SEWAGE WORKS JOURNAL

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SEWAGE WORKS JOURNAL

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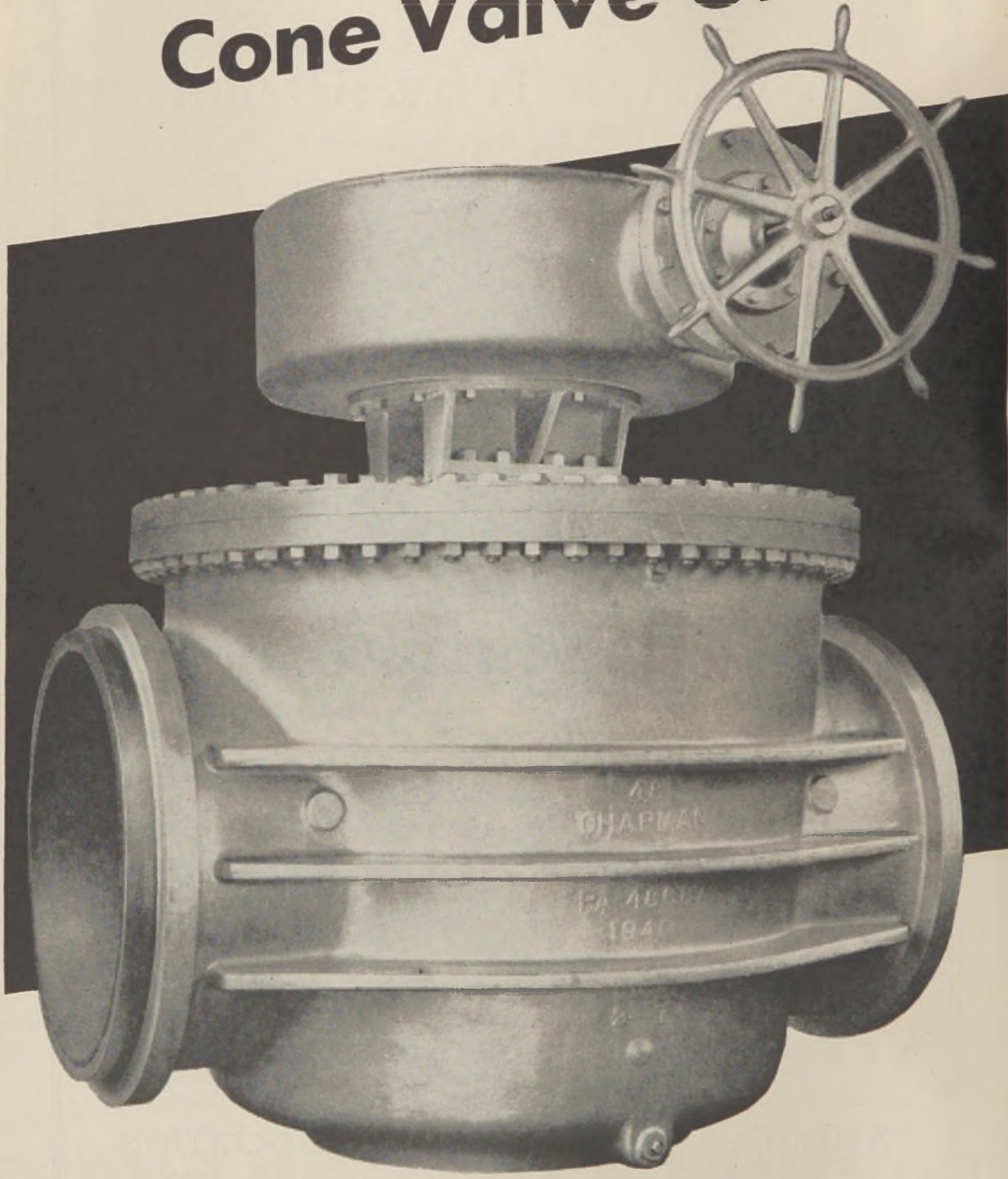

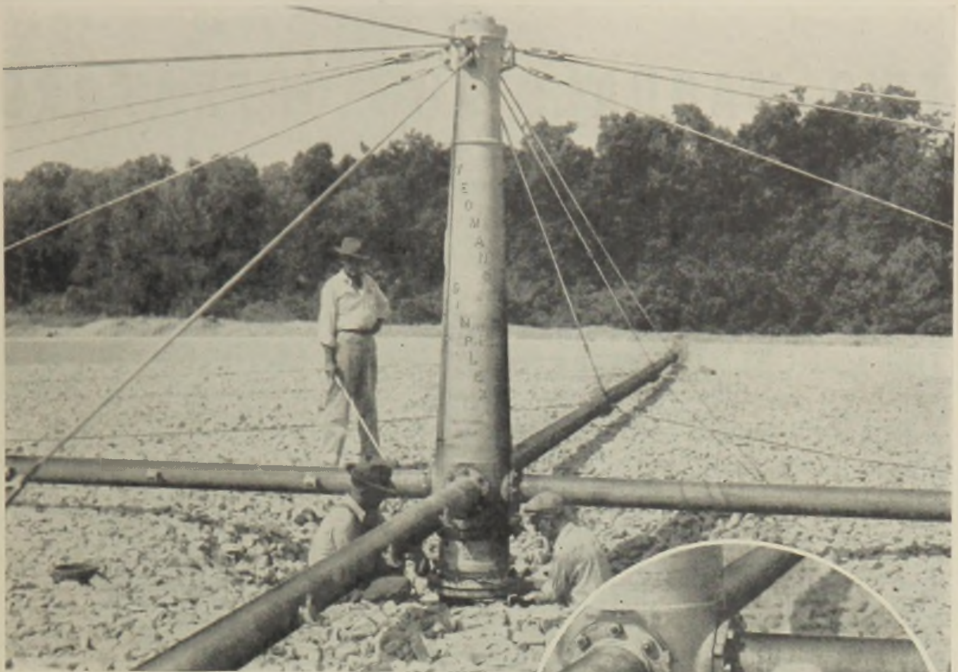

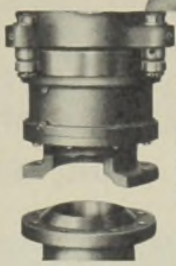

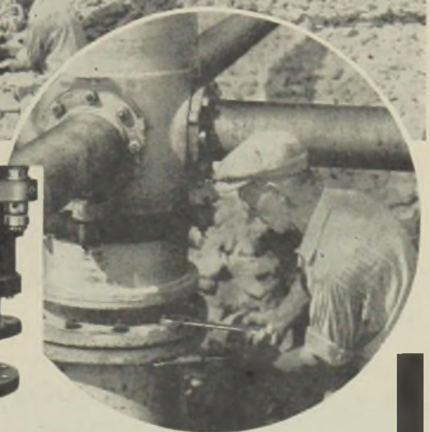

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Plant Operation

INLET AND OUTLET DESIGN FOR SEDIMENTATION TANKS *

By J. Henry L. Giles

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The writer has had an opportunity to observe sedimentation tank operation at a large number of sewage treatment plants for a number of years. It is not planned to review problems encountered in the operation of these plants but to present observations and suggestions that are believed to be helpful in obtaining greater efficiencies from present sewage sedimentation tanks.

There are generally three types of sedimentation tanks used in sewerage works practice: Tanks with longitudinal flow, circular or square tanks with radial flow from a central inlet, and tanks with vertical or upward flow. The longitudinal flow-through tanks are by far the most popular design, so for the purpose of this discussion only that one type will be covered. Much work remains to be done on the others. Only honest and complete discussions of experiences by designing engineers and operators can lead to the solution of our problems.

Much has been written by engineers and operators on sedimentation tank design. It is well for us to go back over the records and bring ourselves up to date on work done by others so as to make improvements at our plants to get greater efficiencies. For this reason the writer has added a bibliography for reference with the hope that many can add to it the high points of practical experience to go with many theoretical discussions on sedimentation.

Simple Inlets and Outlets.—The simplest form of inlet or outlet is the straight pipe or narrow opening at one end of a settling tank. These inlets alone give the poorest characteristics for sedimentation of sewage solids, as short circuiting carries solids through a tank in a matter of minutes when the theoretical design indicates that two to four hours detention should be available. The simplest improvement of straight inlets is to place a baffle six inches to four feet from the end wall to stop the straight flow and to direct it downward. A baffle at the outlet is installed to trap floating solids and take the effluent from a supposedly clearer layer of liquid.

The "T" or elbow inlets and outlets as used in septic tanks and small sedimentation tanks are just a modification of the baffle principle. They are improvements, as the flow is submerged and floating solids cannot escape.

* Presented at the New England Sewage Works Association Meeting, New Haven, Conn., May 26, 1943.

These types of inlet and outlet arrangements appear fairly efficient for narrow, deep tanks with length to width ratios of six to eight and depths at least twice the width.

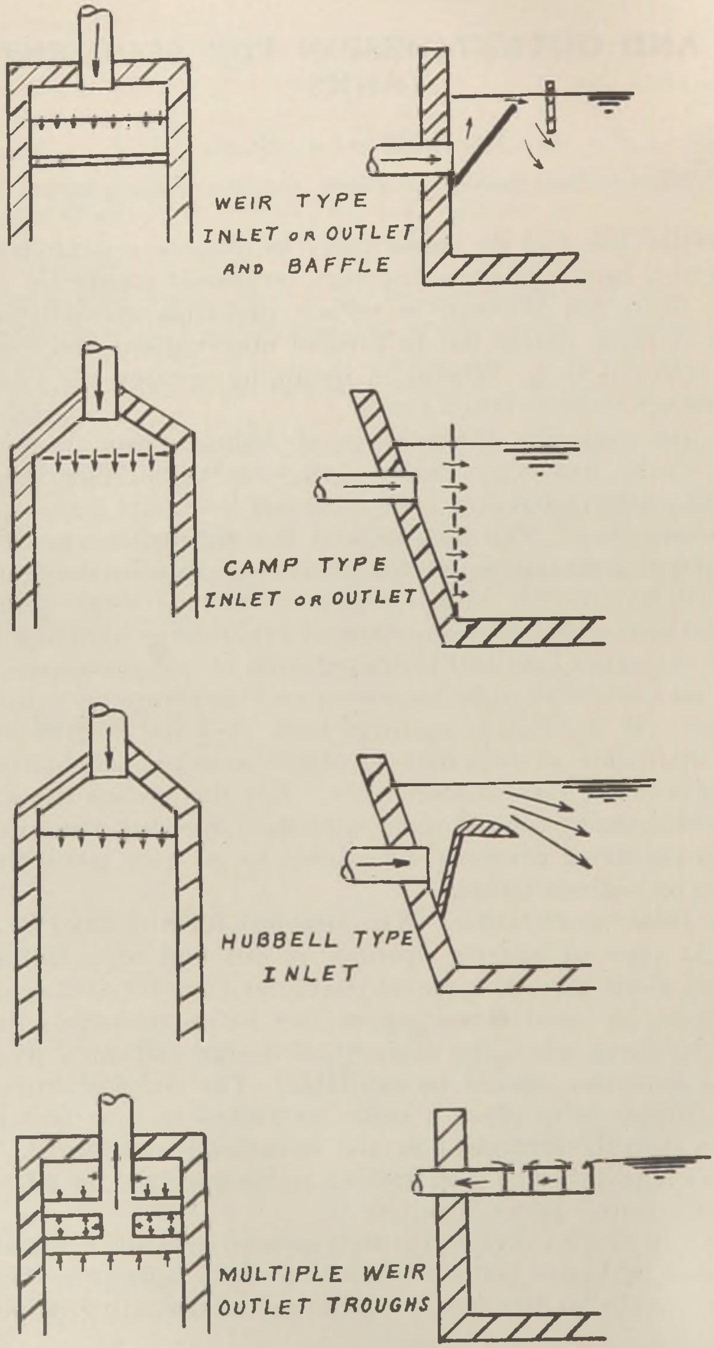

Fig. 1.

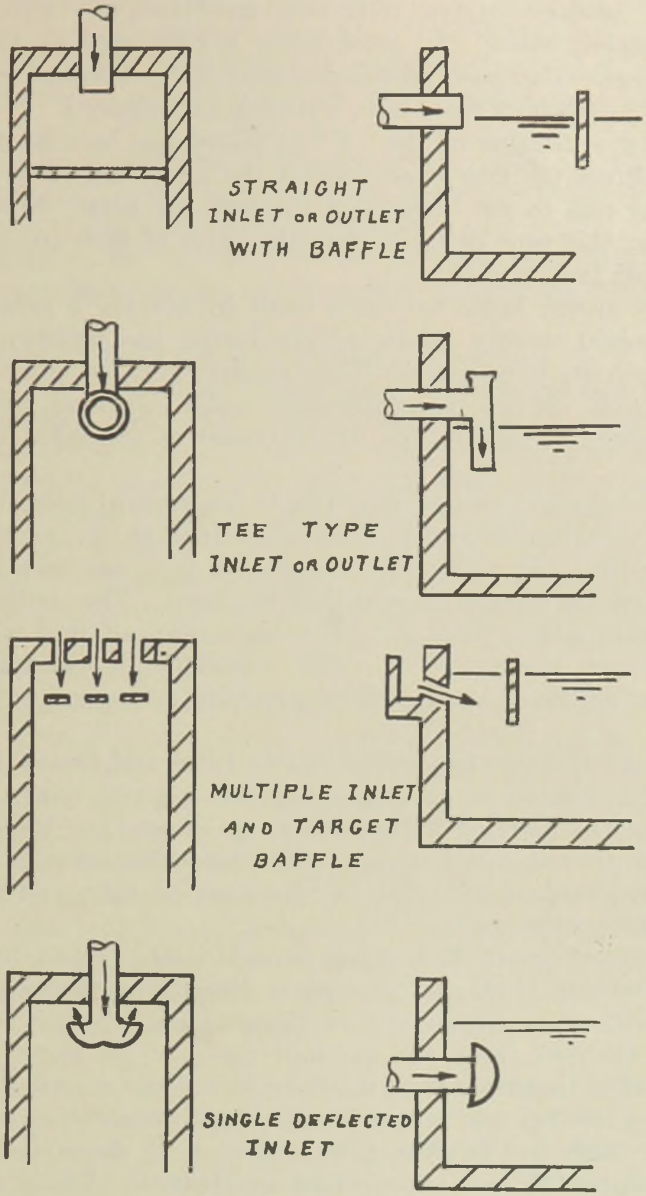

Fig. 2.

However, either the baffle or "T" or elbow usually directs the flow downward, stirring up solids that have already settled or causes upward currents at the outlet, and in many cases short circuiting frequently occurs at lower levels in the tank.

Modifications of Simple Inlets and Baffles.—In attempting to improve design, some engineers have provided multiple inlets six to twelve inches in width and a foot or two apart; sometimes they have placed these multiple inlets so as to get the flow dispersed across the entire width of the settling compartment and sometimes they have even provided submerged inlets. In most cases a baffle has also been used. Generally, reasonably good efficiencies have been obtained with this design as long as too high flows have not been experienced.

Another modification of the "T" or elbow has been to use another elbow and direct the flow back against the inlet wall so as to kill the inlet velocity and to get dispersion through the tank. Sludge is still stirred up by this type of inlet when the rates of flow are high, unless the tank depth is excessive.

A change in the baffle has been made by placing a target baffle in front of straight narrow inlets, accomplishing less downward flow, as the target permits flow around the sides, thus getting better dispersion across the tank. It can be said that for relatively long tanks, not experiencing excessive flows, this arrangement at the inlet is relatively good.

The outlet design used at most plants for several years has been to use a weir extending the entire width of the tank at the end opposite the inlet. An adjustable weir plate or sawtooth weir has been used to get equal distribution across the width of the tank. This outlet has been generally acceptable except for very high rates of flow when lifting velocities permit the escape of solids, especially in secondary settling tanks used at activated sludge, chemical precipitation and trickling filter plants.

