chlorine for decolorization. It was found that the color could be reduced from 600 to 75 p.p.m. by application of 1,400 p.p.m. chlorine, equal to 1.9 tons of chlorine per day for the plant under consideration (4).

Further studies, however, showed that by taking account of the stream flow in various rivers, providing for storage of wastes direct from the wash house in large holding basins at times of minimum river flow, and discharge of the stored wastes at later periods of increased river flow, no treatment of wastes would be necessary. In cases where the river water downstream is used for water supply, after filtration, experimental studies were made of the effect of alum, coagulation, sedimentation, filtration and chlorination on dilutions of the combined wastes and the river water in question (5). These studies showed that the major problem in all cases was the reduction of color, and this was obtained by proper relation of the flow of wastes to river discharge. Alum was ineffective in removal of the color in even high dilutions and amounts of chlorine that would ordinarily be used in water filtration did not reduce the color appreciably.

The turbidity or natural color of the various river waters in question influenced the resultant color of the wastes in the same dilution. For example the following results were obtained with various river waters:

Color of TNT Wastes Diluted with Various River or Lake Waters

River or Lake	Color Dilution of 1 Part Combined TNT Wastes to			Color River or Lake Water	Increase of Color in Dilution of		
	5,000 Parts	10,000 Parts	20,000 Parts		5,000 Parts	10,000 Parts	20,000 Parts
Ohio River	75	55	50	30	45	25	20
Lake Michigan	45	30	25	3	42	27	22
Susquehanna River	53	32	—	13	40	19	—
Wisconsin River	150	130	120	100	50	30	20
Missouri River	14	11	9	7	7	4	2

The increase of color for the first three normally clear waters varied from 40 to 45, in 1 to 5,000 dilution and from 19 to 27, in 1 to 10,000 dilution. For the colored Wisconsin River, the increase was slightly higher; but for the Missouri River, with the excessive average annual turbidity of 1,900 p.p.m., the color increase was much less than for the clear rivers, because of adsorption of the color on the suspended silt and clay.

For several large TNT works, dilution alone, with provision for storage of the concentrated wastes, has been adopted. Where the water is used for water supply an increase of color of 15 to 20 in the filtered water has been advocated and accepted, based on capacity of the TNT works and minimum river flow, with storage for the period of insufficient dilution. Where the water is not used for water supply, increase of color in the river water up to 75 has been approved by at least one State Board of Health, as permissible during the emergency war period.

The alternative to this scheme comprises a very expensive and elaborate system of neutralization of wastes, evaporation to a syrup in multiple-effect evaporators, incineration of the syrup to an ash or a thick syrup in rotary kilns, and flushing of the ash or liquid to the nearest watercourse. This process has been installed at several plants where dilution is clearly inadequate for the storage and dilution procedure, and also at one plant where there is a large amount of dilution. The utilization of stream dilution, however, has saved large sums of money (several million dollars) and use of critical materials.

This use of stream flow in wartime appears justifiable, where the only effect on the stream is a slight increase in color, no appreciable reduction in alkalinity, no odor, no killing of fish, and no toxic effect on those who drink the filtered water. These other factors have been given consideration and it has been shown that if the dilution is sufficient to reduce the color to acceptable amounts in a filtered, potable water, that is, in a dilution of 1 to 10,000, the other possibilities of harm, including objectionable taste, are eliminated. If the water is not used for drinking purposes, a dilution of 1 to 3,000 is acceptable.

The effect of the wastes on fish has been studied at the University of Illinois, involving the use of hundreds of fish (6). It was shown that the fish would live in dilutions of 1 to 40 and die at 1 to 20. The samples of waste used were diluted considerably, however, and could not be related satisfactorily to the red and yellow wastes, but the dilution was possibly 1 to 20, which would indicate that all fish remained alive at a dilution of combined wastes of 1 to 800 and died at 1 to 400. These dilutions are much lower than the dilution of 1 to 10,000 required for elimination of color.

The Haskell Laboratory of the duPont Company made tests of the toxicity of the concentrated wastes and found that "both TNT acid waste and spent sellite liquors are innocuous when fed to rats in dilutions up to 1 to 240."

A few tests by the U. S. P. H. S. were made at the National Institute of Health, with results as follows (7): "Tests were made of the toxicity of the concentrated waste. The waste was brought to a pH of 7, made isotonic with sodium chloride, and sterilized in an autoclave for 1 hour. Two mice were each given a 0.5 ml. intraperitoneal injection of the sterilized waste and a guinea pig was given 2 ml. intraperitoneally. A rabbit was given an intravenous injection of 15 ml. and observed for any temperature rise. All results were negative and the animals showed no ill effects from the different injections. Apparently the waste is nontoxic to warm-blooded animals."

The use of stream dilution for these wastes, where practicable, has proved a reasonable application of the principle that, in wartime, streams should be utilized for disposal of wastes that have little or no health significance, no obnoxious odor or unsightly properties, and no hazard to the normal uses of the stream.

Picrates.—The manufacture of ammonium picrate as an explosive for naval ammunition involves manufacture of picric acid, by one of two methods (2), followed by treatment with ammonia to give the stable, safe ammonium picrate. In one method, the so-called "American," phenol is sulfonated with sulfuric acid, nitrated with mixed nitric and sulfuric acids, filtered and washed. In the other, or "European" method, dinitrochlorbenzene is treated with caustic soda to give sodium dinitro-phenolate, and the third NO_2 group is added by an easy nitration with mixed nitric and sulfuric acids. In either method, the major wastes are from the wash water used in the "lines," plus a large flow of cooling water from the acid area, where the spent acid is concentrated for re-use.

The problem of disposal of these wastes (8) is quite similar to that of TNT wastes, as the waste waters are colored bright yellow, and the color persists into high dilution. However, with a dilution of 1 to 650, equivalent to a minimum river discharge of 700 c.f.s., it was determined by laboratory tests that the increase of color would be 63 p.p.m. Inasmuch as the river water is not used for drinking purposes, and as fish survived concentrations of picric acid nearly fifty times this concentration, it was concluded that no storage would be necessary, and the wastes are discharged into the stream untreated, with no difficulty through the past summer even with a stepped-up production 50 per cent more than the initial estimate.

Smokeless Powder.—The wastes from smokeless powder manufacture are far more acid than those from TNT or picrate plants, and have a low B.O.D. Tests by the U. S. P. H. S. (7) at several plants showed an average discharge of 50 tons per day of sulfuric acid, and about 13 tons of nitrate nitrogen, per 50 tons of powder production. The loss of alcohol is from 0.2 to 0.3 lb. per pound of powder (9), and this accounts largely for the B.O.D. The acidity of the wastes is neutralized with lime or limestone before discharge.

Shell Casings.—Shell casings are stamped out of brass or steel. The substitution of steel for brass has been one of the interesting developments of this war. The steel sheets are about 5 ft. long by 11 in. wide by ¼ in. thick. Discs are first stamped out of these sheets and the discs are cleaned in a caustic bath, followed by a pickling solution of sulfuric acid. The discs are then coated with a thin deposit of copper, by passing through a solution of copper sulfate and common salt ("cuprodine"), which merely protects temporarily against corrosion. The discs are then stamped into cups, which go through a heat-treatment annealing process, followed by another cleaning, pickling and coating with copper.

The wastes from this process are mainly the usual ferrous sulfate pickling waste, plus a small amount of copper. In one large plant of this type in Chicago, the company was permitted to discharge the waste to the sewers, after a basin had been installed for neutralizing the acidity, including lime feeding machines and air agitation. The production has been considerably below the original estimates, so that the installed equipment has been ample.

Where brass shell cases are made, there are two problems—the copper in the pickling wastes and wash waters, and the oil in the wastes from the hot rolls. A survey was made of the wastes from an ordnance plant of this type in Chicago. Weirs were installed, samples collected every 15 minutes and composited according to flow. The results of flow measurements and analyses were as follows:

Measurement and Analyses of Wastes from Brass Ordnance Works

Date 1943	Flow, C.F.S.		Copper, P.P.M.		pH		Oil, P.P.M. Ethyl Ether	
	Day	Night	Day	Night	Day	Night	Day	Night
May 27	2.175	2.128	27.0	2.0	3.0	5.4	54	61
28	2.007	2.093	18.6	14.2	4.4	4.8	101	58
29	2.204	2.053	21.4	20.8	5.2	6.0	123	63
30	1.241	1.938	23.7	11.5	4.5	5.1	21	33
June 1	2.230	2.312	10.3	15.3	4.0	6.1	70	64
2	2.321	2.354	21.4	16.6	7.0	7.0	120	111
3	2.347	2.343	22.0	18.0	4.0	3.8	599	220
4	2.313	2.372	26.1	13.5	3.8	4.0	117	137
8	2.314	2.197	28.4	14.9	4.6	5.1	215	128
9	2.279	2.368	44.3	13.2	6.5	6.3	242	159
10	2.394	2.297	31.5	42.5	4.5	2.9	244	186
11	2.273	2.345	50.6	45.6	2.7	2.9	119	146

The average discharge of copper was 277 lb. per 24 hr. and of oil 1,744 lb. per 24 hr. The oil discharge varied from a minimum of 243 lb. on Sunday, May 30th, to a maximum of 5,188 lb. on Thursday, June 3rd. The high oil content was present in spite of a number of large proprietary oil separators through which the wastes flowed. The average oil content was 146 p.p.m.

The loss of copper from this plant was too small to affect the West Side Imhoff tanks, where the volume of sewage treated averages 400 m.g.d. However, other instances have been reported (10) where copper wastes have almost completely inhibited gas production in sludge digestion plants. As little as 1 p.p.m. in the sewage is objectionable, because of the concentration of the copper in the sludge by precipitation. The only remedy therefore appears to be either diversion of the wastes from the sewage treatment works, or disposal of the sludge by incineration. It is doubtful whether the copper can be removed to a sufficient degree by lime, and lime precipitation is very expensive. The use of sodium or calcium sulfide for reducing the solubility of copper in the digestion tank liquor has been suggested in the Eighth Report of the Connecticut State Water Commission (11), but no tests of this procedure have been reported for full plant-scale operation.

Copper-bearing wastes have long been known to be toxic to biological processes of sewage treatment or sludge disposal, and particular care should be taken to investigate the waste waters from copper mills prior to installation of sewage treatment works.

Airplane Motors and Parts.—The use of aluminum and magnesium for airplane motors has introduced new types of pickling waste—a chromic acid bath for pickling and anodyzing aluminum, and a hydrofluoric acid bath for magnesium. Waste solutions of both types are to be discharged from the reportedly largest airplane motor plant under one roof in the U. S., in Chicago, but the volume of wastes and amounts of acids involved are not large. It has been recommended that a waste solution of caustic soda, used for cleaning magnesium castings, be used for neutralizing the acid wastes, with the caustic solution properly strengthened by additional solid caustic soda. This appears desirable, in spite of somewhat increased cost over the use of lime or limestone, especially for the hydrofluoric acid, inasmuch as the lime or limestone might be rendered ineffective by a coating of calcium fluoride. The company agreed that caustic soda would be preferable, and its use also will be more convenient.

New Industries

Oil Refining.—The production of high-octane gas has introduced more complex operations in oil refineries, including catalytic crackers of various types. The clarification of refinery wastes has been given considerable attention by the American Petroleum Institute, which has issued a manual (12) giving basic data for the design of the so-called "A.P.I. Separator." A number of these separators have been installed, including one at a refinery near Chicago. This plant has a small catalytic cracker. The A.P.I. separator was installed in 1941, and careful records have been kept of the results of daily determinations of the oil content of the effluent. The basin is greatly oversize for the present flow of 1,000 gal. per minute, having been installed for an expected flow of 4,000 g.p.m. The average oil content of the effluent has been approximately 35 p.p.m., and only rarely has the content been as low as 15 p.p.m. The latter concentration is frequently cited as the result obtained by this type of separator, which is generally agreed to be one of the best, for the purpose. Detention periods of one hour or more are recommended, and baled straw is used in the second tank of the separator for final, rough and rapid straining of the effluent.

Ethyl Alcohol.—The use of alcohol in the manufacture of smokeless powder had created a demand for increased production even before Pearl Harbor, but when the requirements of the synthetic rubber industry became known, the alcohol production quotas were again greatly increased. The requirements for various uses in 1943 and 1944 are as follows (9), as compared with use in 1942:

Ethyl Alcohol Consumption
Millions of Wine Gallons, 190 Proof

	1942	1943	1944
Direct Military and Lend-Lease	49.4	94.8	115
Synthetic Rubber	—	22.6	265
Chemical Mfgr.	74.0	76.0	80
Anti-freeze	36.6	27.8	40
All other	94.1	50.9	50
Total	254.1	272.1	550

The shortage in receipts of molasses in 1942 resulted in the conversion of many alcohol plants to the use of corn, but the Commodity Credit Corporation restricted this use of corn, and technologists then adapted the process to the use of wheat, and later wheat grits, which do not include the bran, germ and other non-starch constituents of the wheat. Thus about 20 lb. of the 56 lb. bushel of wheat can be recovered for feed, and not discharged to the sewer. The yield of alcohol is reported to be 2.8 wine gal. per 56 lb. bushel of the wheat grits.

More recently, however, it appears that molasses may return to use, inasmuch as there is enough molasses in storage in the West Indies to produce 150 million wine gallons of alcohol, as much as was made in 1942 from this source. In the estimates for 1944, only 40 million gallons are based on this source, but if shipping facilities improve, this estimate may prove to be low.

The significance of this increase of alcohol production on stream pollution is tremendous. According to the U. S. Public Health Service (13), 5,000 gal. per day of 100 proof spirits produces still slop with a population equivalent of 55,000 to 60,000. The fermentation alcohol in the 1944 program (9) is estimated at 40 m.g. from molasses, 160 m.g. from industrial alcohol plants (new) and 235 m.g. from whiskey and other liquor distilleries, all 190 proof. This totals 1,192,000 gal. 190 proof, or 2,265,000 gal. 100 proof spirits per day, which gives a population equivalent of $\frac{2,265,000}{5,000} \times 60,000 = 27,180,000$, if no evaporation or other recovery of still slop were practiced. Fortunately a number of evaporator plants have been installed, but far from enough to reduce the population equivalent to a large degree. For example, distilleries and alcohol plants at Peoria, Ill., are estimated to discharge wastes with a population equivalent of possibly 1,500,000. This enormous waste discharge threatens to wipe out all fish next summer in the Illinois River below Peoria. A few trips by Sanitary District chemists in the summer of 1943 showed the dissolved oxygen below Peoria to be much lower than in any previous summer on record. Results farther downstream, obtained by the Illinois Sanitary Water Board, are even lower, approaching complete deoxygenation.

To cope with this problem of alcohol wastes, evaporators have been installed in some cases, including one small new plant at Peoria, plants at Omaha, Kansas City, Frankfort and Louisville, each with a capacity of from 10,000 to 20,000 bushels of wheat per day (2.5 wine gal. alcohol per bushel). It is to be hoped that the evaporators have been allocated to the plants where they will do the most good in abatement of stream pollution.

Sulfite Pulp.—The production of ethyl alcohol from waste sulfite liquor of pulp mills is being advocated as preferable to the use of grain, at least during the war. A plant is in operation at Thorold, Ont., with a capacity stated to be around 800,000 gallons of alcohol per year. The 1941 production of 80 sulfite mills in the U. S. (9) was 2.9 million tons of pulp, which at 12 gal. alcohol per ton is equivalent to 35 million gallons of alcohol. As only the larger plants could hope to support this process, it is estimated that only 17 mills would be involved, with a capacity of 1.4 million tons pulp per year, or 16.2 million gallons of alcohol.

The process ferments only the sugars present in sulfite liquor leaving the lignin still discharged to streams. The possibilities of alcohol production for utilizing the wood sugars, followed by the Howard Process for removing lignin, deserve study.

Investigations have been under way for some time at Appleton, Wis. (14), on methods of treatment of sulfite wastes, recently including operation of a 15 ft. trickling filter and study of methane fermentation, contact aeration and ponding with stream-flow control. It is gratifying to note the increasing interest in the study of this major problem of stream pollution.

Synthetic Rubber.—The manufacture of ethyl alcohol for making butadiene is the most important source of wastes in the synthetic rubber industry. Butadiene made from petroleum does not produce wastes much different from those of the usual refinery, and styrene manufacture also is analogous to refinery operation. However, the co-polymer plants, where the butadiene and styrene are polymerized in a soap bath in contact with a catalyst, followed by discharge of the spent soap solution, may have considerable significance from the standpoint of wastes. It is estimated that 200 million pounds of soap or equivalent fatty acids will be used in this process in 1944. Information is needed concerning the polluting effect of these wastes. Co-polymer plants are installed as follows (15), with the estimated tons per year and percentages of the total program:

Co-polymer Plants, Synthetic Rubber

Location	Thousand Long Tons per Year	Percentage
Northeast		
Naugatuck, Conn.	30	4.1
Institute, W. Va.	90	12.2
Akron, Ohio	60	8.2
Sarnia, Ont.	30	4.1
Louisville, Ky.	90	12.2
Total	300	40.8
Southwest		
Borger, Tex.	45	6.0
Baytown, Tex.	30	4.1
Houston, Tex.	60	8.2
Port Neches, Tex.	120	16.4
Lake Charles, La.	60	8.2
Baton Rouge, La.	30	4.1
Total	345	47.0
Pacific		
Los Angeles, Cal.	90	12.2
Total	735	100

Apparently the stream pollution problems may not be of serious importance in view of the comparatively few plants and their locations, in some cases, on large rivers.

Dehydration of Food.—The dehydration of food products has had considerable development during the war, for obvious reasons of logistics. The wastes from a potato dehydration plant in California have been measured, sampled and analyzed (17). Losses of dry solids average about 20 per cent of the original content, with a corresponding 5-day B.O.D. of 40 lb. per ton of potatoes, amounting to a population equivalent of 240 per ton of potatoes per day, or 1,200 per ton of dehydrated potatoes, dry.

The quota of dehydrated potatoes to be produced in the U. S. in 1943 is 136 million pounds, or 187 tons per day. Wastes from this production would have a population of about 224,000.

The total quota of dried vegetables in 1943 is 356 million lb., of which potatoes comprise 136 million, sweet potatoes 39, cabbage 34.5, beets 26, onions 20, corn 20, tomatoes 18.5, and others in less amounts.

The quota for fruit is 51 million lb., of which the largest is 31.4 million lb. of lemons and 14.5 of apples.

Assuming losses for all fruits and vegetables to be as great as for potatoes, which is unlikely, the total population equivalent for the vegetable and fruit quota, spread over the entire year, would be only about 670,000. The effect during the brief canning season is of course much greater.

The meat dehydration quota is likewise low, totalling 120 million lb. of pork, and practically no beef. It is doubtful whether even the pork quota will be filled to any appreciable degree.

It is obvious that the waste problems of the food dehydration industry are insignificant for the country as a whole, although possibly troublesome for plants on small streams or lakes. This industry appears to be essentially a wartime necessity and it is generally agreed that it may again practically disappear after the war, plus a brief postwar period, as it did after the first World War. The quotas are low in comparison with the pack of the canning industry, and likewise the overall waste problem of the dehydrated food industry is not so important as that of the nation's canneries, whose quota for 1944 approximates 300 million cases of 24 cans each.

Industries with Increased Production Because of the War

Various industries normal in times of peace have required expansion because of war needs, and in some cases the increased volume and solids content of the liquid industrial wastes have affected the operation of sewage treatment works either detrimentally or by contributing increased organic loadings on the treatment process. For example the population equivalent of the West-Southwest Treatment Works of the Sanitary District of Chicago has increased by more than half a million since 1940, as shown in Fig. 1, based on flow and B.O.D. The largest population equivalent occurs each year in the winter, from November to January, when the kill at the stockyards is heaviest. There is a large difference in strength of week-day and Sunday sewage.

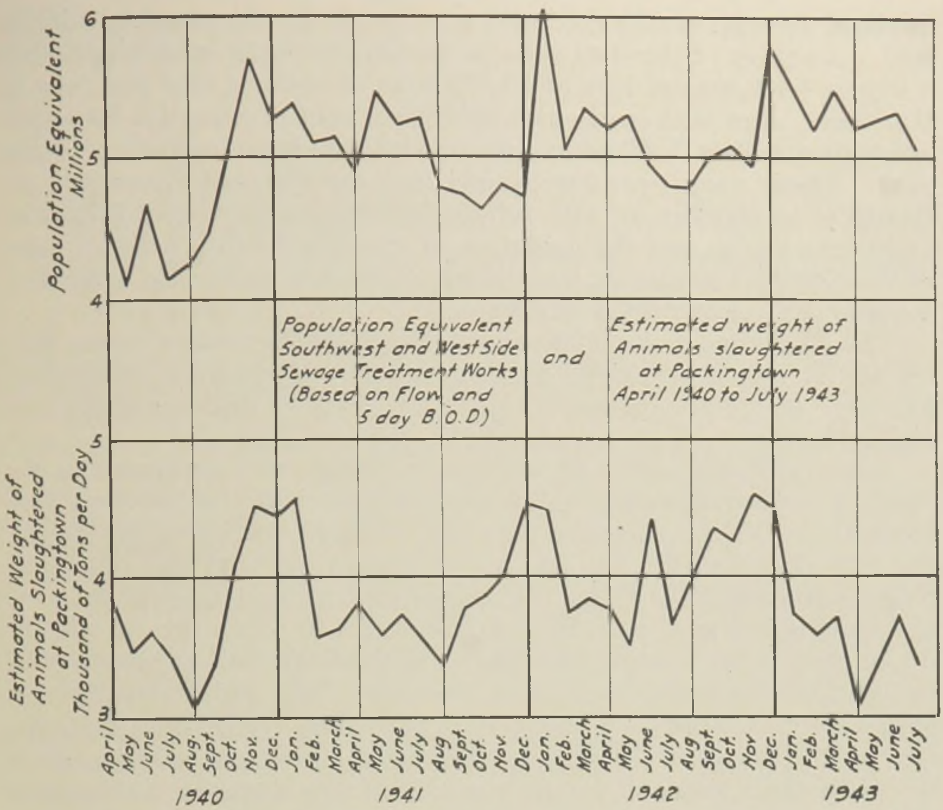


FIG. 1.

The corn products industry has suffered somewhat increased losses during the past several years, with production pressed to the limit of capacity and the necessity of using corn from various sources and of varying suitability for the separations involved. The losses of the Corn Products Refining Company at Argo, on the Main Channel of the Sanitary District of Chicago, have shown the increases shown in the table below for the years 1936 to 1943, inclusive:

Corn Products Refining Company Grind and Population Equivalent of Wastes

Year	Grind, Bu. per Day	Pop. Equiv. Wastes
1936	69,250	30,400
1937	71,820	41,000
1938	73,110	40,100
1939	69,690	49,200
1940	71,240	51,300
1941	85,460	56,100
1942	88,420	82,300
1943*	88,900	64,300

* Through September.

The iron and steel industry has undergone great expansion and increased production. There are many iron and steel plants in the

Sanitary District of Chicago, most of which pickle the metal in sulfuric acid. A survey of the steel mills in the Calumet area in 1938 indicated a loss of 1,400 tons of iron and 1,335 tons of sulfuric acid per year at that time. Now with production at 100 per cent of capacity, the losses are approximately 3,500 tons of iron and 3,340 tons of sulfuric acid per year. These wastes are discharged into the Calumet River and although of no significance with reference to health, the iron precipitates and forms sludge and the oxidation of the ferrous iron uses up some of the dissolved oxygen in the stream, equivalent to 63 c.f.s. river flow containing 8 p.p.m. dissolved oxygen.

The pickle liquor problem seems to be just about where it was during World War I, in spite of the large amount of work and money that has been spent on investigations of the recovery of disposal of the iron and acid (18).

One gratifying aspect of wartime industry, with reference to the effect of industrial wastes on streams, has been the fat recovery program of the WPB. A committee of the Chicago Section of the American Chemical Society (19) has been co-operating with the Industrial Salvage Branch of the WPB, for the purpose of promoting fat recovery and lending technical assistance to industries in which fats or oils are discharged to the sewers. Improved methods of testing catch basins in meat-packing plants have been developed (20) and standards suggested for good practice in recovery of fat. The WPB Consultant, Mr. Marcus B. Hinson of Chicago, has organized a program among packers to reduce their losses of fat by various salvage methods, in the plant and at the outlet sewer, and he estimates that 100 million pounds of fat could be recovered per year by adoption of efficient methods of salvage and skimming. The recovered fat has a glycerine content of around 10 per cent. The household fat recovery program has been helpful in keeping fat out of the sewers. A recent release of the Fat Salvage Committee of the Glycerine and Associated Industries stated that 150 million lb. of household fats has been salvaged during the past 12 months by the American housewives and the Army and Navy.

Recovery of salable grease from skimming tanks in sewage treatment works may be feasible during the war if the recovered grease is low enough in unsaponifiable matter, but in most cases mineral oil, waxes, and other contaminants so lower the value of the grease that it cannot be sold. However, New York City reports sale of recovered skimmings at 80 cents per 100 lb. and the Chicago Sanitary District has been offered 55 cents per 100 lb. for an estimated daily production of 14,000 lb. of skimmings at the Southwest Treatment Works. The cost of removal and loading must be investigated to determine the economics of the proposition. The unsaponifiable matter in the rendered grease averages 13 per cent, which is comparatively low, due to the presence of stockyards wastes in the sewage.

In view of the rather widespread increase in stream pollution by wartime industrial wastes, it is gratifying to report these various possibilities of diminution of the discharge of fats and greases to sewers, sewage treatment plants and streams.

References

1. "The Chemistry of Powder and Explosives." Vol. I. By Tenney L. Davis. John Wiley and Sons, 1940.
2. "A Manual for Explosives Laboratories." Vol. I. By G. D. Clift and B. T. Fedoroff. Lefax, Inc., Philadelphia, 1942.
3. "Laboratory Study of TNT Wastes." By Stuart Schott, C. C. Ruchhoft and Stephen Megregian. *Ind. Eng. Chem.*, **35**, 1122 (Oct., 1943). Abstracted in *Eng. News-Record*, **131**, 80 (Aug. 26, 1943).
4. "Report to Pennsylvania Ordnance Works." By Paul Hansen and F. W. Mohlman, 1942.
5. "Report to West Virginia Ordance Works." By Paul Hansen and F. W. Mohlman, 1942.
6. "Study of the Toxicity of Ammunition Plant Wastes to Fishes." By J. G. Degani. Thesis for M.S., Zoology, U. of Ill., June, 1942.
7. "Surveys of Liquid Wastes from Munitions Manufacturing. I. TNT Wastes." By Russell S. Smith and W. W. Walker. *Public Health Reports*, **58**, 1372 (Sept. 10, 1943).
8. "Report to New York Ordnance Works." By F. W. Mohlman, 1942.
9. "Industrial Alcohol for War and Post-War. Staff Report." *Chem. and Met. Engineering*, **50**, 120 (Aug., 1943).
10. "Wartime Industrial Wastes—Good and Bad. Copper Affects Digestion, Iron Improves Settling at Kenosha." By H. T. Rudgal. *Sewage Works Engineering*, **14**, 94 (Feb., 1943).
11. Connecticut State Water Commission. Eighth Biennial Report, 1938–39.
12. "Disposal of Refinery Wastes. Section I. Waste Water Containing Oil." American Petroleum Institute, 1941.
13. Ohio River Pollution Survey. Supplement D. Industrial Waste Guides. U. S. Public Health Service, 1942.
14. "Cooperative Research Program on Sulfite Waste Liquor." By J. P. Weidner. *Paper Mill News*, Aug. 24, 1943.
15. Progress Report 3, War Production Board, Office of the Rubber Director, Washington, D. C. Statistical Appendix, 1943.
16. Data from Editor of *Food Industries*.
17. "Characteristics and Treatment of Potato Dehydration Wastes." By Harold F. Gray and Harvey F. Ludwig. *Sewage Works Journal*, **15**, 71 (Jan., 1943).
18. "The Steady Pursuit of Waste Pickle Liquor Utilization." *Chem. and Eng. News*, **20**, 446 (April 10, 1942).
19. "Industrial Fat Recovery Program." *The Chemical Bulletin*, Chicago Section, Am. Chem. Soc. **30**, 184 (June, 1943).
20. "Are You Losing War Materials and Dollars Down Your Sewers?" By E. N. Mortenson. *The National Provisioner*, April 24, May 1, 1943.

Discussion

By LeRoy W. Van Kleeck

Senior Sanitary Engineer, Connecticut State Department of Health

The problems discussed by Dr. Mohlman reflect in a striking manner the present war tempo of our nation. The writer will consider primarily the third aspect of the paper: "The effect of expanded industries on sewage treatment works operation."

Dr. Mohlman's reference to adequate stream dilution, where practical, for TNT wastes, hits a sound key for the war emergency, and in planning peacetime disposal of other industrial wastes difficult of treatment. Manufacturers discharging such wastes should consider this in planning factory locations or expansions, and state sanitary officials should guide them along sound lines.

The acceptable discharge of pickling liquors and copper into the Chicago sewers also shows the advantage of high dilution. Such wastes discharged to a small municipal treatment plant or into a small stream might cause undesirable conditions, as I will show later.

The chromic acid bath for pickling and anodyzing the aluminum in airplane motor parts mentioned by Dr. Mohlman has been encountered at one large manufacturing plant in Connecticut. The sewage plant in question treats domestic sewage from the factory by plain settling, sand filtration and chlorination. Rinse waters from the chromic acid vats discharge, after limestone treatment, to the plant sewer. The pH of the raw sewage is about 7.5. The soluble chromium content of the raw sewage averages around 10 p.p.m. The settled sewage contains about 6 p.p.m. soluble chromium and the sand filter effluent 6 p.p.m.

The chromium reacts with ortho-tolidin giving a high color reaction which interferes seriously with the chlorine residual test. Studies to date indicate that ortho-tolidin testing for free chlorine will be unsatisfactory. It was considered possible that chromium, which is a poison, might accomplish satisfactory bacterial destruction without the use of chlorination. Bacterial samples recently collected have not supported this belief.

Good nitrification of the filtered effluent has continued through six months of operation, indicating so far no poisoning effects on the bacterial life in the filters.

While the rinse waters have not affected sludge digestion, a single discharge of the concentrated waste chromic acid liquors dropped the pH of the sludge materially, stopped gas production, and completely upset digestion. Future discharges of the strong liquors, relatively small in amount, will be diverted from the treatment plant.

The following remarks deal with the particular war industrial wastes that have affected municipal sewage treatment in this discussor's state. Our problem will be appreciated by stating that Connecticut, while standing only 46th in the nation in area, is first in dollars per capita for federal war contracts. Furthermore, of Connecticut's peacetime population, about 70 per cent is served by public sewers, of which over 75 per cent of the sewage is treated.

The four war industrial waste horsemen of Connecticut are:

CUTTING OIL; IRON; SULFUR; FIBER

CUTTING OIL

This is the oil used in machine shops. The increased volume of this oil used in Connecticut since the start of the war is tremendous. While most kinds of cutting oil mix with water, a percentage separates, forming a scum. So great has been its volume that the man hours required to remove it have increased over 400 per cent at some treatment plants.

Its effects on air diffusers, vacuum filter cloths, and sludge digestion activity have not been noticeably adverse. Its unsightly appearance and the manual labor involved in removing it have been the major difficulties.

Local communities are controlling the volume of such oil discharged into municipal sewers by the following methods:

1. Public education through newspaper releases, the radio and circular letters to manufacturing establishments.
2. Removal of the waste rancid oil at the factories in containers. The material is dumped or incinerated.
3. Wider use of oil clarifiers. One type of clarifier yields a heavy black sludge which is concentrated in volume and relatively easy to discard.
4. The source of oil, especially heavy oils, has been traced by daily inspection of floating white discs in key manholes. Offenders have offered little argument when confronted with the evidence.

Iron

Iron wastes discharged to one Imhoff tank plant blocked the tank slots, stopped sludge digestion, and produced a pasty-brown, slimy sludge, very difficult to dry. At another location iron fungus growths and sludge deposits have increased in the receiving stream, and chemical precipitation of the raw sewage was upset.

In the first community the use of Ferrisul for cleaning brass parts in the factory was discontinued, and a so-called Blakeslee degreaser using sulfuric acid, soap, and hot water was substituted. This eliminated the iron from the raw sewage, and also resulted in better cleaning of the brass.

In the second community a copperas recovery plant was being poorly operated by the offending factory. Conferences between the factory management, municipal officials and state authorities have resulted in operating improvements. Regular check-ups have been and will be necessary to produce satisfactory results.

Where iron wastes can be sufficiently diluted with domestic sewage, municipal treatment plants have been able to handle them.

Sulfur

Sulfur dyes from a textile mill dyeing army uniform cloth have raised the chlorine demand of the sewage at one large municipal plant far in excess of the chlorinator capacity. The normal domestic sewage demand of 10 to 12 p.p.m. has increased to 60 p.p.m. (500 lb. of chlorine per million gallons of sewage treated) and higher. One of the major difficulties with this waste has been the wide fluctuations in chlorine demand, making proper adjustment of the chlorine dose a physical impossibility. The first corrective step in this problem was the construction of concrete holding basins for the spent dye and first rinse from the dye jigs. Subsequent rinses are discharged directly to the sewer as formerly. The strong liquids are bled from the lagoons into the sewer to even out the chlorine demand. While these basins should remove the peaks in the demand, it will be necessary to materially increase the chlorinator capacity at the treatment plant to obtain satisfactory residuals. Changes at the sewage plant were considered more practical from both an economic and operating standpoint than treatment of the dye liquors at the mill. Laboratory tests conducted by the Connecticut State Water Commission also showed that chlorine was the cheapest and most satisfactory oxidizing agent for the sulfur dyes.

Fiber Wastes

These wastes from textile and carpet mills were a problem with us long before the present war. Fine screening, mechanical scum stirrers in digestion tanks, and other specialized equipment have been employed at municipal plants in Connecticut to control the clogging and matting properties of this waste. The major difficulty with fiber wastes is the accumulation of a heavy thick scum in digesters. This scum resists digestion and increases in depth until no supernatant can be removed from the decanting pipes. Under war conditions, the quantities of these wastes have greatly increased in some communities.

One temporary remedy has been use of a fire hose for breaking up the scum. Use of supernatant liquor from the digesters rather than cold water is preferable. The liquid is introduced through manholes in the covers of digestion tanks. Not only does some of the scum thus settle out and digest, but sometimes it can be made fluid enough to draw off to sludge beds or vacuum filters.

Another remedy is the use of screens with ½-in. to 3/32-in. openings in the mill waste water channels. This is of material aid in reducing the quantities discharged to sewers. They are especially needed in wool scouring departments or where cotton or wool napping is washed.

A rather unusual occurrence at one sewage plant was the balling up of fiber in raw sewage sludge conditioned with ferric chloride and lime. The fiber could not be coagulated and its quantity was so great (about 50 per cent of the dry solids sludge weight) that it would not adhere to the vacuum filter drums. The material actually flowed like lava over the rim of the filter vats and along the filter operating floor. With the co-operation of the Connecticut State Water Commission, a detention tank of considerable proportions equipped with a series of screens of various size openings was installed at the offending mill for retaining the bulk of the fiber.

In another city where screens have been installed in woolen mills with wastes tributary to the sewerage system, it has required periodic visits to the mills to see that the screens to remove wool fiber are kept in place and regularly cleaned. It is evident from our experience that some supervising agency must check the operation of mill installations or they will be neglected due to the press of other work.

Other Wastes

Plating solutions have caused us some concern, as a great deal of industrial metal plating is done in Connecticut. Fortunately, however, to date the concentrations of the spent wastes from these processes have been below any detrimental amounts. The soluble copper and chromium quantities in municipal sludge digestion tanks have been below 10 p.p.m. in the digesting sludge, and no reduction in gas production or appreciable increase in digestion time has been noted. It is a situation, however, that warrants periodic testing at plants subject to such wastes.

At the East Street plant of the City of New Haven, Conn., large amounts of copper are present in the raw sewage. This was known years before any treatment was given this sewage, and I believe that Dr. Mohlman had a great deal to do with the original investigations that were made. Therefore the plant vacuum filters and incinerates a raw sludge without digestion because of the digestion difficulties that would surely occur.

As a peacetime note, our war experience indicates the need of careful surveys by a designing engineer of the industrial waste load on a proposed treatment plant in communities now discharging raw sewage to watercourses. Such a survey is worth while in avoiding the possible deleterious effects of certain wastes on the proposed treatment units.

The four war horsemen of Connecticut: oil, iron, sulfur and fiber, are not riding as high and handsome as they were a year ago. In most cases we had them with us before the war and it is a question of volume and concentration when dealing with wastes of this character. The steps that have been taken to control the oil, iron and fiber have involved just that—reduction in their amounts to a point where they can be handled with domestic sewage. Our sulfur problem will require oxidation with chlorine.

THE OPERATOR'S CORNER

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

"BLUEPRINT NOW!" . . .

is the terse but encompassing postwar planning slogan of the new Committee on Water and Sewage Works Development which has been organized under the joint sponsorship of the Water and Sewage Works Manufacturers Association, American Water Works Association, Federation of Sewage Works Associations and New England Waterworks Association. With Mr. E. L. Filby (on leave from the organization of Black and Veatch, Kansas City) as full-time Field Director, the Committee has assumed an immense task, comprising the following activities:

1. Appraisal of water and sewage works construction needs.
2. Development of orderly programs to meet such needs.
3. Bringing about preparation of detailed plans and specifications for needs of first importance.
4. Consideration and development of financing plans.
5. Reappraisal of constructing authorities, including promotion of any necessary legislation.
6. Definite scheduling of the construction program, including purchase of land and right of way.

The Committee has cut out quite a substantial chore for itself, but not one impossible of accomplishment if everyone in the sewage and water works fields lends his aid!

Personnel engaged in the administration and operation of sewage works may be of immeasurable assistance. In fact, who could possibly know more about the shortcomings and needs of existing facilities than the man responsible for operating them? Your contribution to postwar planning resolves into two fundamental parts: first, to determine the nature and extent of the improvement necessary to afford the best possible service to your community; second, to carry your recommendations to the governing Council or Board of Trustees with such emphasis that they will be made a definite part of the municipality's postwar construction program.

As the existing facilities in your charge are analyzed for the pur-

* Also Engineer-Manager, Urbana and Champaign Sanitary District.

pose of ascertaining needed improvements, make sure that the following questions are answered in the final appraisal:

1. Has provision been made for enlargement or installation of additional units to supplement works now at or approaching overload?
2. Have you recommended replacement or conversion of obsolete units and equipment of limited efficiency?
3. Have you considered repair or replacement of items which are suffering ''accelerated depreciation'' due to wartime overloads or as a result of ''baling-wire maintenance'' during the war?
4. Has provision been made for restoring inventories of operating tools and equipment which are being depleted during the war?

In other words, take a complete inventory of your facilities and compile it into a report that cannot be ignored!

The second part of your postwar planning responsibility, that of ''selling'' the Board or Council on the local program, may be far more difficult. Remember that the technical aspects of your recommendations may be beyond the comprehension of the usual business and professional man who make up such groups. Be sure that the submission of the recommendations is augmented by an explanation of how service will be improved, where efficiency can be increased, why operating costs will be reduced, and other advantages which will accrue.

Above all, be persistent! Don't be satisfied with the action taken until it includes authorization for preparation of detailed plans and specifications, promulgation of financing arrangements and purchase of necessary land and/or right of way.

''Blueprint Now'' for improvements later!

W. H. W.

PROBLEMS OF PLANT OPERATION AND COORDINATION *

By Walter E. Gerdel

Superintendent, Westerly Sewage Treatment Plant

The Westerly Sewage Treatment Plant of Cleveland was put into operation in 1922. The treatment provided for at that time consisted of screening, grit removal, and sedimentation and digestion in Imhoff tanks. Chlorination of the sewage effluent was practiced also during the summer months, the Westerly Plant being one of the early pioneers in this form of treatment.

Sludge disposal has always been accomplished until recently, by means of pumping the sludge into the plant effluent, and subsequently discharging it into Lake Erie. The original plans for sludge disposal,

* Presented at 17th Annual Meeting of Ohio Conference on Sewage Treatment, Mansfield, Ohio, June 23, 1943.

due to limited area at the plant site, contemplated barging the material to dumping grounds in the lake, but this method was never utilized.

Additional sewage and sludge processing improvements and units have been added to the plant from time to time. Some of these were experimental in nature, and served as demonstration units. Important data and information were obtained from the operation of this experimental equipment, which served as a basis of design for a considerable portion of the additions and improvements to the Easterly and Southerly Sewage Treatment Plants of Cleveland.

At the present time, the sewage treatment provided consists of screening, both mechanically and hand-operated; maceration of the

Fig. 1.—Aerial view of Westerly Sewage Treatment Plant, Cleveland, Ohio.

screenings in a hammer mill; grit removal, both by grit chambers and a detritor; aeration for grease removal; sedimentation in the Imhoff tanks, and chlorination of the raw sewage and the plant effluent during the summer months. (Fig. 1.)

A water spray skimming system on the Imhoff tanks (Fig. 2) now provides a very convenient method of removing grease skimmings, which at the Westerly Plant amount to considerable quantities. The sewage treatment is still partial in nature, and the various additions and improvements in the sewage processing units have been for the purpose of overcoming former shortcomings and to improve the treatment to the extent possible without changing it radically.

The greatest changes and improvements have been in connection with processing and disposal of the sludge.

Six separate heated digestion tanks were built and put into operation in an effort to overcome serious gas vent foaming of the Imhoff tanks; to provide suitable disposal of grease skimmings; and to abate the odor nuisance. It was intended to use the Imhoff tanks only as sedimentation tanks. Disposal of the digested sludge from the digesters continued to be by means of discharging into the lake until 1938, when the sludge vacuum filtration and incineration unit was put into operation.

The increase in the number of treatment processes and equipment has correspondingly greatly increased the operating problems. This is especially true of the sludge vacuum filtration and incineration proc-

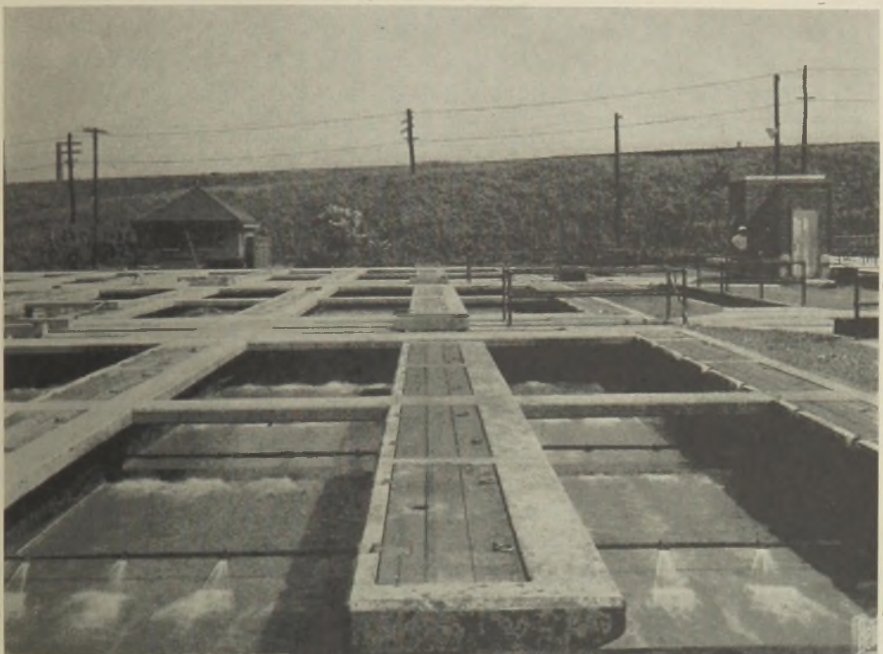


Fig. 2.—Water sprays at Imhoff tanks for concentrating surface scum, Westerly Sewage Treatment Plant, Cleveland, Ohio.

esses which are highly mechanical in nature, and requires considerable control and coordination with the rest of the plant in order to make them operate in an efficient and satisfactory manner.

The operating problems at a sewage treatment plant are often also associated with those of maintenance and control, and during these times include those dealing with plant personnel. I am presenting some problems encountered at the Westerly and other Cleveland plants, along with some others of a more general nature.

The problems at the Westerly Plant are by no means unique in the sewage treatment field, and are presented with the thought that discussion concerning them may be of interest, since they are similar to many encountered at other plants. As a matter of fact, the Westerly Plant is regarded as a plant that generally operates quite smoothly, with shutdowns and trouble the exception rather than the rule.

Personnel and Supplies

The problems of personnel and supplies are quite universal these days, and are perhaps the greatest cause of concern at a good many sewage treatment plants. The Westerly Plant, for example, does not have a single technically-trained supervisor or chemist who was in the plant in 1938 when the expanded plant was put into operation, with the exception of the superintendent. A good many of the men who replaced the original group of supervisors have been, in turn, replaced by others. At the present time, there are practically no technically-trained supervisors at any of the Cleveland sewage treatment plants, except on the day-time shift, whereas normal operations require a supervisory force twenty-four hours of the day. To a lesser degree, the same thing has occurred in the operating force, so that many of these men are now working 48, 56 and even 66 hours a week. These changes in personnel have sometimes resulted in poor and inefficient operation, due to the lack of experience and knowledge on the part of the new men, and also due to a general lowering of the qualifications of these men. The experienced men whose services we have been able to retain, have shown commendable loyalty and service in the way they have taken on new responsibilities and additional work, often without any financial benefits.

The procurement of material and supplies for both operations and maintenance work has, as a general rule, not been excessively difficult, except for a few things like wire for our vacuum filters, high temperature alloy castings for the incinerators, and of course, replacement of equipment like aluminum aeration pans. Allowances have to be made, however, for poor and delayed deliveries. It has been much more difficult to obtain the raw stock material with which to fabricate and work in our own machine shop, than to buy the finished product from the manufacturer of the equipment. The Westerly Plant was blessed with a fairly well-stocked storeroom at the time of our entrance into the war, and this has helped out considerably in being able to continue maintenance repairs without undue delays. Salvage and repair of worn parts is practiced whenever possible by such methods as building up with welding rod, turning down and using sleeves, and other ways which conserve material, but require much more labor.

Grit

Removal of grit is one of the oldest and commonest operations that is performed in the sewage treatment field, and yet it presents problems of proper removal, processing and disposal that, at one time or another, will trouble every plant containing devices for this service. It is also unfortunate that some plant operators do not consider this process as important or interesting enough to command their attention.

Many times a little change or improvement will relieve considerably points of trouble further on in the plant. The past year has been notable in Cleveland for its large volume of rainfall, and this consequently has been reflected at the Westerly Plant in high sewage flows and large quantities of grit being removed. Despite improved control, changes, and the increased attention which has been given this problem, grit continues to occasionally get through to the Imhoff tanks, where it will sometimes block up sludge hoppers. Considerable work is necessary to free the hoppers and to remove the grit from the Imhoff pipe galleries where it settles out in the sludge gutters after it is removed from the hoppers. Even when the sludge hoppers are not blocked up, the grit causes trouble by passing with the sludge to the digesters and then to the vacuum filter sludge sump. No difficulty has been realized at the digesters with this mixture of sludge and grit, but a considerable amount of trouble at the vacuum filter sump, sludge mixing chambers, and sludge pipe lines to the vacuum filters has resulted. The filter sump especially presented quite a problem in that it has to be periodically cleaned out (every four to six weeks) to get rid of accumulated grit, scum, and heavy sludge. It was formerly a tough, disagreeable and time-consuming job at the best and was never relished by anyone. This has now been greatly facilitated by extending a six-inch raw water line into the sump and introducing the water in the form of jets and sprays with enough pressure and agitation to get the gritty material stirred up and in suspension so that it can be pumped out. The improvement, of course, does not improve the fundamental conditions which permit the grit to settle out with the sludge, but it does overcome a troublesome point.

Gas Vent Foaming Nuisance of the Imhoff Tanks and Unbalanced Loading of the Digesters

Despite the fact that catabolism of the sludge is accomplished as much as possible in the heated separate digestion tanks, a considerable amount of digestion still goes on in the Imhoff tanks, resulting in foaming of the gas vents. The primary reason for this occurring is the accumulation of scum, grease and sludge in the gas vents during the winter months, when it is impossible to clean out this material because of weather conditions. The removal of this substance in the spring and early summer months, along with the normally greater removal of suspended solids from the sewage during this same period, produces serious overloading of the digesters, and also results in the need of operating the filtration-incineration unit at full capacity during the hottest portion of the year. The fact that 1.8 times as much gas is produced per day in the months of May, June and July, as compared with December, January and February, and that often during the winter months there is a shortage of gas, shows the desirability of leveling out sludge processing operations. Increased frequency of removing raw sludge from the Imhoff sludge hoppers during the winter months has merely resulted in a thinner sludge with a greater volume of water to be heated up in the digesters. It has been found that pre-chlorination of the raw sewage is helpful in overcoming the gas vent foaming condition after the winter accumulated sludge solids have been removed.

Digestion Tanks Scum Formation

The separate digestion tanks at the Westerly Sewage Plant produce excessively thick scum formations, which have been the source of considerable trouble and annoyance. Up to 1938, the rate of charging of the digesters was such that the scum formations would increase in depth until a maximum depth would be established, at which portions of the scum layer would drop to the bottom of the digesters about as fast as it formed, thus maintaining more or less an equilibrium as to the thickness of the scum layer. During the last few years, however, the rate of charging has been increased considerably, and the scum formations have increased in depth, and quite regularly the hot water heating coils have been broken by the movement of the scum mass. This necessitated taking the digester out of service, pumping it down, cleaning it out, repairing the broken heating pipe coils and sludge inlet piping support, and then putting it back into operation. This happened a number of times before a permanent remedy was found that has been successful in preventing additional breaks in the coils. However, a new trouble has arisen from this condition to plague us, which consists of the scum layer increasing in depth until it enmeshes the hot water pipe coil, and acts as an insulator preventing heat from reaching the sludge. This excessively thick scum layer also prevents drawing off supernatant liquor even from the lowest takeoffs, and seriously affects the normal operation of the tank. Circulation of the contents of the digesters has been of no appreciable benefit, and our only recourse at the present time is to pump the tank down and clean it out.

Operation Flexibility

The average sewage plant operator wants flexibility perhaps more than anything else. This is especially true when it comes to those processing units which follow one another in series, and any one of which simply cannot be by-passed. (Fig. 3.)

Favorable circumstances sometimes permit plant operators to achieve considerably more flexibility at little cost. Originally, the scheme of operations of the sludge filtration and incineration unit of the Westerly Sewage Plant called for the removal of digested sludge directly from the digesters to the filter sludge sump. This method of operation, however, ties the two units too closely together and any unusual occurrence or maintenance difficulty in the filtration-incineration unit immediately affects the digestion unit operation, which in turn restricts the withdrawal or raw sludge from the Imhoff tanks, and may affect the heating systems of the plant buildings, which are all dependent on sewage gas. In order to overcome this difficulty and to provide the desired flexibility, one of the Imhoff tanks was taken out of service as a sewage sedimentation tank and converted into a sludge storage tank which receives all of the sludge withdrawn from the digesters. Besides acting as an expansion tank between the two units, it serves to provide a more uniform and composited digested sludge with higher solids content than would otherwise be the case. It has also been noticed that when sludge is drawn directly from the digesters and filtered, the ammonia odor generated is much more apparent than when the sludge is drawn from the open storage tank.

A similar mutual dependency relationship existed between the

Fig. 3.—Vacuum sludge filtration and incineration equipment, Westerly Sewage Treatment Plant, Cleveland, Ohio.

vacuum filters and the incinerators which were designed on the basis that all of the filter cake produced would be incinerated and there was no provision for diverting this material for other usage. A forced shutdown of the incinerators would immediately necessitate the stoppage of the vacuum filters and this proved to be awkward and undesirable. An outside filter cake chute was built in order to overcome this situation, and to also be able to supply a public demand for filter cake. The use of a portable belt conveyor that was available, in conjunction with this chute, provides a very convenient alternative outlet for the filter cake. During some months of the year, as high as 56 per cent of the total filter cake produced has been hauled away by the public, and an average of about 23 per cent of the total production during 1942 was thus taken.

Sludge Chemical Conditioning Control

A great deal of time and effort has been spent in trying to control as closely as possible the dosages of chemicals necessary in order to properly condition the sludge for vacuum filtration. Control methods, based on laboratory analysis of the sludge, quick solids determinations, and Buechner funnel tests, have the disadvantage that they are slow and can usually only be performed by personnel familiar with laboratory equipment and procedure. In addition, the sludge is variable enough in its chemical demand so that frequent tests would be necessary if control were to be based entirely on any of the above methods. The method of control now used at the Westerly Plant is based on determining the amount of chemicals used per ton of filter cake produced. This is easily done by taking readings on the ferric chloride, lime feeders, and the filter cake weightometer at suitable time intervals. It is readily applied and will quickly inform the operators of the equipment whether the chemical dosages are in the normal range or not. Occasionally, abnormal sludges which filter poorly are met with. The only thing that can be done in such cases is to vary the chemical dosages until the sludge filters reasonably well, and try to locate and rectify the cause of the abnormal sludge.

Incinerator Operation

The chief objective in operating the incinerators relates to temperature control. Normal operations should be consistently below some established safe maximum temperature, and changes in temperatures should be as small as possible. These are both important factors in the life of the brickwork and metal work of the incinerators. It has been found that a uniform rate of feed to the incinerators assures more than anything else steady incinerator temperatures, and anything that is done to improve the uniformity of loading is sure to benefit the incinerators. This can sometimes be accomplished by increasing the number of vacuum filters operating, and decreasing the output per filter proportionately. The lower filter output usually also permits lower chemical dosages than would otherwise be the case, and produces drier filter cake, which is usually beneficial. Proper draft conditions in the incinerators is of utmost importance, in order to operate at the desired capacity. It is sometimes possible, when low drafts exist because of excessive losses through air preheaters, to improve draft conditions by installing gas bypasses around the preheater sections.

Post-Chlorination Control

Post-chlorination of the effluent sewage at the Westerly Sewage Plant is practiced about one hundred days of the year during the bathing season. Since the sewage only receives partial treatment and contains large amounts of industrial and stockyard wastes, it is extremely variable in its chlorine demand. At the present time, our method of control is to run samples for residual chlorine at frequent intervals (every two hours when supervision is available) and accordingly change the chlorine dosages as is required. At times when no residual chlorine tests are made, the dosages are changed according to a prepared schedule, which is based on previous experience. This method of control is at best not entirely satisfactory, as it does not follow variations in the sewage closely enough, and generally requires the services of someone who is capable of running the chemical test and making the necessary calculations. There is a definite need for automatic control equipment to do this work that is beyond the experimental stage and is rugged enough to stand continuous operation for months at a time.

Maintenance

The amount of maintenance work necessary in order to keep a plant operating properly, vitally affects operations. A piece of equipment that is forever getting out of order and forcing the shutdown of some particular unit, is aggravating to say the least. Equipment which fails frequently and requires a disproportionate amount of labor spent on it, but which does not necessitate the shutdown of a unit, is usually not worth its upkeep. There are many cases, though, in which equipment has been condemned when it has been the fault of the plant operator to give it the normal attention that it required.

A certain amount of normal maintenance work is to be expected. No equipment will last indefinitely, even with ideal conditions as to usage and lubrication.

Pumps

Pump maintenance is probably the commonest maintenance problem in the sewage treatment plants. It is also the most important. Practically every operation that is carried on is by means of one or more pumps somewhere down the line. Countless articles have been published on this subject and it has been thoroughly covered, so I shall just mention its importance. Most makes of pumps do a good job when they operate under suitable conditions. The more frequent difficulties encountered are packing replacement, worn shaft sleeves, worn impellers and wearing rings, air binding and cloggage.

Vacuum Filter Screens

In plants where the lime, ferric chloride type of sludge conditioning is used, a great deal of trouble has been encountered with clogged vacuum filter screens. Removal of the screens and sandblasting has been one way of correcting this condition. Another method uses muriatic acid with an inhibitor, which is poured over the screens which are left in place. The acid method is probably the simplest and cheapest way of cleaning the screens.