Examples of Major Improvements to Inlet and Outlet Design.—A few designing engineers and operators have given much thought to improvements of existing arrangements at plants, for the purpose of getting more than design flows or to increase efficiencies of sedimentation in order to take higher flows or stronger sewages and to maintain at least existing efficiencies.

Several years ago G. E. Hubbell devised inlets for old Imhoff tanks at East Dearborn, Michigan, at a plant already up to design capacity with a theoretical detention of over three hours, where it was desired to increase the flow three and one-half times to get about a one-hour detention. The improved inlet is reported to have resulted in a 50 per cent increase in efficiency even with the reduced detention period.

Several plants in Connecticut have been built these past few years with inlets approaching those devised by Hubbell. These plants have given reasonable efficiencies for relatively high flows and short detentions.

This inlet designed by Hubbell has many desirable features and only relatively unimportant undesirable ones.

1. The entire flow is submerged previous to sedimentation and divided evenly between several tanks by calculated orifices into the inlet chambers.

2. The inlet or approach velocity is reduced practically to zero and an upward, but diverging direction is taken by the flow in each inlet device.

3. The top of the device is the width of the sedimentation compartment so that even distribution across the tank is obtained.

4. The top of the inlet device is submerged nearly 1.5 feet, so the upward velocity is slowed up both by the divergence and the submergence.

5. A flare lip is provided at the top of the device so that what little approach velocity is left is used up in distributing the flow over the vertical depth of the sedimentation chamber.

To summarize, the Hubbell inlet device gives maximum distribution over the cross-section of the sedimentation basin with a minimum inlet velocity.

A few years ago Professor Thomas R. Camp of M. I. T. proposed inlet and outlet chambers with calculated orifices outside the vertical walls of a settling tank. This orifice plate is expected to gain complete dispersion of the flow over the entire width and depth of the tank. A practical objection raised to this plate with many orifices has been that rags, fiber, or large solids will clog the ports and result in solids accumulation and eventually in poor distribution. It is believed that this objection can be overcome by an opening at the bottom of the plate but above the sludge storage area to permit rapidly settling solids to escape the orifices. The writer would like to know of any installation using this device for inlet or outlet.

A few plants have been built during the past few years with outlet weirs away from the outlet end of the tank to avoid vertical lift and the escape of light solids. Some plants have been built with a baffle at the half way point so as to avoid the escape of floating solids. These tanks have been provided with weirs on both sides of an effluent channel so as to take off clear flow from half way through the tank to nearly the outlet end. Weirs built along the sides of the tank and multiple outlet weirs have been very helpful in secondary settling tanks and the writer believes that greater use of this same type outlet weir for primary tanks would increase their efficiency. A recent study in New York City indicates that outlet weirs can be located very near the inlet end with proper design.

With this last outlet design one will find a clarified sewage following an inlet baffle. By taking off some of the flow at this point, slower velocities will result through the remainder of the tank. By several such weirs through the last half of the tank, the advantage of circular tanks can be obtained without inefficiency of construction, that is, ever slower velocities for removing the slower settling suspended solids.

Miscellaneous Ideas on Settling Tanks.—The writer has discussed the following items with other members of this association and these ideas are presented as thoughts to use for new construction:

Sloping inlet and outlet walls instead of vertical walls may help to get inlet and outlet devices installed to give greater efficiencies of sedimentation. Especially outlet sloping walls should help to avoid the escape of rising solids from the bottom of the tank on the outlet side of an outlet baffle when either hopper bottom settling tanks or scraper mechanism is used.

Areas between inlet ports and any inlet baffle should have some grating or opening available in the top of the tank for loosening or removing grease and other floating solids.

Tanks designed to operate with pumping stations that may discharge infrequently at high rates can be provided with an inexpensive stilling chamber of about twenty baffles for around-the-end flow. One is in operation in Connecticut which gives a practically even rate of flow and is absolutely self-cleaning.

Care is needed in providing straight flows in approach to settling tanks in order to avoid circular flow currents if the best inlet devices are not used.

Inlet devices, which drop the flow into the settling compartment, should be avoided. Such drops draw air entrapped with the flow and give such a stirring action that the motion is never entirely lost.

Outlets that can be affected by the flow from other tanks should be avoided. Tank effluent from outlets submerged in an effluent channel show a drawing action with swift flow from other tanks.

Inlet devices in new sedimentation tanks should be carefully worked out. Much can be accomplished by stilling and distributing the flow outside the settling compartment.

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SOLVING WARTIME POLLUTION PROBLEMS WITH MINIMUM USE OF STRATEGIC MATERIALS *

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Concentrations of population around war plants produce increased loads of sanitary sewage. In addition, new industries, and changes or expansion in old establishments, add to the industrial waste loads reaching streams directly or via existing sewage or waste treatment works, often overloading such works. If the public waters and watercourses are to be maintained in suitable condition for present wartime and future peacetime use, new or additional treatment must be provided which will reduce these added pollution loads sufficiently to permit the satisfactory assimilation of the treated effluents by the streams which receive them.

The principal factors of pollution are putrescibility, toxicity, dissolved and suspended solids, acidity, color, taste and odor. Treatment works are designed to eliminate or reduce these factors.

It is well to remember that after the war, barring depression or other national calamity, the normal demand on the public waters for domestic as well as industrial use will be considerably greater than the normal demand to which we were accustomed before the fall of France.

The authors of this paper approach the subject with a recent background of industrial wastes disposal rather than sewage treatment, but with enough experience in the latter to be sure that methods of disposal, and especially types and materials of construction suitable for the one, would be satisfactory for the other. Lack of time for search of records has prevented inclusion of supporting data to confirm some statements. Hence, this paper is quite general in its coverage of the subject.

It is intended primarily to remind the profession that, due to the dependence placed in recent years on mechanized devices and the application of special materials of construction, it may have lost sight of some of the simple and elementary methods of sewage and waste treatment which have proved efficient over long years of experience. Much strategic material can be saved by the use of some of the tried and true methods and devices which may be viewed as obsolete by engineers who have come to think only in terms of factory-made mechanical screens, mechanical sludge collecting or skimming devices, air compressors, diffusers, centrifuges, and all manner of beautiful and intriguing contraptions. But, since it is not now possible to secure materials to construct the sewage or waste treatment works on the production line, to be later set up on the foundation work which is largely of non-strategic mate-

* Presented at the Pennsylvania Sewage Works Association Meeting, June 9, 1943, Harrisburg, Pennsylvania.

rials, it becomes necessary to fall back on that latent ingenuity for which we Americans are noted, whether or not justifiably.

The terms "strategic" or "critical" now apply to many more materials, including new lumber, than was the case only a few months ago. A few others no doubt will be added, but no further marked extension of the list seems likely. The relative scarcity of critical materials, chlorine for example, probably will continue to vary from time to time and in different localities.

Non-strategic materials still include cement, terra-cotta pipe, broken stone, sand and gravel, and secondhand material such as lumber, iron pipe, valves, fittings, and with certain limitations, pumps and motors. The use of these materials for sewage and industrial waste treatment is limited only by their availability—limitation enough for most of us.

One of the first items thought of as now unavailable, except on high priorities, is metal pipe. Terra-cotta, asbestos-cement, and wood-stave pipe, and even wooden flumes or wood-box pipes are adaptable to almost all but high pressure requirements and, even with the present shortages, one or another of these materials should be available. Of course, wooden flumes are likely to warp and leak if not soundly constructed and terra-cotta pipe joints leak if not properly made but, nevertheless, it is reasonably practicable, with honest and intelligent workmanship, to make such materials give long years of good service.

Mechanical *screens* are efficient and great conveniences and labor savers. However, it is entirely feasible to construct efficient wire mesh screens of the manually cleaned type, particularly if they are graded in series from coarse to fine to minimize clogging and if they are constructed in removable frames with a simple hand-operated hoist to permit lifting for easy cleaning. An overflow by-pass should be provided. The average net submerged screen area is about 0.00025 sq. ft. per capita of contributory population. Hand-cleaned inclined racks or bar screens of wooden construction using hardwood slats are practical and, if sturdily built, should have a useful life long enough to pay for themselves in terms of interest saved on the small investment which would have been made in normal times for the purchase of metal bar screens. This remark applies to much of the semi-permanent construction with which this paper deals.

Metal valves, shear gates, et cetera, appear to be almost impossible to secure for many purposes, but some of the more primitive devices such as stop-planks, plug valves, and stone or concrete balls are often adaptable to present day requirements.

Sumps, which should be circular in plan to take advantage of the horizontal arch, can be lined with cement block, brick, or concrete without reinforcement. The floor of the sump, if below ground-water level, may require some steel.

Earthen excavation and embankment is conventionally used for lagoons, of course, and may be used alone or in combination with wooden partitions for sludge-drying beds and sand filters. Excavated ditches frequently may be made to serve in place of pipe for temporary installations where space and sufficient head are available. Such ditches may be open, or filled with large stones to form french drains, if they are to handle non-clogging liquids.

Reinforced concrete construction has become standard for *equalization tanks and sedimentation basins,* including oil and tar separators, with launders or distributing troughs of steel or concrete. However, there is no reason why, in the absence of steel, basins or tanks for many purposes cannot be constructed of non-reinforced concrete, concrete block, wood, or brick. Many old tanks of such construction have served for years and even basins in earth excavation have proved satisfactory in many installations, such as at a number of leather tanneries and some paper mills in Pennsylvania. Earthen settling basins are probably better suited for industrial wastes with sludge of relatively low putrescibility, than for sanitary sewage, but when properly designed and operated should be practicable for either waste or sewage.

Influent distributing troughs and effluent launders of wood construction have been found quite satisfactory if substantially constructed and anchored to minimize warping and prevent heaving or sinking from frost or other cause, and may be used in main structures of earth, concrete, masonry, or lumber.

Some further discussion of plain settling basins may be worthwhile since these units alone, if well designed and operated, without screens, chemical treatment, aerating devices, or filters, are capable of removing 95 to 98 per cent of the settleable solids from sewage or industrial wastes, and up to 70 per cent of suspended solids. The sewage B.O.D. can often be reduced by 40 per cent. This value is generally equalled and sometimes exceeded with industrial wastes. Furthermore, settling basins by the use of old and very simple devices, described later in this paper, can be made to provide equalized discharge of their effluent daily over the 24 hours. The strong sewage or wastes having been mixed with the weaker in the basins, the effluent can be made quite uniform in quality as well as in rate of discharge, and the effect on the receiving stream often may be reduced to one-third that of an ordinary 8 hour day, especially for the downstream reaches in the vicinity of the plant, where the greatest damage is usually caused. This reduced effect is due largely to the greater dilution afforded by making use of the night-time flow. If this receives no pollution load, it nevertheless cannot restore the damage done during the day by the relatively heavy load then discharged. This benefit is most marked in the case of wastes from factories running 8 hours per day. It applies with considerable force, however, to equalization of discharge from sewage treatment. Where earthen basins are used for industrial wastes, a small additional cost is sufficient to provide the extra capacity necessary for uniform discharge during the 7 days of the week, 24 hours per day, permitting an increased dilution factor of over 15 per cent.

Probably *the fill-and-draw type of basin* is the most versatile and generally satisfactory sort of settling unit, especially for installations adapted to wartime conditions.

If due allowance is made for sludge storage plus an over-lying quiet layer to prevent disturbance of sludge as the basin is drawn down, fill-and-draw basins can provide efficient settling, uniform discharge, and are the most satisfactory type for manual sludge removal. Such basins may be of almost any shape, although a rectangular plan with a length to width ratio of 4 or 5 to 1 is convenient. It is desirable to make them relatively deep as compared to surface area so as to minimize sludge disturbance. However, the advantage (and sometimes today the necessity) of gravity withdrawal of sludge as well as of settled sewage will often overbalance the advantage of depths over 6 to 8 feet. The arrangement of the influent device is not particularly important (a single-entry channel will generally serve) but a wooden splash-board or other means must be provided to prevent disturbance of previously deposited sludge and erosion of basin floor or end wall if these are of earth.

A satisfactory arrangement for removing the clarified liquid from a fill-and-draw tank consists of a horizontal pipe with a row of 1 in. holes drilled along its length about 4 in. c. to c. so that it acts like a discharge weir. This pipe is supported by wooden barrel floats attached to it by steel clamps for which wooden yokes with bolts might be substituted. This horizontal pipe is connected by means of a tee to a swinging arm; this in turn is joined by an elbow and loose nipple to a discharge pipe leading to an "orifice box," or a discharge regulating device. The collector pipe is adjusted by means of the float and clamps so that it is held in a level and a slightly submerged position. The settled wastes are then withdrawn evenly across the full width of the basin and from the clearest portion of the liquid, while the swinging arm permits the whole collector pipe to move in a horizontal position up and down as the basin level rises or falls. A rope or wooden bench prevents the collector pipe from being lowered into the sludge.

The rise and fall of the basin level as just mentioned is an essential part of this whole arrangement, and in connection with the discharge regulator described below, makes it possible to withdraw the settled wastes at a uniform rate, 24 hours per day, instead of merely during working hours. This alone contributes materially to the improvement of stream conditions.

The orifice box, or discharge regulator, may be a wooden box equipped with a float valve through which the wastes are admitted, and a plate at the lower front end containing standard orifices through which final discharge occurs. By setting the float in a given position it is an easy matter to maintain the water level in the box at a constant height regardless of the level in the main basin and this results in uniform discharge through the orifices. By changing the setting of the float or by plugging or unplugging some of the orifices, the discharge can be varied from day to day to handle different sewage or waste flows reaching the treatment plant.

To keep floating solids, grease, or oil from leaving the tank with the effluent, a scum board is often needed and should extend across the width of the tank and be placed a few feet ahead of the outfall. In most cases a 4 in. x 4 in. floating wooden boom, anchored at each end by ropes which permit it to rise or fall with the liquid level in the basin, should be satisfactory.

If fill-and-draw basins are designed for *sewage treatment,* three units are needed, the capacity of each to be equal to one day's sewage flow plus an allowance for sludge storage, which may be taken at 15 per cent if of concrete or wood, or 25 per cent if of earth. The overall capacity of each basin then should be 115 to 125 gallons per capita for sewage treatment. One basin receives the day's sewage flow while the second is decanted at uniform rate to the stream, and the third is out of service and being cleaned or repaired if necessary. Sludge is allowed to accumulate until entrained gas drives sludge particles into the settled sewage. This will probably be weekly in summer, bi-weekly in winter.

For hand cleaning, the basin floors should slope at 5 per cent for earth, 2 per cent for concrete, to a sump to which the sludge is flushed or allowed to flow by gravity or is moved by wooden pushers after the basin has been drawn down to the sludge line. The sludge is removed from the sump by gravity, pumping, or by hydrostatic pressure after the tank has been refilled. In the latter case the sump must be large enough to contain the sludge from one cleaning. Sludge outlet pipes should be not less than 8 in. in diameter. Sludge drains should be open where possible to facilitate cleaning. Grades should be at least 2 per cent.

For *industrial wastes* and controlled discharge 6 days per week, two fill-and-draw tanks will suffice if limited space or funds preclude the always desirable stand-by unit. The two tanks can be used alternately and cleaned on Sundays. They may be designed and operated as described above, the capacity of each basin being equal to one day's raw waste volume plus about 30 per cent for sludge storage. Greater or less sludge storage space may be required, depending on the load of settleable material. If the basins must be cleaned oftener than once each week, the discharge may be adjusted to 18 or 20 hours on cleaning days, using the balance of the time for cleaning.

For uniform discharge of industrial wastes 7 days per week and 24 hours per day, a third basin will be necessary, equal to each of the two just described.

Settling basins of the flow-through type are generally of concrete or wood, and mechanically cleaned. They may be of earth, however, and will give good service if carefully operated. A satisfactory design is rectangular in plan with a length about 5 times width and depth of 3 to 10 feet, depending on necessary sludge storage, available head for gravity discharge, and the character of the material to be settled.