Conveyor Belts

Maintenance of rubber-covered conveyor belts is a problem that the present war conditions has brought into the foreground. Experience has shown that it is of great importance to keep moisture from getting under the rubber covering and into the cotton fabric. The usual point of entrance is at the splices or at worn places. Rubber cement and rubber compounds applied at these points help somewhat in retarding rot and decay, but are not the solution of the problem. In plants that have enough belting to justify the cost, the purchase of portable vulcanizing equipment to make belts endless, would undoubtedly prolong belt life and reduce the maintenance work now necessary in renewing splices. Experience has also shown the advisability of using synthetic oil and grease resisting rubber on belts. Those belts which are subjected to the heat of incinerators and pressure from plows and scrapers require the synthetic rubber coverings more so than others not operating under these conditions.

Aeration Plates and Pans

The war effort has produced, in most communities, greater industrial activity which has resulted in greater volumes of industrial wastes entering the sewers. These wastes contain oil, acid and iron salts, to mention a few of the more common ingredients. Clogging of aeration plates and corrosion of the pans have resulted, in some plants, to a serious degree. The non-usage of aluminum outside of the war industry has created a tough situation at these plants requiring replacement pans. Corrosion of aluminum pans can be retarded considerably, or stopped entirely, by application of bituminous paints and coverings applied either hot or cold. The cleaning and reconditioning of air plates is not so serious. During the last several years, distinct advancements in the procedure and method of cleaning plates has been carried out at the Easterly Plant of Cleveland, and information relative to this work is available in the literature.

Conclusions

The past ten years in the art of sewage treatment have been one of tremendous development, and there have been many new and experimental devices incorporated in the sewage treatment plants built and extended during this period. We are now going through what may be termed the proving period under actual plant operations. The results now being achieved; success or failure of certain types of equipment; difficulties in plant operation; degree of purification attained, will all determine the design of future plants. The responsibility of gathering and reporting this information to the best of their ability is fundamentally that of the plant operators who are actually in these plants. Depending on how well this job is done, will determine the rate of progress in the field of sewage treatment in the future.

WARTIME EFFECTS ON TREATMENT PLANTS *

By T. C. Schaetzle

Superintendent, Sewage Treatment, Akron, Ohio

It is not my purpose in this short paper to discuss the man-power situation which confronts all of us but rather to discuss the changes which have taken place in the sewage strength due to war time production and the steps taken to solve some of our problems through substitution of materials and equipment.

War broke out in Europe in September, 1939. By October of that year we noted a change in the concentration of suspended solids at the Akron Treatment Plant. In August of that year the suspended solids reaching our Imhoff Tanks contained 262 parts per million and by October this had risen to 335 parts per million. During 1940 there was some reduction in this concentration but by 1941 the trend was again upwards and has continued to rise so that the yearly averages for 1941 and 1942 were 314 and 324 parts per million, respectively, as against 331 for the first five months of this year.

The Akron Sewage Treatment Plant was designed for an hydraulic capacity of 33 million gallons daily and a solids load of 25.4 tons per day. In 1938 the flow was 36.3 million gallons daily and the tonnage of dry solids received was 42.8. For the first five months of 1943 the flow had increased to 58 million gallons daily and the dry solids to 86.4 tons. In other words, between pre-war days and the present time we have found ourselves confronted with an overload of 75.7 per cent hydraulically, and 239.8 per cent on a dry solids basis. Naturally with this excessive solids and flow load there has been a falling off in plant efficiency with no immediate remedy for the same.

Part of the increases just referred to are due to heavy rains but to a much greater extent to increases in population because of the war effort in Akron, together with the greater discharges from the rubber reclaiming and synthetic rubber plants. The reclaiming plants are operating on a 24-hour basis for seven days a week. The exact schedule of the synthetic plants is not known to the writer. Both the rubber reclaiming and synthetic rubber plants do have some type of recovery process but in the case of the reclaiming plants the production is such that their waste recovery units were not of ample capacity as of seven months ago. The synthetic rubber plants present a different type of problem in that the crumbles of synthetic rubber have a specific gravity just below 1.

* Presented at 17th Annual Meeting, Ohio Conference on Sewage Treatment, Mansfield, Ohio, June 23, 1943.

Because of this it is very difficult to remove those particles which escape the manufacturing process. This fact is true to such an extent that some of the synthetic rubber particles are reaching our treatment plant and passing through all settling units as well as the trickling filters so as to be found in the final effluent.

The fact that the reclaiming plants do have a considerable bearing upon the nature of the Akron sewage is shown by the results obtained in our raw sewage during the recent rubber company strike in the latter part of May. During this strike period the suspended solids content of the sewage reaching the Imhoff tanks dropped to 180 parts per million as against 339 parts per million for the other days of this month. The B.O.D. of the raw sewage also reflects a similar condition with 96 parts per million during the strike as against 185 parts per million for the balance of the month.

Naturally, this heavy solids load has required some action on our part to dispose of the resultant sludge. As is well-known no major improvement can be made during the present emergency, even if ample funds were available, so we are forced to continue to enlarge our enormous number of lagoons. Area for these is becoming scarcer so that we were obliged to build lagoons on a hill east of the plant which required a booster pump and in our case additional transformers for an electrically-driven unit. Consequently, we resorted to the installation of a gasoline-driven pump made from an abandoned Federal truck and some obsolete pump parts which in normal times would have been considered pure junk. For a sludge line we used Universal cast iron pipe salvaged from our old treatment plant. The pump is not entirely satisfactory but does a job after a fashion.

Along with the need for handling our solids load is the need for excavating additional lagoons. This is done by a city-owned Byers Crane which has broken down on two occasions and has been repaired both times by our mechanical force because the Byers Company is so tied up with government war contracts that they will not under any conditions accept one of their units for overhauling at the factory.

Perhaps one other item concerning our wartime problems might be of interest. For the last three months of 1942 we were without heat from our steam boilers in the detritus building because of a broken steam line. Priorities, delays in shipment, and the like, made it necessary for us to return to the "horse-and-buggy days," that is, to use small boomer coal stoves, such as are used in the country stores, for some kind of heat in the large detritus building.

The City of Cuyahoga Falls discharges its sewage into Akron's sewers and, then, treats a proportional amount of Cuyahoga Falls and Akron sewage at their own plant which uses the Guggenheim process.

Their contribution to our sewers is 1½ million gallons daily. Thus it can be seen that they are in reality treating Akron sewage although their flow can be so regulated as to eliminate fluctuations from hour to hour and from day to day. They, too, have felt the results of the industrial load during these war times. The average flow treated by them during May, 1943 was 1.26 million gallons daily, which figure was rather uniform through the entire month. Air was added at the rate of 0.97 cubic feet per gallon. Again referring to the recent strike period their raw sewage suspended solids content was 173 parts per million as against 269 parts per million for the balance of the month, and the B.O.D. content of the raw sewage was 113 parts per million as against 153 parts per million for these two periods. Perhaps of still more significance are the figures for suspended solids, B.O.D. and D.O. in the final effluent of their plant during the strike period as compared to the other days of the month. These were 25, 16, and 5.1 parts per million as against 52, 43, and 2.1 parts per million.

The Falls Treatment Plant is equipped with a modern type primary settling unit as against our Imhoff tanks. In spite of this condition

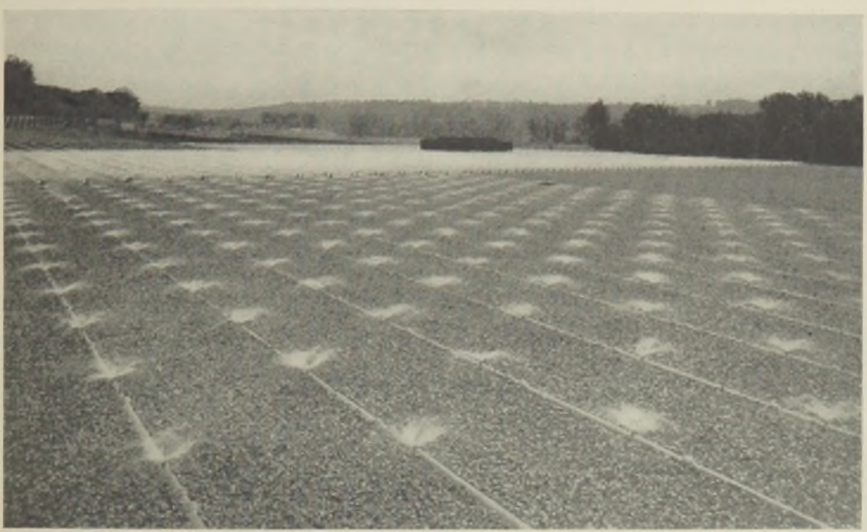


FIG. 1.—View of trickling filters at Akron, Ohio.

there are times when their settling efficiency is as low as ours. The exact cause of this is not known but I do know that some of the synthetic rubber passes through their primary units fully as easily as it does through our Imhoff tanks.

At times the sludge which they incinerate becomes very light and fluffy causing considerable difficulty in the incinerating unit and conveying equipment. Much of this sludge seems to contain a considerable amount of fabric-like substance. Whether or not this is fabric from the reclaiming process, we do not know.

Finally it might be stated that both the Falls and Akron Plants have had intermittent "shots" of very heavy oil which apparently came from one particular source as it has been eliminated since we have contacted the authorities at the apparent point of origin. It was traced through observation of the various racks in the sewers around the city. We are still confronted, however, with intermittent "shots" of a blue-green substance of such a concentration that the entire flow of as much as 60 million gallons will be discolored for a period of from 5 to 50 minutes.

In conclusion, I might state that there are intervals when our incoming sewage looks like a good activated sludge mixed liquor. Whenever this occurs our pH is 8.5 or better. Although we have this increase in solids load, we are fortunate that it is on the alkaline side because of our trickling filters and, in spite of the fact that at least a portion of the synthetic rubber wastes have a pH value as low as 5.0.

BARK FROM THE DAILY LOG *

June 2—Only six months since we entered the war and the pinch of the labor shortage is already acute. Spent several hours making the rounds (taverns, sidewalk curb conclaves, front porches and back yards) after the local employment services were unable to furnish extra laborers for cleaning sludge drying beds.

Was there not a day when men came around to **ask** for work?

June 5—Another personnel problem! Our chemist, who has been corresponding recently with local Selective Service officials, has decided to analyze bullets in an ordnance plant. His successor, a young lady equipped with chemistry and bacteriology training acquired during her Home Economics course at the University, began work today.

June 11—Our park was the scene of robbery last night—a local chap having made the mistake of exposing his pay envelope at a nearby tavern. Called on the sheriff to request that a squad car make the rounds of our property once or twice each evening (particularly romantic ones) in an effort to control further robberies, vandalism and other incidents.

June 16—Investigating the cause of unusual currents in Imhoff Tank 1, discovered that one of the inlet cone valves had come apart, dropping the cone portion into the submerged inlet pipe. You guessed it! Fishing out the cone and reassembling the valve was quite a party!

June 20—Another diamond ring to look for when grit is next removed at the screen chamber. Advised the unhappy loser to have a plumber open the house sewer and place an observer at the first city sewer manhole below the house connection for several hours. Has anyone ever heard of an object being recovered under such circumstances?

June 24—The annual chore of resanding half of sludge beds now completed for this year. On the basis of the sand purchased this year, the sand requirement was 5.05 cu. yds. or 7.15 tons per 1000 sq. feet of bed per year. A clean, fine, bank-run sand was obtained locally at only $1.10 per ton (delivered) and the resanding cost of $7.86 per 1000 feet of bed per year is considered quite reasonable.

July 7—How far should a municipal agency go in providing recreational facilities in the grounds of a sewage treatment works?

About five years ago, a very attractive open oven was installed for the use of picnickers visiting the 47 acre park in which our plant is situated. Today,

* Based on 1942 daily records of Urbana and Champaign (Ill.) Sanitary District.

due to vandalism and just plain carelessness on the part of users of the oven, it is little more than a heap of rubble and is to be completely removed. No replacement is planned.

July 13—Informed that asphaltic road materials are "frozen" by WPB and that we cannot obtain the supply needed to give a second surfacing treatment to the new black-top surface begun last year. This is most unfortunate as it probably means that the work and money expended on the road last year will be sacrificed.

Nevertheless the experience has been worth much and we shall know how best to start over after the war!

July 29—Tried out something new while cleaning the filter distribution system (nozzle type) today. The drain valves on the main headers were opened, allowing air to enter the partially emptied piping between doses. Then the end nozzles on each lateral were rmoved. Under these conditions, each time the nozzles began to discharge, a veritable geyser would occur at the open end risers—the air-sewage mixture spewing 20 to 30 feet high. The first flushes were black and full of suspended matter but this progressively cleared up after the nozzle field operated 8 or 10 times. The "blow-off" thus accomplished is now a routine part of our distribution system maintenance procedure and is believed to be just as effective as it is spectacular.

August 4—A pleasant visit by Superintendent F. E. Johnson of the Elgin (Illinois) Sanitary District. As we enthusiastically described the "new" filter distribution system "blow-off" procedure, imagine the deflation that took place when Johnson informed us that the same method has been routine at Elgin for several years!

Nevertheless, there was much satisfaction in the knowledge that the practice was subscribed to in such a well-operated plant as that at Elgin.

August 6—Rendered assistance to a local industry in abating a minor stream pollution problem involving oil and sanitary wastes. Although the industry is not located within our District, the wastes were being discharged to our outlet stream at a point about 3 miles above us. Charged the job off to community service and good will.

August 10—The most serious accident in the 19-year history of this plant—a near tragedy—occurred today. While painting the superstructure of the clarifier mechanism in the final settling tank, our valued senior operator fell through the truss-like structure to the tank bottom, a distance of some 15 feet. Upon regaining consciousness, the man complained of a severe back injury so no attempt was made to carry him up a ladder but this left a difficult problem as to how to get him out on a stretcher.

The solution is illustrated in Fig. 1. The local Fire Department was called and a 30-foot ladder placed with one end on the tank bottom and the other end on the wall beside the truss. The stretcher was then fastened firmly into the lower end of the ladder, to which ropes had been affixed, and thus raised to the level of the clarifier superstructure walkway. It was then a simple matter to carry the injured man to the waiting ambulance. Upon arrival at the hospital, just 35 minutes after the accident, the injuries were listed as a broken vertebra, double compound fracture of the left arm and a severe scalp laceration. The attending physicians approved completely of the careful procedure in effecting removal of the patient from the tank.

August 14—Haven't much heart for the clarifier painting job since the accident last Monday but did try a different method of applying paint to the steel walkway gratings, which are in fairly small sections. Filled flat pans with paint to a depth of about an inch and dipped the grating sections, first one side, then the other. Wasted a little paint but obtained positively complete coverage with a great saving in time over brush application.

August 20—Engaged in pumping gas vent scum from Imhoff tanks in preparation for next winter. May seem somewhat early to be concerned about

Fig. 1.—Proof that serious accidents do happen in sewage treatment plants.

winter preparations but the logic involved here is to get the drying beds, which will receive the scum, free for further service before rainy weather sets in. The scum requires twice as much time to dry as does digested sludge and might tie up much of the drying bed capacity for several months if drawn later in the year.

August 27—Another accident! The second shift operator slipped on a wet spot on the concrete floor at the dosing tanks and suffered a painful wrist sprain in falling. Investigation revealed the slippery area to have been caused by a drip-leak in the bottom of the dosing tanks where a wood form spreader had been left embedded in the concrete and had eventually rotted away. A carefully placed cement-Ironite patch eliminated the cause of this fall.

August 31—So ends a bad month for accidents. Mighty glad it's over!

SAMPLING AND ITS RELATION TO SEWAGE TREATMENT PLANT OPERATION *

By C. D. McGuire

Superintendent, Columbus, Ohio, Sewage Treatment Works

Tests of sewage, sewage plant effluents, sludges, gases, trade wastes, chemicals, etc., in connection with sewage treatment works operation are made as a means of controlling and measuring the efficiency of plant performance. It is, therefore, important that the results of these tests be as nearly a true measure of the qualities sought as is possible to obtain. However, there is a certain point to which accuracy should be carried and beyond which refinements are wastes of time and effort.

In attempting to test anything, one of the most important factors is the securing of a sample which truly represents the material to be tested. With mixtures this is theoretically impossible but, practically, by exercising the necessary precautions a sample can be secured which does approach a true sample.

So called "catch" or "grab" samples of sewage can only give the character of the material passing the sampling point at the instant when they are taken. By collecting and compositing samples at fixed time intervals, an average result may be obtained. If these fixed interval samples are taken in proportion to the quantity of flow at the time, then a still more correct sample is secured. If equal volumes of sample are taken and composited at fixed intervals of flow, such as every 10,000, 100,000 or 1,000,000 gallons, then the accuracy is only affected, practically, by the length of interval and physical difficulties.

All samples should be collected or at least stored in clean clear glass bottles of sufficient size to be representative and in an amount sufficient for the proposed tests.

Where continuous flow measurements are made, samples can be taken in proportion to the flow at fixed intervals and composited for the day or part thereof. Samples taken at short intervals tend to be more representative than those taken farther apart. Much care should be used in selecting the sampling point. Samples should not be taken at the top or bottom of a flowing channel. Usually, a point about two-thirds of the distance to the bottom of the channel is considered proper. After securing the sample, a portion conforming to the flow at the time is measured out and added to the compositing container. If possible, this compositing container should be kept at a temperature of 10° C. (50° F.) or lower, during the storage period.

In sampling by hand, samples should be taken as nearly as possible in the same manner each time. Persons taking samples should be either thoroughly trained so that they understand just what they are doing and why, or be taught to do the job purely mechanically.

* Presented at 17th Annual Meeting, Ohio Conference on Sewage Treatment, Mansfield, Ohio, June 23, 1943.

In most plants the period of flow through the plant is at least two hours. A sample of the plant effluent taken at 9 A.M., would be the result of treatment of sewage which came into the plant at or before 7 A.M., and would have practically no relation to a 9 A.M. raw sewage sample just arriving at the plant. Because the character of sewage, except when modified by some predominating trade waste, is in direct relation to the habits of the persons in the community and because our daily habits are almost routine, the daily difference in sewage composition does not vary as much as does the hourly. This means that a composite sample of raw sewage for Wednesday will not differ as much from Friday's sewage as will the 6 A.M. sample differ from the 6 P.M. sample on the same day. Daily composite samples, therefore, are more comparable than hourly. It follows that the more nearly the samples represent the 24 hour period, the more nearly they are true samples.

In the small plant where one man is the whole works and has a few other duties besides taking and testing samples, it is usually necessary to reduce this part of the work somewhat. The experience has been that the small operator can take hourly samples over a 5-hour period (six samples) composite them and run the routine tests necessary during a regular eight hour day. This gives a much better sample than attempting to figure or guess the period of flow through the plant and take related samples.

In sampling sewage and sewage plant effluents, certain points are to be considered.

1. Character of tests or examinations to be made:
   (a) Biological tests.
   (b) Biochemical tests.
   (c) Chemical tests.
2. Use or purpose of results obtained:
   (a) Operation control.
   (b) Comparative research.
   (c) Litigation or court testimony.

Samples for biological or biochemical tests must be kept as nearly as possible as taken. Samples for oxygen content because of both biological and physical effects of storage should be tested as soon as possible after collection, preferably, at the time and place of sampling. Shaking, stirring or any undue mixing of a sample will change its oxygen content. Acidifying such samples stops any biological activity but does not control physical changes.

Samples for the determination of solids and for straight chemical tests, such as nitrogen and chlorides, may be preserved by treating with chemicals.

Wet sludge samples should be secured by compositing of small samples taken during the drawing period. The interval between portions will depend upon the length of the drawing period.

Cake from sludge filters can be sampled by taking small portions at regular intervals and combining in a composite covering whatever period the sample should represent.

Dried sludge on beds should be sampled by compositing small portions from symmetrical points about the bed, making certain that the portions include the entire thickness of the cake.

In sampling trade wastes the character, variation in strength and rate of flow must be considered. All these factors vary with the source of the waste. Trade wastes may vary with the hour of the day, day of the week or even with the month of the year.

All composite samples should be mixed well and a portion of the mixed sample used for the test.

The fundamental idea in sampling is to secure a test portion which as nearly as possible represents the material to be tested. Mixing is very important. With wet or damp materials, drying of a larger sample to a point where it may be ground to a finer consistency makes the material more easily mixed. (Of course, corrections must be made for moisture removed.)

Quartering, which is dividing a pile of material into four parts by cutting it in two diameters at right angles to each other, then taking opposite quarters, helps to get arbitrary mixing and selection of material for sampling.

If liquids such as ferric chloride solution, sulfuric acid, fuel oil, etc., which are received in cars are sampled soon after the car is set (because of the mixing which moving of the car has effected) a drawn or dipped sample will usually serve the purpose. Otherwise, portions should be taken at different depths in the car.

Any statement made relative to the sampling of sewage, sewage effluents or sludges is equally applicable to any other liquids or solids.

This paper is presented, not as anything original but as an effort to call your attention to the reason for sampling and its importance in the proper operation and control of sewage treatment works.

SLUDGE CONCENTRATION AND DISPOSAL AT MARION, INDIANA *

By David Backmeyer

Superintendent, Sewage Treatment Plant

The sewage treatment plant at Marion, Indiana, is located on a tract of land which adjoins the northern residential section of the city, and for this reason sludge solids disposal must be carried out in a manner reasonably free from odor nuisance. Sewage and garbage solids are digested in two heated sludge digestion tanks. These tanks have a combined capacity of one million gallons, and are both equipped with floating covers.

* Reprinted from *Sewage Gas*, June, 1943, published by Division of Environmental Sanitation, Indiana State Board of Health.

Experience with Vacuum Filter

Until March 15, 1943, the digested sludge was dewatered on a vacuum filter which delivered a sludge cake having a dry solids content of 25 to 28 per cent. This sludge cake was hauled by truck to surrounding farm land and used as fertilizer. Since March 15, liquid sludge disposal has been practiced, and the vacuum filter has not been operated.

The operation of the vacuum filter has presented many interesting problems, some of which have been solved and some have not. In December, 1940, when the first filtration tests were made as routine check on the new equipment furnished, a digested sludge of 6.8 per cent solids content was dewatered on the filter to 26 per cent solids by using ferric chloride and hydrated lime as conditioning chemicals. A filter yield of 5 pounds per square foot per hour was maintained by feeding ferric chloride at 4.6 per cent rate and lime at 8.7 per cent rate. The cost for chemicals alone, per ton dry solids removed, was $2.47. (Ferric chloride can be purchased in the liquid form at $1.70 cwt. anhydrous basis, and hydrated lime of 72.0 per cent calcium oxide content costs $10.50 per ton delivered to the treatment plant.)

During the first several months that the filter was operated the rates of chemicals used were varied considerably in an effort to reduce the filter operation costs. In August, 1941, we were obtaining a filter yield of 10 pounds per square foot per hour by feeding ferric chloride at 1.8 per cent rate and lime at 13.0 per cent rate. The cost of chemicals for this operation was $1.94 per ton solids removed. The sludge filtered at that time had a solids content of 7.1 per cent. Several evils soon resulted from using a lime feeding rate as high as 13 and 14 per cent. Lime carbonate scale blinded the filter cloth and drum openings, and the filtrate pump had to be dismantled every few days and cleaned with acid. Strong ammonia fumes in the filter room made working conditions there very unpleasant during the hot summer months.

Sludge Elutriation

In December, 1941, several elutriation tests were made on the sludge in an effort to reduce the amount of lime needed for conditioning. This process is patented by Mr. Albert D. Genter, Sanitary Engineer and Consultant, of Baltimore, Maryland.

Laboratory tests were made to determine if it would be practical to wash the sludge sufficiently to permit its being filtered with ferric chloride only and no lime. It was found that additional plant facilities would be required to accomplish this on a plant scale, which, due to priority regulations, seems to be out of the picture for several years in the future.

Sludge Washing in Primary Settling Tank.—As a plant scale experiment, we decided to use one of our primary settling tanks as a sludge washing and concentration tank for a period of about one month. In this test the plant effluent from the final settler was pumped by a portable pump and mixed with the digested sludge from the bottom of the secondary digester as it was pumped into the primary settling tank. Two volumes of effluent were added to one volume of sludge and this mixture was allowed to settle for 6 to 8 hours. When the primary settler became filled, the supernatant was pumped off and discharged into the influent end of the other primary tanks. More sludge and effluent was added and the process was repeated until the sludge blanket in the wash tank was close to the outlet weirs. The sludge was then filtered.

Although counter current elutriation was not employed in this test, we did succeed in washing the sludge so that it would filter in a satisfactory manner with 1.51 per cent ferric chloride and 8.6 per cent lime. The filter yield was 5.7 pounds per square foot per hour and the cost for conditioning chemicals was cut to $1.42 per dry ton solids handled. Trouble from lime scale and cloth blinding was reduced by 50 per cent as a result of the reduction of lime application from 13 per cent to 8.5 per cent.

Some of the sludge removed from the elutriation tank had a solids content as high as 10 per cent. During the late summer months of August and September when the digesters were pretty well loaded with garbage solids, we have often been forced to filter sludge as thin as 4.5 and 5.0 per cent solids. Sewage gas production raised to 60,000 cu. ft. daily and the gas being generated in the secondary digester was sufficient to keep this tank from giving a suitable supernatant for return to the raw sewage wet well. As a result, large volumes of thin sludge had to be handled by the vacuum filter, and filtration costs were higher than they would have been had a thicker sludge been handled.

Sludge Washing in Secondary Digestion Tank.—An experiment was next made to see if present plant facilities would permit the carrying out of some method of sludge concentration in the secondary digester. Such a system would not require the sacrificing of a primary settling tank, and at the same time would save the cost of considerable sludge and water pumping.

In carrying out this experiment, connections were made so that sludge could be pumped from the bottom of the primary digester to the secondary digester through a 6-inch line and so that water from a nearby stone quarry lake could be pumped into the secondary digester through the same 6-inch sludge line. It was decided to use the quarry water instead of the plant effluent water as done in the previous experiment because the quarry water was much colder both summer and winter. The temperature of the quarry water during the winter months is as low as 35° F. The temperature of the sludge in the primary digestion tank is kept at 95° F. And this tank has a capacity sufficient to give a digestion period of about 18 days. The sludge was pumped at a rate of 50 gallons per minute and the quarry water at a rate of 110 gallons per minute. The electrical cost for pumping the quarry water averaged about 8 cents per 10,000 gallons.

Table I summarizes the results obtained in thickening the sludge by dilution with cold water. The action of the two volumes of water mixing with one volume of sludge results in a mixture that has very little tendency to continue gasification. The solids settle rapidly and concentrate at the bottom of the digester, leaving a clear supernatant that can be withdrawn and returned to the raw sewage wet well.

A typical day's operation includes the following: (1) raw sludge added to the primary digester, 25,000 gallons, (2) sludge transferred to the secondary digester 25,000 gallons at 50 gallons per minute rate for a total of 8.5 hours, (3) water added to the sludge in 8.5 hours time, totals 56,000 gallons, (4) supernatant withdrawn from secondary digester tank 81,000 gallons. When suitable supernatant liquor can be withdrawn from the primary digester, it is not always necessary to transfer as much sludge as is equivalent in volume to the raw sludge pumped in.

TABLE I.—*Results of Transfer Sludge Dilution*

Date	Solids Concentration in Secondary Digester—Percent	Temp. in Secondary Digester Deg. F.	Temp. of Primary Digester Deg. F.	Gallons Dilution Water Added to Secondary	Total Power Cost of Pumping Dilution Water—Dollars
Oct. 1942	4.46–5.46	80–70	96	445,900	3.57
November	5.53–6.75	76–66	98	758,000	6.07
December	6.78–7.65	65–55	97	1,425,000	11.40
Jan. 1943	7.75–8.53	55–54	96	1,362,000	10.90
February	8.45 (Ave.)	54–60	92	1,207,260	9.65
March	8.45–8.58	60–63	97	991,190	7.94
April	8.58–9.06	62–66	96	1,231,100	9.86

Since this rather unique method of digester tank operation has been successful to date, several tables of pertinent data are given to present a clearer picture of the operation results obtained. Of course these data will have to cover a period of at least a full year before definite conclusions can be drawn as to the overall efficiency of the method.

TABLE II.—*Solids and Volatile Matter Comparison at Two-Stage Digesters*

Date	Primary Stage *		Secondary Stage *		Digested Sludge	
	Per Cent Solids	Per Cent Volatile	Per Cent Solids	Per Cent Volatile	Per Cent Solids	Per Cent Volatile
Mar. 1– 7	5.88	35.7	8.65	32.3	8.39	30.3
8–13	5.47	37.5	9.05	33.6	8.42	32.0
15–20	5.48	36.6	9.14	32.1	8.57	35.6
27–27	5.77	34.6	9.55	33.5	8.79	32.9
29–Apr. 3	6.00	36.0	9.00	33.7	8.74	30.9
5–10	5.86	35.2	8.83	32.1	8.66	32.5
12–17	5.98	36.3	9.17	30.5	8.55	31.7
19–25	6.29	32.7	9.32	30.5	9.55	31.7
26–May 1	6.65	30.3	9.94	30.6	9.28	30.5

* Samples taken at bottom of tanks.

TABLE III.—*Digester Loadings and Gas Production During Five Month Test Period* *

Date	Primary Digester Loading		Per Cent Volatile Raw Sludge	Per Cent Volatile Digested Sludge	Cu. Ft. Gas per Lb. Volatile	Primary Digestion Period in Days
	Lbs. Volatile Solids per c.f. per month	Lbs. Solids per c.f. per month				
Dec. 1942	2.07	3.75	53.6	38.1	8.12	18.2
Jan. 1943	2.30	3.68	56.6	31.3	7.20	20.9
Feb.	2.28	4.33	51.6	33.5	7.23	18.7
March	2.31	4.58	51.3	31.9	7.52	19.4
April	2.10	4.42	46.0	32.1	7.43	19.8
Average	2.21	4.15	51.8	33.7	7.50	19.4

* Raw sludge is a mixture of sewage solids, garbage solids, waste activated solids and supernatant solids.

In Table II, data are shown indicating the change in solids and volatile content of the sludge following the dilution and concentration procedure as outlined above. The digester loadings are shown in Table III, together with the gas production efficiencies and digestion periods in days.

In Table IV, the volume and quality of the supernatant liquor handled is shown. Further data will be available when more operation time will enable us to compile same.

TABLE IV.—*Volume and Quality of Supernatant Liquor* *

Month	Supernatant Volume		Total Supernatant Solids			Pounds Vol. Solids per Month
	Per Month (1000 Gal.)	Per M.G. Sewage (Gallons)	Per Cent	Per Month (Pounds)	Per M.G. Sewage (Pounds)	
Dec. 1942	1957	15,900	0.275	44,700	364	17,000
Jan. 1943	1705	15,600	0.158	21,326	195	7,130
February	1048	10,300	0.294	23,989	235	8,150
March	1579	13,750	0.312	40,440	352	13,200
April	1700	14,550	0.347	52,757	452	17,690

* From second stage digestion tank.

Liquid Sludge Disposal

During the first part of March plans were made to remove the digested thickened sludge in the liquid form without dewatering on the filter. A cypress tank was built to fit into the bed of the sludge truck (Fig. 1) so that the truck could be used for hauling sludge cake from the filter or for hauling liquid sludge. This tank has a capacity of 930 gallons, and was constructed at a cost of $95.

The tank is filled by a trap door on top and is emptied through either one or two outlets each 2½ inches in diameter. One outlet is connected to a portable pump which is mounted on the tail gate of the truck. This pump will pump the sludge through a 50 ft. section of fire hose at a rate of 100 to 150 gallons per minute.

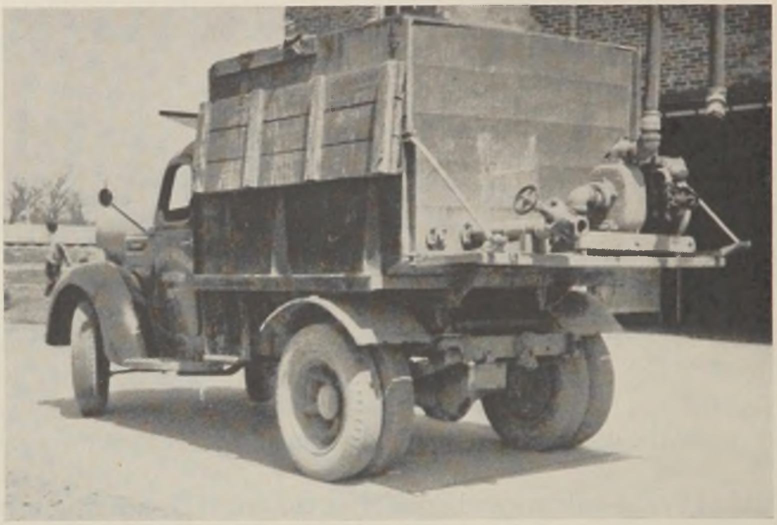


FIG. 1.—Truck equipped for liquid sludge disposal at Marion, Indiana.

Throughout the past months of February, March and April, many Victory gardens in Marion and vicinity have been covered with our liquid fertilizer. A full tank, comprising 930 gallons of sludge is delivered and applied to the garden plot (Fig. 2) for a cost of from $1.00 to

FIG. 2.—Marion, Indiana: Applying liquid sludge to farm land. Splatter plate attachment at end of drain pipe treats 6-foot strip when truck can be driven over area to be treated.

$2.50 depending on the distance the sludge must be hauled. The average distance traveled per round trip has been five miles and the average cost per load has been $1.50. Revenues received from liquid disposal from March 15 to April 30 total $215.

Since the sludge will average 8.6 per cent total solids, a tank load will contain 667 pounds of dry solids. The nitrogen content of the solid material is approximately 2.0 per cent and the phosphorus content is 2.4 per cent. Each truck load therefore contains about 13 pounds of nitrogen and 16 pounds of phosphate which have a combined value of $2.62 when figuring nitrogen at 14 cents per pound and phosphate at 5 cents per pound.

It is apparent from the above figures that even if the soil conditioning value of the sludge is disregarded, its application in a concentrated liquid form to farm and garden land makes an attractive bargain for the purchaser. Several orders ranging from 25 to 100 loads are now in the process of being filled. In most of these cases the sludge is applied to farm fields by draining a tank through a gravity line controlled by a gate valve. The truck is driven at a slow speed over the field and a very satisfactory distribution can be accomplished without operating the portable gas engine driven pump.

The following table compares the costs per ton dry solids of sludge disposal by filtration to that by liquid disposal as practiced during a 45-day testing period:

Removal by vacuum filtration:	
Chemical (conditioning)	$1.25
Cloth and wire	.05
Electricity	.55
Acid wash	.05
Labor (operators)	.30
Truck driver	1.20
Truck operation	.35
	$3.75
Removal by liquid disposal:	
Truck driver	$1.80
Truck operation	1.05
Sludge pump (loading truck)	.05
	$2.90

It is assumed that the same expense would be required for concentration of the sludge in either type of removal. Although the mileage driven for the liquid disposal method is three times that for the filtration method, the time required for loading and unloading is less in the case of the liquid, and therefore the labor cost for operating the truck is increased by only about 50 per cent. The cost of maintaining the truck in operation is figured at 7 cents per mile. The truck drivers work 42 hours per week and are paid $120 per month.

INTERESTING EXTRACTS FROM OPERATION REPORTS

GALESBURG (ILLINOIS) SANITARY DISTRICT (1942)

By L. W. Hunt

Plant Superintendent

Trickling Filters Overloaded

The most unsatisfactory operating condition was the excessive volume load on sprinkling filter. Flows above the 4.5 m.g.d. rate cause it to spray continuously at low head, resulting in very uneven distribution over the area of the stone.

Evidence also points to the fact that the top stone on the bed is too fine, which is conducive to "ponding" due to smaller voids between the stone. A very pronounced increase in turbidity during the colder months, as well as a marked decrease in efficiency is observed annually.

It is believed that an increase in filter area, as planned, will greatly reduce all of the above conditions.

Gas Production Rate vs. Digested Sludge Solids

Since 1938 gas production has noticeably increased due to the addition of secondary tank sludge as well as an increase in raw sludge solids. Extended periods of excessive gas production (above 30,000 cubic feet per day) seem to definitely decrease the concentration of solids in the digestion tanks and cause excessive scum in the digesters. The data given below (and Figure 2) show the relation between gas production per square foot of tank area and concentration of sludge withdrawn to the drying beds:

Year	Raw Sludge—Per cent Solids		Digested Sludge—Per cent Solids		Cu. Ft. Gas per Sq. Ft. Tank Area per Day
	Total	Vol.	Total	Vol.	
1935	7.3	59.6	13.9	39.7	3.8
1936	7.7	61.2	12.0	37.4	5.0
1937	6.4	63.7	11.4	40.5	4.9
1938	6.7	57.9	10.2	38.7	5.7
1939	6.7	59.0	7.8	40.2	6.9
1940*	6.5	64.4	6.5	43.8	8.3
1941	7.9	62.0	7.5	42.3	6.9
1942	7.9	62.0	7.7	40.4	6.5

* Very dry year.

Attention is called to the fact that the above data represents yearly averages and not periods when excessive gas production caused the above mentioned effects to be particularly troublesome. For example, in 1940 there was an eight weeks period when gas per square foot of

Summary of Operation (Galesburg Sanitary District)

Item	1942 Average	
Estimated tributary population	26,000	
Sewage flow—ave. daily	4.187	m.g.d.
Per capita daily	161	gal.
Screenings removal—per m.g. sewage	0.692	cu. ft.
Grit removal—per m.g. sewage	6.45	cu. ft.
Unit loadings:		
Primary sedimentation period	2.87	hrs.
Trickling filters—flow applied	3.99	m.g.a.d.
Daily B.O.D. applied (6 ft. depth)	2,687	lbs. a.d.
Final sedimentation period	1.33	hrs.
5-Day B.O.D.—raw sewage	165	p.p.m.
Primary effluent	113	p.p.m.
Removal primary treatment	35	per cent
Filter effluent	43	p.p.m.
Final effluent	30	p.p.m.
Removal complete treatment	80	per cent
Suspended Solids	193	p.p.m.
Primary effluent	76	p.p.m.
Removal primary treatment	61	per cent
Filter effluent	57	p.p.m.
Final effluent	32	p.p.m.
Removal—complete treatment	83	per cent
Sludge Digestion:		
Raw sludge quantity per m.g. sewage *	1,390	gal.
Solids content	7.5	per cent
Volatile content	62.6	per cent
Digested sludge—solids content	7.7	per cent
Volatile content	40.4	per cent
Gas production—per m.g. sewage	5,682	c.f.
Per capita daily	0.91	c.f.
Per lb. vol. matter added	8.67	c.f.
Operation cost—per m.g. sewage treated	$15.94	
Per capita per year	$0.84	

* Primary sludge plus filter humus.

Summary of 1941–42 Operation Data, Danbury, Conn.

Item	1941–42 Average	
Population—estimated tributary	22,650	
Sewage flow—average daily	4.08	m.g.d.
Per capita daily	180	gal.
Coarse screenings removal—per m.g.	2.6	c.f.
Fine screenings removal—per m.g.	34.5	c.f.
Sludge to digestion:		
Primary sludge quantity—per m.g. sewage	2,080	gal.
Solids content	3	per cent
Filter humus quantity—per m.g. sewage	470	gal.
Solids content	6	per cent
Gas production—per m.g. sewage	4,150	c.f.
Per capita daily	0.75	c.f.
Operation Cost—per m.g. sewage	$17.06	
Per capita per year	$ 1.14	

FIG. 1.—Administration Building, Galesburg (Illinois) Sanitary District.

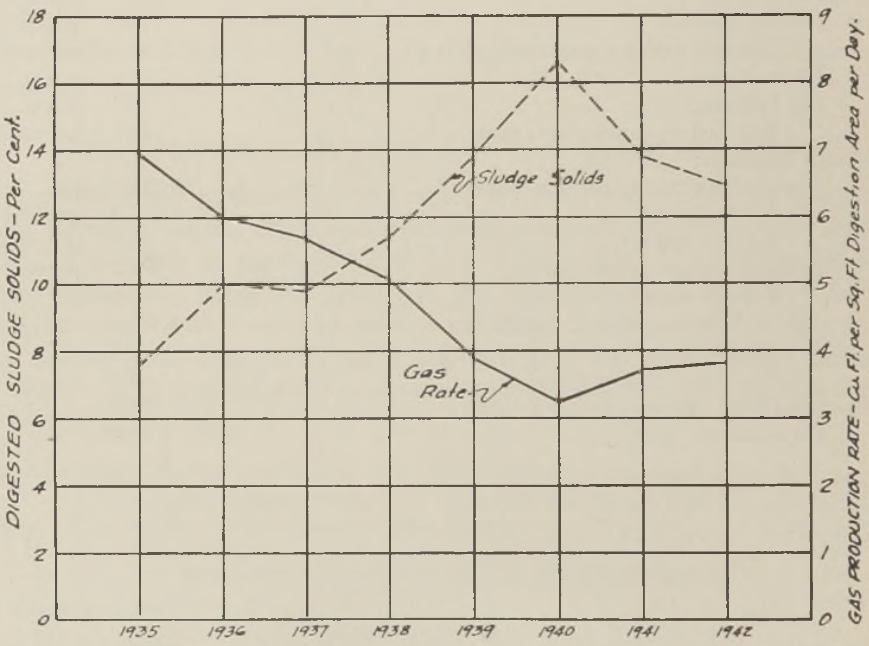


FIG. 2.—Effect of gasification rate on digested sludge solids concentration at Galesburg, Illinois.

tank area per day was 9.2 cubic feet. Within this same period maximum daily gas production on two occasions was 40,800 and 40,500 cubic feet.

Gas Engines Effect Economy

Since this report concludes 27 months of gas engine operation, a review of this relatively recent phase of plant operation should be of interest. (Fig. 3.)

Estimated cost for all-electric pumping (27 mos.)		$10,265.00
Cost of power (27 mos. engine operation)	$3820.70	
Cost of engine operation (exclusive of fixed charges)	745.10	
Cost of power, plus engine operation		$ 4,565.80
Total saving—27 months		$ 5,699.20
Total hours of service to January 1, 1943		17,104.
Per cent of total time in service		86.7
Per cent of total flow gas-engine pumped (24 hours)		86.4
Gallons of cylinder oil used		227
Hours of operation per gallon of cylinder oil		61.7
Cubic feet gas consumed per m.g. sewage pumped (1941–42)		3,354

The cost of the engine, including installation, was $5,100.00 and the saving effected thereby paid for the engine in 24 months. The esti-

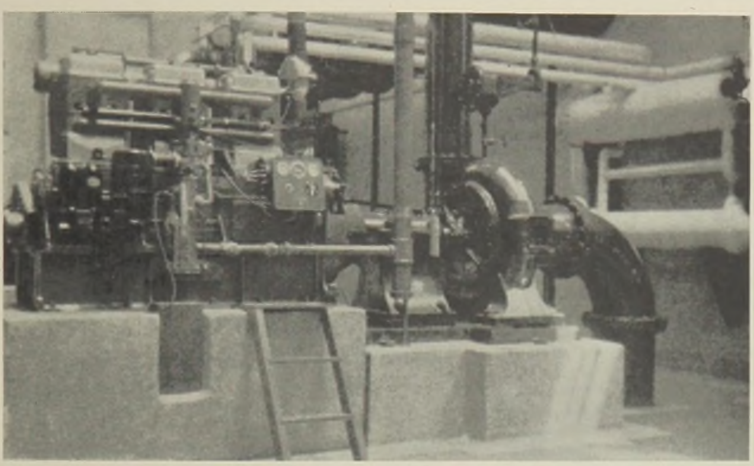


Fig. 3.—Gas engine driven pump, Galesburg (Illinois) Sanitary District.

mated time of 36 months made by the consulting engineers was therefore quite conservative.

DANBURY, CONNECTICUT (YEAR ENDED JUNE 30, 1942) *

By W. M. Kunsch

Plant Superintendent

Fine Screens Eliminate Difficulties

Coarse screenings and grit totalling about 9,700 cu. ft. per year were removed by hand until the installation in September, 1935, of a mechanically cleaned coarse screen and two 14 ft. diameter Riensch-Wurl fine screens. Since that time removal of screenings and grit has averaged 57,000 cu. ft. per year and 34.6 cu. ft. per m.g. The good results

* Combined with Ten-year Report.

of this installation have been numerous and can be listed mainly as follows: (1) the elimination of fur and hat manufacturing wastes from the sewage by means of the fine screens removes serious problems in operating the digesters, trickling filters and slow sand filters; (2) the elimination of all coarse solids permits operation of sludge pumps without clogging difficulties; (3) mechanical removal of screenings eliminates previous insanitary working conditions.

Observations on Ten Years of Digestion Experience

Digester operation, in the main, has accomplished its purpose of sludge digestion, but has nevertheless been spotty rather than smooth. Mechanical troubles due to heavy sludge or scum and to wearing of parts have made necessary the emptying of either the Dorr or Link-Belt digester almost every year. Since the fine screens were installed

Fig. 1.—General view of sewage treatment plant, Danbury, Conn.

the scum problem has been greatly reduced. At present, mechanical troubles, such as wearing of bearing shoes in the Link-Belt digester, though not eliminated, are predictable. Heavy overflow liquor, the nemesis of many single stage digestion units, has given much trouble especially in winter. This is believed to have been mainly the result of an extreme temperature variation between the heavy digesting sludge and the sludge liquor. Unavoidable periodic overloads of raw sludge also have had a direct bearing on this. As far as existing facilities will permit, the causes of heavy overflow liquor have been eliminated. Digester capacity is normally sufficient. In winter if the addition of humus sludge from the final settling tanks tends to overload or produce too low a temperature in the digesters, area has been provided so that it can be pumped directly to sludge beds. It has been found that another help toward maintaining more even digester temperature in winter is to lower the seed sludge level in the tanks to a minimum before winter begins and, if weather and bed area allow, to keep this level at the low optimum point. To insure continuously smooth operation, however, it is recommended that, as soon as it is possible to obtain materials, boiler capacity, and radiation capacity in the digesters be increased. Oftentimes gas that might have been put to good use has been wasted in winter because of this limited capacity.

Chlorination During Filter Flooding

Chlorination facilities were installed and first used early in 1937. The original practice of chlorinating settled sewage, previous to its distribution on trickling filters, continuously during the summer months has been altered so that chlorine is added only at those times when the filters are being flooded. This routine, which we are able to carry out without odor nuisance only because the wastes arrive at our plant in a fresh condition, saves 20 per cent of the original 15 tons of chlorine consumed per season.

Trickling Filter Operation

Two of our four trickling filter distributor motors were completely overhauled and required some bearing replacements. A new set of thrust rollers was purchased for each distributor. Though only one old set has been replaced to date, it is expected that the others will require replacement in the near future. Constantly smooth operation of these thrust rollers, which keep the two arms of the distributors level, is of vital importance to long life of the entire mechanism. Frequent inspection, greasing and cleaning is necessary to obtain good operation and reduce wear.

One difficulty of winter operation which has not yet been overcome is the freezing of distributor spray, during long cold spells or cold accompanied by high winds, to such a thickness that the distributor motors must be stopped to prevent damage to the arms. A clearance of 12″ to 15″ between the top of the stone and bottom of splash plates or distributor pipe would greatly reduce the possibility of damage from ice. None of our beds have this much clearance. During the winter of 1941–42 about 150 cu. yd. of stone were removed by hand from one bed on which clearance was only 2 inches in some spots.

Final settling tanks were drained once during the year to permit removal from the hoppers of grit and small broken stone which had washed in from the trickling filters. The accumulation of this hard-to-pump material was considerably less than in previous years. The ready accessibility of a converted slow sand filter for receiving humus sludge in winter, flushings from the sludge line between the digesters and humus sludge pump, and contents of final settling tanks when cleaning is necessary, has helped to keep these polluting liquids from the effluent stream on several occasions, and has also contributed to smoother digester operation.

Laboratory Needed

It would be greatly to the city's benefit to act promptly, when restrictions on construction are removed, in order to provide the plant with a laboratory where tests could be made which would permit proper planning for industrial waste treatment as well as increased efficiency in the operation of present plant units. The construction of such a laboratory was first recommended in 1939 when plans were drawn for a utility building to contain this and also a garage, workshop, toolroom, locker room, and sanitary facilities for the maintenance personnel.

TIPS AND QUIPS

Superintendent Otto C. Rimmele of Janesville, Wisconsin, reporting via *The Clarifier* (new bulletin of the Wisconsin Conference of Sewage Works Operators), suggests a practice which is quite in line with the WPB program of electric power conservation as well as a saver of wear and tear on the memory process of plant operators:

"Wartime precautionary measures suggested that our plant grounds and the various treatment units be illuminated during hours of darkness. We have connected the switch controlling these lights to the same automatic time control that operates the screen cleaning equipment, so that the lights can be set to go on at any pre-determined time and are automatically turned off without attention by the operator on duty. As daylight hours vary, we change the settings on the automatic control to correspond."

* * *

The late Luther Burbank has nothing on Superintendent Ben H. Barton of Findlay, Ohio, who has "crossed" conventional sludge drying beds with a semi-natural lagoon area and ended up with what he terms "Begoons." Regardless of what they are, Barton finds them most convenient for disposing of the consistently heavy digester supernatant liquor produced in the plant.

* * *

Experience with maintenance of grease-lubricated plug valves used to control the flow of air to the individual banks of air diffusers in the aeration tanks at Fort Wayne, Indiana, is cited by Chief Chemist Paul L. Brunner. A total of 132 of these valves are in use (Fig. 1) and it was found impossible to turn them after one year of service due to oxidation of the grease and corrosion of the valve body induced by the continuous flow of air. As each aeration tank was drained for inspection, the valves were removed and the valve bodies turned down about 0.005 of an inch, just sufficient to remove the oxidized coating and leave a smooth surface. The valves were then coated with a mixture of SAE–30 oil and powdered graphite and reassembled. The original

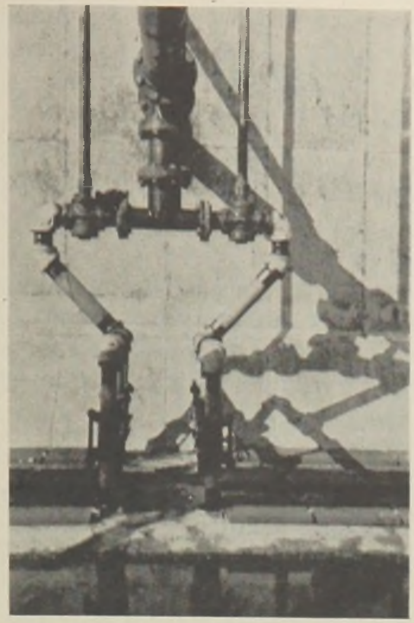


FIG. 1.—Plug valves in aeration tanks at Ft. Wayne, Ind.

trouble has not recurred after 18 months of service by the overhauled valves.

* * *

Another Indianan with ideas is Superintendent David Backmeyer of Marion, whose unusual but effective procedure for concentration of sludge in secondary digesters by adding cooling and dilution water to the transfer sludge from the primary stage, is described elsewhere in this issue. Could this be a prophecy of sludge digestion units consisting of a preheater followed by a refrigerator?

* * *

While on the subject of Hoosier experiences, we repeat that of Superintendent R. R. Baxter of Anderson, Indiana, as relayed by the State Board of Health *Sewage Gas.* Upon assuming his duties early this year, Baxter found some 26,000 cubic feet of grease in the digesters, with the heating coils covered by a heavy scale which deposited while high temperatures had been developed in an effort to melt the grease. Finding the scale to reduce heat transfer materially, he had just about become resigned to digester temperatures of only 60°–70° F. when he was pleasantly astonished to observe that the grease had become fluid at the *lower* temperatures, thus substantially relieving the situation!

Which merely adds to the proof that one can never tell what might happen in a sewage treatment plant.

Noting the reference to preservation of cannery waste samples in the *Bark From the Daily Log* column in the January, 1943 issue of *This Journal* (page 96), Consulting Chemist William A. Ryan of Rochester, New York offers an interesting suggestion:

"If representative samples of the waste are placed in clean No. 10 cans, the cans can be capped and sterilized in the retort and shipped for analyses of the samples at any future date. The waste can be reseeded for B.O.D. determinations."

Mr. Ryan points out further that the same method can be applied to the preservation of any organic waste but that it is particularly adapted to cannery wastes because facilities are conveniently available in such plants for capping and sterilizing the cans.

* * *

It is gratifying to observe the reaction of the substantial number of Federation members who have acknowledged receipt of the priorities material which was distributed in September. The demand for the information by sewage works operation personnel can be readily understood but the many expressions of appreciation were hardly anticipated.

This service to our members is just an example of what the Federation can do for its members. It will perform more, bigger and better functions of a similar nature in the future. It is full time that all of our members realize that the Federation is no longer only a journal distributing organization!

* * *

As this is written, the multitude of arrangements for the Fourth Annual Meeting and Second Wartime Sanitation Conference of the Federation are just approaching completion. With full realization of the difficulties of wartime travel, we are so presumptuous as to forecast that this meeting may draw the highest registration of any of those previously held!

Paid registrants at Chicago in 1940 numbered 556; the present record of 569 was set at New York in 1941 and the First Wartime Conference drew 412 to Cleveland in 1942. If early inquiries regarding the meeting constitute any indication, the 1943 meeting should attract at least 600. Furthermore, the superlative program and provisions being made for the enjoyment and entertainment of those attending are deserving of a record-breaking registration!

* * *

ADVISORY SHORT STORY

Postwar planning?

Here's how—

Select the jobs and

"BLUEPRINT NOW!"

Editorial

THE JOURNAL AND THE FEDERATION

It doesn't seem very long ago when William Buffum, Willem Rudolfs and a few more of us got together at a dinner during the American Chemical Society Meeting in St. Louis in 1928, and Mr. Buffum told us that he would underwrite the publication of the SEWAGE WORKS JOURNAL. George W. Fuller had completed the organization of the Federation in his usual competent, forceful manner, and Harrison P. Eddy had laid the groundwork in 1927, leading to the organization of the Committee of One Hundred, with Charles A. Emerson as Executive Chairman. But no funds had been raised nor organization effected for the publication of the *Journal* until Mr. Buffum offered his office, the personnel of the Chemical Foundation, and the remaining funds of the Imhoff Tank patent fees, which had been seized by the Alien Property Custodian and were being administered by the Chemical Foundation for the promotion of research in sanitary chemistry and engineering at several experiment stations throughout the U. S.—New Jersey, Iowa, Pennsylvania, Illinois State Water Survey and possibly others.

With this guarantor, patron and able executive behind the venture, the financial security of the *Journal* was assured, and for many years, until Mr. Buffum's death in June, 1940, he handled all of the business affairs of the *Journal*. He was a true friend of research and was always interested primarily in the advancement of scientific sewage disposal. He also was pleased by the recognition accorded the *Journal* in foreign lands, and often said that the seven thousand dollars invested in the *Journal* was the best use that could have been made of the funds entrusted to him by Mr. Garvan.

As I look back over the past fifteen years, I feel strongly that the *Journal* has attained its standing primarily because of its research character, more than for any other reason. There was always the desire to give the plant operator papers that would be of practical value to him, and to publish news of the proceedings of member associations, but the solid, enduring corner-stones on which the *Journal* has been built have been the laboratory, plant, stream pollution and industrial waste research articles.

In the abstract section, the intention has always been to abstract, at length, foreign articles which would be unavailable to most of the readers. Since the war started, foreign journals are scarce, and more space has had to be given to American and Canadian journals.

In recent years, more attention is being paid to articles on plant operation and Federation affairs. This is as it should be because, as we have grown, we have more money to develop the personal and personnel aspects of the Federation. However, I worried a little about the rapid growth of the practical operating articles in 1941 and 1942, and tried to bring back the relative proportion of research articles in 1943. A tabulation of the space devoted to each section is shown below:

Year	Research Pages	Operation Pages
1936	356	401
1937	378	447
1938	331	411
1939	384	375
1940	329	412
1941	255	458
1942	260	606
1943	339	489

The research section has been brought back to approximately its relative volume of earlier years. Of course, this has not been accomplished entirely by the desire of the Editor, but also because research and investigation have not been stifled by the war, but rather stimulated, in spite of the loss of manpower. Whether this ratio can be maintained is questionable, but I am glad to pass on the editorship to Pete Wisely with the banner of "research" at the masthead of the *Journal,* and know he will carry on with all possible effort to maintain this distinctive character of the *Journal.*

The Federation is now firmly on its financial feet, and more service can be rendered the members, especially through committee work, improvement of operator status and attention to personal requests. The burden of the *Journal* has been so heavy in the past few years that I have barely been able to see that each issue appeared, and late at that. However, it has always been a pleasure to accomplish the publication of each issue, and certainly the measure of satisfaction was far in excess of the $75 per month salary received for many years, about enough to pay for the time spent in reading manuscript and proof, from which I will now have welcome release.