Wooden influent distributor troughs have been developed by dint of experience and found quite satisfactory. They are intended to spread the influent evenly over the cross-section of a basin at the upper end above the sludge level, and at the same time to check its velocity. An open trough is used, with short wooden weir boards fastened along its forward edge by bolts inserted through slots in the boards. By loosening the bolts, each board can be leveled and raised or lowered, and in this way the raw sewage or wastes can be caused to flow evenly over all of them across the full width of the basin. This adjustment is easily made by eye. A baffle then causes the influent to be submerged about a foot in order to produce a mushrooming effect, and therefore a more even distribution throughout the effective depth as well as across the full width of the basin. There should, of course, be little or no velocity near the floor where the sludge is deposited.

An effluent, or take-off, device for a flow-through basin consists of a trough equipped with adjustable weirs exactly like those of the influent trough except that they are placed on the rear or upstream side, so that the settled wastes will flow from the surface of the basin and evenly across its full width, into the trough, over the adjustable weirs. The effluent pipe is directly connected to this trough.

For sewage, the nominal detention period of a flow-through basin is ordinarily taken as 1 to 4 hours. The higher figure should be used for hand-cleaned or earthen basins. The overall capacity of the basin must include sludge storage, and probably should be 30 to 40 gallons per capita for sewage.

For *industrial wastes* the nominal detention period may vary from 3 to about 8 hours, depending on the type of waste. The overall capacity should be 3 to 8 times the average hourly flow, plus about 1/3 of a day's waste volume for sludge storage.

For hand-cleaning or repairs, a gravity drain should be provided if possible, or a pump if necessary, so that the settled wastes (which would normally remain at the level of the outfall weir) may be drawn off. The sludge is then removed as described for fill-and-draw basins. If the sludge is not too putrescible and flows readily, a considerable part of it may be removed from beneath the surface without de-watering the basin, by the use of a wooden sludge conduit laid in a shallow trench in the basin floor along its center length. Ports are cut at 10 or 15 foot intervals in the top of this conduit and closed by leather gasketed, hinged and weighted wooden covers. These ports are hand operated by wooden lifting rods. The conduit is connected with a pump or gravity discharge line, and the sludge is removed by opening and closing each port in turn.

Flow-through and variable level, or fill-and-draw, tanks can sometimes be used in series with good effect.

Temporary and makeshift settling basins and their accessories are described here in some detail because if such units are constructed with care and if pains are taken in their operation, they will prove fully satisfactory for the period of emergency and probably long after. Contrariwise, careless construction or improper operation, often due to prejudice, can result in miserably poor performance.

The old conventional *trickling filter* designed to operate at a rate of about 2 m.g.a.d. (2.2 sq. ft. per capita) may be suffering from overloading, with resultant ponding and greatly reduced efficiency. It may not be possible to secure materials for complete construction of additional low rate units or of a high velocity unit. However, it may not be too difficult to convert the old filter, with procurement of a minimum of high priority materials, to operate successfully at dosing rates up to 20 m.g.a.d. (0.22 sq. ft. per capita) and, in some instances, considerably higher, and with overall efficiencies per unit of filter at least 2 to 3 times those of standard rate filters. Imhoff and Fair in their recent book on sewage treatment report that re-circulating trickling filters usually are 3 ft. to 5 ft. deep. Of course, new distributing equipment, recirculating pumps, and often improved resettling facilities would be required but, if a real pollution problem exists, it should be possible to secure priorities on reasonable amounts of strategic materials.

Distributing systems of wood troughs with adjustable spillways are possible but not very efficient for low velocity filters. Metal *distributing devices* of the whirling nozzle type, such as the Halvorson nozzle, require little metal but may be difficult or impossible to obtain. Home-made revolving arms and a feeder head of extreme simplicity were used successfully 24 hours per day for a year on a 33-foot diameter experimental trickling filter by the Tannery Waste Disposal Committee of Pennsylvania. Standard pipe and fittings were used with no special shopwork whatever except turning down the outside diameter of a 9-in. piece of 1¼-in. pipe and brazing a collar on it for the feeder head. The apparatus operated under a total head of 7 feet. Roller bearings or even a shoulder bearing on a flat ring free to rotate, should materially reduce this head.

New trickling filter units when required can be constructed without sides, using the angle of repose of the filter medium, or with side walls of gravity section using dry rubble, cement block, non-reinforced concrete, or any convenient material. Extra concrete can be substituted for steel in the filter floor. Drainage systems in common use do not employ critical materials.

Re-settling basins for filter effluents can very well be of earth with wooden influent ports, outfall weirs, etc. The needed capacity should be divided among several units with one extra, so that a unit may always be out of service for cleaning or repairs.

Re-circulating basins can likewise be of earth, or plain concrete with gravity wall sections, and can provide primary settling as well as flow-equalization and re-settling for high-rate trickling filters.

The value of the *intermittent sand filter* for high degree treatment of sewage and other decomposable wastes should not be forgotten. Constructed in earth excavation with farm tile underdrains on a ridge and valley floor, and with sand of effective size about 0.1 to 0.2 mm., and about 24 inches deep, these filters in themselves need not utilize strategic materials. Automatic dosing siphons of iron and a very small amount of incidental piping are a prerequisite, but diversion boxes, main pipes, dosing troughs, and splash plates can all be of readily available materials. On a basis of 1½ acres per 1000 contributory population, or about 100,000 gallons of average sewage per acre, such inexpensive filters have in many places effected reductions in pollution load, as measured by B.O.D., of the order of 80 to 85 per cent over many years.

Their usefulness is not limited to liquids of relatively low polluting strength, as is evidenced by the record of reduction in B.O.D. of corn canning wastes from 7000 p.p.m. to 1500 p.p.m., an efficiency of practically 80 per cent, with a dosing rate of about 80,000 gallons per acre per day. The two small filters treating the plain settled corn wastes became surface clogged with starchy slime near the end of the four to six week operating season but addition of a third unit, or 50 per cent increase in surface, would undoubtedly provide complete solution of this difficult waste treatment problem, even if all units were almost completely clogged at the end of the canning season. Furthermore, a sufficient number of filter units would permit drying and surface skinning in rotation, to make a waste treatment works of this type capable of continuous operation.

Separate digestion tanks for sewage sludge may be constructed of unreinforced concrete, concrete block, brick, or wood. Capacities of 1.5 cu. ft. per capita should be provided. In the SEWAGE WORKS JOURNAL for March, 1943, Paul E. Langdon describes designs for digestion tanks with round sides and conical bottoms of plain concrete and with floating or fixed wooden covers. Heating coils are eliminated; sludge is to be heated by direct steam application before entering the tanks. Alternate designs have been made for tanks built entirely or partly above ground by using a gravity wall section, or below ground water level by sinking as a caisson.

Open *sludge drying beds* frequently are constructed with earthen banks made of the excavated material from the beds themselves, which consist usually of 4- to 6-in. layers of sand (effective size 0.3 to 0.5 mm.) supported on 12 inches of gravel, slag, or cinders, with tile underdrains.

For digested *sewage sludge* about 1 sq. ft. of bed is required per capita, and for undigested sludge about 4½ sq. ft. per capita. For *sludge from industrial wastes*, more drying area is likely to be required. In such cases an estimated minimum number of beds may be prepared initially and additional units added as needed.

After removal from the drying beds, usually by hand with shovels and wheelbarrows, the *"dried" sludge* is sometimes used for fertilizer, sometimes for fill, or may be piled where it cannot be washed into any stream. As the war continues and animal manures become increasingly scarce, the demand for sewage and for some industrial sludges (*e.g.* cannery and tannery) will probably increase. Spartansburg, South Carolina, sells digested sewage sludge to a fertilizer company. The sludge at Spartansburg as removed from the drying beds contains 50 per cent moisture. It is stored in a concrete-paved drying yard (presumably uncovered) where the moisture content may drop as low as 7 per cent. The city receives $1.00 per ton base price for the humus value of the sludge and $1.00 per unit of nitrogen. Since the nitrogen content is about 2 per cent, this amounts to $2.00 per ton for the nitrogen, or a total of $3.00.

If the locality permits, large and deep (8 to 12 ft.) earth-dyked *sludge-storage lagoons* may be used, to which the wet sludge may be discharged directly from the settling basins for permanent or long-time disposal. Such lagoons are in use at numerous places for industrial wastes. In several instances these have been dosed for about 10 years, allowed to dry for one or two years, and then cleaned by power shovel. In such cases swinging decanter pipes have been installed at the time of the construction of the dykes, to permit continuous removal of top water through the years and to facilitate air-drying.

Those whose responsibility it is to control pollution of the public waters by the operation of existing treatment works which may be overloaded or inefficient in performance, may be able to increase the effectiveness of such works, by refurbishing them, making alterations which do not require much if any critical material, and by careful operation based on a regular schedule of performance tests. Settling tanks often can be much improved by removal, relocation, or installation of baffles, or the installation of well designed influent and effluent launders of wood or concrete.

If second-hand pipe and a valve or two plus sufficient head are available, uniform 24-hour discharge of the tank effluent may be accomplished by the installation of a swinging draw-down pipe and regulator box with float valve as previously described, increasing the dilution factor in the receiving stream.

Where highly polluting individual discharges, particularly from industrial establishments, are small in volume and can be separated from the other wastes or sewage, the condition of the receiving stream can be markedly improved by impounding such concentrated wastes in earth-dyked lagoons during periods of low flow, and discharging at high stream stages at controlled rates approximately proportioned to the flows of the stream. This scheme is in routine use in Pennsylvania for handling spent tanning liquor from leather tanneries and waste sulfite liquor from a large pulp and paper mill.

Chemical coagulation may be used to improve existing plain sedimentation, provided the resultant sludge can be handled and is capable of digestion or other disposal. Where chemical precipitation is already in use, a few experiments or jar tests from time to time will greatly assist in adjusting the dosing rate to obtain improved results and not infrequently a saving of chemicals, especially for industrial wastes.

Certain methods of treatment appear especially applicable to the wartime disposal of some industrial wastes.

Since *the canning season* is usually short, and many canneries are located away from population centers, promising results have been obtained by *the use of lagoons* for storage of an entire season's waste. Sedimentation, soil absorption, and controlled discharge during seasons of high stream flow gave some relief from the gross pollution caused by the direct seasonal discharge of untreated wastes. Recent studies in Wisconsin and other states indicate that the use of sodium nitrate, where available, in a dosage sufficient to satisfy 20 per cent of the 5-day B.O.D. of the cannery wastes after fine screening (pea and corn wastes were treated at different plants) would control offensive odors and stimulate biological life that feeds upon and breaks down the organic matter. Lagooning should be used only after careful consideration of the possibility of nuisance at any given location.

Oil separators of unreinforced concrete or plain earth excavation should be practicable, with wooden cells for broken stone or clinker to coalesce entering oil globules and distribute flow, and wooden scum-boards and weirs. Floating oil can be removed by a movable wooden boom and wooden tipping trough if metal skimmer pipes are not obtainable. Settlings can be cleaned out by hand after the top water has been pumped off or drained by gravity, if there is sufficient head, through a wooden or tile drain which may be closed by a long-handled wooden plug or a stone ball.

The temporary and somewhat makeshift methods discussed in this paper for wartime construction have some compensating advantages. They would be relatively cheap to construct although requiring more space than modern units, and, especially with industrial wastes, opportunity is afforded to observe their performance and effectiveness so that the knowledge gained can be used to secure improved design when permanent post-war construction is undertaken.

Some temporary units can be made permanent later on. Earthen basins can be lined with concrete floors and aprons on the sloping sides, or vertical reinforced concrete side walls can be built and mechanically cleaned units installed, or the excavation can be used for entirely new modern units. Open sludge-drying beds can be glassed in if desired.

Sanitary engineers and industrial plant managements must not lose sight of the desirability of making studies and preparing plans for future works *now,* when the cost is deductible from taxable surplus profits, and when the engagements of sanitary engineers are less pressing than in the recent past.

Discussion by S. A. Kowalchik

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May I state at the outset that I do not propose to comment on Messrs. Siebert and Milligan's paper in too much detail for two reasons: First, insofar as the aims and objectives implied in the title are concerned I have but few criticisms to offer; manifestly their suggestions and recommendations are the result of tried experiences and in my opinion are meritorious for the most part. Secondly, I am not entirely in accord with the suggested policy that all war time pollution problems should be solved with the use of minimum strategic materials. To this end I shall digress.

I am of the firm conviction that the control of the pollution of the waters of any State, particularly in highly industrialized and inhabited areas, is not a non-essential activity which can be discontinued for the duration of the war, such as the manufacture and sale of automobiles, refrigerators, radios, and the like. It is an essential Governmental activity protecting health and property; and is as vital as the collection and disposition of garbage, maintenance of public streets and highways, and police and fire protection.

The Army and Navy Departments themselves recognize that pollution control is an essential activity. There is silent evidence of this recognition in the State of New Jersey. For example, both Departments have constructed and are still constructing sewage treatment plants in naval and military posts. They are complying completely with the treatment standards established by the New Jersey State Department of Health. And—MIND YOU—not without the use of strategic materials.

It is conceded that owing to the impact and the demands of the present war emergency industrial activity has expanded tremendously, and has brought about concentrations of population in areas adjoining war plants, thereby producing corresponding increases in the volume of industrial wastes and domestic sewage.

It is also conceded that the stream pollution resulting therefrom outstripped the progress of the development and the construction of treatment works, particularly in industrial plants.—WHY?—The expected and general cry is that we are living through a period of an extreme emergency which overtook us by surprise and in which we are experiencing all the difficulties and shortcomings of emergency effort; the most disastrous shortcoming being the lack of critical war materials which are also required for the construction of the treatment works.

But how conveniently the "Crier," particularly the industrialist, forgets that for the past years he was polluting the streams, in a lesser degree of course, with the excuse that because of the outcome of World War No. 1 he was operating at a financial loss during a period of unprecedented depression, or that he knew not how to treat the wastes adequately. He also claimed that the State or local authorities could not, or refused to, advise him as to a method of treatment which he could employ successfully.

Yet when the war demands called upon his ingenuity to devise manufacturing processes for production of equipment and the like needed to vie with the ingenuity of the foe, he readily responded and produced, on a profit basis to be sure. Did it concern him that this undertaking of the new activity, or the expansion of his present industrial activity, would result in the production of greatly increased volumes of industrial wastes which might destroy a most valuable natural resource on his home front? Did it appeal to him to address himself with equal zeal to the development of methods for the treatment of these wastes before their discharge into the waters of the State?

It has been the writer's experience that save for a few industries, and this applies with equal force to municipalities, the creation and installation of works for the treatment of industrial and sanitary wastes is an unsavory task—non-profit bearing in the first instance, and non-vote getting in the second. Therefore, every effort has been and is still being made by industries and municipalities to advance some excuse to justify their alleged inability to provide works for the treatment of their wastes.

We well remember that during the depression the convenient and logical excuse offered—which was in keeping with the times—was the lack of funds. The public was sympathetic. And the local, State, and Federal officials hesitated to press the issue.

Then followed the era of the Public Works Administration which, with the approval of the President, made available Federal funds for the construction of public works.

But where was "Town A," needing a sewage treatment plant? If I may borrow the expression of a former PWA official, "Town A" appeared before the PWA with hat in hand, with no organized plan, and with a letter to Santa Claus, requesting meekly that favorable consideration be given to its application for Federal funds, knowing all the time that the funds would not issue in the absence of an organized plan.

In the case of the industrial "Crier," he still insisted that he was operating under a financial loss and that unlike the municipalities he was unable to obtain Federal aid. He also insisted that he had not developed a satisfactory method of treatment.