I foresee a bright future ahead for the *Journal* and the Federation. There are so many interesting committee activities that can be fostered; our annual conventions, of which we have had two in Chicago, are now well-established and self-supporting; local meetings are active and well-attended; our Canadian colleagues are interested in the Federation and are closely bound to us with ties of mutual interest and respect; and our cosmopolitan President, commuting between Washington and California, ties together the East and West of our country. One disappointment, however, is the failure of the New Jersey Sewage Works Association to enter the Federation whole-heartedly, after the many years of hopes and conciliatory actions of the Federation heads. We would like to have a better representation from this oldest of sewage works associations, which antedates the Federation many years, and should be a strong member association.

I believe there should be bright prospects for extending the activities of the Federation and *Journal* into the field of industrial waste disposal. Already we have many members who are engineers or chemists in industry, interested in disposal of various types of industrial wastes. We should cultivate and increase these members, and attempt to build up programs and symposia on industrial waste disposal. The magnitude of this problem is probably as great as the entire problem of disposal of human sewage, and we should attempt to develop this field and attract industrial engineers and chemists to the Federation.

This is about enough along this vein, and my final two pages of Editorial are finished. I will only add the title of an editorial of some years back—"Ave atque Vale."

F. W. Mohlman

Proceedings of Local Associations

MICHIGAN SEWAGE WORKS ASSOCIATION

Nineteenth Annual Conference

Lansing, Michigan, May 5–6, 1943

The Eighteenth Annual Conference of the Michigan Sewage Works Association was held at Michigan State College May 5–6, 1943. As in the past the Conference followed a short course school for plant operators under the direction of members of the faculty of Michigan State College. A streamlined war-time course was given for the benefit of operators who either had not previously had an opportunity to attend or had not completed the short course school in the past. The School and Conference are both sponsored by the College, the Association and the Michigan Department of Health. Registration for the school was limited by the facilities available and numbered thirty-five. Registrations for the Conference totalled sixty-seven.

The short course curriculum included the following:

Chemical laboratory analysis
Bacteriological laboratory analysis
Fundamentals of hydraulics
Sedimentation and sludge digestion
Chlorination and filtration
Sampling and activated sludge.

Papers presented at the Conference were as follows:

"The Priority Problem"—Paul Stegeman, Superintendent, Midland, Michigan.

"Maintenance of Electrical Equipment in Sewage Plants"—H. V. Crawford, Industrial Engineering Div., G. E. Co., Schenectady, N. Y.

"Two Years Operating Experience at the Detroit Sewage Treatment Plant"—W. M. Wallace, Supt. Sewage Treatment Plant, Detroit, Michigan.

"The Treatment of Sewage by Vacuum Flotation"—Dr. A. J. Fisher, The Dorr Co., Inc., New York City.

"Treatment of Milk Wastes at the Mead Johnson Co."—Paul Wolterink, Plant Operator, Zeeland, Michigan.

"Control of the Midge Fly"—R. B. Jackson, Jackson, Michigan.

"Inter-County Sewage Treatment on Trial"—Milton P. Adams, Exec. Sec'y, Michigan Stream Control Comm., Lansing, Michigan.

Operators' Round Table

Again the "Roundtable" resulted in a lively discussion of "Pollution by Wastes from War Industries" under the able leadership of Mr. A. B. Cameron, Supt., Jackson, Mich.

Business Meeting

The treasurer's report was presented and accepted as read. The nominating committee presented the following slate:

President—Mr. C. P. Witcher, Ann Arbor
Vice-Pres.—Mr. H. M. Leonhard, Trenton
Secy.-Treas.—Mr. R. J. Smith, East Lansing
Directors—Mr. R. B. Jackson, Jackson
Mr. G. F. Wyllie, Lansing
Mr. C. A. Habermehl, Detroit
Representative to Federation Board of Control—Mr. E. F. Eldridge, Mich. State College, East Lansing.

As no additional nominations came from the floor the secretary was instructed to cast a unanimous ballot for the above slate.

The president, vice-president and secretary-treasurer will serve for the years 1943–44. Mr. Jackson will serve a two year term as director, while Mr. Wyllie and Mr. Habermehl will serve the balance of 1943–44. Mr. E. F. Eldridge will serve as representative to the Federation Board of Control for a term of three years commencing at the next Federation Board meeting.

Smoker

A smoker and dinner was held at Hunt's Food Shop, East Lansing, May 5, 1943. The entertainment was arranged by Mr. R. B. Jackson as master of ceremonies, with the assistance of Messrs. C. A. Habermehl and W. M. Wallace of the Detroit plant.

A quiz contest was held and appropriate prizes presented. The quiz contest was followed by a half hour's entertainment by a magician.

Annual Banquet

Ladies were invited to attend the annual banquet held at Hunt's Food Shop, East Lansing, Thursday, May 6, 1943. A very interesting dinner address entitled "Plastics in Their Use Field" was presented by Mr. Donald L. Gibbs, Sales Manager of the Plastics Division, Dow Chemical Company, Midland, Michigan.

R. J. Smith, *Secretary*

SOUTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

Ninth Annual Meeting

Mitchell, South Dakota, September 15–16, 1943

The advisability of developing plans and specifications and arranging for financing of contemplated post-war improvements was emphasized at the Ninth Annual Meeting of the South Dakota Water and Sewage Works Conference held simultaneously with the League of South Dakota Municipalities and the South Dakota Secretaries Association. Seventy-six persons were in attendance, all of whom are either actively engaged or directly connected with the water and sewage works facilities.

The Conference got off to a good start on the night of the 14th when the three groups were the guests of the City of Mitchell at a Dutch lunch served at the Country Club.

On the morning of the 15th all groups met at the Court House where Mayor Walter Dixon gave the address of welcome and responses were made by a member representative of each group. The Water and Sewage Works men and the Secretaries were then excused and our group opened their meeting at the City Hall with the Secretaries as guests.

Through the courtesy of the American Plumbers Association the film of the "Ominous Arms Case" was shown and created quite an interest among the group. The Layne-Western Company of Minneapolis showed their film "The Test of Time." The showing of the film "Oil for War" was made possible through the Barrett Division, Allied Chemical Dye Corporation, N. Y.

Gunder Nelson of Pierre presented a very interesting paper on the Gas Wells of Pierre, bringing out the fact that the gas is never found dry but is always accompanied by a large flow of water; therefore, they have to erect large separation tanks in which there is an arrangement of baffles to separate the gas from the water. He also stated that the gas and water were very corrosive to the pipe; that there was a constant cost for maintenance causing it to be a losing undertaking from a financial standpoint to the City.

Mr. G. S. Schroepfer, President of the Federation of Sewage Works Associations, discussed the advantages of being a member of the Federation, bringing out that it was not only national but international in scope; that through *The Journal* members receive the benefit of the experience of operators throughout the world and all of the latest news from the research laboratories. He also impressed upon those present that now was the time to plan for post-war work, stating that engineers are now available and could give more time to planning, that the chances were it would be more economical in that the municipalities would get better planning. They could have an estimated cost on the improvements, thereby being able to work out their financing. He advised the group that the Federal Government in all probability would expect the cities to pay for the improvements and that it could not be planned as a W.P.A. project such as before Pearl Harbor.

Charlie Price, sewage plant operator of Rapid City, told how he kept his records and the value derived from them. He brought out how he kept a daily record on flow, gas produced, solids and pH. Each month this was put on graph paper for the month and then transferred to a yearly graph. He has a daily, weekly, monthly and yearly average on the plant operation since the plant was put into operation.

At the close of the first day's session there were inspection trips arranged for the spillway, Air Base and sewage disposal plant.

The banquet was held at 7:30 in the evening at the Masonic Temple. John Griffin, Mayor of Pierre and President of the League of Municipalities, presided and after thanking the City of Mitchell and expressing the appreciation of the three bodies for the real hospitality shown on the part of the City, he introduced the Officers of the League, then George Simpson, Vice-President of the Secretaries Association, who in turn introduced their officers. The Director of the Engineering Division of the State Board of Health at Pierre, Glen J. Hopkins, was introduced and in turn he introduced the officers of the Conference and also Doctor Gilbert Cottam, Superintendent of the State Board of Health. Dr. Cottam gave a short but interesting talk, explaining that the Board of Health always stood ready to help in every way it could and inviting the municipalities to make use of it whenever possible.

The principal speaker of the evening, Dr. Patterson, University of South Dakota, Vermillion, was then introduced. His subject was "Small Town Stuff" in which he brought out that no matter where you were from, a large city or a small town, people were the same and it was up to you if they were to be friendly or otherwise.

John DeWild gave a talk on what the state and municipalities could expect in the way of expenditures after the war and warned the state and municipalities to prepare now so that they will be able to keep abreast of the times.

The second morning was given over to a general session of the water and sewage works meeting and business session.

Wm. Mailloux, sewage plant superintendent of Sturgis, gave a paper on the improvements to their plant that were made necessary because of the increased personnel at Fort Meade and the trouble that he was having with air binding in the heater coils of the digester.

C. R. Bowman, Assistant Engineer State Board of Health, Pierre, presented a paper on grease removal in which he brought out the advantages and disadvantages of the different methods of grease removal and separation. He also cited what some of the plants are doing with the waste grease and that some were installing economical stills to prepare the grease for sale. He also brought out that the largest amount of grease could be separated from the sewage by the use of aerochlorination in a retention basin.

The business session followed and after the passing of resolutions, approval of the Secretary's report and Treasurer's report, the auditing and nominating Committees' reports, the discussion was brought up as to the joint meeting with the League of Municipalities for the ensuing year. A motion was made, seconded and passed that this matter be left to the discretion of the Board of Directors. The Board of Directors will also decide where and when the next meeting will be held. The meeting then adjourned.

The afternoon session was held jointly with the League and Secretaries at the Corn Palace where the Governor of South Dakota gave a talk on the Development of the Missouri River Valley.

This talk was followed by a discourse by Gideon Seymour on "The Next Ten Years" in which Mr. Seymour stated how our government and all that we had done had followed the British set-up but now things had changed and that we would have to change with the times and that Russia was a world power with the United States and Britain.

New officers for the ensuing year are:

President—C. A. Polley, Lead
Vice-President—M. J. Hoy, Watertown
Secretary-Treasurer—Glen J. Hopkins, Pierre
Directors—Harry Steckler, Yankton; Henry Pierce, Huron; George Barnes, DeSmet; C. R. Stout, Bryant; Chas. Price, Rapid City; Joe Stromme, Madison; Rhea Rees, Sioux Falls.

GLEN J. HOPKINS, *Secretary*

ROCKY MOUNTAIN SEWAGE WORKS ASSOCIATION

Seventh Annual Meeting

Denver, Colorado, September 15–17, 1943

At our 1943 annual meeting held in Denver, September 15, the following new officers were elected:

President—Frank C. Hill, Montrose, Colo.
Vice-President—Dana E. Kepner, Denver, Colo.
Secretary-Treasurer—Carroll H. Coberly, 1441 Welton St., Denver, Colo.
Trustee—E. C. Reybold, Denver, Colo. (two year term).

Mr. Henry G. Watson of Cheyenne, Wyoming, will serve the remaining one year of his term as Trustee.

The following papers were presented at this meeting:

"Operating Experiences at Army Sewage Treatment Plants," by John T. Franks and Lt. Chester A. Obma. Discussed by L. C. Osborn.

"Operating Experiences at the Montrose, Colorado, Sewage Treatment Plant," by Frank C. Hill.

"Grease Collection and Salvage," by C. P. Gunson.

A motion picture entitled "Sewage Treatment" was presented by the Cast Iron Pipe Research Association. Following this film a round table discussion was held covering sewage plant maintenance and repairs, priorities, and miscellaneous problems.

At the close of the afternoon session an inspection trip to Denver's new Lowry Field sewage treatment plant was made.

Dana E. Kepner, *Secretary*

NEW ENGLAND SEWAGE WORKS ASSOCIATION

Fall Meeting

Boston, Massachusetts, September 22, 1943

The fall meeting of the New England Sewage Works Association was held on September 22, 1943, at the Parker House in Boston, Massachusetts. Eighty-six members and guests attended. This was a one-day conference with President Roscoe H. Suttie presiding.

The business meeting was at 10:00 A.M. Reports by the Secretary-Treasurer were read and accepted. Mr. E. Sherman Chase, Chairman of the Committee on Post-War Planning, presented a progress report. He outlined the present membership of the committee and the nature of the problem. It was voted by the membership to merge our committee with a similar committee in the New England Water Works Association. Mr. Chase was to amalgamate the membership of both committees with some revision.

The operators' report committee made awards for the best operation reports to operators. Mr. Stuart Coburn, a member of the committee, presented the awards. The first prize of five dollars and a certificate of merit was presented to Mr. George H. Craemer of Hartford, Connecticut. A prize of three dollars was awarded to Mr. Walter Kunsch, former superintendent of the Danbury Sewage Treatment Plant, Danbury, Connecticut. Third prize was awarded to Mr. John R. Szymanski of New Britain, Connecticut.

At 10:30 A.M. there was a symposium on "Problems in the Design and Operation of Very Small Sewage Disposal Plants." The opening paper was presented by Mr. Frank L. Flood, Chief of Sanitary Engineering Section, Repairs and Utilities Branch, First Service Command, U. S. Army. Mr. Flood presided over the symposium.

Informal discussions were given by Mr. Edward Wright, Sanitary Engineer, Massachusetts Department of Public Health; Mr. Warren J. Scott, Director, Bureau of Sanitary Engineering, Connecticut State Department of Health; Mr. Water J. Shea, Acting Chief, Bureau of Sanitary Engineering, Rhode Island State Department of Health.

At 11:45 A.M. there was an operators' symposium. First subject was "Servicing Sludge Gas Burning Equipment," opened by Mr. Walter M. Kunsch, Superintendent, Sewage Treatment, Camp Endicott, Rhode Island.

At 12:15 P.M. Mr. John R. Szymanski, Superintendent, New Britain Sewage Treatment Plant, New Britain, Connecticut, opened a discussion on "Types of Wire for Vacuum Filter Cloths."

Luncheon was served in the Hawthorne Room of the hotel at 1:00 P.M. Following luncheon Doctor Vlado A. Getting, Health Commissioner, Commonwealth of Massachusetts, was the guest speaker. His subject was "Looking Ahead in Public Health Work."

The main subject for the afternoon symposium was on "The Operation and Design of High Rate Trickling Filters." Mr. Samuel M. Ellsworth, Consulting Engineer, Boston, Massachusetts, opened the discussion and was the leader.

Informal discussions were given by Majors G. E. Griffin and Rolf Eliassen of the United States Army, and Mr. John T. Norgaard of the Office of the Chief of Engineers, War Department, Washington, D. C. A model of a high rate trickling filter plant was on display through the courtesy of Mr. Norgaard.

At 4:00 P.M., there was another operators' symposium. The first subject was "Maintenance of Sewage Booster Pumping Stations," opened by Mr. Charles H. Copley, Superintendent, Sewage Treatment, New Haven, Connecticut. The second topic was opened by Mr. Joseph Doman, Sanitary Engineer of Greenwich Department of Public Works, Greenwich, Connecticut, on "Kinds of Lime Suitable for Use in Separate Sludge Digestion Tanks and Imhoff Tanks."

LeRoy W. Van Kleeck, *Secretary*

NORTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

Fifteenth Annual Convention

Grand Forks, North Dakota, October 5–7, 1943

With post-war planning as the theme highlighting the Fifteenth Annual Convention of the North Dakota Water and Sewage Works Conference, a very successful three day meeting of the organization came to a close at Grand Forks on October 7, 1943. Swelled by a delegation of thirteen representatives from Winnipeg, St. Boniface, and St. Vital, Manitoba, the total registration reached 116, a figure surpassed only by the 1940 and 1941 meetings, with 117 and 118, respectively. Two representatives from Parshall, North Dakota, a village without water or sewerage facilities, traveled over three hundred miles to attend the meeting and learn the details of a properly co-ordinated post-war planning program for water and sewage works development.

An unusually full three day program headed by several nationally known figures was completed. Such men as E. L. Filby of the Committee on Water and Sewage Works Development; O. C. Hopkins of the Public Health Service; Lindon J. Murphy of the Office of Civilian Defense; H. Lloyd Nelson of the Office of War Utilities; George J. Schroepfer, President, Federation of Sewage Works Associations; and O. E. Brownell of the Minnesota Department of Health constituted the drawing power, bringing together representatives from North and South Dakota, Minnesota, and Canada. Further participation in the program by Conference members and the faculty of the University of North Dakota rounded out the interesting and informative session.

Presiding at the sessions was Joe Morrissey of Jamestown, President of the Conference. At the schools conducted at the University of North Dakota, A. L. Bavone, Burke-Ward Health Department, presided at the general school; Jerome H. Svore, Sanitary Engineer, State Department of Health, presided at the water school; and F. W. Pinney, Sewage Works Superintendent of Fargo, presided at the sewage school.

E. L. Filby, Field Director, Committee on Water and Sewage Works Development, captivated the audience with an explanation of the Committee's six-point program based on the premise that every well managed city should have, and is entitled to pay for, an adequate and safe water supply and a satisfactory means of sewage disposal. His motivating manner induced the Conference later in the session to adopt a resolution endorsing the program with instructions to the secretary that the resolution be transmitted to every official body in the State.

President George J. Schroepfer, of the Federation of Sewage Works Associations, reviewed the work of the Federation, citing as activities post-war planning, establishment of operators' qualifications, annual awards for distinguished service in the sewage field, raising the standards of sewage works operators, correlating sewage research, and representing member associations in problems of national scope. Service valued at eight to nine dollars per member was rendered at a cost of three dollars during the past year.

Major Lindon J. Murphy of the Office of Civilian Defense, Omaha, presented the problems of water and sewage works operators in maintaining uninterrupted service. Listed among the possibilities causing interruptions were power failures, main breaks, tornadoes, floods, material scarcities, air raids, sabotage, explosions, fire, freezing, et cetera. Measures for avoiding or minimizing damage included provision for standby power, emergency repairs and parts through mutual aid, elimination of pump pits, lighting, fencing, personnel investigations, and to a lesser extent guards and police protection.

The symposium on flood experiences with John Kleven of Grand Forks as discussion leader revealed that anything can happen during high water. Gil Junge, Wahpeton, sewage works superintendent, learned that the stork was amphibious and he would have missed the event entirely if the boat scheduled to town had not been on time. Mr. Junge says that it is quite a sight to look out through the windows of a sewage plant and see fish swimming up against the panes. By sandbagging and caulking crevices, together with keeping the pumps running, flood waters were kept out of the plant, thus preventing serious damage. Conclusions from the discussion were: We can always expect a higher flood than we have had in the past; build everything on high ground, not only water and sewage works, but also warehouses, homes, etc.; never build a sewer lift station or water pumping plant with electrical pumping equipment located below ground level; design such works so that the motors will be mounted with sufficient free board above high water level; provide backwater valves, shut-off valves, etc., to protect pumping works and structures.

North Dakota laws affecting water and sewage works construction and operation were discussed by Attorney General Alvin C. Strutz. Tracing the development of such legislation historically, he followed by describing North Dakota statutes. Mr. Strutz related how special assessment bonds can, upon default, become general obligation bonds in North Dakota. Although strengthening the security of the special assessment bonds, such a statute is inconsistent because the entire city is obligated by the will of a comparatively small portion of the city. Attempts to change this legislation have been unsuccessful.

Alex C. Burr, Vice Chairman of the Engineering Registration Board, described the engineering registration law.

Included in the schools at the University of North Dakota conducted on the second day were: Discussion of the "Public Health Service Drinking Water Standards" by O. C. Hopkins, U. S. Public Health Service; "Ground Waters and the Geologist" by Wilson M. Laird, State Geologist of Grand Forks; "Care of Electric Motors" by M. G. Holling, Minneapolis; "Care of Valves and Hydrants" by Peder Amundson, Fargo; "Design, Operation and Maintenance of Sewage Lift Stations" by D. L. McLean, Winnipeg. Co-operation of the University faculty in demonstrating the practical application of water and sewage laboratory tests proved highly interesting and informative.

Officers for the coming years are Dave MacDonald, Bismarck, *President;* F. W. Pinney, Fargo, *Vice-President;* K. C. Lauster, Bismarck, *Secretary-Treasurer;* and Joe Morrissey, Jamestown, and A. C. Bromschwig, Minneapolis, *Directors.*

K. C. Lauster, *Secretary*

Federation Affairs

FOURTH ANNUAL CONVENTION
NATIONAL CONFERENCE ON WARTIME SANITATION

Chicago, Illinois

October 21–23, 1943

The Fourth Annual Convention of the Federation of Sewage Works Associations was held at Chicago, Illinois, October 21–23, 1943, as a Conference on Wartime Sanitation, in conjunction with the Sixteenth Annual Convention of the Central States Sewage Works Association. Total registration was 612, including 63 ladies. This was the largest registration of the four conventions of the Federation. The first, at Chicago in 1940, had 556 registrants; the second, at New York, 569; and the third, at Cleveland, 412.

A Pre-Convention Get-Together was held Wednesday evening, October 20th. Registration continued the following morning, and the Conference was called to order by President Schroepfer at 10:30 A.M. Mr. Edward J. Kelly, Mayor of Chicago, welcomed the Federation to Chicago, not only as Mayor, but also as an engineer who grew up with the Sanitary District of Chicago, first as rodman, and finally as Chief Engineer, prior to his long term as Mayor of Chicago.

The business meeting Thursday morning was followed by the Federation Luncheon, with Edward J. Cleary, Managing Editor of *Engineering News-Record,* as speaker. His illustrated discussion of "Sanitation Activities in the Latin American Republics" was intensely interesting to the large luncheon audience of 275.

In the afternoon, the first technical program was called to order at 2:00 P.M. The program was as follows:

Thursday Afternoon

High Rate Biological Sewage Treatment
  Samuel A. Greeley
 Discussion
  R. M. Dixon
Industrial Wastes in Wartime
  F. W. Mohlman
 Discussion
  LeRoy W. VanKleeck
The Significance of the Finding of the Virus of Infantile Paralysis in Sewage. A Review
  Kenneth F. Maxcy, M.D. Paper presented by Howard A. Howe, M.D.
 Discussion
  G. M. Ridenour
Grease Removal at Army Sewage Treatment Plants
  Rolf Eliassen
 Discussion
  Harry W. Gehm
Effect of Various Treatment Processes on the Survival of Helminth Ova and Protozoan Cysts in Sewage.
  Eloise B. Cram
 Discussion
  W. D. Hatfield

The papers by Greeley, Mohlman, Maxcy and Cram are published in this issue.

Thursday night the Smoker was held in the Bal Tabarin. Harry Schlenz, as Chairman of the Entertainment Committee, had provided first-class entertainment, and plenty to eat and drink.

The technical session Friday morning was devoted to a discussion of priorities, personnel problems, and the operation of sewage treatment works in wartime. The program was as follows:

Friday Morning

Priorities
- Maury Maverick
- A. M. Rawn

Discussion
- Frederick G. Nelson
- Donald E. Bloodgood

Personnel Problems Under Wartime Conditions
- C. W. Klassen

Discussion
- William W. Wallace

Maintenance of Sewerage Systems in Wartime
- John H. Brooks

Problems of Sewage Treatment Plant Operation Under Wartime Conditions
- William W. Mathews

Discussion
- Roy S. Lanphear

Adjournment

The Luncheon of the Central States Sewage Works Association was held at 12:30, followed by the Friday afternoon technical session, as follows:

Friday Afternoon

The Chlorination of Sewage and Industrial Waste
- Harry A. Faber

Symposium—Post-war Problems
- Leader: Morris M. Cohn. The Ten-Year Plan of Sewage and Waste Treatment
- The Consulting Engineer and Post-war Planning. C. A. Emerson
- The Canadian Point of View on Post-war Planning. A. E. Berry
- Post-war Projects of Sewage Works Equipment Manufacturers. W. B. Marshall
- Aims and Methods of Operation of the Committee on Water and Sewage Works Development. E. L. Filby
- A Municipal Post-war Project for Sewerage Developments. Clyde L. Palmer

The papers presented in the Symposium on Post-war Problems are published in this issue.

The Central States Association held its business meeting at 5:30 P.M. In the evening, at 7:30 P.M., occurred the main social event of the Conference—the Dinner Dance. An excellent orchestra, a first-class floor show and professional emcee work by Chairman Schlenz made this a very pleasant evening. Honors were announced and presented by President Schroepfer as follows:

Election to Honorary Membership

Charles Gilman Hyde (California Sewage Works Assn.)
Howard Eugene Moses (Pennsylvania Sewage Works Assn.)

Harrison Prescott Eddy Award (For Research)

Harry Willard Gehm

George Bradley Gascoigne Award (For Operation)

Kerwin L. Mick

Charles Alvin Emerson Award (For Federation Service)

Floyd William Mohlman

Kenneth Allen Awards (For Service to Member Associations)

Robert S. Phillips (North Carolina Sewage Works Assn.)
Alfred Henry Wieters (Iowa Waste Disposal Assn.)
John Kurtz Hoskins (Federal Sewage Research Assn.)
William H. Wisely (Central States Sewage Works Assn.)

Further Kenneth Allen nominations are yet to be made by the Pacific Northwest S. W. Assn.; Texas Section, A.W.W.A.; New Jersey S. W. Assn.; and Institute of Sewage Purification (England).

The Saturday morning session was devoted to the operators:

Saturday Morning

Operators' Breakfast Forum
    Leader: John C. Mackin
The Use of Sludge in the Victory Garden Campaign
    A. H. Niles
    Henry A. Riedesel
    David Backmeyer
Secondary Treatment—Present and Future
    Arthur S. Bedell
    A. W. West
    Linn H. Enslow
Wartime Operating Problems in Municipal and Army Sewage Treatment Plants
    Rolf Eliassen
    Martin A. Milling
    Edward C. Cardwell
Broad Conservation Program—War Production Board
    H. Lloyd Nelson
Award of Attendance Cup (Won by Central States S. W. Assn.)

Adjournment

The Ladies' Entertainment Program was as follows:

Ladies' Entertainment Events

Thursday, 12:00 Noon. Federation Luncheon in Louis XVI Room. The ladies are cordially invited to attend the luncheon and to hear the address of the speaker, Edward J. Cleary, Managing Editor, *Engineering News-Record.*

Thursday, 2:45 P.M. Exhibit at Harding Museum. An interesting exhibit of rugs, paintings, and armor is on display at the Harding Museum, 4853 South Lake Park Avenue.

Thursday, 8:00 P.M. Bridge Party in the "House on the Roof." This event has been arranged exclusively for the ladies.

Friday, 7:45 A.M. Broadcast. Broadcast of the NBC "Breakfast Club" program in the Merchandise Mart, a few blocks from the hotel.

Friday, 12:30 P.M. Luncheon and Style Show. Luncheon for the ladies in the Wedgewood Room, 7th floor, Marshall Field and Company.

Friday, 7:30 P.M. Federation Dinner Dance in Grand Ballroom. Informal dress. Program includes dinner, music, entertainment, and dancing.

The following Officers of the Federation were elected for 1944:

A. M. RAWN .... *President*
A. E. BERRY .... *Vice-President*
W. W. DEBERARD .... *Treasurer*
W. H. WISELY .... *Executive Secretary and Editor*
F. W. MOHLMAN .... *Advisory Editor*

The 1944 Convention will be held in Pittsburgh, Pa., next October.
Convention Committees for this Second Chicago Convention were as follows:

Convention Committees

CONVENTION MANAGEMENT COMMITTEE

F. W. Mohlman, *Chairman*
Norval E. Anderson, *Vice-Chairman*

O. T. Birkeness (Local Finance)
Frederick G. Nelson (Hotel Arrangements)
K. V. Hill (Registration)
H. E. Schlenz (Entertainment)
Arthur T. Clark (Exhibits)
Frank W. Lovett (Manufacturers)
Langdon Pearse (Local Host)
Mrs. Langdon Pearse (Ladies Entertainment)

PROGRAM COMMITTEE

(FEDERATION PUBLICATIONS COMMITTEE)

F. W. Gilcreas, *Chairman*

F. W. Mohlman
Rolf Eliassen
R. S. Phillips
E. W. Steel
Carl E. Green
F. M. Veatch
F. S. Friel
C. C. Larson

PUBLICITY AND ATTENDANCE COMMITTEE

Edward J. Cleary, *Chairman*

Morris M. Cohn
Linn H. Enslow
W. S. Foster
A. Prescott Folwell

REGISTRATION COMMITTEE

K. V. Hill, *Chairman*

Emanuel Hurwitz
W. W. Mathews
John R. Palmer
John C. Mackin
F. Woodbury Jones
for the Quarter Century Operators' Club

LOCAL FINANCE COMMITTEE

O. T. Birkeness, *Chairman*

Norman Dawson
Paul E. Langdon
W. H. Wisely

HOTEL ARRANGEMENTS COMMITTEE

Fred G. Nelson, *Chairman*

Paul O. Richter
G. J. Rettig

MANUFACTURERS COMMITTEE

Frank W. Lovett, *Chairman*

Milton Spiegel G. C. Karr

ENTERTAINMENT COMMITTEE

H. E. Schlenz, *Chairman*
Clinton Inglee, *Advisory Chairman*

L. E. Langdon C. C. Abplanalp

LOCAL HOST COMMITTEE

Langdon Pearse, *Chairman*

W. W. DeBerard E. J. Kelly
Paul Hansen W. H. Trinkaus
L. R. Howson W. W. Mathews

LADIES ENTERTAINMENT COMMITTEE

Mrs. George J. Schroepfer, *Honorary Chairman*
Mrs. Langdon Pearse, *Chairman*

Mrs. N. E. Anderson Mrs. F. W. Mohlman
Mrs. O. T. Birkeness Mrs. Frederick G. Nelson
Mrs. K. V. Hill Mrs. H. E. Schlenz
Mrs. L. E. Langdon Mrs. J. J. Wirts
Mrs. C. C. Larson Mrs. W. H. Wisely
Mrs. F. W. Lovett

Miss Josephine Mutter, *Hostess,* Sherman Hotel

The exhibits by manufacturers were restricted by wartime shipping requirements, but nevertheless there were 34 exhibitors, occupying 47 booths. The exhibits were instructive and interesting. Mr. Arthur T. Clark was in charge of exhibits for the Water and Sewage Works Manufacturers' Association.

Dr. George Symons edited the *Convention Daily,* which included the names and addresses of all registrants, as well as a few sidelights on the proceedings.

There were two lengthy meetings of the Board of Directors, dealing with business affairs of the Federation. Two of the Committee Reports are published in this issue, and the others will be published in the January, 1944, issue.

F. W. M.

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

REPORT OF SPECIAL COMMITTEE ON EXPANSION OF SECRETARY'S OFFICE *

September, 1943

The special committee appointed to consider the advisability of expansion of the Secretary's office presents the following report and recommends copies of it be furnished to the Directors of the Federation for their information and study preliminary to its final disposition at the Annual Meeting of the Board of Control to be held in Chicago on October 23, 1943.

It will be recalled that when the revised Constitution and By-Laws were adopted in principle at a special meeting of the Board in Chicago on October 5, 1940, and also

* This report has been reviewed and has been unanimously adopted by the Executive Committee as the recommendation of that body. The Executive Committee comprises President G. J. Schroepfer, Chairman, J. K. Hoskins, A. E. Berry, H. E. Moses and D. S. McAfee.

when reorganization was completed and the revised Constitution put into effect by appropriate actions at a regular meeting of the Board on January 5, 1941, it was not possible to forecast the effect of the authorized increase in membership dues and in advertising rates. In the face of this uncertain financial outlook, the Board decided to proceed cautiously and to refrain from any commitments which would exceed a very conservative estimate of income for the year 1941. W. H. Wisely agreed to serve as Secretary on a part-time basis for that year and the Urbana-Champaign Sanitary District kindly allowed us rent-free use of a room in their Administration Building, as the Secretary's office. All budget allotments were fixed on a minimum basis. At the annual meetings of the Board on October 11, 1941, and October 24, 1942, decision was reached to continue operations on the same minimum basis because of uncertainties attendant on war conditions.

The wisdom of the Board in adopting and continuing a conservative policy during the initial years of our reorganization has been definitely proven. It afforded opportunity for gradual adjustment to new conditions and for establishment of finances on a sound basis which would have been possible in no other way. Development of the Federation during this trying period has been greater than was anticipated by anyone and it has everywhere been accorded a warm and cordial reception by operators, engineers, research workers, equipment manufacturers and others of the sewage treatment fraternity.

Our vigorous growth and present healthy condition are evidenced by the following resume of our finances:

Surplus and Net Worth, December 31, 1940—$ 3,075.75
Surplus and Net Worth, December 31, 1941— 7,098.54
Surplus and Net Worth, December 31, 1942— 13,489.73

The financial reports of the Secretary and Treasurer for June 30, 1943, show Cash on Hand and Federal Bonds to a total of $23,109.51 with Accounts Receivable at $1,118.01 and Bills Payable at $1,751.10, making our cash resources as of that date the satisfying sum of $22,476.42. There is reason to believe that the next annual audit will show Net Worth in the neighborhood of $20,000 as of December 31, 1943, an increase of nearly $17,000 in three most trying and unpredictable years.

This Committee is firmly of the opinion that the Federation has fully demonstrated its ability to serve all workers in the broad fields of sewage and industrial wastes treatment and that need for its services will multiply during the remaining period of the war and throughout the postwar era.

Furthermore, after careful consideration, the Committee is unanimous in belief that mere continuation of activities at the present restricted level in the face of this increasing need and opportunity will not only impede future growth, but very probably will seriously undermine our present well-established position.

Additional to the foregoing relative to future possibilities, there are compelling reasons for immediate consideration of our present restrictive operating procedure.

(1) Secretary Wisely advises that demands on his strength have been so great since January, 1940, that he cannot continue to serve both the Urbana-Champaign Sanitary District and the Federation after the close of this current year.
(2) Dr. Mohlman is of the opinion that at expiration of his present term as Editor on December 31 he should be relieved of the onerous burden of detailed work in connection with publication of the Journal which he has borne so cheerfully and capably for 15 years.
(3) It is uncertain whether Chemical Foundation will serve as Advertising Manager beyond the end of this year. Their consent to handle the work during the past two years has been largely in recognition of the great interest in the Federation manifested throughout a decade or longer by their former President, Mr. Francis P. Garvan and former Business Manager, Mr. William W. Buffum.

In short, it is mandatory that the Board of Control take definite action at the October Meeting to provide a Secretary, Editor and an Advertising Manager to commence work on January 1, 1944.

Conclusion

It is the Committee's opinion that the soundest, safest and most logical solution of this problem is the one which is under consideration; namely, the establishment of the Secretary's office on a fulltime basis with a staff adequate to continue all present activities of the office, take over the routine editorial work and advertising for SEWAGE WORKS JOURNAL, and take a leading part in efforts to increase membership, develop closer contact with Member Associations, participate in postwar planning activities authorized by the Board, and in numerous other matters which will undoubtedly arise.

Recommendation

To effect this expansion, Committee recommends:

(1) The procurement and equipment of a suitable office in the Urbana-Champaign area.
(2) The appointment of W. H. Wisely as fulltime Secretary, Editor and Advertising Manager at a salary of $6,500 a year.
(3) The retention of Dr. F. W. Mohlman as Advisory Editor for general supervision of editorial matter in SEWAGE WORKS JOURNAL and as Editorial Advisor to the Publications and Sewage Works Practice Committees, without salary, as requested by him.
(4) Increase the office staff by not more than two additional employees.

Since two of the members of the special committee are also members of the Financial Advisory Committee and since the third member of the special committee is a member of last year's Financial Advisory Committee, we respectfully submit the following tentative Budget of Receipts and Expenditures for 1944 for your consideration:

Receipts		
Dues (all classes)	$ 9,000.00	
Non-member Subscriptions	1,500.00	
Advertising Receipts (Net)	12,000.00	
Net Sale Misc. Public.	300.00	
Miscellaneous	250.00	
Manufacturers	5,000.00	$28,050.00
Expenses		
Journal Printing and Mailings	$12,000.00	
Editorial Expense	900.00	
Exec. Secretary Salary	6,500.00	
Office Salaries	4,500.00	
Rent	900.00	
General Office Expense	900.00	
Secretary's Traveling Expense	700.00	
Officers' Traveling Expense	400.00	
Committee Expenses	400.00	
Contingencies	850.00	$28,050.00

Though the receipts contemplate increased receipts from dues and from advertising, we believe that with the efforts of a fulltime Secretary, the estimates on these items are reasonable. It should be noted that we have not budgeted any expense to the Association for the Annual Conference because our experience in the last two Annual Conferences has shown them to be self-supporting.

This tentative budget would make it appear that the Association could carry itself for the year 1944 without depletion of surplus, save to the extent necessary to purchase office equipment—a non-recurring expense which should be less than $1,000.

Respectfully submitted,

CHARLES A. EMERSON
ARTHUR S. BEDELL
WILLIAM J. ORCHARD

REPORT OF 1943 COMMITTEE ON QUALIFICATIONS OF SEWAGE TREATMENT PLANT OPERATORS

(As amended by General Policy Committee, October 23, 1943)

L. W. Van Kleeck, *Chairman*
A. F. Dappert
M. W. Tatlock
P. J. Kleiser

Notice!

This important report was presented to the Board of Control in session at Chicago and referred to the General Policy Committee for review and report back to the Board. The General Policy Committee recommended favorable consideration of the report as published herewith. In order to give every sewage works operator an opportunity to present his view in the matter before final action is taken, the Board of Control directed that the report be published in the Journal, and that the Program Committee provide for an open forum on the subject at the time of the next annual meeting.

It is further recommended that time for discussion of the report be included in the programs of Member Association meetings to be held prior to October 1, 1944. In the meantime, any member is welcome to submit comments to the Executive Secretary, who will forward them to the Committee.

Introduction

During the past year this Committee has carefully reviewed the existing rules and regulations governing the certification, approval and licensing of sewage plant operators in the United States where either a voluntary or compulsory plan is now in effect. The Committee is indebted to those associations in this Federation and to the State Departments of Health having certification plans for their aid. The Committee wishes to thank in particular the California Sewage Works Association, the South Dakota State Board of Health, the Ohio State Department of Health, the New York State Department of Health, and the Connecticut State Department of Health for their help. The plans in use by these organizations have been drawn freely upon by the Committee in formulating a recommended plan for national adoption.

Relation of Competent Operation to Post War Planning Program.—It is generally agreed that the post war era will see an expanded program of all public works projects, one of the most important of which will be the construction of new sewage treatment plants and the modernization and enlargement of many existing plants. Large expenditures for these plants will be utterly wasted funds unless the plants are competently operated. The Committee therefore feels that the setting up of definite qualifications for plant operators is an important part of the post-war sanitation program without which the entire movement may be seriously handicapped.

Committee Standards

If the standards as set up in this report seem arbitrary, the Committee wishes to point out that anything short of a specific set of standards tends to let the bars down with resulting circumventing and waiving of the rules. The members of the Committee, through close personal contacts with plant operating personnel, feel that the standards as herewith suggested are reasonable and just to the operator and local community, and will meet the desires with modifications of the state supervising agency.

Major Subjects in this Report.—The specific items covered in this report are:

1. General policies on certification recommended by this Committee.
2. Advantages of certification.
3. Grades for operators.
4. Qualifications for operators.

5. Means for providing special training of operators.
6. Examinations for operators.
7. Suggestions for a "Model Law" for state agencies charged with enforcing operators' qualifications.
8. A suggested "Application Blank" for operators' certification.
9. A suggested "Certificate of Qualification" for operators.
10. The future work of this Committee.

Section I

General Policies on Certification Recommended by This Committee

1. Passing on the qualifications of sewage treatment plant operators should be vested primarily in the State Agency having supervision of plant operation. The personnel of the supervising agency might well be augmented by a leading educator in Sanitary or Civil Engineering within the state and by a recognized leader in sewage treatment operation in the state, preferably a superintendent of a large plant chosen by majority vote of the existing operators in the state.

2. State regulations on qualifications of plant operators should be compulsory; not voluntary.

3. Operators should be certified; not licensed. Certification should continue in effect as long as the person certified is rendering satisfactory service as an operator or as long as the certifying agency is satisfied that such person is entitled to such certification; certification, however, should be issued subject to cancellation by the certifying agency for just cause after a hearing.

4. All chief operators and chemists, as well as superintendents, should be subject to approval of qualifications as set forth in Section III.

5. The best classification for operators requires at least three grades or classes with laboratory technicians making up a fourth.

6. Where short school or university training courses are not available to unqualified operators, provision should be made for temporary waiving of the "Special Training" requirements of the recommended regulations. Following home study or other special training arrangements, such operators should be subject to a written or oral examination or both, to be held at least yearly.

7. Because of the importance of this subject, the Committee respectfully suggests that an open forum be conducted by the Federation at its next annual meeting to discuss the recommendations contained herein.

Section II

Advantages of Certification

Certification of operators is advantageous for the public, for local officials, the state supervising agency, and the operator.

The public should and usually will support a sound certification plan for operators as a good business proposition to protect the community's investment and secure the best operating results possible from the plant.

Local officials should support certification by the State since the standards set up are a desirable guide to the appointing authorities. Political pressure for turn-overs in operating personnel with changes in parties can be circumvented because of state requirements. This means that trained men remain at the plant, resulting in better operation at lower cost to the municipality. Local officials can likewise anticipate a higher class of men to be attracted to enter and remain in the field.

From the State standpoint, certification of operators means improvement in operation as well as better public health protection, and facilitates state control of treatment plants. State supervision of operation is also simplified since qualified operators once trained are generally kept on by municipalities and there is therefore much time saved in training new ones and straightening out plants upset by personnel changes.

The operator has much to gain under certification. This Committee favors certification by the State Agency (usually the State Department of Health) over Licensing or Civil Service.

Civil Service may assure operators of tenure of office, frequently paramount in the operator's mind, but some operators so appointed may not be on their toes and some become actually lazy. While Civil Service may be desirable and is a step in the right direction, the qualifications for operators by the local Civil Service Board should be set up in close co-operation with the State Supervising Agency, or the requirements for positions at sewage treatment plants are more than likely to be poorly framed.

Where an effective and well-managed system of Civil Service is in operation or can be instituted, the Committee recognizes the value and advantages of the same and would not discourage regulation of operator qualifications through Civil Service procedures. However, if such Civil Service system is well managed and effective, it will provide proper co-ordination between Civil Service and the agency administering the certification system as recommended herein to the end that operator qualifications established through Civil Service will be the same or equal to those recommended in this report. Such coordination exists, for example, in New York State between the State Civil Service Commission and the State Department of Health. Under existing laws the State Civil Service Commission administers Civil Service in most of the municipalities of the State and the State Health Department has received excellent co-operation in having the requirements of the State Sanitary Code relating to operators incorporated in the requirements for operator positions as established under Civil Service procedures. Civil Service, if honestly and intelligently administered by the encouragement given to the establishment of decent salary scales and retirement arrangements, offers some advantages which a simple certification system does not offer. Civil Service should not, however, be regarded as a substitute for but rather as an adjunct to a certification system.

The distinction between certification and licensing may seem like a fine one, yet is none the less important. Licensing in the true sense requires an official listing of available personnel from which communities within a State must pick a candidate. The certification method involves approval of local men and permits home rule. Charles C. Agar[1] in a paper entitled "Licensing of Sewage Plant Operators" before this Federation on October 4, 1940, stated in this connection:

"Even though so-called political expendiency may enter into the appointment of sewage plant operators, the State should not use this as a principal argument for compulsory licensing and control of the hiring and firing of municipal employees. Centralization of authority is, of course, a trend of the times, but this writer feels that the principle of home rule with only sufficient restraint or guidance by the State to assure a reasonable measure or standard for an appointment is for the best interests of the municipality and the State.

"A plant, in order to operate effectively, must not only have a competent operator, but also must be supplied with the wherewithal to accomplish satisfactory results. This means that an operator must be able to work with and secure from the municipal authorities what is needed. His relations, therefore, in order to be successful must be in harmony with the local administration. It is conceivable, therefore, that with the operator responsible primarily to the State under a statutory license plan, relations between the operator and the municipality might at times become strained, resulting in defeat of the principal object of the licensing; namely betterment of plant operation."

Warren J. Scott in discussing a paper on "Administration of New York State Requirements Relative to Qualifications of Sewage Treatment Plant Operators" by A. F. Dappert[2] has said along the same lines:

[1] "Licensing of Sewage Plant Operators," Charles C. Agar, SEWAGE WORKS JOURNAL, Vol. 13, No. 1, pp. 89.

[2] "Administration of New York State Requirement Relative to Qualifications of Sewage Treatment Plant Operators," A. F. Dappert, SEWAGE WORKS JOURNAL, Vol. 10, No. 6, pp. 988.

"Neither the New York law nor the Connecticut law definitely guarantees tenure of office for sewage plant operators. However, as already mentioned, the fact that replacements must be made from the ranks of qualified men tends to promote a degree of Civil Service. The fact must not be lost sight of, that while the State has a very definite interest in seeing that plant operating results are satisfactory, the plant is municipally owned and it is absolutely necessary that there be co-operation between the sewage plant operator and the municipal government. The most qualified operator in the world cannot do a first-class job in the face of constant lack of co-operation by the municipal finance body and other municipal agencies."

Under certification operators receive a professional rating, and improvement in status, resulting inevitably in better salaries. Plant operation is taken out of the category of political appointments and tenure of office by the live-wire operator is generally assured.

Section III

Grades for Operators

Three grades for superintendents based on the size and type of sewage treatment plant to be operated are recommended following the New York State pattern, with certain modifications as follows:

Grade I Operators

1. Operating plants serving more than 40,000 population.
2. Operating plants serving 20,000 to 40,000 population, employing activated sludge, separate sludge digestion with gas collection, biological oxidation, chemical precipitation or mechanical de-watering and incineration of sludge, or other highly mechanized or specialized methods of sewage treatment.

Grade II Operators

1. Operating plants serving 20,000 to 40,000 population, not designated as Grade I.
2. Operating plants serving 10,000 to 20,000 employing secondary treatment other than sand filters, separate sludge digestion with gas collection and burning, chemical precipitation, mechanical de-watering or incineration of sludge.
3. Operating plants serving less than 10,000, employing the activated sludge process, chemical precipitation, separate sludge digestion with gas collection, or mechanical de-watering with incineration of sludge.

Grade III Operators

1. Operating plants serving less than 20,000, not designated as Grade II.

Chief operators in responsible charge of scheduled shifts at all plants having 24 hour operating supervision or at plants served by more than 40,000 population should possess qualifications for the grade below that of the superintendent under whom they serve.

Chief chemists at plants served by more than 40,000 population should be approved as such. Applicants for such a position should possess a college degree in engineering or chemistry which has included acceptable courses in sanitary science.

Section IV

Qualifications for Operators

In addition to the requirements below for the specific grades, all operators of sewage treatment plants should possess a sufficient degree of application, initiative and judgment so as to enable them in practice to secure satisfactory plant operating results.

Operators should be sufficiently familiar with the end to be accomplished in plant processes so as to recognize faulty operating conditions and where such conditions exist, to overcome them if practicable. Ability and experience in handling men is frequently as important as specialized knowledge, and for this reason, an operator's experience qualifications should be given careful review and heavy weight.

Grade I

General: All applicants shall be in good physical condition, read and write the English language, submit satisfactory evidence of at least two years of acceptable administrative experience in an industrial field and pass a written examination to be given within one year of provisional approval by the State Supervising Agency, and,

1. Possess a college degree in sanitary, chemical, civil or mechanical engineering; or
2. Possess a college degree in engineering or chemistry which has included acceptable courses in sanitary science; or
3. Be a high school graduate possessing special mechanical experience, with a minimum of five years responsible administrative experience in sewage treatment or in an acceptable industrial field, and who completes within one year a special course of training (short school or university extension course) or other home training course.

Grade II

General: All applicants shall be in good physical condition, read and write the English language, submit satisfactory evidence of at least one year of acceptable administrative experience in sewage treatment or an industrial field, pass a written or oral examination to be given within one year of provisional approval by the State Supervising Agency, and,

1. Be a high school graduate possessing acceptable mechanical or chemical experience, and complete within one year a special course of training (see Grade I, (3)) approved by the State Supervising Agency.

Grade III

General: All applicants shall be in good physical condition, read and write the English language, pass an oral examination given by the State Supervising Agency, and,

1. Be a grammar school graduate and possess acceptable experience for the work required.

In the case of all grades, the reviewing authority may in specific cases accept the qualifications of an applicant without examination when it is satisfied that such examination is unnecessary.

Section V

Means for Providing Special Training of Operators

The requirement of special training for Grades I and II operators brings up the question of how such training can best be provided. The Committee reviews below the facilities which are now available, together with suggestions for the future.

In some states, for example New York and New Jersey, special short course schools, lasting one to three weeks are sponsored by the State Departments of Health. These schools, in some cases open to out-of-state residents, offer studies leading to qualifications for operating different types of plants. Operators may frequently improve their status and qualifications by attendance at subsequent sessions. Such training is generally offered once or twice yearly.

The Committee recommends that more short-time courses be made available to operators in the various states, lasting from one to five days. This enables the small plant operator to get away for a limited period and provides a study course that can be adequately retained by the operator.

Another means of training operators is at colleges and universities offering special courses for either limited periods or at night. Such training has for example been available at New York University. The nature and coverage of the course would determine the type of plant for which the graduate might be qualified.

In some states having sufficient sanitary engineering personnel, operators tentatively approved on their past industrial experience and basic education can be trained in the fundamentals of sewage treatment practice, at least for their own plants, by such personnel coupled by occasional informal conferences called by the State Supervising Agency for instruction in the theory of sewage treatment and in laboratory procedures. Passage of an examination within one year of tentative approval would be evidence that the operator had acquired the fundamentals required.

Technical supervision of plant operation as well as the training of new operators can sometimes be secured by arrangements with experienced personnel at the larger sewage treatment plants. Under some conditions laboratory training can also be obtained in this manner.

In many communities, especially the larger, consulting sanitary engineers, state sanitary engineers, teachers and other qualified persons are sometimes available for private tutoring or consultation. Some home study courses in sewage treatment operation are also available from mail training schools. The contents of such courses should be approved by the State Supervising Agency before being acceptable as a training course. There is a way for the ambitious and determined man.

Not the least of the available means for providing special training for operators are the books and manuals which have been published. The data in various published material might well serve as a special home course of study. Following is a list of some of these publications that are especially suitable:

List for New Operators

1. "Sewage Plant Operation," booklet published by *Sewage Works Engineering* Magazine, 24 West 40th Street, New York City.
2. "The Operation of Sewage Treatment Plants," published by *Public Works* Magazine, 310 E. 45th Street, New York City.
3. Pamphlet on "Operation and Control of Sewage Treatment Plants," New York State Department of Health, Bureau of Sanitary Engineering, Albany, New York.
4. A Laboratory Manual for "The Chemical Analysis of Water and Sewage," by Theroux, Eldridge & Mallmann. McGraw-Hill Book Co., Inc., New York City.
5. "Principles of Sewage Treatment," by Dr. Willem Rudolfs, National Lime Association, Washington, D. C.
6. "Questions and Answers on Sewage Plant Operation," Vol. I and II. *Sewage Works Engineering* Magazine, 24 West 40th Street, New York City.
7. "Laboratory Control of Sewage Treatment Plants." *Sewage Works Engineering* Magazine, 24 West 40th Street, New York City.

List for More Advanced Study

1. "American Sewerage Practice," Vol. 3, Sewage Treatment (1935) by Metcalf & Eddy. McGraw-Hill Book Co., Inc., 310 Seventh Avenue, New York City.
2. "Sewage Treatment" by Karl Imhoff and Gordon M. Fair. John Wiley & Sons, Inc., New York City.
3. "Standard Methods for the Examination of Water and Sewage," published by American Public Health Association.
4. "Sewage-Treatment Works," by C. E. Keefer. McGraw-Hill Book Company, Inc., New York City.
5. "Industrial Waste Treatment Practice," by E. F. Eldridge. McGraw-Hill Book Company, Inc., New York City.

The Committee feels that the "Manual of Sewage Works Practice" being prepared by the Federation's Committee on "Sewage Works Practice" will be an excellent study book for new operators and we sincerely hope the manual will be completed as soon as possible so as to be available for this purpose.

Section VI

Examinations for Operators

Whenever the Supervising Agency deems an examination necessary for approval of plant operation, as will be true in the majority of cases, the following specifications and procedures are suggested.

Examinations should be held at least yearly at places designated by the State Agency and all operators tentatively approved on their basic education and experience should be required to take this examination for final approval of their qualifications. Operators having less than one year's experience in sewage treatment may postpone the taking of an examination upon their request.

Operators failing to pass the examination should be entitled to re-examination preferably within six months. Only one re-examination should be allowed.

The Committee believes that these examinations should be straightforward, that the questions should require only brief answers and that the subject matter should pertain specifically to operation and the fundamental theories of treatment.

We further believe that operators should be advised in advance, of the character of the material to be covered in the examination for their grade. The purpose of an examination should be to determine in a fair manner whether an operator has acquired the necessary fundamental knowledge required to operate his plant. It should also measure, where required, an operator's mechanical aptitude and manual dexterity. Much confusion and unnecessary worry can be avoided by informing operators of the character of the subject matter for examinations.

The following general guide is suggested for the guidance of state approving agencies. More specific recommendations might well constitute a portion of the future work of this Committee as suggested in Section X.

Grade I Operators

1. A knowledge of the purpose, operating details, and common troubles with all standard designs of sewage treatment units, such as grit chambers, screens, comminutors, settling tanks, digestion tanks, sludge drying equipment, chlorinators, chemical feeding apparatus, pumps, etc. Questions on treatment units should permit a choice, so that the operator may answer and be graded only on those devices in use at his plant.
2. A knowledge of all the standard laboratory tests in use for checking sewage solids removal; sludge quality; nitrogen; moisture and solids content of screenings, sludge cake, grit; and procedures for B.O.D. tests, gas analyses, or bacteriological testing and should be able to interpret the results of such tests.

Grade II Operators

1. See (1) under Grade I.
2. The simpler laboratory control tests only should be required, including pH, chlorine residual tests (if chlorination is being practiced), settleable solids, relative stability test and total and volatile solids.

Grade III Operators

1. See (1) under Grade I.
2. Knowledge of laboratory tests should be limited to those required for control of a plant which a Grade III operator is entitled to operate. Examination in this grade being oral, they should be conducted on as informal a basis as possible.

Section VII

Suggestions for a "Model Law" for State Agencies Charged with Enforcing Operators' Qualifications

The essential provisions to be incorporated in such a law should include:

1. All public institutions, cities, towns, boroughs or other municipal districts or subdivisions, or any person, firm, institution or corporation operating a sewage treatment plant should be effected by the regulations.
2. A statement that such treatment works shall be under the supervision of trained individuals whose qualifications to perform the duties required shall have been approved by the Department.
3. The agency should have the authority to classify sewage treatment plants according to their type and the population served; to classify the operators in charge of such plants according to the skill, knowledge, experience, and character necessary for them to have in the successful operation of such plants; and to adopt rules and regulations for the classification of such plants and the approval of their operators, and to make provision for the issue of "certification of qualification for approved operators in the grades indicated by their qualifications and examinations."

Section VIII

A Suggested "Application Blank" for Operators Applying for Approval

Data to be Submitted by Persons Desiring to Qualify as Sewage Plant Operators

Date ....

Location at which you are applying for position ....

Name of Plant Owner ....

Your name ....

Address ....

(street and town)

Date of birth .... Place of birth ....

Ht. .... Wt. .... Are you color blind? ....

Do you suffer from any chronic ailment or do you have any physical impairment? ....

If so, give details ....

....

....

Experience during the past 10 years listing present position held under (1)

Dates of Employment Name and Address of Employer Wages Type of Work From To Total Years

If any of the above positions were with reference to operation of a sewage treatment plant, please state which ....

If any of the above positions were with reference to care of mechanical or electrical equipment, please state which ....

Are you in your opinion qualified to carry out repairs on mechanical equipment? ....

....