Although I cannot conceive of any industrial establishment operating over any prolonged period of time at a financial loss, I am not prepared to counter the claim. I do agree, however, that the treatment of industrial wastes is a much more difficult problem than that of sanitary wastes, and in many cases is a very stubborn and complex one. I further recognize that the treatment of industrial wastes is now going through the same period of research, experimentation, and trial and error which preceded the establishment of the various methods of the treatment of sewage. But, with few exceptions, I am convinced that if an industry, producing a waste which does not lend itself to the treatment by established methods, retains a competent sanitarian and energetically applies itself to the study of the problem, it can with reasonable dispatch evolve a solution.

Assuming that to be the case, and that a solution is evolved, we are still faced with this question of critical materials. I may have, although it was not my intent, minimized the seriousness of this problem. Unquestionably, there is an acute shortage of strategic or critical materials, which now include lumber, and every effort should be made to conserve these materials in the interest of the war effort. But may I reiterate that in my opinion the control of stream pollution is an essential war activity, and equal effort should be made to obtain such essential materials as may be needed for the proper and efficient operation of industrial and sewage treatment plants, before any consideration or encouragement is given to the construction, with the use of minimum critical materials, of inefficient, short-lived treatment plants.

As stated heretofore, the critical materials required in the construction of treatment works at the Army and Navy posts in the State of New Jersey were made and are being made available, and certain municipalities were equally successful in obtaining such materials. In the latter case, however, it was necessary to furnish the War Production Board and the United States Army with bona-fide evidence that the watercourses were being polluted to such a degree as to create a health hazard to the inhabitants of the State, particularly those inhabitants comprising the military personnel and war workers; also, that with the release of such materials for the construction of adequate treatment works, this threatened menace to public health would be suppressed. And so it should be; for in this war emergency we should deal only with pollution cases producing a health hazard.

Undoubtedly there are materials required in the construction of certain treatment plants, particularly industrial wastes treatment plants, such as special acid resisting materials, alloys, and equipment, which are not available and may not be available for the duration of the war. In those cases—YES—you must resort to some temporary expedient, using only such materials as can be obtained.

There are several such cases in the State of New Jersey. Two war plants in particular are confronted with the problem of ceasing the discharge of large volumes of acid wastes, amounting to several hundred tons daily. After years of experimentation they have developed a method of treatment by which they are able to recover the acids and reuse them in the manufacturing process. It appears, however, that the Ordnance Department will not release the necessary acid resisting metals required for this recovery plant.

As an alternate and temporary expedient, they are, under the pressure of the mandates of the Department of Health, attempting to neutralize the acid. Here is a specific demonstration, however, of the inefficiency and inadequacy of a makeshift treatment process which was resorted to because of the lack of critical materials. The process is manual; labor is used to mix a slurry of lime which is added to the millions of gallons of wastes which issue at irregular periods. There are no means of regulating the flow, and, therefore, no means of proportioning the lime, the net result being that at one moment the wastes are over-limed and at another under-limed. Although this mode of treatment reduces somewhat the pollution load, obviously it is not the solution; nor is it a satisfactory substitute even during a war emergency. Much damage may be done to the stream if such discharge continues even over a relatively short period of time. For this reason the Department of Health of the State of New Jersey is not satisfied with this operation, and is continuing to exert its powers to the fullest extent in an attempt to impel these industries to further their negotiations with the powers that be, to release such minimum critical materials as will insure a more adequate and reliable treatment.

I generally agree with the authors that undue dependence has been placed in recent years on mechanized devices and the application of special materials of construction, and that the profession is inclined to the opinion that some of the more simple and elementary methods of sewage wastes treatment, which have proved efficient over long years of experience, are obsolete.

On the other hand if the engineer still leans to the mechanized type of plant, there is no doubt that much strategic material can be saved by the elimination for the duration of such mechanical contrivances as screenings shredders, mechanical screens, possibly mechanical sludge scrapers, skimming devices, centrifuges, upflow and downflow rapid strainers, and many other pieces of equipment.

In any event, whatever type of design is selected it should be built with a view to permanency and long-range planning, omitting only those items requiring critical materials, which would not seriously affect the objectives sought in the building of the treatment works; and making provisions for the installation of the omitted items at a date when the materials are available.

I am of the definite opinion that it is not a wise policy to encourage the construction of treatment plant structures, particularly the main units, of materials which may have a life expectancy of only a few years with the hope that such substitutes will carry us over the present war emergency. The State of New Jersey has no actual experience with such temporary structures. It is reported, however, that in other states where sewage treatment plant structures were constructed of such materials, they have found it to be both uneconomical and impractical.

In conclusion, may I state that in dealing with pollution problems we should bear in mind that our watercourses are a most valuable natural resource; our mode of living, our happiness, and in fact our very existence, are dependent upon them. During normal periods much has been accomplished in the abatement of past pollution and in the control of then existing pollution. Let not this war emergency destroy this definite accomplishment. Instead, let us hold on to this gain and conduct our activities on a long-range plan with a view to furthering progress.

Sewage Research

MODIFIED SEWAGE AERATION.—PART I

By L. R. Setter

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Since early in 1941 a pilot activated sludge plant located at the New York City Wards Island Sewage Treatment Plant has been in almost uninterrupted operation. During the first three days of operation before the aeration tank solids had risen above 500 p.p.m., rather phenomenal reductions of sewage impurities were observed. This coincided with the practical operating experiences of Mr. Donaldson, Director of the Bureau of Sewage Disposal, New York City Department of Public Works. A program of experimentation covering this phase of the problem was planned and alterations were completed and modified sewage aeration experiments were begun in October, 1941.

Three main types of sewage aeration were considered, as follows: sewage aeration without the return of activated sludge or liquor, sewage aeration with the continuous return of fourth or last pass aeration tank liquor, and sewage aeration with the return of ''activated'' final settling tank sludge to maintain an aeration tank suspended solids concentration less than 500 p.p.m. In each type of study, constant sewage influent and return flow and relatively constant aeration tank suspended solids were maintained for one or more weeks before one of three variables was altered to cover the desired range of conditions. In some tests a combination of the return of fourth pass liquor and thin return sludge was investigated while in others step aeration (increment influent feeding) was studied.

The Pilot Plant

A photograph of the pilot plant is reproduced in Plate I, showing the essential features of the two units. Each aeration tank having a capacity of 2300 to 2900 gallons, depending on the hydraulic conditions, is divided into four channels or passes interconnected at the end of one pass through a small port to the head of the succeeding pass. Each channel has a hopper bottom with four 20-in. lengths of 2.5 in. diameter diffuser tubes located in the apex of the hopper. The left or ''Y'' unit has two 700-gallon conical steel final settling tanks whereas the right or ''X'' unit has one identical final settling tank not shown in the plate. Each final tank has a Carter-Reeves variable speed, variable stroke return pump with pipe line connections through a three-way valve so that it is possible to return either final tank sludge or the effluent from the aeration tank. A weir trough collects the final tank effluent for common discharge, thus providing for the measurement of effluent flow and sampling. Excess sludge is wasted to drums for measurement and sampling.

The available flow of Wards Island primary settling effluent to the pilot plant was 15 to 20 gallons per minute. For short aeration periods, all of the available flow was used in the "Y" aeration unit. For very short aeration periods (1.5 hours) the port between the second and

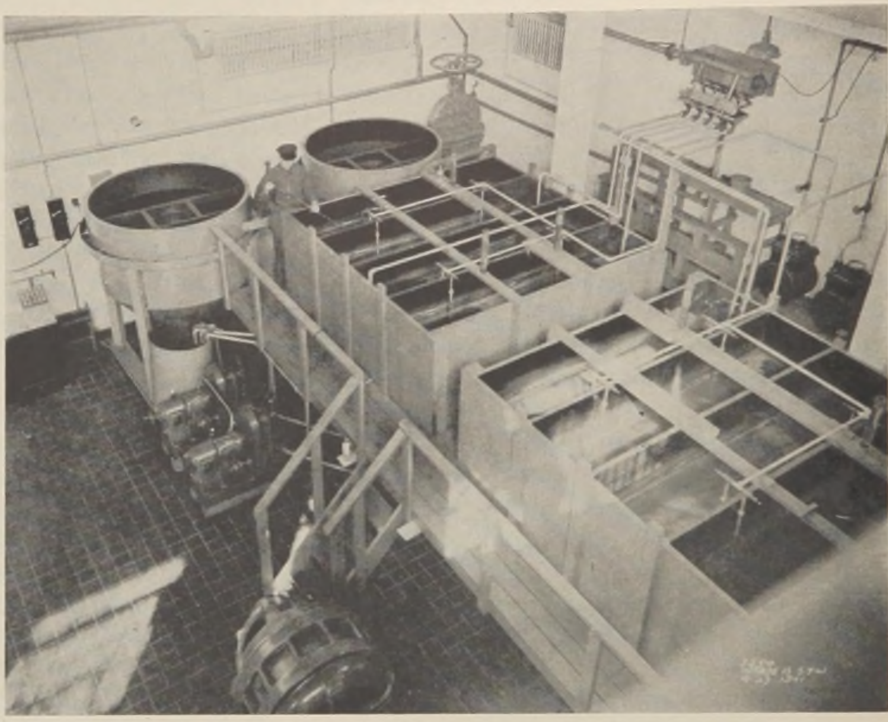

PLATE I

third passes was closed and all the sewage and return sludge was diverted to the head of the third pass with fresh water stored in the first two unused passes.

Results

A summation of the three types of modified sewage aeration studies is presented in Table 1. Column 1 shows the number of test runs of somewhat different operating conditions with respect to the amount or concentration of return sludge or liquor, the temperature or season of the year, the concentration of the influent load, the quantity of air utilized, the settling character of the sludge produced, and the adoption of step aeration. However, the results produced did not warrant a further subdivision.

Column 2 is a summation of the total days involved in a test.

Column 3 is the mean aeration tank detention period in hours. In straight sewage aeration without return flow it is the capacity of the aerator divided by the flow. In sewage aeration with the return aeration tank effluent equal in volume to 20 to 100 per cent of the sewage flow, the mean detention period is the average of the sewage detention period obtained by dividing the aerator capacity by the sewage flow and the contact period obtained by dividing the aerator capacity by sewage plus return flow. In sewage aeration with the return of a thin sludge con-

Table I.—*Correlation of the Effluent B.O.D. and Suspended Solids with the Mean Aerator Detention Period for the Three Types of Sewage Aeration Studies*

No. of Tests	Length of Tests Days	Average Mean Detention Hrs.	Range of Mean Detention Hrs.	Average Influent		Average Effluent		Reduction	
				Susp. S. p.p.m.	B.O.D. p.p.m.	Susp. S. p.p.m.	B.O.D. p.p.m.	Susp. S. per cent	B.O.D. per cent
1	2	3	4	5	6	7	8	9	10
Type 1. Sewage Aeration without Return Flow.									
2	16	0.76	0.6–0.8	126	118	75	81	40	31
2	16	2.28	2.2–2.4	126	118	51	45	59.5	62
2	16	3.05	3.0–3.1	126	118	40	39	68	67
1	7	4.4	——	136	100	23.5	29.5	83	70
1	7	6.2	——	112	104	16.5	22.5	85	78
Type 2. Sewage Aeration with the Return Last Pass Aeration Tank Liquor equal to from 20 per cent to 100 per cent of the Sewage Flow. Aeration Tank Solids equal to the Influent Suspended Solids but less variable.									
1	8	0.7	——	109	91	54	54	50	41
1	8	2.06	——	109	91	38	40	65	56
2	15	2.87	2.7–3.0	118	97	30	36.7	74.5	62
5	35	3.96	3.8–4.2	113	110	26	31	80.5	72
12	82	5.09	4.5–5.6	118	107	21	24	82	77.5
3	18	6.8	5.6–7.4	134	121	19	21.5	86	82
Type 3. Sewage Aerating with the Return of Thin "Fresh" Sludge from Secondary Settling Tanks equal to from 6 per cent to 25 per cent of the Sewage Flow. A Weekly Average Suspended Solids in the Aerator of 145 to 530 p.p.m. or an Average of 308 p.p.m. for All Tests.									
6	68	0.65	0.6–0.8	120	117	40	59	66.5	49.5
7	66	1.36	1.2–1.5	123	128	27	36	78	72
3	43	1.92	1.8–2.2	123	117	22	24	82	79.5
7	83	2.72	2.2–3.2	125	120	18	18	85.5	85
3	21	5.15	5.0–5.5	131	109	17	15	87	86

taining 1000 to 5000 p.p.m. suspended solids and a volume equal to from 6 to 25 per cent of the sewage flow, the mean detention is similarly an average of the sewage detention period and the contact period. In tests involving the use of step aeration in which the sewage flow was divided between the first and second passes, the contact period frequently exceeds the sewage detention period even though there is a substantial return flow. Again the mean detention period is an average of the two theoretical detention values.

Column 4 shows the range of mean detention periods considered in a group of tests.

Columns 5 and 6 give the p.p.m. of suspended solids and 5-day B.O.D. in Wards Island settled sewage.

Columns 7 and 8 give the p.p.m. of suspended solids and 5-day B.O.D. of the pilot plant effluent. In one-half of the tests involving short periods of aeration, the effluents were artificial in that a 3-gallon sample taken at the end of the first and third pass were settled quiescently for 10 minutes before decanting an effluent sample one inch below the surface. Control tests showed that this procedure produced an effluent comparable to 0.68-hour detention in the pilot plant final tank. In each test run the validity of this procedure was established by a comparison of the artificial aeration tank effluent and the final tank effluent analysis. Further control tests showed that the average of 9 to 11 A.M. grab samples and 2 to 4 P.M. grab samples produced effluent values comparable to a 24-hour composite sample for aeration periods less than 3 hours, whereas the average of 10 A.M. grab samples and 11 P.M. grab samples were comparable to a composite sample for aeration periods of four or more hours.

Columns 9 and 10 give the percentage reduction of the pilot plant influent suspended solids and B.O.D. by aeration and final settling, exclusive of the 30 per cent reduction of the raw sewage suspended solids and B.O.D. by primary sedimentation for 1 to 2 hours.

The effluent results plotted against the mean detention period for the different types of sewage aeration are presented in Fig. 1. The curves more clearly show the effect of the detention period and the type of aeration on the quality of the final effluent. For an aeration period of 2 hours the final effluent would have 50 to 60 p.p.m. B.O.D. and suspended solids for straight aeration, 35 to 45 p.p.m. for aeration with return of aeration tank effluent equal to 20 to 100 per cent of the volume of sewage flow, and 20 to 25 p.p.m. for aeration with the return of final tank sludge containing 1000 to 5000 p.p.m. suspended solids and a volume equal to 6 to 25 per cent of the sewage flow.

For an aeration period of 4 hours the final effluent would have the following suspended solids and B.O.D.: 25 to 35 p.p.m. for sewage aeration without return or with the return of aeration tank liquor, and 15 to 20 p.p.m. for sewage aeration with the return of thin sludge. In this instance there is little apparent difference in the quality of the effluent by returning aeration tank effluent over no return flow. However, individual results show that the return of liquor has a tendency to level the peaks of effluent quality, which may have a significant bearing in comparing the merits of the two processes.

Temperature.—Experiments having detention periods less than four hours were performed at weekly average temperatures of 68 to 78° F., whereas many of the longer detention tests were performed at weekly temperatures as low as 57° F.

Air Supply.—The quantity of air used in pilot plant experimentation bears no direct relationship to the quantity that would maintain comparable conditions in a large aerator. The diffusers were submerged about 4 ft. below the surface, thus providing a very short contact per bubble of air. The diffuser area is about 10 per cent of the surface area. The channels are narrow so that the aeration is more typical of ridge-and-furrow aeration than spiral flow. Longitudinal mixing within a pass is very great. The quantity of air necessary to prevent the classification of solids was used for long periods of aeration and that necessary to maintain an adequate dissolved oxygen in all

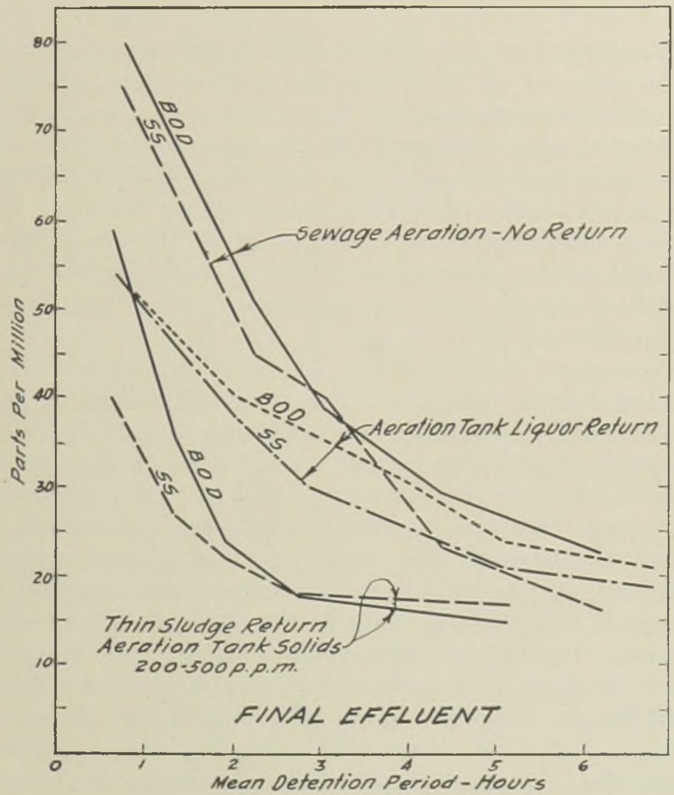

FIG. 1.—The effluent quality produced by three types of modified sewage aeration for varying periods of detention.

passes of the aeration during peak B.O.D. loads for short periods of aeration. Although the quantity of air used probably exceeds that necessary under carefully controlled conditions of practical operation, the values are of interest. Metered under a pressure of 6 to 8 inches of mercury, 0.2 to 0.5 cu. ft. of air per gallon of sewage treated was used for aeration periods less than one hour, 0.6 to 1.0 cu. ft. for aeration periods of 1.5 to 3.0 hours, and 0.8 to 1.2 cu. ft. for aeration periods exceeding 3 hours.

Dissolved Oxygen.—The dissolved oxygen of the aeration liquor fluctuated over the entire range of saturation values in these low aeration solids, tests with high B.O.D. loading tests. Values of less than

0.5 p.p.m. in the first pass often reflected a deterioration of the effluent. There was usually a sharp rise in the D.O. gradient from the first to the last pass, particularly during peak B.O.D. loadings. The gradient is generally more pronounced in step aeration studies due to the decreasing solids gradient through the aeration tank and least pronounced in the high return of aeration tank liquor. When only traces of D.O. persisted for the greater part of the day, the microbial population underwent a decided change and large numbers of film organisms such as alophorous and rotifers migrated to a succeeding pass or to the final tank.

Wall Film Organisms or Solids.—There are between 1.1 and 1.2 sq. ft. of wall surface per cu. ft. of aeration tank capacity in the pilot plant or about 20 times as much surface to volume as is present in the Wards Island aeration tanks. Attempts to measure directly the effect of the wall surface have been unsuccessful since the effective microbial film is apparently established within 24 hours or about the time when representative final tank samples can be obtained. The microbial film continues to build up to a maximum thickness within about 3 days when the film solids if dispersed in the aeration tank volume would amount to from 100 to 150 p.p.m.

The Respiration or Short-Time B.O.D. of Aeration Tank Liquor.—The difference between the D.O. of aeration tank liquor samples analyzed upon collection and that analyzed 10 minutes after collection indicated the respiration or ten-minute B.O.D. In the ten-minute period, from 0.4 to 1.0 p.p.m. oxygen was consumed in straight sewage aeration studies and from 0.8 to 2.1 p.p.m. for sewage aeration with the return of aeration tank liquor or thin sludge depending on the concentration of aeration tank suspended solids, the momentary rate of B.O.D. loading, the location of sampling point in the aerator, and possibly the detention period. Obviously some of these factors are interrelated. In general, the first pass 10-minute B.O.D. was as much as double that of the 4th pass B.O.D. The afternoon 10-minute B.O.D. during high aeration tank solids return and high B.O.D. loading was as much as double the morning value. Considering the mean 10-minute B.O.D. acting over the length of the contact period, some 15 to 30 p.p.m. of oxygen are consumed in two to three hours' aeration and some 8 to 16 p.p.m. of oxygen are consumed in 1.25 to 1.5 hours' aeration. Obviously, on this basis the greater bulk of B.O.D. reduction by sewage aeration is not due to the above absolute destruction of B.O.D. but by coagulation and transformation of matter to a settleable state.

Sludge Index and Concentration of Excess Sludge.—Liter settling tests on aeration tank liquors, concentrated usually 4 to 1 in 10 minutes' presettling, were used to calculate the Sludge Index (Donaldson), which directly gives the average percentage concentration of solids in the sludge after thirty minutes of settling. The Sludge Index bears a direct relationship to the probable ultimate concentration of sludge to be wasted. The weekly average S.I. of the settleable solids remaining after primary settling varied from 1.3 to 2.1. The minimum was influenced by decanting to the head of the clarifiers from Wards Island excess activated sludge storage. The maximum was influenced by rainfall. Modified sewage aeration usually produced from a slight to a decided decrease in the S.I. depending on the length of the aeration period and the concentration of suspended solids in the aerator. The longer the aeration period and the higher the aeration tank solids, the lower the S.I. and the concentration of excess sludge. In two tests having the lowest S.I. of 0.62 and 0.76, the aeration tank solids were highest with a detention period of 2.6 to 2.4 hours, respectively, the excess sludge as drawn after 24 hours thickening contained 1.3 to 2.3 per cent solids. In most tests the S.I. varied from 0.83 to 1.8 or the excess sludge as drawn varied from 2.4 to 4.34 per cent solids. The sludge as drawn from the pilot plant is considerably thinner than what might be expected from continuous judicial withdrawals in a large tank. For instance, the maximum solids content of excess sludge during three batch withdrawals was 5.6, 5.4 and 5.0 per cent when the average concentration of the batches was 2.4, 4.34 and 3.4 per cent, respectively. Apparently it would be possible to withdraw 5.0 per cent excess sludge or better on a practical scale if the aeration period does not exceed 3 hours and the aerator suspended solids do not exceed 350 to 400 p.p.m.

Nature of the Excess Sludge.—Although the aeration tank solids settle rapidly and the solids compact to a thick, granular, grayish brown sludge, the following observations are considered of importance. The final tank has a tendency to become quite septic if the detention period exceeds 1.5 to 2 hours. This fouls the effluent with nonsettleable solids and, in extreme cases, floating islands of presettled sludge filled with macroscopic and microscopic gas bubbles. This condition is also reflected in a thinner excess sludge, very black in appearance, and particularly odorous if the sludge was allowed to thicken in the final tank for 18 or more hours at summer temperatures.

Nature of Microscopic Organisms.—For aeration periods of 3 hours or less and an aeration tank suspended solids less than 400 p.p.m. a very distinctive type of non-activated sludge organisms prevailed. Observed under a magnification of 100 the floc appeared relatively sparse, diffuse, and lifeless with an occasional aquatic earthworm, considerable stalked ciliates and colonial *zooglea ramigera,* some filamentous organisms, and some free swimming ciliates. Observed under a magnification of 450 the sample contained an agile mass of higher forms of bacteria and related organisms. Motile large rods 1 to 5 times the size of *B. subtilis,* large and small cocci, and literally ropes of intertwining spirochaetaceae having six or more spirals were predominant. Many of these isolated organisms had a very rapid corkscrew forward movement until they collided with floc or other organisms; then they would reverse their direction for a distance equal to twice their length and again ram into the same or a nearby obstacle. Beautiful tree-like colonies of *zooglea ramigera* were particularly prominent under good D.O. conditions. Under poor oxygen conditions and high loading numerous small saprophytic flagellates appeared. A single sample of 4th pass liquor containing 158 p.p.m. suspended solids was thoroughly shaken with glass beads. The total 37° C. count and *B. Coli* content was then found to be 106,000,000 and 100,000 per ml., respectively. The wall film solids had a population more closely approaching that of activated sludge except for the very large number of aquatic earthworms (occasionally tubifex but mostly aulophorous) which have been consistently present in the pilot plant studies. Thus large numbers of one or more species of stalked ciliates, filamentous organisms, and worms appear attached to the walls and diffuser tubes and form the base which harbors

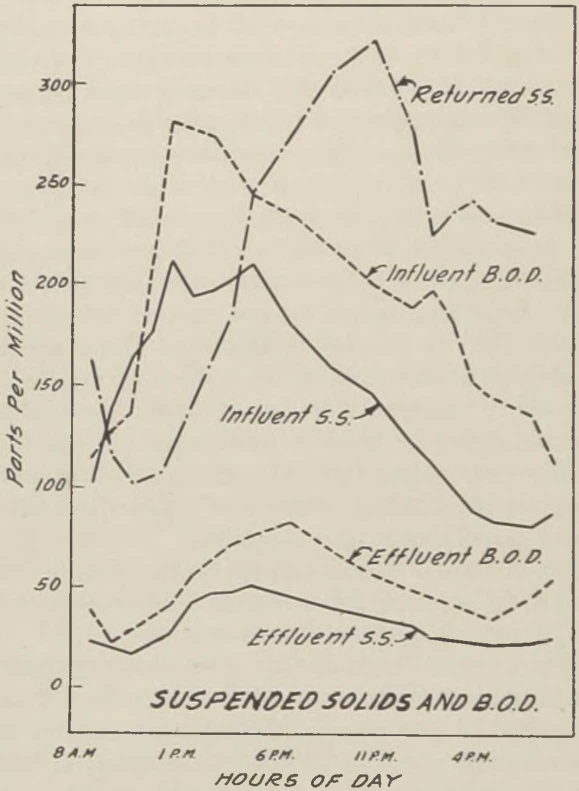

FIG. 2.—Experiment 5L. Average hourly results from 8:00 A.M. November 18th to 8:00 A.M. November 20th.

a multitude of free swimming ciliates, rotifers, and the above free floating organisms. The aulophorous attached themselves in a film ¼ to ½ in. thick on the walls where good oxygen conditions prevailed and around the diffuser tubes, ultimately causing poor air distribution. The stalked ciliates predominated in intermediate oxygen conditions and the filamentous organisms predominated in the poorer oxygen conditions of the first pass, with considerable intermixing of species in all locations. The prevalence of aulophorous, rotifers, and spirochaetaceae was fairly closely correlated with the abundance of dissolved oxygen.

For long periods of aeration the organisms more closely resembled those of activated sludge.

Final Effluent.—For aeration periods in excess of 3 hours, the influent nonsettleable suspended solids was quite completely transformed into settleable floc or living matter. A small amount of pinpoint floc, consisting essentially of the prevailing organisms, appeared in the final effluent and settled within one or two hours leaving a sparkling clear effluent. Occasionally large numbers of free swimming ciliates such as colpidium and *paramoecium* would develop in the aeration tank liquor and become classified near the surface in the final tank. Under these conditions the relatively high turbidity of the final effluent was almost exclusively one or two species of ciliates, which on standing in a bottle congregated at the water-glass-air interface.

For aeration periods less than 3 hours and a mean aeration tank suspended solids less than 350 p.p.m., the quality of the effluent changed considerably during a 24-hour period. Early morning samples would be sparkling clear, while late afternoon and night samples would have considerable turbidity or a milky appearance. Most of this turbidity appeared to be the bacteria, cocci, spirochaetaceae, short filamentous organisms, some *zooglea ramigera,* and free swimming ciliates, *i.e.* essentially living matter, which might be construed as being excellent fish food rather than pollution.

The higher the influent B.O.D., the shorter the detention, and the less the aeration tank solids, the greater was the fluctuation of effluent quality. If the final tank contents were allowed to become partially septic this was reflected in a higher effluent turbidity, suspended solids, B.O.D. and a dark color due in part to the greater surface classification of aerobic organisms and the development of a higher flagellate population.

An example of the wide fluctuations of effluent quality and the conditions contributing to such fluctuation is shown in Experiment 5L, presented in Table II and Fig. 2. The table and figure show the average hourly conditions during the last two days of a test over a seven-day period when the operating conditions were as follows:

Experiment 5 L
Date—Sept. 12 to 20, 1942
Rainfall—None
Temperature—68° F.

Aerator capacity	1350 gallons
Sewage flow	14.9 gallons per minute to head of 3rd pass (last two passes in operation)
Return flow No. 2 final tank	1.47 g.p.m.
Aerator effluent to No. 2 final tank	11.14 g.p.m.
Aerator effluent to No. 1 final tank	5.23 g.p.m.
Aerator sewage detention period	1.51 hours } Ave. 1.44 hours
Aerator contact period	1.37 hours }
No. 1 final tank detention	1.92 hours
No. 2 final tank detention	0.90 hours
Percentage return flow	9.9 per cent of sewage flow
Estimated average suspended solids in return sludge	2440 p.p.m.
Influent suspended solids	137 p.p.m. of which 67 p.p.m. are non-settleable
Influent 5 days B.O.D.	155 p.p.m.

B.O.D. loading	4.12 lb. per day per cu. yd. of aerator capacity
Average aeration tank liquor susp. solids	349 p.p.m.
Sludge index of influent	1.30
Sludge index aeration tank solids	1.41
Air supply	11.0 cu. ft. per min. at 10 in. Hg or 0.74 cu. ft./gal. sewage
Dissolved oxygen	4.1, 6.3 and 4.8 p.p.m. for morning samples and 1.1, 2.5 and 1.1 p.p.m. for afternoon samples in head of first pass, end of last pass, and final tank near effluent weir, respectively
Estimated wall film in 220 square feet of surface	4.3 gal or 3.0 lb. dry solids
No. 1 final effluent suspended solids	30 p.p.m.
No. 2 final effluent suspended solids	31 p.p.m.
Weighted effluent B.O.D.	45 p.p.m.
Average volume of excess sludge wasted per day	66 gal. or 0.31 per cent of the sewage flow
Average dry solids in waste sludge as drawn	3.4 per cent
Maximum dry solids during one withdrawal	5.0 per cent
Estimated suspended solids captured in waste	85 p.p.m. based on sewage treated

Hourly rate of loading varied from 2.19 to 9.2 lb. 5-day B.O.D. per day per pound-hour of aeration tank suspended solids.

During the last two days of hourly sampling, the influent solids and B.O.D. (Table II) were abnormally high for Wards Island primary clarifier effluent which is reflected in the generally poorer quality of the effluent B.O.D. The average suspended solids and B.O.D. in columns 2 and 3 were 144 and 194 p.p.m. as compared to a long time average of 125 and 110 p.p.m., respectively, for Wards Island 24-hour composite samples. Column 5 is the so-called effective return solids or culture obtained by deducting the influent suspended solids in column 2 from the total aeration tank solids in column 4. The weighted average effluent suspended solids and B.O.D. from the two final tanks in operation is given in columns 6 and 7, respectively.

The course of the hourly fluctuations of influent impurities, the effect on the weight of microbial culture returned, and the effect on the quality of effluent from Table II, can be more readily analyzed in Fig. 2. It should be noted that for very short periods of aeration, 1.4 to 1.5 hours, under the method of operation, the concentration of solids in the influent largely determines the rate of charging the final tank with solids, which in turn determines the weight of return solids or culture. The resultant lag period permits an unequal loading of the return culture which is reflected in the quality of the final effluent. The curves show that when the return solids in p.p.m. slightly exceed the B.O.D., then equilibrium conditions of effluent quality exist such as 9 A.M. and 3 P.M. When the B.O.D. exceeds the returned solids, the effluent progressively deteriorates. When the return solids exceed the B.O.D., the effluent progressively improves within limits.