Education

	Circle the last grade completed	City and State	Did you Graduate?	Give date of leaving or graduation
(a) Last Common School	1 2 3 4 5 6 7 8			
(b) Last Junior High (if any)	7 8 9			
(c) Last High School (if any)	1 2 3 4			
(d) College or University	1 2 3 4 5 6 7			
(e) Operators' Schools Attended	....			

(f) Give any other education or training you have had: Business College, Correspondence

courses, etc. ....
Have you ever studied sewage chemistry? ....
If so, where? ....
Have you ever studied sanitary, mechanical, civil or electrical engineering? ....
If so, which course and where? ....
Have you ever carried out any laboratory tests? .... If so, have you had laboratory training? .... If so, where and what kind of training? ....
Give reference to three of your previous employers:
Names .... Adresses ....
....
Signed

Please give any additional data on separate sheet, or on back page, particularly with regard to training and experience.

Section IX

A Suggested "Certificate of Qualification" for Approved Operators

No. .... Date issued ....

Certificate of Sewage Treatment
Plant Operator

State of ....

Be it known that .... having submitted acceptable evidence of his qualifications by education, training, and experience, and having passed the required examination, is hereby granted this Grade .... Certificate as Sewage Treatment Plant Operator.

(SEAL)

....

Commissioner of Health Dir. Bureau of Sanitary Engineering

Section X

Future Work of This Committee

This Committee realizes that the art of sewage treatment is a changing field and that the qualifications of operators of sewage treatment plants may require revision with new types of treatment and changing methods of operation. For this reason, it would be well to recommend from time to time changes in the qualifications of operators and the nature of the material to be covered in examinations.

The Committee might also render additional advice to states instituting a certification plan for sewage treatment plant operators and review on request their proposed regulations. It might also assist state agencies in specific problems that may arise in the administration of a certifying law and perhaps grade operators' examination papers on request of the state agency.

IMPORTANT NOTICE!

WIN A $100 WAR BOND FOR MEMBERSHIP ACTIVITY!

While plans were being laid at the Federation's Annual Meeting in Chicago for the further development of membership, an anonymous donor who has been vitally interested in the Federation for many years announced that two $100 War Bonds would be made available as prizes for individual membership activity during the period October 1, 1943, to September 30, 1944. One of the $100 denomination bonds will be awarded to the **individual** in the Member Association which enrolls the greatest number of new Active and Corporate Members during the above period, chosen by that Association as having contributed most to its growth. The other $100 bond will be awarded to the **individual** designated to have contributed most to membership development in the Member Association which shows the greatest percentage increase during the period of the contest. The rules governing the awards follow:

1. All Active and Corporate Members of the Member Associations comprising the Federation shall be eligible for the prize, **except** the Executive Secretary of the Federation.
2. Only those who have never belonged to any Member Association prior to October 1, 1943 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 as published in SEWAGE WORKS JOURNAL, **13,** 337 (March 1941).
4. The term of the contest shall be from October 1, 1943, to September 30, 1944. At the close of the period, the Executive Secretary of the Federation shall determine (1) the Member Association which has enrolled the greatest number of new Active and Corporate Members and (2) the Member Association which has shown the greatest percentage increase in Active and Corporate Members during the period of the contest. The Executive Secretary of the Federation shall immediately notify the secretaries of the Member Associations so determined and request that nominations be submitted for the prizes. Each of the two Member Associations shall submit but one nominee.
5. Each of the two individuals nominated for the prizes shall be awarded a $100 denomination, Series E, U. S. War Bond.

Reviews and Abstracts

A CUBIC YARD OF PERCOLATING BED MATERIAL AND A FEW ASSUMPTIONS BASED ON EXPERIMENTAL EVIDENCE

The Surveyor, 102, 243–246 (June 11, 1943)

This article is a discussion of the above paper by Dr. Goldthorpe which was published in *The Surveyor,* April 23, 1943.

With regard to optimum filter depth, Mr. Lovett cited experiments and research by the Royal Commission which indicated that a cubic yard of filter material would do about the same work in either a shallow or deep filter. He also cited Baltimore and Philadelphia experiments which led to the conclusion that no useful purpose was served by constructing filters greater than 6 ft. deep. The Lawrence experiments indicated that filters 10 ft. deep could operate at rates ten times greater than that of a 4 ft. filter and produce an effluent of equal quality, and an 8 ft. filter could operate at nearly twice the rate of a 6 ft. unit. Buswell's experiments indicated no increased purification from a 10 ft. filter over that secured from a 6 ft. unit.

Mr. Lovett's experience in operation of a rectangular filter 7 ft. 6 in. deep with intermittent dosage indicated better results than secured from a 6 ft. deep circular unit operating at less loading.

Dr. Watson in discussing results secured from fine and coarse media thought that results depended upon the degree of flushing action of sewage and whether or not even patches of slime were built up on the media or whether heavy deposits were formed in the voids which would prevent free circulation of air. He thought Lovett's rectangular filter might be considered as high rate for very short periods and that the instantaneous heavy intermittent dose helped to flush the filter voids.

Mr. C. Lumb said that the relation between time of contact and purification would hold up to the point where the slime growth became so heavy as to cause ponding when purification would fall off. He said further that the area of air-liquid surface in a filter was 200 to 300 times that in an activated sludge plant. The times of contact, however, were not so disproportionate, suggesting that this air-liquid interface in activated sludge was fundamentally more efficient than in normal percolating filters.

Regarding frequency of dosage, he could not subscribe to the doctrine that a small instantaneous dose applied at frequent intervals produced better results than more intermittent doses and cited an example at his own plant where a rotary distributor's characteristics were changed to permit application of small doses at 20 to 30 second intervals, where formerly it had applied heavy doses at 3 to 4 minute intervals. Purification by the filter decreased after the distributor was changed.

Mr. E. H. Staynes disagreed with Dr. Goldthorpe's statement that rectangular beds dosed heavily at 7 to 10 min. intervals were less efficient than those dosed lightly and continuously and cited several cases to indicate the contrary result.

Mr. L. F. Mountfort discussed, at length, time of contact as related to media size and introduced the subject of liquid content of filters. At the East Middlesex Main Drainage Works with filter media of 1½ to 2½ in. clinkers the drainable water amounted to 4 gal. per cu. yd. The dosing rate averaged 150 gal. per sq. yd. per day and the amount of growth was below average. The liquid content of a filter in terms of the water taking part in the movement, from which the mean contact time should be calculated, was about 20 per cent greater than the drainable water.

Dr. S. Nixon, speaking on the effect of size of filter media on purification, cited experiments at Huddersfield with a filter containing fine media in the top half and normal larger media in the bottom half. The fine media gave better results only so long as it remained unponded. He felt that heavy intermittent doses on a rectangular filter probably mashed material into the lower depths of the filter where the macro-fauna could digest it before the next dose came along.

K. V. Hill

SEWAGE PURIFICATION AND THE MUNICIPAL ENGINEER

By N. H. Stockley

The Surveyor, 102, 251–253 (June 17, 1943)

The author presents specific items of the subject to promote discussion.

Treatment of storm water flow in excess of three times the dry weather flow by sedimentation only is required by the Ministry of Health. It is pointed out that screening and removal of grit could also be given to this flow as well as to the 3 times dry weather flow which is given complete treatment inasmuch as screenings and grit have to be removed from the storm water tank later on in a laborious manner.

Detritus tank design, types of screens and the disposition of screenings are discussed briefly.

Various advantages and disadvantages of round and rectangular sedimentation tanks are stated particularly as regards desludging.

A novel design for filter bed walls is described.

K. V. Hill

SANITARY ENGINEERS AND POST-WAR CONSTRUCTION

The Surveyor, 102, 271–272 (July 2, 1943)

At a summer meeting of the Institution of Sanitary Engineers post-war sanitary construction was discussed, largely from the viewpoint of comprehensive planning.

Discussion brought out that 60 per cent of all building in the post-war period would be housing. At present, many bodies sought to satisfy their own needs without envisioning the needs of others. Some changes were needed which would bring about greater co-operation of local bodies, whether by nationalization or regionalization. The catchment area should be the basis of future planning. Regional planning boards would be required on which local authorities would sit and vote according to rateable value or area. Discussion pro and con brought out both advantages and disadvantages of regionalization.

K. V. Hill

WEST RIDING OF YORKSHIRE RIVERS BOARD

By C. W. Beardsley

The Surveyor, 102, 315–316 (July 30, 1943)

A review of the activities of this Board was presented by the chairman at the Board's 50th annual meeting.

The West Riding has an area of 2,780 square miles, an estimated population of 3,288,300 and a rateable value of 21,103,224 pounds. The Board's officers inspect a total length of rivers and main tributaries of 2,000 miles. The dry-weather flow of several of the rivers consists of 50 per cent sewage effluent.

In 1893 there were 126 sewage works, mostly small and inefficient, and now there are 450 sewage works, including some very large plants.

There are over 2,000 trade premises producing waste liquids. Sixty per cent are connected to sewers; the remainder have provided some form of treatment of wastes before discharge to streams. The Board's policy is to induce trade premises to connect with sewers wherever circumstances permit.

For many years the Board sought to control impounding of streams or diversion of water from streams which would rob the stream of dilution water. As a result of Parliamentary proceedings, the Board has statutory rights under fourteen local Acts to inspect compensation water gauges, and in some cases to sue for penalties if the prescribed amount of compensation water is not flowing to the stream.

The Board has instituted and maintained an extensive system of stream gauging, which is particularly valuable in determining available dilution.

During fifty years, the Board has established the principle from experience that friendly co-operation will accomplish more than rigid regulation and recourse to legal proceedings.

During the war, the Board has functioned to gain priorities for needy works to prevent pollution of streams within its jurisdiction.

K. V. Hill

REGIONAL CONTROL OF SEWAGE

By C. B. Townend

Civil Engineering (London) 38, 200 (Sept., 1943)

It appears that the need of planned control in the reconstruction of cities and towns and the development of the country as a whole is generally recognized. There seems to be no doubt that a policy of decentralization of our largest areas of population will be adapted. This would involve the establishment of new towns, satellite towns, and so on, separated from one another by belts of open country. There would be a greater dispersal of these developments throughout the country, with closer association of urban and rural interests.

In this program the disposal of sewage must be given most careful consideration and not treated as an afterthought. Whatever is done in a national reconstruction plan, it is certain that a large number of plants will require extension, reconstruction or scrapping. In other cases entirely new works will be required. The shortcomings of the present system, as set forth in the Memorandum of the Institute of Sewage Purification, should be avoided. The conclusions of this Memorandum are, briefly, that the service suffers in efficiency through being subject to the limitations of the local government area. This has led to the haphazard multiplication of sewage works and much unnecessary duplication and expensive construction of sewers.

The public has been largely ignorant of matters of drainage and sewage disposal. The importance of drainage has been brought home to many people for the first time only when it has been interrupted by war damage. The necessity of providing and maintaining adequate facilities must be brought home to the public to help clear up confusion of outlook which exists among taxpayers over questions of municipal finance.

Rivers have always been used as dumping grounds for refuse. There has been some improvement in attitude but it is still common to find that local bodies will not provide funds for extensions to sewage works until serious pollution has already taken place. However, Parliament has recognized the evil of this outlook from the point of view of the greatest good for the greatest number and from time to time has passed legislation. In 1876 the Rivers Pollution Prevention Act was passed but, as often happens when the public is not really interested, Democracy has never had the will to carry out its decisions properly.

The Memorandum of the Institute points out the advantages of regionalization. The problems become more difficult as the science of sewage purification proceeds. By large scale organization an expert staff can be made available at a lower cost per capita served than the wages of a foreman laborer left in charge of so many small plants.

Another advantage to be gained by regionalization is the equalization of rate charges over the whole district.

Where the drainage of a large area is planned to follow the natural features of the district, without regard to artificial administrative boundaries, great economy is possible in development cost. Duplication of sewers so often found along a boundary between two municipalities will be avoided.

Research work would be facilitated by regionalization and the cost would be spread over the people receiving benefit of the results. All such research work should be coordinated nationally, but each authority would provide its own contribution to the national research effort and would be expected to carry out work suited to its conditions and facilities.

As regards population several millions might conveniently be organized as one unit. However, adequate financial resources would always be available from populations of 1,000,000 upwards. For a minimum figure it would appear unwise to select a watershed grouping containing less than about 200,000 if a unit with a proper staff were to be achieved.

T. L. HERRICK

RECOVERY OF FREE ACID FROM PICKLING LIQUORS

BY HARRY W. GEHM

Ind. and Eng. Chemistry, 35, 1003 (Sept., 1943)

Sulfuric acid was recovered from spent pickling liquor by separation of the ferrous sulfate by treatment with acetone. The process is similar to that proposed by de Lattre in which methanol was used to produce precipitation. In his work Dr. Gehm sought a more economical crystallizing agent and tried several alcohols and ketones, finally selecting acetone as the most effective.

By treating a series of 250 ml. samples from a batch pickling process (analysis: $FeSO_4$, 15.75 per cent; H_2SO_4, 4.88 per cent; water, 79.37 per cent) with varying amounts of acetone, the greatest amount of copperas was removed when 400 ml. of acetone was used; the greatest acid concentration was reached with 250 ml. acetone. The table shows the results obtained. The figures are taken from the curves given.

Ml. Acetone	Per Cent Copperas in Recovered Acid	Per Cent Sulfuric Acid in Recovered Acid
0	15.75	4.88
100	8.50	7.00
200	4.00	8.20
250	2.75	8.30
300	1.50	8.30
400	1.25	8.00
500	1.75	7.50

Apparently optimum conditions were obtained with 250 ml. of acetone. Using this amount for further experiment it was found (1) that the ferrous sulfate content of the pickling liquor could be reduced approximately 85 per cent; (2) the acid concentration could be increased 71 per cent; (3) dry, acid-free copperas containing 10 molecules of water of crystallization was obtained; (4) the copperas before removal held only 7 per cent of the acetone; (5) only 3 per cent of the acetone was lost—this can be reduced to practically nothing in a closed system; (6) the acetone separated from the recovered acid was practically free of water and the recovered acid was completely free of acetone.

An attempt to reduce the ferrous sulfate content of the recovered acid by increasing the acid concentration to 10 per cent with make-up acid before treatment, was not successful. Approximately the same amount of copperas remained in the recovered acid as before this treatment.

Using pickling liquor from a continuous pickling process (analysis: $FeSO_4$, 7.88 per cent; H_2SO_4, 10.00 per cent; water, 82.12 per cent) optimum treatment was obtained with 400 ml. acetone. The copperas content was reduced to 2.3 per cent and the acid concentration increased to 11.8 per cent. The failure to obtain greater acid concentration is explained by the fact that the copperas concentration of the spent liquor was too low to remove much water of crystallization.

E. Hurwitz

MICHIGAN SEWAGE WORKS OPERATORS ASSOCIATION

Engineering Experiment Station *Bulletin* No. 98 (July, 1943)

Maintenance of Electric Equipment in Sewage Plants. By H. V. Crawford, pp. 5–12.—Maintenance of electrical equipment is unlike upkeep of mechanical equipment in that there are no audible indications of trouble until, usually, it is too late. Only by thorough periodic inspection can trouble be reduced to a minimum.

At plants where power is obtained from generators the operators will be familiar with the maintenance procedure. The most important points to bear in mind are overloading, temperature rise, and care of brushes. Where stand-by generators are provided such units should be operated for an hour or so a week to keep them in running order and to prevent damage from moisture in the windings.

Transformers usually require but little maintenance. When changes or additions are made to the plant the matter of overloading should be checked. Readings of temperature, load in amperes, and voltage should be taken across each phase. In the case of oil insulated transformers the oil level should be checked, as well as the condition of the oil, particularly as regards the moisture content. If overheating is noted at ordinary loads the ventilation should be checked. Switchgear likewise requires only a minimum of maintenance. Yearly inspection should be sufficient. Bushings and potheads should be kept clean.

Motors present the most important problem in the sewage treatment works. In many cases severe operating conditions are imposed on them and they are operated continually. Proper selection of a motor to suit the particular job is most important. If a motor of proper characteristics is installed and it is kept dry, clean, and well lubricated, there is little reason for trouble. It is good practice to check the temperature each day by placing the hand on the hottest part of the frame. If the hand can be held there for at least 10 seconds it is fairly certain the motor is not too hot.

Motors which are used but infrequently should be checked from time to time because windings may deteriorate due to moisture. The insulation value of the windings should be determined and if found too low the motor should be dried out before using. It is always good practice to check the insulation value of a new motor before starting it.

Motors located in dirty places should be cleaned carefully at regular intervals. The best practice is to use a vacuum cleaner with long rubber nozzles. In extremely dirty locations it is best to take the motor out of service and disassemble it for complete cleaning.

The maintenance of motor bearings is very important and regular inspections should be made to determine the wear that is taking place. Lubrication is of utmost importance and many motors are ruined by improper lubrication or greasing, particularly by using too much lubricant. Motors of the splashproof type should be closely inspected to assure properly sealed joints.

Electrical control equipment should be carefully inspected and serviced at regular intervals and a record kept of any work done on them. No one should be allowed to do this work unless he is entirely capable. It is good practice to have a copy of the wiring diagram framed and mounted on the wall near the control.

Vacuum Flotation of Sewage and Industrial Wastes. By A. J. Fischer, pp. 13–28. —The vacuum flotation process has been tried on a number of different types of sewage as a means of removing very light solids that tend to float or settle very slowly. The process precedes the conventional type settling tank, and is preceded by a short period of aeration and a period of deaeration.

It is necessary to use pre-aeration with most wastes, though in some cases there may be enough entrained gases present that the step may be eliminated. Rather violent agitation is best so that a maximum number of finely divided bubbles will be entrained. The quantity of air is estimated to be 0.025 to 0.050 cu. ft. per gallon, and the aeration period may be as low as 30 seconds. A very short deaeration period, to remove large air bubbles, is necessary immediately ahead of the vacuator.

The two general types of vacuators are described.

The power required to maintain a 9 in. vacuum, once the tank is filled, is estimated at 0.5 horse power per million gallons for a 20 ft. diameter tank operating at an overflow rate of 10,000 gallons per square foot per 24 hours.

Laboratory tests were made on raw sewage at a number of sewage treatment plants. In these tests a 2-liter separatory funnel was used. The vacuum was maintained at 9 in. to 10 in. for 3 minutes after aerating by agitation for 30 seconds. Results are shown in the following table.

Laboratory Tests—Raw Sewage

Sewage	Coagulant Added		Susp. Solids, P.P.M.		Per Cent Removal
	Kind	P.P.M.	Influent	Effluent	
A	None	—	483	223	53.8
	$FeCl_3$	34	483	140	71.0
B	None	—	580	168	71.0
	$FeCl_3$	17	580	80	86.8
	$FeCl_3$	30	580	39	93.3
	$FeCl_3$	43	580	28	95.2
C	None	—	516	141	72.7
	$FeCl_3$	44	516	20	96.1
D	None	—	58	39	32.8
E	None	—	200	115	42.5
F	None	—	340	135	60.3

Tests of fruit and vegetable cannery wastes showed suspended solids removals ranging from about 70 to 98 per cent.

The removal of most of the solids in the float was also noted in a test on spinach wastes. Tests on pear and string bean wastes indicated a ratio of solids removed as float to that removed as sludge of about 1:1. With asparagus the ratio was 1:3.5.

A pilot plant was built at the Terminal Island plant at Los Angeles in order to obtain test results on a continuous flow basis. This unit was 7 ft. in diameter and the results obtained established the basic factors used in the design of the commercial units. Results were obtained on sewage and oil wastes. The table below shows the results obtained on raw sewage. During the tests the sewage contained a considerable amount of industrial wastes.

At the highest overflow rate the aeration period in these tests was only about 10 seconds.

When the Vacuator effluent was post-settled the complete absence of scum was noted. Laboratory tests indicated that greater overall suspended solids removal could be obtained when Vacuator treatment preceded clarification than when settling alone was employed. A number of grease determinations were made and it was indicated that the removal of grease closely followed that of suspended solids.

Continuous Vacuator Tests—Terminal Island

Type Aeration	Overflow Rate, Gal. per Sq. Ft. per 24 Hr.	Detention Period, Min.	Suspended Solids, P.P.M.		Per Cent Removal	Per Cent Solids in Float
			Influent	Effluent		
None	1,610	20.3	544	343	37.0	4.2
None	2,440	13.5	438	286	34.7	5.6
None	11,700	20.8	367	320	12.8	7.3
Diffused Air	4,840	6.9	450	228	49.3	7.3
Diffused Air	11,700	2.8	357	294	17.6	7.5
Mech.	1,610	20.3	544	265	51.3	4.5
Mech.	2,440	13.5	524	286	45.4	5.6
Mech.	4,840	6.9	406	244	40.2	7.7
Mech.	9,100	3.6	414	262	36.6	8.4
Mech.	11,700	2.8	381	234	38.5	7.5

Results of pilot plant tests on oil refining waste water are given.

The vacuum flotation process can now be considered a valuable adjunct in the treatment of sewage and trade wastes. In sewage treatment its field lies in the removal of scum and light solids ahead of clarification. In the treatment of many trade wastes, such as oil refinery waste waters and canning wastes, the process should provide such treatment that the effluent could be discharged to a municipal sewer system, a secondary treatment system, or a receiving body of water.

Two Years Operation of the Detroit Sewage Treatment Plant. By W. M. Wallace and C. A. Habermehl, pp. 29–41.—The Detroit sewage treatment plant, designed for a population of 2,400,000 and a flow of 420 m.g.d., was placed in service February 28, 1940. The plant provides sedimentation, chlorination, partial digestion, filtration, and incineration. Detroit is the largest city in the world served by a single treatment plant.

The year 1940 may be regarded as a tuning-up period, with a stable operating procedure established by 1941. During the early weeks of operation a tremendous volume of solids, which had been deposited in the older parts of the interceptor, was handled. This material caused considerable trouble in the settling tanks but it had a beneficial effect in the sludge filtration plant. During the first four months the raw sludge averaged 12.8 per cent solids and 53 per cent volatile. Filter cake averaged better than 35 per cent solids and the yield from the filters ranged from 14 to 17 lb. per sq. ft. per hour, dry basis.

The pumping station has operated without trouble and with no interruption in pumping. Sewage flows for 1941 and 1942 were as follows:

	1941 M.G.D.	1942 M.G.D.
First Quarter	264	287
Second Quarter	281	313
Third Quarter	303	312
Fourth Quarter	262	300

During dry weather periods the pumps are operated to maintain flow in the interceptor between definite levels to secure uniform velocities. Once daily during dry weather periods the level in the interceptor is pumped down to provide flushing.

Screenings removed for the two years averaged four wet tons per day containing 73.8 volatile matter. Grit removal amounted to 41.3 wet tons per day with 35.3 per cent volatile matter.

Seven of the settling tanks have been operated continuously, the eighth having not yet been placed in service. Seven tanks provide a period of 1.5 hours at 300 m.g.d. Average results for the two years are as follows:

B.O.D.			Suspended Solids		
Influent	Effluent	Per Cent Reduction	Influent	Effluent	Per Cent Reduction
232	122	47.5	132	80.6	38.9

A sludge depth of three or four feet has been maintained at the inlet end of the tanks which apparently aids in providing a more dense material. Two of the tanks are connected to pipe sludge either to the digestion tank or to the filter room; the others deliver sludge only to the filters. Monthly averages for per cent solids and per cent volatile matter in the sludge drawn have ranged from 7.5 per cent to 13.0 per cent, and 53.8 per cent to 70.4 per cent, respectively. The scum collecting equipment has caused trouble principally due to twigs, leaves, and other material clogging pumps, hoppers and pipe lines. This material, mostly grease, averages about 80 per cent total ether soluble, of which 80 per cent is saponifiable. A study is being made of the possibility of the commercial recovery of this grease.

The digestion tank (300,000 cubic feet capacity) was placed in service in October, 1940. Operation started smoothly, without foaming or necessity for lime treatment. Raw sludge feed rates were increased to 40 tons per day from July through October, 1941. This rate is equivalent to 8 lb. dry solids per cu. ft. per month. By October, 1941, scum had built up to a depth of 8 feet. Analysis showed that 80 per cent of this material was ether soluble and it appeared to consist of solid particles entrapped in oil. It was planned to use sedimentation tank No. 8 for storing the oil and feeding it slowly to the other tanks for removal with the skimmings, but this proved unsuccessful. When the feed rate was reduced to 30 tons dry solids per day it was estimated that there were nearly 400,000 gallons of relatively clean oil in the tank. The material did not build up to any extent in 1942. An attempt will be made to remove some of this material before the advent of the next heating season. During 1941 the reduction in volatile matter amounted to 41.0 per cent and in 1942 it was 33.5 per cent. Average gas production has been 8 cubic feet per pound of volatile matter added.

The elutriation tanks have never been used as such. They were placed in operating condition in October, 1942, and starting with that date were used to concentrate supernatant liquor from the digestion tank prior to filtering. This material contains about 4 per cent solids and has a marked effect on the chlorine demand if discharged to the incoming sewage. In the elutriation tanks it concentrates to about 11 per cent solids with a supernatant containing some 1,200 p.p.m. total solids.

Beginning in April, 1942, the practice of mixing raw and digested solids prior to filtration was started. Before that time, under normal conditions, one filter handled all digested sludge and two or three were required for raw solids. During 1941 the chemical conditioning requirements were as follows:

Sludge	Per Cent CaO, Dry Basis	Per Cent $FeCl_3$, Dry Basis	Yield of Filters Lb. per Sq. Ft. per Hr.
Raw	7.7	2.6	7.0
Digested	9.6	2.6	6.0

Considerable experimenting was done on filter cloths and a canton flannel cloth standardized on, placed with the nap out. Normal life is slightly in excess of 400 hours. The cloths are not cleaned or otherwise treated.

The more important data on operation of the incinerators are shown in the table below.

	1941	1942
Total loadings tons—wet	161,695	166,945
Screenings—wet	1,085	1,733
Grit—wet	8,637	11,024
Sludge cake—wet	151,973	153,511
Tank skimmings—wet		677
Oil used—gallons		58,707
Gallons oil per ton material burned		0.351
Cost oil per ton at 4½¢ per gallon—cents		1.58

Only two of the units were operated in 1941. In 1942 it was necessary to use the third unit for a 30-day period to keep up with the production of sludge. The greater portion of the oil shown above was used for warming up or cooling down units, or for maintaining heat during times of plug-ups or stoppage in filter cake production. There has been considerable maintenance, but in view of the unprecedented size of the units and the large load handled, it is felt that the performance has been creditable. The preheaters have not been used to date.

The chlorinators were first placed in service July 4, 1940, with a shift chemist on duty at all times to provide 24-hour control. Provisions were made for applying chlorine either ahead of or following the settling tanks, but it appeared more practical to use post-chlorination. This was done until October 24, 1941, when it was found that the post-chlorination diffuser was in need of repair. Pre-chlorination was used from that date until July 16, 1942, when post-chlorination was resumed. Pre-chlorination was not satisfactory because of back pressure in the solution feed line that limited the rate to 55 per cent of capacity. Also, it was not possible to obtain uniform dosage of the flow in each settling tank. Chlorine is dosed in equal amounts to each of two influent conduits, one serving four tanks and the other three (one tank out of service). Certain pump combinations give even more unequal dosage rates.

When post-chlorination was resumed in July, 1942, chlorine demand tests were made on settling tank influent samples rather than on effluent samples. Changes in rate of feed are made at a time interval following sample collection corresponding to the detention time in the tanks. Chlorine residual tests are made hourly.

The following table shows data on chlorination in 1941 and 1942.

	1941	1942
Chlorine applied, lb. per day	13,500	15,650
Chlorine applied, p.p.m.	5.66	6.15
Chlorine demand satisfaction, per cent	89.6(a)	103

(a) Dosage limited during period of pre-chlorination.

The Chironomid Fly and Its Effects on the Activated Sludge Process. By R. B. Jackson, pp. 42–44.—The Chironomid fly is found at all sewage plants but normally does not do any harm. With severe infestations they may, however, destroy the effectiveness of activated sludge floc. It has proven troublesome at plants in Connecticut, New York, Illinois, Ohio and Michigan.

There are a great many species of the fly, with over 50 species of the Thummi group, a type commonly found in activated sludge. It has a life cycle of the following stages: (1) egg; (2) larva; (3) pupa; (4) adult. The eggs are laid by the female in dark calm corners of aeration or settling tanks. Development of the eggs is destroyed only by complete darkness or dryness. The larvae are generally ½ to ¾ inches long and develop from the eggs in 2 or 3 days. They develop a fleshy color which gives rise to the popular name, bloodworms.