It would appear possible to anticipate an incoming B.O.D. load and to provide storage for return sludge to satisfy the apparent equilibrium conditions so that a relatively constant effluent quality could be produced by modified sewage aeration. Some form of reaeration or short time storage in the final tank may solve this problem on a practical

TABLE II.—*Experiment 5L—Nov. 12 to 20, 1942. Average Hourly Results from 8 A.M. Nov. 18th to 8 A.M. Nov. 20th. Results in p.p.m.*

Hour	Influent		Aeration Tank Susp. Solids p.p.m.	Returned* Susp. Solids p.p.m.	Effluent	
	Susp. Solids p.p.m.	B.O.D. p.p.m.			Susp. Solids p.p.m.	B.O.D. p.p.m.
1	2	3	4	5	6	7
8 A.M.	94	112	255	160	22	38
9	139	125	255	115	19	19
10	162	135	260	100	16	27
11	175	207	290	115	20	34
12 Noon	210	280	305	95	26	40
1 P.M.	193	276	345	150	41	56
2	195	273	345	150	46	63
3	201	260	385	185	46	70
4	209	242	455	245	49	75
6	178	233	455	275	44	81
8	157	215	465	305	39	67
10	145	198	465	320	34	56
12 Midn.	120	187	395	275	31	48
1 A.M.	111	195	335	225	25	46
2	99	180	335	235	23	41
3	87	150	330	240	22	46
4	82	143	310	230	21	33
6	80	135	305	225	22	45
7	87	112	350	260	25	53
Ave.	144	194	360	216	31	52

* Exclusive of wall film solids which rose from zero on November 12th to 3.0 lb. of dry solids on November 20th.

scale but pilot plant operation difficulties have not permitted experimentation along these lines. Another very important factor in the operation of modified sewage aeration systems is that when the total suspended solids in the aerator exceed 500 or more p.p.m. the efficiency of the final settling tank decreases at a rapid rate independent of the final tank detention period.

Discussion

An excellent bibliography on mechanical flocculation and bioflocculation of sewage was prepared by Heukelekian (*This Journal,* 13, 506 (1941)). The relatively poor suspended solids and B.O.D. reductions achieved by the various investigators on treatment processes akin to sewage aeration as compared to the present studies naturally make one wonder why. The answer varies with the specific investigation but the two more important reasons appear to be:

1. Only the weaker sewages are amenable to effective aeration treatment in less than three hours.
2. It is mandatory that good aerobic conditions be maintained in both the aeration tank and the final tank every hour of the day.

Some of the advantages of modified aeration are:

1. The treatment plant can be designed to produce any average quality of effluent desired between that of plain settling and activated sludge. The poorer the acceptable effluent quality, the shorter the sewage aeration period and the less compressed air operation cost and capital investment.
2. If an effluent B.O.D. of 30 to 50 p.p.m. is satisfactory, the short time aeration period necessary to give this effluent will produce a sludge for final disposal probably twice as concentrated as activated sludge.
3. Although the modified sewage aeration process may be as readily "upset" by industrial wastes as the activated sludge process, the recovery will occur in hours rather than days or weeks, and the gross pollution during the period of "upset" will not be much worse than untreated sewage.
4. By providing adequate flexibility in design, a combination of plain sewage aeration, the return of aeration tank liquor, and return of final tank sludge or a combination of these processes, could be practiced to compensate for the seasonal fluctuation of temperature, and desired plant effluent quality, and the hourly and daily fluctuation of influent B.O.D. load. It appears that the return of fourth pass liquor or possibly final effluent in conjunction with return sludge would be desirable if the influent B.O.D. exceeds 250 p.p.m. for several hours during the day.
5. In the event that the raw sewage is relatively weak, design features might combine primary settling, aeration and final settling into a single tank having a total detention period of less than four hours, with the production of a fair effluent.

Some of the disadvantages of modified sewage aeration are:

1. Operation must be more carefully controlled.
2. For short aeration periods the effluent probably will vary considerably during the day and have considerable turbidity during the daylight hours.
3. The design of the final tank must be improved to give effective settling in preferably less than one hour probably with facility to aerate the contents to prevent septic action.
4. The waste sludge will deteriorate much more rapidly than activated sludge and must be disposed of with dispatch to prevent the production of obnoxious odors and thickening difficulties.

Summary

1. Plain sewage aeration, sewage aeration with the return of fourth pass liquor, and sewage aeration with the return of sludge to maintain less than 500 p.p.m. suspended solids in the aerator were studied in an experimental plant supplied with a constant flow of 15 gallons per minute of primary settled sewage.

2. The results showed that for 1.5 hours' aeration a reduction of 30 to 40, 60 to 65, and 65 to 75 per cent of the suspended solids and B.O.D. could be achieved by plain aeration, the return of fourth pass liquor and the return of sludge, respectively.

3. For three hours of aeration, suspended solids and B.O.D. reductions of 60 to 65, 65 to 70, and 75 to 85 per cent were achieved by plain aeration, aeration with the return of fourth pass liquor, and aeration with return of sludge, respectively. The quantity of returned aerator effluent varied from 20 to 100 per cent of the sewage flow. The amount of sludge returned varied from 6 to 25 per cent of the sewage flow at a concentration not exceeding 5000 p.p.m. The aerator suspended solids varied from 150 to 500 p.p.m. in the return-sludge studies.

4. The sludge produced from aeration periods of less than 3 hours could be wasted at a concentration of 4.0 to 5.0 per cent solids when fresh. On storage the sludge undergoes rapid deterioration at summer temperatures, having a tendency to bulk and produce vile odors.

5. The shorter the aeration period the greater the fluctuation of effluent quality during a 24-hour cycle. For 1.5 hours' aeration the lowest and highest B.O.D. in a 24-hour period varied from 60 to 160 per cent of the average hourly B.O.D.

6. The microorganisms presumably responsible for the flocculation of sewage impurities by modified sewage aeration appear distinctive. The bulk of the organisms are large bacteria, cocci, spirochaetes, *zooglea ramigera,* filamentous bacteria, and a small number of a large variety of free swimming and stalked ciliates, rotifers and aquatic earthworms. Wall film organisms such as stalked ciliates, rotifers, and equatic earthworms may also play an important part in the purification achieved, but the area of contact surfaces may be reduced to a fraction of that of most contact aerators.

CONCENTRATION OF ACTIVATED SLUDGE BY COMPACTING AND FLOTATION *

By Willem Rudolfs

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Concentration of activated sludge by various physical methods and additions of chemicals has been attempted in laboratory experimentation and plant practice. A dense and compact sludge is of particular importance when the waste activated sludge is to be dewatered preparatory to drying or incineration, or when it is digested or stored for barging.

There are two general ways of concentrating sludge, namely: (1) inducing the sludge to compact at the bottom of a tank, (2) forcing the sludge to float to the surface of the liquor with subsequent compacting. The first, conventional, method is almost universally utilized. However, this does not necessarily mean that for certain purposes flotation is not an equally good or better method, especially when continuous removal of sludge is desired for drying and incineration or when sludge is disposed of by barging.

With this in view a series of experiments were conducted principally along the following lines:

A. *Settling:* (1) Formation of a small particle size floc, compact and scaly, capable of rapid compacting; (2) coagulation with suitable chemicals inducing compacting; (3) retardation of biological activities with poisons resulting in layering of sludge; (4) weighting down of floc by inert materials; (5) combinations of poisons, coagulants and inert materials.

B. *Flotation:* (1) Production of large flocs with considerable quantities of entrained water within the flocs, and without undue jellyness; (2) production of large flocs with relatively large volumes of entranced gases, forcing the floc formed to float, but allowing the gases to escape on reaching the surface; (3) dehydrating the floc by suitable chemicals, producing a "tough" floating floc; (4) retardation of biological activities which causes expansion of sludge on flotation; (5) combination of various methods.

In a previous paper a considerable amount of experimentation was reported showing the effect of physical conditions, including aeration, temperature, pressure, concentration, shape and depth of containers, stirring, staleness of sludge and addition of fresh solids, on the settling of activated sludge (1). Incidentally the effect on compacting was shown. Clifford and Windridge (2) have studied the effect of aeration and chemicals on settling and to some extent on compacting of

* Journal Series Paper, N. J. Agricultural Experiment Station, New Brunswick, N. J., Division Water and Sewage Research.

sludge. They found that settling and compacting increased with the quantity of ferric hydroxide or aluminum hydroxide added, but with too large quantities of chemicals settling was retarded. McLachlan (3) found that sodium chloride has a densifying effect on the sludge. Whitehead and O'Shaughnessy (4) were interested to separate the activated sludge floc from the purified liquor by sedimentation in a reasonably short time. Various chemicals and inert materials were tried to induce more rapid settling and greater compacting of the sludge. Of the many substances tried separately it was found that red marl, added to the amount of 25 per cent of the dry matter in ordinary sludge, produced a remarkable brilliant effluent and yielded a sludge which settled out rapidly and to a dense and well compacted sludge.

Adding 25 per cent calcium carbonate in addition to an equal quantity of red marl improved the clarifying power still more. Experiments have been made in this country with road dust to produce a denser sludge. Compacting of sludge with the aid of chlorine has been reported to be effective with sludge thickeners by Goudey and Bennett (5). Excess activated sludge removed as mixed liquor in a clarifier, allowing considerable depth of sludge, was concentrated for delivery to digestors. A similar scheme has been reported by Travaini (6) for mixed crude and activated sludge placed in sludge thickeners, using chlorine to specifically control the septicity of the sludge. Sludge concentrations amounting to 3.5 to 4.25 per cent of dry solids could be obtained.

Methods and Materials

For the compacting studies sludges obtained from different activated sludge plants were treated and permitted to stand for several hours or days if necessary, while the volume and behavior of the sludge was noted at various intervals and the solids concentration determined. The types and quantities of materials added are shown in the respective tables where results are reported. On account of the large amount of data secured, only examples are presented. The effect of the materials on the rates of settling of the sludges was considered incidental, but the possibility of correlating dewatering and compacting was kept in mind, although optimum results for good dewatering usually require the formation of large flocs while for optimum compacting a smaller compact particle size is more favorable.

Results

Compacting by Settling

Coagulation and Dehydration.—Several chemicals have been used for conditioning activated sludge for dewatering. Among the best is ferric chloride. The floc formed with certain quantities of this chemical increases in size. Some of the results obtained intending to show the effect of the chemical on compacting, are given as an example in

Table I. Approximately 280 p.p.m. of ferric chloride was required for optimum dewatering with vacuum filtration. The coagulation of the floc with this quantity of chemical permitted a somewhat more rapid settling during the first three hours than without the chemical, but the

TABLE I.—*Effect of Ferric Chloride on Compacting of Sludge*

Settling	Ferric Chloride, p.p.m.				
	0	70	140	280	360
Hours	Per Cent Solids				
0	0.59	0.59	0.59	0.59	0.59
3	0.98	1.00	1.08	1.05	1.10
7	1.34	1.33	1.16	1.09	1.20
24	2.11	1.50	1.59	1.84	1.60
48	2.68	[2.22	1.84	2.26	1.92

larger particles of floc, which permitted an increase in drainability, prevented increased compacting of the sludge after 48 hours. The poorer compacting of the sludge treated with 140 p.p.m. $FeCl_3$ was caused by partial coagulation of the floc and partial flotation of the sludge by the gases produced.

Sulfuric acid has been used to increase the dewatering of sludge. The acid does not produce as large flocs as ferric chloride, but results

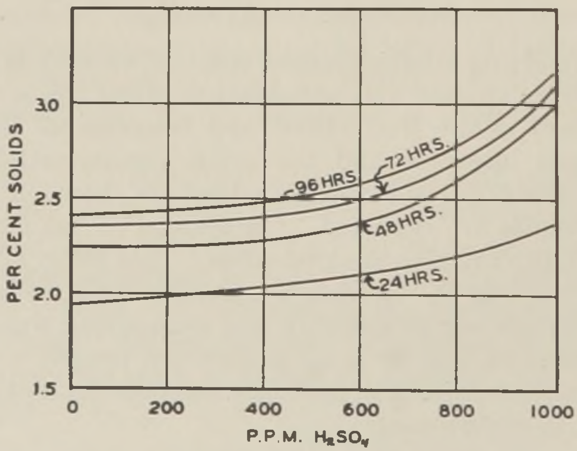

FIG. 1.—Effect of H_2SO_4 on compacting with increasing time intervals.

in greater dehydration with the formation of a smaller, denser, floc. Some results obtained are graphically shown in Fig. 1. It is evident that compacting increases with increasing quantities of acid, but the quantities of acid required are relatively large before additional compacting is accomplished. Even with larger quantities of acid the degree of sludge concentration reached in a relatively short time is insufficient to warrant its use alone for this purpose.

Small, dense floc can be obtained with the addition of calcium hydroxide (Table II). With comparatively small quantities of lime compacting is increased. The increase in density of the sludge after a short period (2 hr.) is material. However, when compacting was allowed to continue for a period of 72 hours, the increase in density of the sludge was less than 20 per cent, even when as much as 10 per cent lime on a dry basis of the sludge was used.

TABLE II.—*Effect of Lime on Compacting of Sludge*

Settling	$Ca(OH)_2$, p.p.m.		
	0	250	500
Hours	Per Cent Solids		
0	0.58	0.58	0.58
2	0.77	0.88	1.23
24	1.93	2.14	2.23
72	2.52	2.75	2.90

A number of other coagulants tried, including aluminum, iron and lead salts, did not materially increase sludge concentration when the material was allowed to compact for 24 hours or more.

Weighting.—For weighting the floc a number of inert materials were used. As examples some results obtained with roasted copperas (Fe_2O_3), diatomaceous earth and fly ash added in different quantities are given in Table III. The results indicate that inert materials which will cause compacting must be dense. With reasonable quantities none of the inert materials had a marked effect on compacting.

TABLE III.—*Effect of Roasted Copperas, Diatomaceous Earth and Fly Ash on Compacting (in per cent Solids)*

Hours	0	16	48	72
	per cent	per cent	per cent	per cent
Control	0.51	1.57	2.04	2.12
Fe_2O_3 250 p.p.m.	0.51	1.64	2.12	2.22
500 p.p.m.	0.51	1.74	2.22	2.31
700 p.p.m.	0.51	1.93	2.31	2.43
1000 p.p.m.	0.51	1.96	2.37	2.49
Diat. earth 250 p.p.m.	0.51	1.62	2.12	2.22
500 p.p.m.	0.51	1.70	2.17	2.27
750 p.p.m.	0.51	1.70	2.22	2.31
1000 p.p.m.	0.51	1.85	2.37	2.37
Fly ash 250 p.p.m.	0.51	1.54	2.04	2.12
500 p.p.m.	0.51	1.67	2.17	2.31
750 p.p.m.	0.51	1.76	2.22	2.31
1000 p.p.m.	0.51	1.73	2.22	2.31

Iron oxide, which was not free from acid, produced some coagulation, followed by subsequent compacting. This is graphically shown in Fig. 2, where the results obtained with iron oxide containing "native" acid are compared after 48 and 84 hours compacting. The volume of sludge to which 1 per cent Fe_2O_3 had been added was reduced by 31 per cent, in spite of the increased bulk caused by the added material.