The larvae, after leaving their eggs, descend into the sludge and construct spinning tubes. They will die in the absence of dissolved oxygen. The pupa develops in the tubes in 6 or 7 days at 70° F. At maturity they ascend to the surface where they remain for one or two days, changing to the adult stage in a matter of two or three seconds.

The larvae and pupae will be found throughout the entire activated sludge system, since they are circulated with the returned sludge. They will not survive anaerobic environments. The larvae appear to devour everything entering the tubes, and in severe cases can destroy all of the activated sludge in the system. In severe cases clumpy masses of activated sludge containing cast-off tubings and tubings of living worms are formed.

Chemical means are most effective for controlling the fly but other measures may be helpful under some conditions. The larvae are killed by septic conditions accomplished by shutting off the air and allowing the sludge to remain quiescent. Some eggs will be destroyed by lowering the level in the tanks. Screening of the returned sludge has also been tried. These measures have disadvantages and give but partial control.

The pyrethrins compounds appear to be the most effective means of controlling the fly. The action is one of paralyzation of the nervous system. The insecticide is best applied to the returned activated sludge as it is thus carried through the aeration and settling tanks. One pound of powder to 5,000 gallons of plant capacity will kill the larvae in a few hours time. One pound to 20,000 gallons appears a safe dose to use. The strength of the powder should be from 0.7 to 0.9 per cent pyrethrins.

Inter-County Sewage Treatment on Trial. By Milton P. Adams, pp. 45–55.—For some time there has been a lack of proper community sanitation in Southern Oakland and Macomb Counties adjacent to the northern boundary of Wayne County. Until a few years ago all urban communities of these three counties, with a few exceptions, were in violation of the pollution control laws of the state.

Detroit's big treatment plant and collection system was placed in service early in 1940, followed closely by several other Wayne County projects. New plants also appeared in Birmingham, Utica, Rochester, Milford, and Richmond. Mt. Clemens and St. Clair Shores in Macomb County and the southern Oakland Counties applied for PWA assistance without success. By 1940 new industries were under construction in the Oakland-Macomb defense area and with this and other increased activity it was apparent that a plan must quickly be adapted to take care of the present problem as well as provide means of taking care of new users. A plan was worked out containing the following principles:

1. The sewage and wastes of southern Oakland and Macomb Counties to be collected and routed separately into Detroit for final disposal.
2. A new governmental agency or function acting in behalf of Oakland County's political subdivisions, to contract for service with the city of Detroit.
3. A new governmental agency or function within Macomb County to contract with Wayne County for sewage delivered into Wayne County at Eight Mile Road; the latter in turn to contract with Detroit for accepting and disposing of southern Macomb and certain Wayne County sewage.

The Oakland project has been slower in maturing into the construction stage than Macomb. It is less complicated, though it involves more units of government. It is founded on a City of Detroit and Oakland County contract, and Oakland County contracts with the several political subdivisions served. There are eight municipalities and parts of three townships involved. A 5 ft. 6 in. interceptor is being built to bring the sewage to a pumping station located at the county line at Highland Avenue. Here the flow will be metered and lifted to a high level interceptor, thence to the Seven Mile Road sewer in Detroit. Under the terms of the contract the City of Detroit sells Oakland County a 30 c.f.s. flowage right through its sewer system for $137,883.60 and provides that additional flowage rights up to 50 c.f.s. may be secured at a rate of $4,596.12 per c.f.s. In addition, there is a maintenance charge of $689.00 per year. Sewage treatment is to be paid for at a rate of $28.90 per million gallons of water passing master meters as it enters the Oakland County municipalities, subject to certain corrections. The contract purportedly is to run for 50 years.

The agreements between Oakland County and the several municipal subdivisions provide:

(1) For sewage service beginning with the diversion of sanitary sewage from the improvement drains.

(2) For all subdivisions to agree to dispose of all the sanitary sewage from their respective boundaries within the sewage disposal district through the new system.

(3) For all political subdivisions to agree to pay for the disposal of sanitary sewage at rates determined in accordance with provisions of Act 342 of the Public Acts of 1939 as amended.

(4) That the rates, charges and assessments to each political subdivision shall be based on the quantity of water consumed therein.

(5) That each political subdivision shall determine its own rates for individual users.

(6) That Oakland County shall have the right to terminate sewage disposal services to any subdivision in the district if such subdivision shall be delinquent in payment of the charges due to the county for a period of ninety days.

(7) That the agreement is to be in force and effect until the bonds have been retired, but not for a period longer than 40 years.

Oakland County has been most meticulous as to legal procedure and authority. A test suit has passed the lower court and has been argued before the State Supreme Court. The outcome of this suit is not expected to change the line of action or construction. The Federal government has offered to take the Oakland County bonds if they are not privately subscribed.

When in operation the project is expected to accomplish:

(1) Remove the burden of pollution from Red Run, adversely affecting Warren Village, Warren Township, and Mt. Clemens, opening the way for Red Run dredging and storm water improvements for southern Oakland County.

(2) Re-open southern Oakland County municipalities to eligibility for F.H.A. mortgages without local septic tank requirements.

(3) Provide sewage treatment for the entire area without providing their own treatment facilities.

(4) Obviate the necessity of further operation of the Royal Oak plant.

There are some uncertainties in connection with the plan. First there is the workability and permanence of the Detroit-Oakland County master contract and the Oakland contracts with the eleven political subdivisions. Another uncertainty is the effectiveness of pollution control in Red Run with sewage and storm overflow considered in the light of not causing excessive loading on the interceptor and the Detroit Seven Mile Road sewers. As the area develops it is conceivable that storm water detritus tanks and chlorination may be necessary as an auxiliary means of control.

It is estimated that the annual service charge to the small home owner will be about \$5.00 (5,000 cubic feet water consumption). The rate established must produce revenue to meet operating and maintenance charges, together with bond interest and redemption on the \$905,000 bond issue. The estimated cost of the project is \$1,567,000 of which \$662,000 is a Federal grant.

The Macomb-Wayne project differs from the Oakland project as Wayne County appears as a party between Macomb County and the City of Detroit. The project is founded on a City of Detroit-Wayne County contract, a contract between Wayne and Macomb Counties, and contracts between Macomb County and the several municipal subdivisions served. The project will also provide an outlet for sewage from Grosse Pointe Woods, Grosse Pointe Shores and the remaining portion of Gratiot Township in Wayne County which discharges into Lake St. Clair through Milk River. The Macomb-Wayne contract provides for Wayne County to bill Macomb County for sewage received and disposed of at a rate of \$43.00 per million gallons of master meter record of the several communities tributary to the interceptor. Deductions are allowed for non-sewage producing water. A master meter is provided at the county line and if the meter record at this point exceeds the above by 8 per cent the overage is to be billed at the same rate as an additional charge. Wayne County in turn has contracted to pay Detroit at a rate of \$28.90 per million gallons, not only for Macomb sewage, but for sewage originating in the northeast corner of Wayne County.

Contracts between Macomb County and the several municipalities are similar to the arrangements made in Oakland. As the Federal government constructed the interceptor in Macomb County as a 100 per cent Federal project, the need of providing for bond interest and redemption in the service charge was eliminated.

The Wayne County portion of the interceptor project includes 14,770 feet of 6 ft. sewer, pumping station improvements, and other appurtenances. The work was 44 per cent complete on April 3, 1943. The cost of this portion of the project is estimated at $580,000, of which 65 per cent is to be a Federal grant.

The Macomb County portion consists of 7,445 feet of 6 ft. sewer, 7,167 feet of 5 ft. sewer, and diversion control chambers. The work was 38 per cent complete April 3, 1943. The cost will be about $535,000.

Operation of the Macomb-Wayne project should:

(1) Remove pollution from the upper Detroit River and Lake St. Clair in so far as caused either by dry weather sewage flows or local plant effluents.

(2) Provide approved sewer outlets for communities in both Wayne and Macomb Counties not now served.

(3) Offer possibility for extension northward to serve as a sanitary sewage outlet for the northern end of St. Clair Shores and places on to the north.

(4) Obviate the necessity for the construction of new local sewage treatment plants in the area served.

(5) Re-open southern Macomb County municipalities to eligibility for F.H.A. mortgages without local septic tank requirements.

Uncertainties of the plan are similar to those outlined for the Oakland County-Detroit project. Further attention is required on the question of storm water overflow hazard to the bathing beaches along the Lake St. Clair shore line.

Estimated annual service charges to the householder are substantially the same as those expected to obtain in Oakland County.

Mosquito Control. By R. B. Jackson, pp. 56–58.—This paper outlines methods for controlling mosquitoes. It contains useful information on the use of oils and mosquito larvicides.

T. L. Herrick

BOOK REVIEW

Plumbing Practice and Design. By Svend Plum. John Wiley and Sons, Inc., 1943. Two Volumes. Price $4.50 each.

Volume I comprises 308 pages in 8 chapters covering the following topics:

Title of Chapter	Pages
Corrosion	13
Materials	12
Pipes and Fittings	94
Valves and Controls	17
Fixtures and Accessories	66
Pumps	27
Fire Protection	33
Air Piping and Equipment	29

This volume is replete with standard specifications and design data pertaining to piping and fittings, fixtures, accessories and other plumbing materials. The chapter on corrosion, though brief, affords an excellent summary of present theoretical concepts of the fundamentals of corrosion. The chapter on air piping and equipment is commendable.

Volume II contains 329 pages and 11 chapters, as follows:

Title of Chapter	Pages
Definitions of Physical and Chemical Terms	31
Codes and Regulations	4
Architectural Practice	13
Pipe Work	20
Water Supply	25
Water Piping	69
Drainage	36
Sewers	13
Sewage Disposal and Treatment	25
Gas Piping and Appliances	18
Water Heating	54

Volume II is essentially a manual of plumbing practice, introduced by an elementary treatment of practical hydraulics in which the importance of cross-connections is emphasized. The chapters on sewers and sewage treatment are also quite elementary and apply primarily to rural residential and small institutional facilities rather than municipal installations. The recommended practices are generally sound, with proper emphasis being accorded to correct usage of various types of sewers as well as the factors involved in the selection of the degree of sewage treatment. Occasional ambiguity of language and arrangement is noted, as where definitions relating to the activated sludge process are included under a section captioned "Tank Treatments."

The author is considered to have achieved his stated purpose of producing a practical and useful handbook in which he proposes to "consolidate the scattered data on the subject and to present them in a uniform terminology." The books are carefully edited, based on well-founded references to the literature and are noteworthy for the profuse definitions. In the sewage works field, the books will be most useful to designing engineers for the information applicable to the design of the myriad of details requiring consideration in modern sewage treatment works, such as details of air, gas and heating piping and equipment. They will also be of value to plant operation personnel in connection with maintenance and replacement of plumbing facilities as well as to public health engineers engaged in the development and administration of plumbing codes.

W. H. W.

Play Safe with P.F.T. BOILER ROOM EQUIPMENT

Protect your boiler plant, digester and Imhoff tanks and other equipment against the gas explosion hazard by installing these P.F.T. safeguards, which are used in hundreds of sewage treatment plants, including more than 225 war projects.

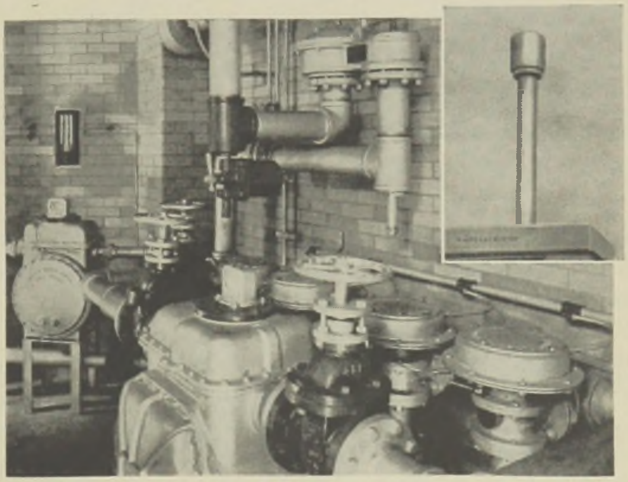
P.F.T. Type "B" Flame Trap **provides full protection against the passage of flames into the supply line, and against burning mixtures. The flame element is rugged, non-corrosive and readily replaceable.**

P.F.T. Type "B" Pressure Relief Waste Gas Flame Trap, **placed in the waste gas line, maintains a constant gas pressure, while eliminating the explosion hazard.**

P.F.T. Pressure Indicating Gauge**—the three scale unit, used with P.F.T. Flame Traps, constantly informs the operator of the gas pressures in digester, service and waste. Also stocked in single units.**

P.F.T. Condensate Drip Trap **safely and effectively removes moisture from gas lines without danger of gas leakage. Installed at lowest point in line for periodical draw-off, during which gas line is positively closed.**

P.F.T. Waste Gas Burner **consists of a burner pot mounted on a pedestal, open at the top, and fitted with a series of fire brick baffles. Below baffles is located terminal of waste gas line, in contact with a pilot light. Combustion chamber is vented, and pilot light is adjustable from the exterior.**



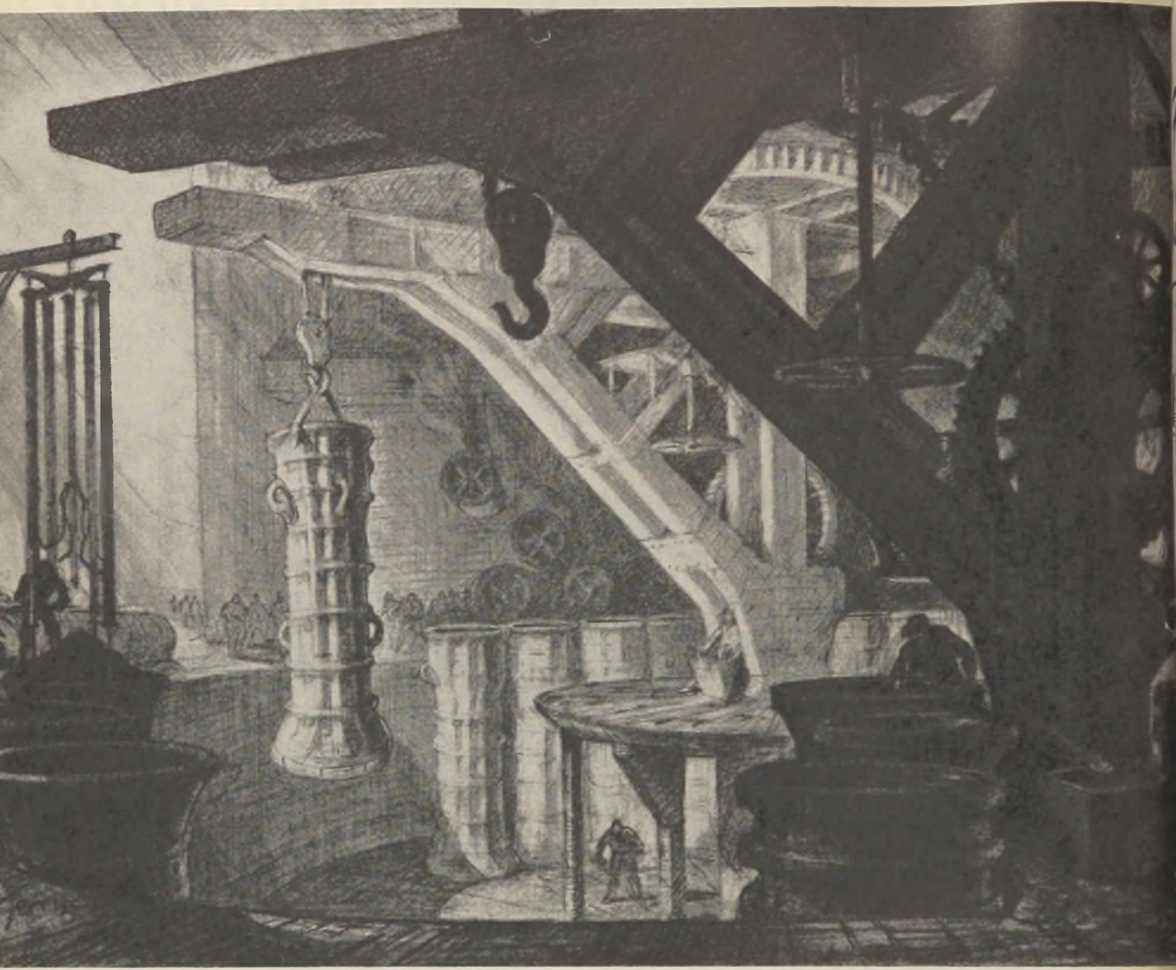
P.F.T.-equipped sewage plant boiler room. Top center: Type "B" Flame Trap; lower right: Type "B" Pressure Relief Waste Gas Flame Traps; center: Condensate Drip Trap; right: Pressure Indicating Gauge; top center: line to Waste Gas Burner, shown in inset.

P.F.T. Pacific Flush-Tank Co.

4241 RAVENSWOOD AVENUE, CHICAGO
NEW YORK CHARLOTTE, N.C.

SEWAGE TREATMENT EQUIPMENT EXCLUSIVELY SINCE 1893

Big pipe made here

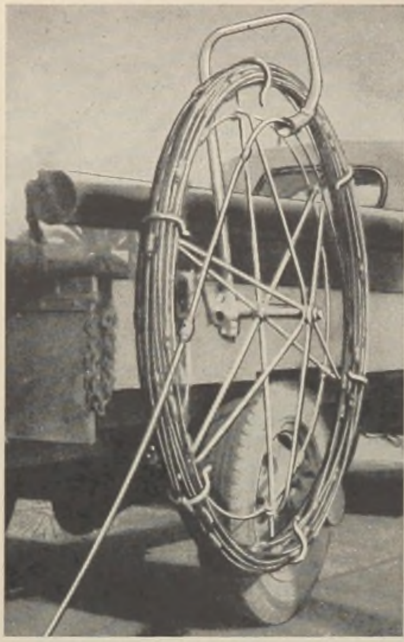


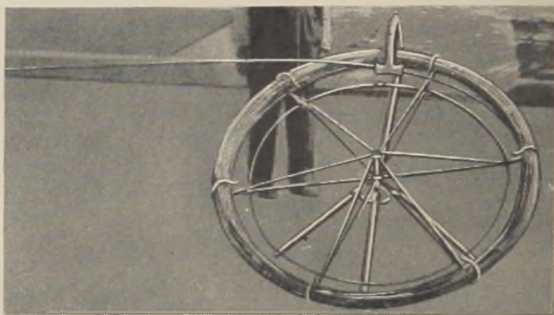
casting pit for large diameter pipe, drawn by Hugh Ferriss.

This drawing shows a pit in one of our foundries producing large diameter cast iron pipe. We can furnish pit cast pipe in diameters 2-inch to 84-inch in accordance with all standard specifications or to meet engineers' special requirements. Pipe can be made with bell-and-spigot, mechanical, flanged or flexible joints—or with plain ends. We also manufacture Super-de Lavaud centrifugally cast pipe in diameters from 3-inch to 24-inch, with bell-and-spigot or mechanical joints or plain ends, and have stocks on hand for immediate shipment. Fittings for these types of pipe can be made promptly in our special fittings foundries.

UNITED STATES PIPE & FOUNDRY CO.

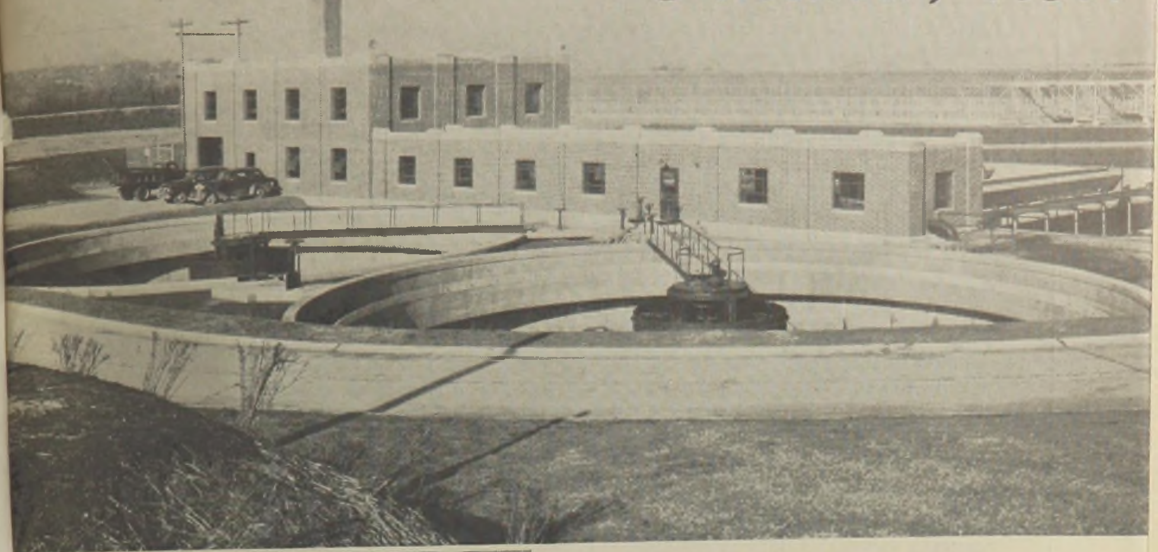
General Offices: Burlington, New Jersey. *Plants and Sales Offices throughout the U.S.A.*

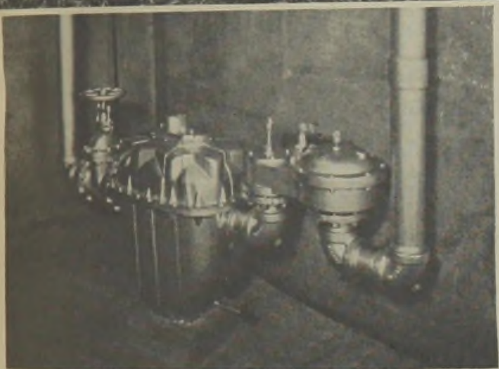




In THE PAPILLION CREEK SEWAGE TREATMENT PLANT

Omaha, Neb.





EMCO No. 4 Sewage Gas Meter measuring gas consumed by Digester Heating Facilities

EMCO No. 2½ Sewage Gas Meters measuring portion of daily gas production at Omaha. In foreground, two floor stands for operating gear driven Nordstrom Valves on sludge lines.

ACCURATE, DEPENDABLE, TROUBLE FRE

METERS AND VALVES

PROVIDE EXACTING CONTRO

THE Papillion Creek District Sewage Treatment Pla in Omaha, Nebraska, a model of its kind, is one the finest in the Midwest. It is designed to serve an ar embracing 60,000 people, with expansion facilities f serving an ultimate population of 100,000.

Designed under the supervision of the la George B. Gascoigne and the successor organization Havens and Emerson, this plant is equipped with th latest and most modern operating and control apparat

The plant uses fifty-three Nordstrom Lubricat Plug Valves for controlling air to the channels ar sludge to and from the digestion units. For the measur ment of hot water, four 1½-inch Pittsburgh Hot Wat Meters are used; and for sewage gas measurement th plant employs four EMCO No. 2½ and two EMC No. 4 Sewage Gas Meters.

PITTSBURGH EQUITABLE METER COMPAN

MERCO NORDSTROM VALVE COMPANY

Main Offices, Pittsburgh, Pa.

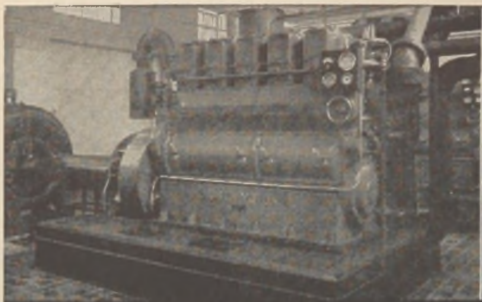
NATIONAL METER DIVISION, Brooklyn, N. Y.

BOSTON · BROOKLYN · BUFFALO · CHICAGO · COLUMBIA · HOUSTON · KANSAS CITY · LOS ANGELES · MEMPHIS · NEW YORK · PITTSBUR · SAN FRANC · SEATT · TULSA

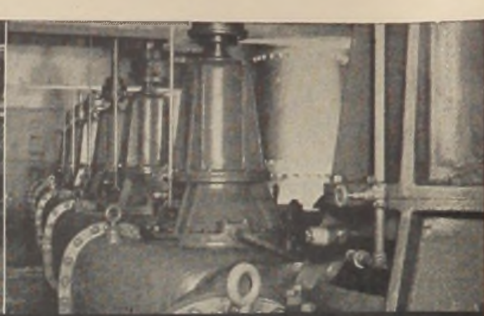
Back The Attack—Buy War Bonds

PITTSBURGH-NATIONAL · EMCO SEWAGE · NORDSTROM

:: DIRECTORY OF ENGINEERS ::

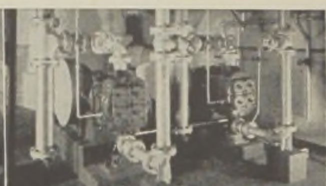


Sewage sludge gas engines



Vertical MIXFLO pumps

Horizontal MIXFLO pumps



Vacuum pumps on sludge filters

Port... rs

MEMBERS OF LOCAL ASSOCIATIONS

Have you paid your DUES to your local association?

If not, do so NOW in order that you will receive Sewage Works Journal without interruption.

Season's Greetings!

With the approach of the Holiday Season, we wish to take this opportunity on behalf of the Federation of Sewage Works Associations and its publication, SEWAGE WORKS JOURNAL, to thank all our members, subscribers, advertisers and friends for their past patronage and cooperation, and of wishing everyone:

A Merry Christmas

A Happy and Peaceful New Year

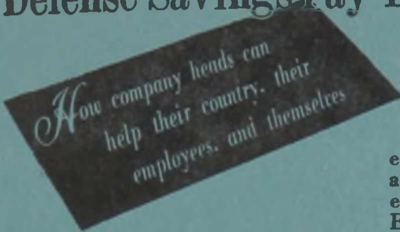
May we have the privilege of serving you again in 1944.

A. M. RAWN, *President*
Federation of Sewage
Works Associations

INDEX TO ADVERTISERS

When writing these, please mention the SEWAGE WORKS JOURNAL

Defense Savings Pay-Roll Allotment Plan



voluntary	**helps workers provide for the future;**
pay-roll	**helps store up tomorrow's buying**
allotment	**power;**
plan	**helps defend America today.**

Business heads are adopting the Voluntary Pay-Roll Allotment Plan as a simple way for every worker to start a *systematic* and *continuous* Defense Bond savings program. It is a sensible step toward reducing the ranks of the post-war needy. It will help spread the financial participation in national defense among all of America's wage-earners. It will materially retard inflation by "storing" part of our pyramiding national income, thus reducing the demand for our diminishing supply of consumer goods.

In emergencies, America doesn't do things "hit-or-miss." **We would get there *eventually* if we just left it to everybody's whim to buy Defense Bonds when they thought of it. But we're a nation of businessmen who understand that the way tc get a thing done is to *systematize* the operation. That is why so many employers are getting back of this voluntary savings plan.**

All you have to do is offer your employees the convenience of having a fixed sum allotted from each pay envelope to the purchase of Defense Bonds. Each employee who chooses to start this savings plan decides the denomination of the bonds to be purchased, and the amount to be allocated from his wages each pay day. You deliver a bond to the employee each time his allotments accumulate to a sufficient amount.

Plenty of help available. **The Treasury Department is ready and willing to give you all kinds of help. Local civilian committees in 48 States are set up to work with you just as much as you want them to, and no more. We will supply most of the necessary material.**

The first step is to take a closer look. **Writing for details in no way obligates you to install the plan. It simply indicates that you'd like to do *something* to help keep your people off relief when defense production sloughs off; *something* to enable *all* wage-earners to participate in financing national defense; *something* to retard inflation and store up tomorrow's buying power. So, write for the free kit of material being used by companies that have installed the Voluntary Defense Savings Pay-Roll Allotment Plan. Address: Treasury Department, Section A, 709 Twelfth Street NW., Washington, D. C.**

D59—BP 1A

LANCASTER PRESS, INC., LANCASTER, PA.