It was indicated above that dehydrating of the sludge with acid caused an increase in density of the sludge. The acid iron oxide caused a marked reduction in volume when appreciable quantities were added. It was expected that by treating the sludge with acid to its iso-electric point in the presence of iron oxide, increased compacting would take

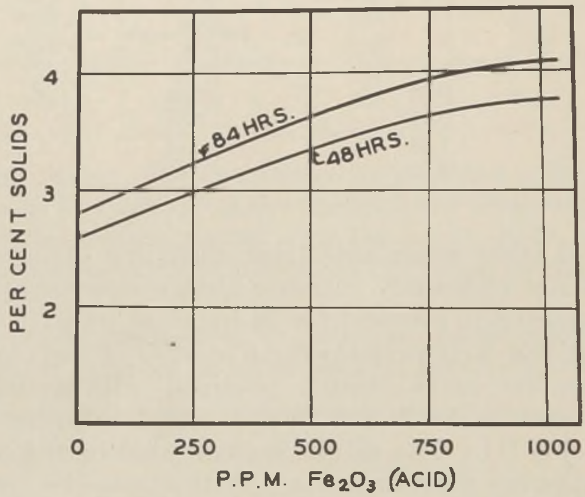

FIG. 2.—Compacting of activated sludge with the aid of iron oxide.

place. To rule out the "native" acid, the iron oxide was roasted until the last traces of sulfur dioxide had been removed. To a series of samples adjusted to pH values, varying from 2.2 to 7.0 with sulfuric acid, 0.75 per cent of the treated iron oxide was added. The results indicated that with a given quantity of inert material, the larger the amount of acid used the better the compacting, but that the highest concentration of sludge obtained amounted to only 2.95 per cent solids after a period of 100 hours compacting. Repetition of the experiments several times showed that under these conditions compacting was best at pH 3.5, but that the density of the sludge could not be increased above 2.8 to 3.0 per cent.

A number of more or less inactive salts such as sodium chloride, sodium sulfate, etc. were added in varying quantities alone or together with inert materials. None of the salts showed an appreciable effect. Sodium sulfate added up to 500 p.p.m. in conjunction with roasted copperas showed a slightly more rapid settling and a few tenths per cent increase in density of the sludge after 48 hours. Large quantities (6 times more) did not increase settling or compacting.

Poisons.—Biological action affects compacting principally by liquefaction and gas formation. Uncontrolled expansion and lifting of sludge by entrained gases results in partial or non-uniform floating. Prevention or reduction of septicity by suitable poisons should increase the density of sludge if the poisons themselves are not factors in dispersion or expansion of the sludge.

Among the several poisons available some results on the effect of copper sulfate, mercuric chloride and sodium arsenate are shown in Table IV. Copper sulfate added in very small quantities did not affect

TABLE IV.—*Effect of Poisons on Compacting (in per cent Solids)*

Hours	Control	$CuSO_4$ 100 p.p.m.	$CuSO_4$ 200 p.p.m.
	per cent	per cent	per cent
0	0.58	0.58	0.58
2	0.77	1.07	1.57
24	1.93	2.32	2.42
72	2.52	2.75	2.90
Hours	**Control per cent**	**Na_2AsO_4 20 p.p.m. per cent**	
0	0.90	0.90	
48	2.57	2.90	
84	2.81	2.90	
Hours	**Control per cent**	**$HgCl_2$ 10 p.p.m. per cent**	
0	0.52	0.52	
24	1.53	1.86	
48	1.86	2.00	

the settling or compacting of activated sludge, but when larger quantities (100 p.p.m. and over) were added, settling was increased markedly, with some increase in compacting. Sodium arsenate added in reasonable quantities to produce near sterility had no effect on settling but may slightly increase compacting. The addition of mercuric chloride has some effect on settling and compacting.

Inert Materials and Poisons.—The effect of combinations of relatively small amounts of poisons in conjunction with inert materials is illustrated by a few results in Table V. A combination of small quantities of ferric chloride and copper sulfate caused a definite increase in sludge volume. There was practically no effect of adding calcium chloride to inert materials, while the addition of small quantities of mercuric chloride was small.

Compacting by Flotation.—Flotation of sludge with the aid of chemicals for dewatering of sludge has been used for a number of years. Acid chemicals reacting with the alkaline substances present in the sludge or liquor to produce numerous small gas bubbles, which in turn cause the sludge particles to rise, and thus aid in the separation of water from the sludge. If such an acid chemical is at the same time a coagulant, such as alum, finely divided particles of sludge are brought together and more water is released. It is clear that sludges consisting of comparatively large flocs will be less benefitted by the alum than finely divided material. When the finely divided material contains some gas, as is the case of partially or completely digested sludge, an additional amount of gas released helps flotation and separation of water, especially when the sludge is poorly digested and still contains considerable amounts of fats and greases.

Using flotation for compacting, a chemical that reacts with the carbonates present, produces gas, acts at the same time as a coagulating and dehydrating agent, causes large flocs to shrink, acts rapidly, prevents septicity without leaving poisonous substances in the separated liquor and does not result in an increased oxygen demand of the liquor, approaches the ideal for use. No such ideal chemical or combination of chemicals has been found, as yet, but results obtained with calcium hypochloride indicate that dense activated sludge may be produced by flotation. As an example, some results on three different activated sludges are shown in Fig. 3. Sludge compacting to 2.60 per cent solids in 48 hours on quiescent standing at about the optimum temperature, could be readily concentrated 2.5 to 3 times. With as little as 8.34 lb. calcium hypochloride per 1000 gallons of sludge, the concentration could be doubled. A sample of sludge is included, which on quiescent standing was capable of condensing to 5 per cent solids in 48 hours. This type of sludge could be concentrated, in the same time allowed for compacting, to 9.75 per cent solids with 8.34 lb. calcium hypochloride per 1000 gallons of sludge. Compacting of the same sludges after 24 hours is illustrated in Table VI.

TABLE V.—*Effect of Combinations of Poisons, Coagulants and Inert Materials on Compacting*

Hours	0	3	7	24	48
	per cent	per cent	per cent	per cent	per cent
Control	0.59	0.98	1.34	2.11	2.68
70 p.p.m. $FeCl_3$ and 10 p.p.m. $CuSO_4$	0.59	1.00	1.33	1.52	2.27
70 p.p.m. $FeCl_3$ and 20 p.p.m. $CuSO_4$	0.59	0.98	1.33	1.59	2.03
Control	0.52	—	1.28	1.53	1.86
750 p.p.m. Fe_2O_3	0.52	—	1.30	1.86	2.26
750 p.p.m. Fe_2O_3 and 500 p.p.m. $CaCl_2$	0.52	—	1.38	2.00	2.26
750 p.p.m. Fe_2O_3 and 1000 p.p.m. $CaCl_2$	0.52	—	1.40	2.08	2.36
750 p.p.m. Fe_2O_3 and 10 p.p.m. $HgCl_2$	0.52	—	1.32	1.86	2.00

The original concentration of the sludge treated does not appear to be a factor in compacting. The character of the activated sludge to be treated plays a role. For instance, the Chatham sludge, with an original concentration of 0.60 per cent, compacted to a considerably less extent, in the same time and with equal quantities of chemicals, than the

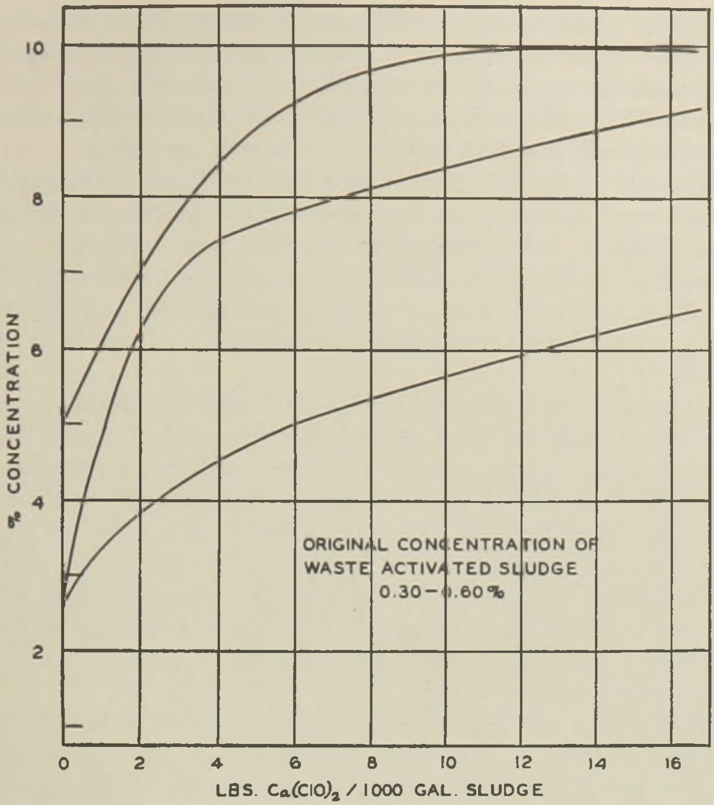

FIG. 3.—Concentration of activated sludge after 48 hours.

Morristown sludge with the same original sludge concentration. Thin sludge may compact to a greater density than thicker sludge.

The 9 to 10 per cent sludges produced were leathery in appearance, forming rather compact cake-like sludges. The excess gases produced by the action of the calcium hypochloride and evolving while the sludge was concentrating, escaped freely when the sludge "cakes" were forming. Nevertheless, the sludge continued to compact materially after the

TABLE VI.—*Effect of Varying Quantities of Calcium Hypochloride of Three Different Sludges*

$Ca(ClO)_2$ in lb. 1000 gal.		0	4.15	8.34	12.5	16.7
Hours		Per Cent Solids				
Chatham	0	0.60	0.60	0.60	0.60	0.60
	24	2.00	3.55	4.62	5.45	6.00
Morristown	0	0.60	0.60	0.60	0.60	0.60
	24	2.40	6.00	6.66	8.56	8.56
Bernardsville	0	0.30	0.30	0.30	0.30	0.30
	24	2.00	6.00	7.51	7.50	7.50

first 24 hours. Larger quantities of chemicals than those shown in Table VI did not cause additional concentration, but the maximum density which could be reached was obtained in a shorter time.

In all cases the sludge floated rapidly and the chemicals had such an astringent action that actual drainage of water occurred.

Breaking up of the floating sludge by vigorous stirring resulted in the dispersion of sludge particles and a considerable reduction in the density of sludge. When vigorous stirring was continued sufficiently long, the sludge returned to a bulky voluminous mass with little compacting. This suggests that subsequent handling of compacted sludge by pumping would be detrimental and removal by scrapers or conveyors is indicated.

Experiments were made to determine whether partial prior compacting would benefit the final sludge concentration and whether sludge allowed to become septic would adversely affect compacting. Prior compacting for a period of 10 to 12 hours and then adding the chemical resulted in the same density of sludge after a total time of 48 hours as when chemicals were added at the beginning of the period without partial concentration. Allowing the sludge to become septic before the chemical was added had no effect, so that neither the age of the sludge nor preliminary compacting was detrimental or beneficial in obtaining maximum sludge concentration.

As stated above addition of larger quantities of chlorine or calcium hypochloride results in increased turbidity of the separated liquor. The increase in turbidity is caused by dispersion of fine floc particles adhering to the larger floc or by peptization of the larger particles. If peptization of the floc was the cause of increased turbidity it could be expected that the B.O.D. of the liquor would increase with increasing quantities of the chemical. Results obtained with adequate and excessive quantities of chemical added showed that increasingly larger quantities of calcium hypochloride did not cause corresponding increases in the B.O.D. of the liquor. The B.O.D. values of the liquor produced with quantities of $Ca(ClO)_2$ varying from 8.6 to 37.5 lb. per 1000 gal. sludge, ranged from 510 to 600 p.p.m. with an average of 550 p.p.m. The results indicated that after initial dispersion of sludge particles by the minimum quantities of the chemical required, no additional material is discharged into the liquor. It appears, therefore, that the immediate peptizing or dispersion action of the chemical affects the small particles held loosely by the larger floc. Additional quantities of chemcal have no further effect on dispersion of the floc or subsequent B.O.D. values of the liquor. This is in accord with previous findings (7) when activated sludge was treated with chlorine.

The turbid liquor resulting from the calcium hypochloride treatment could be clarified either with acids or iron coagulants. Results obtained on the treatment of sludge with sulfuric acid for compacting showed that, with small quantities of acid, compacting was somewhat increased, while with larger quantities of acid the increased size of the floc caused some expansion of the sludge, but the liquor remained clear. Additions of very small quantities of $FeCl_3$ affected compacting somewhat adversely, but produced a clear liquor. A combination of calcium hypochloride and iron salt or acid produced a clear liquor but a slightly less dense sludge than calcium hypochloride alone. The following figures illustrate this, where the percentage sludge concentration, after a given time of compacting, is compared with and without additional $FeCl_3$:

Chemical	None	Ca $(ClO)_2$ 8 lb. per 1000 gal.	Ca $(ClO)_2$ 8 lb. + $FeCl_3$ 0.4 lb.
Hrs.	Per cent	Per cent	Per cent
0	0.5	0.5	0.5
24	1.6	2.9	2.6
48	2.4	4.7	4.5
B.O.D. liquor p.p.m.	200	400	120

The results were the same if 0.4 lb. ferric sulfate or chlorinated copperas or 2 lb. H_2SO_4 were added in addition to the $Ca(ClO)_2$. In all cases the liquor was transparent, but became slightly colored. The coloring of the liquor was greatest with sulfuric acid, indicating that some humus-like materials were brought into solution.

The drainability of compacted activated sewage appears to be enhanced by calcium hypochloride treatment. Experiments showed that the sludge drained rapidly when placed on porous plates or small sand beds. The material formed rapidly a thin, dry sheet, without production of odors. A portion of the water was released within a very short time and subsequent evaporation proceeded rapidly to any degree of dryness desired. On the other hand, vacuum filtration of the concentrated sludge was not enhanced by the calcium hypochloride treatment. To remove additional water practically the same quantities of ferric chloride were required for the $Ca(ClO)_2$ treated as for the untreated sludge.

Weighting down of sludge with certain inert materials aids somewhat in sludge concentration. Roasted copperas, diatomaceous earth and fly ash help somewhat. Experiments with combinations of inert materials and $Ca(ClO)_2$ were conducted to determine whether equally dense or denser sludges could be obtained by partial substitution of inert material than with calcium hypochloride alone. Adding varying quantities of inert materials and increasing amounts of $Ca(ClO)_2$ to activated sludge did not cause material changes. This is illustrated by an example of sludge with an original concentration of 0.6 per cent solids, to which 4 lb. copperas per 1000 gal. of sludge was added and allowed to concentrate for 48 hours:

$Ca(ClO)_2$ Lb. per 1000 Gal.	Per Cent Solids	$Ca(ClO)_2 + Fe_2O_3$	Per Cent Solids
0	1.53	0+4	1.86
8.4	4.72	8.4+4	4.78
16.7	7.43	16.7+4	7.43
25.0	7.43	25.0+4	7.43

Larger quantities of copperas were equally ineffective when sufficient $Ca(ClO)_2$ was added and had a very limited effect with smaller amounts of the chemical. Incidentally, the sludge floated with equal facility whether or not inert materials were added. This shows that the gas produced is intimately held and with a considerable force by the sludge.

The sludge can be compacted readily in a relatively short time with the aid of calcium hypochloride. As an illustration, settled sludge with an original solids concentration of 1.05 per cent was treated with various quantities of $Ca(ClO)_2$ and allowed to compact for 6 hours.

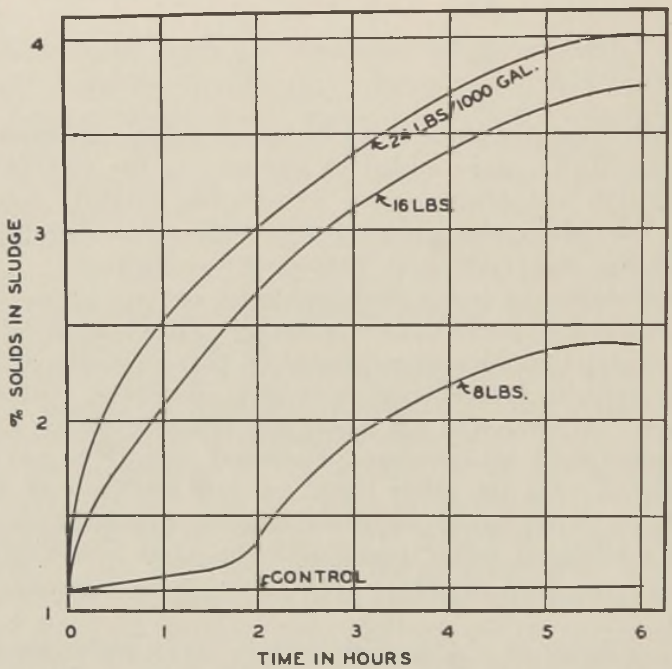

FIG. 4.—Effect of calcium hypochloride on short time compacting.

The rate of compacting and final concentration reached for this particular sludge is illustrated in Fig. 4 and compared with untreated sludge allowed to compact for the same period. No measurable compacting took place without the chemical, whereas with 16 lb. $Ca(ClO)_2$ per 1000 gallons of sludge, the concentration increased to 3.75 after 6 hours.

The amount of calcium hypochloride required for concentration of a given sludge is proportional to the quantity of sludge present and is not affected by the volume of the sludge. As an illustration, waste activated sludge with 12,000 p.p.m. suspended solids, diluted with separated liquor in various proportions, treated with $Ca(ClO)_2$ in proportion to the original suspended solids concentration and allowed to compact for 6 hours, showed the following:

Sludge Conc. P.p.m.	$Ca(ClO)_2$ Gm. per liter	Per Cent Solids (6 hr.)
12000	5	3.7
9600	4	3.8
7200	3	3.8
4800	2	3.7
2400	1	3.6

However, less than maximum compacting can be obtained with the same quantities of the chemical and increasing original sludge concentrations, but the final sludge concentration decreases in proportion to the original concentration. This is graphically illustrated in Fig. 5, where results obtained with a waste activated sludge are shown.

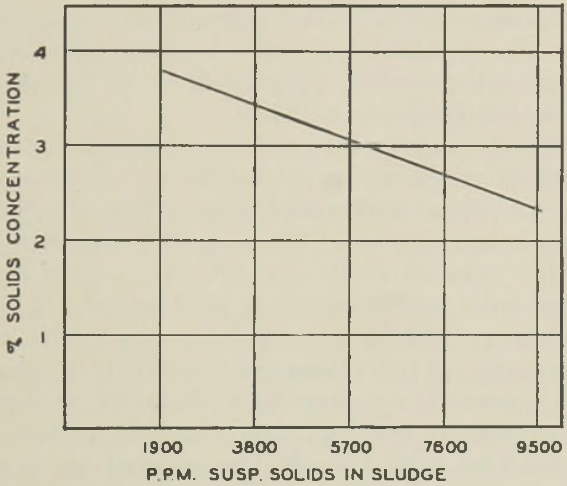

FIG. 5.—Sludge concentration with constant quantity of chemical and increasing original solids concentration.

The original suspended solids concentration of 9500 p.p.m. was diluted with supernatant liquor and treated with a constant quantity of 2.5 gm. $Ca(ClO)_2$ per liter. The activated sludge allowed to compact for the same period, without chemical addition, reached a final solids concentration of 1.4 per cent. It is clear that compacting is directly related to the original solids concentration, but that a certain quantity of chemical is required to produce sufficient gas to add buoyancy to the floc. Hence, the function of the chemical is at least two-fold, namely production of gas to aid in rapid floating and subsequent dehydration of the floc.

Discussion

In an attempt to pursue logically this study on compacting of activated sludge, certain definite factors must be taken into consideration as well as how the sludge is ultimately to be disposed of. From the standpoint of ultimate disposal there are three general methods of preparation: (1) dewatering (for dumping, fertilizer manufacture or incineration); (2) digestion, alone or in conjunction with fresh solids and (3) compacting (preparation for barging to sea). In preparation for dumping, the material should be rather dry or easily lose water on drying beds without creating odor nuisances; for dewatering preparatory to fertilizer manufacturing poisonous substances can not be used; for incineration, high yields on vacuum filters at low costs is advantageous. Compacting for the purpose of digestion should be accomplished without the addition of large quantities of poisons or undue quantities of acids which may interfere with the digestion processes. For sea disposal, maximum compacting, without interference with handling, is of more importance than absence of poisons, acids or alkalies.

A study of actual compacting of sludge is guided by more or less well-known phenomena such as floc formation (type, size, character); flotation induced by chemicals or gases; settling, affected by the nature of the floc, chemicals or inert substances; and the general effect of septicity on either flotation or settling.

The addition of coagulating agents to the activated sludge may produce large flocs which allow quantities of water to remain in the interstices when settling and compacting. The irregular size of the large floc prevents an effective "layering" or depositing. The result is that the sludge remains relatively voluminous and may actually increase in volume with small quantities of chemical. Larger quantities of coagulant, especially if they are acid in character, may cause considerable compacting of individual particles, which when brought together in a mass, have less volume than the original sludge. The acid nature of the coagulant results in partial dehydration of the sludge particles and reaction with the alkaline substances present. This in turn results in smaller volumes of sludge deposited or floated. Flotation occurs when the density of the floc is not increased more than the lifting power of the gas bubbles formed. With large quantities of acid coagulants, the volume of the sludge may be reduced materially on account of greater dehydration and increased deposition or flotation of the floc. These generalized statements are based on results obtained and illustrated by examples given.

For rapid settling and good compacting a small, heavy, scaly floc is desirable. Of the common, inexpensive chemicals, hydrated lime (as coagulant) produces a relatively small, dense floc resulting in equalizing or even overbalancing the desired compacting.

Increasing the specific gravity of the sludge particles with inert materials helps to reduce the volume of the sludge; but the quantities required are large. Combining certain coagulants with inert materials does not decrease the sludge volume greatly, because the size of the floc allows too much water to remain between the particles.

Certain coagulating and dehydrating agents cause the sludge to float, primarily on account of gases formed in the reaction with alkaline substances. Chemicals such as alum, sulfuric acid and calcium hypochloride cause enlargement of the floc. The acidic material reacts with alkaline substances in the liquor and quantities of gas lift the sludge to the surface, allowing the water to drain from the mass. If the amounts of chemicals are insufficient to produce numerous gas bubbles or if the amount of gas produced is excessive so that it can not readily escape but coalesces in large bubbles, the volume of sludge may increase. For instance, if small quantities of calcium hypochloride are used, the volume of the sludge may increase with certain sludges. With larger quantities of chemical the sludge compacts readily and rapidly.

Of practical and theoretical interest is the fact that the effect of calcium hypochloride is not influenced by the original density but by the quantity of the sludge. With equal quantities the character of the sludge or floc determines the amount of chemical required as well as the ultimate sludge density which can be obtained. A well oxidized activated sludge requires less chemical than a poorly oxidized sludge of equal original density. Even when the original density of a well oxidized sludge is less, it produces a more compact sludge with an equal quantity of chemical, provided the chemical addition does not result in an overdose. In general a well oxidized sludge has a more compact floc, is physically more stable and does not have the extensive frayed edges of a less oxidized sludge, whereas a well clarifying sludge may be bulky.

The gross effect of calcium hypochloride appears to be the result of several factors. When calcium hypochloride is added to water in rather large amounts, solution is slow and the evolution of free chlorine is gradual. The sludge and liquor contain numerous substances with which the chlorine may react. Gas bubbles are formed gradually as the size of the floc grows, carrying the floc upward. When chlorine is added reaction with the alkaline substances is practically instantaneous, so that much gas is formed in a short time. This results in coalescing of the bubbles, rapid rising and escape of the gas.

The importance of the chemical reaction resulting in gas bubbles is shown by the fact that when sludge is treated with H_2SO_4 and the gas formed removed by vacuum filtration prior to addition of $Ca(ClO)_2$ floating and compacting is less. Even calcium hypochloride additions sufficient to cause flotation fails to float degasified sludge.

Other gases than those produced by reaction of calcium hypochloride, chlorine or sulfuric acid may be used for flotation. Carbon dioxide, oxygen, nitrogen and air cause flotation, but have little or no effect on size or type of floc. This means however, that gases produced by biological activities are of importance. These biologically produced gases, principally CO_2, which may be augmented materially when quantities of nitrates are present and allowed to be reduced under partial anaerobic conditions, can be utilized to enhance flotation.

If the amounts of chemical added is excessive or when the acidity is increased by H_2SO_4 beyond the requirements, the gas bubbles formed may be larger, and if retained in the floc, result in rapid flotation and less dense sludge.

The reaction of the calcium hypochloride with the sludge causes some coagulation of the sludge and also some dispersion of finer particles. The increase in turbidity may result in lowering the surface tension of the liquor and thus aid the retention of bubbles in the floc. The coagulation of the floc is important in the dehydration of the floc to permit layering and compacting. The soluble material added as calcium hypochloride increases the specific gravity of the liquor, thus aiding in the buoyancy of the floc.

Dispersion of activated sludge particles by chlorine has been demonstrated before (7). The peptizing effect results in larger quantities of suspended and soluble substances in the liquor, hence higher B.O.D. The addition of small quantities of an effective coagulant ($FeCl_3$) prior to the addition of calcium hypochloride offsets the dispersion effect of the chlorine, because the coagulant partially dehydrates the sludge and causes the loosely held small particles to adhere more tenaciously to the mass. A similar result can be accomplished by the addition of acids.

The addition of an acid coagulant is more effective than an alkaline coagulant, because the calcium hypochloride lowers the pH of the sludge and liquor. Of considerable interest is the fact that after addition of the hypochloride the pH of the sludge is lowered to a greater extent than the liquor. For instance, sludge and liquor with pH values of 7.20 were changed to 6.40 and 6.75, respectively, after addition of 1.5 gm. calcium hypochloride per liter. This seems to indicate rather definitely that the chlorine acts directly on the floc. Since there is only a certain quantity of small particles loosely held by the floc which can be dispersed easily by the chlorine, the turbidity and B.O.D. of the liquor does not increase with increasing quantities of excessive amounts of calcium hypochloride.

The total B.O.D. of the liquid after treatment with ferric chloride followed by calcium hypochloride is not large and usually less than the original sewage. This liquor contains some residual chlorine and upon return to the influent would have no detrimental effect or might conceivably aid in control of odors.

Summary

Experiments conducted on the compacting of activated sludge by producing large flocs, small flocs, flotation, dehydration, weighting, retardation of decomposition and combinations of these methods with the aid of chemicals, inert materials, poisons and gases, have shown that a dense sludge can be produced. The production of large flocs by iron or aluminum coagulants results in some compacting. The same is true with chemical additions to produce small flocs. Weighting down the floc with inert substances such as roasted copperas, diatomaceous earth and fly ash, either alone or in combination with iron salts does not result

in greatly denser sludge. Dehydrating with acids or more or less inactive salts, alone or in combination with inert materials, was not very effective. Poisons such as copper sulfate or sodium arsenate are somewhat beneficial to compacting either alone or in conjunction with coagulants or inert materials. Flotation resulting from the addition of calcium hypochloride produces a dense sludge, varying from 6 to 10 per cent solids in 48 hours compacting. The quantity of calcium hypochloride required varied from 8 to 16 pounds per 1,000 gallons of waste sludge. Compacting with this chemical is not affected by the original density of the sludge but by the character of the sludge. Well oxidized sludges requires less chemical for compacting than poorly settling sludges. Staleness of sludge does not affect compacting. Turbidity and B.O.D. of the liquor increases, but the addition of 50 p.p.m. or less of $FeCl_3$ prior to the addition of calcium hypochloride produces a clear, transparent liquor with a lower B.O.D. than the original sewage. The liquor contains some free chlorine. Drainability of the sludge is enhanced by the treatment, but experimentation with vacuum filtration indicates that a sludge compacted to 8 to 9 percent solids dewaters slowly, even when ferric chloride is added. Some factors operative in compacting with calcium hypochloride are discussed.

Acknowledgment

I am indebted to several research assistants, who performed various experiments included in this study.

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DIGESTION STUDIES ON PURE VEGETABLES

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Introduction

Dr. W. L. Malcolm after completing his digestion studies on garbage (1) indicated that additional studies should be made to investigate the effect of the addition of pure vegetable solids to heated, well-seeded separate sludge digestion tanks. This problem was assigned to the writer as part of his research program on digestion studies of paper pulp. This work was conducted under a McMullen Research Scholarship at Cornell University, Ithaca, New York, from October, 1939, to August 1940.

The results presented herein may be used to evaluate the effect of the addition of vegetable solids discharged from canneries on the digestion process and to determine whether these solids will digest when added to heated well-seeded separate sludge digestion tanks without the benefit of additional sewage solids.

Equipment and Materials

Five experimental digestion units of a battery of sixteen shown in Figs. 1 and 2 were used. Each unit consisted of two 55-gallon steel drums arranged as shown in Fig. 3. These units had been used previously by Prof. C. L. Walker (2) in studies on the effect of activated carbon on sewage sludge digestion, Dr. W. L. Malcolm (1) in studies on the digestion of ground garbage, and Mr. M. T. Hill (3) in studies on the digestion of paper pulp.

An average temperature of 80° F. was maintained in the laboratory where the digesters were kept, by a thermostatically controlled Buffalo steam unit heater. Temperatures were read at the north end, center, and south end of the laboratory; the temperature differences were approximately 1 to 10° F.

The fresh and digested sludges were obtained from the City of Ithaca sewage treatment plant. The fresh sludge was drawn from the primary settling tanks through a valve on the sludge pipe leading to the digester, and the digested sludge used for seeding was taken from the sludge digestion tank. Fresh sludge was delivered to the University laboratory in 40-quart milk cans three times each week. The vegetables used were purchased fresh from one of the chain stores in Ithaca in bushel lots during the winter months when they could be stored, and in smaller quantities during the warmer months when there was danger of spoilage. Cabbage, carrots, and potatoes were used since they could be obtained most readily at all times of the year.

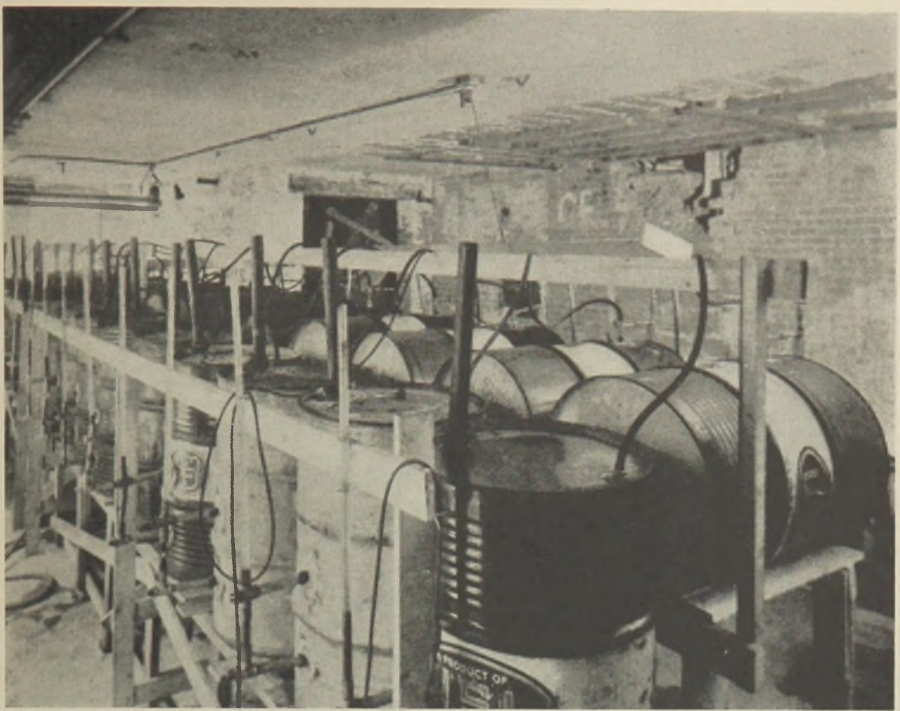


FIG. 1.—Fifty-five gallon experimental digestion tanks.

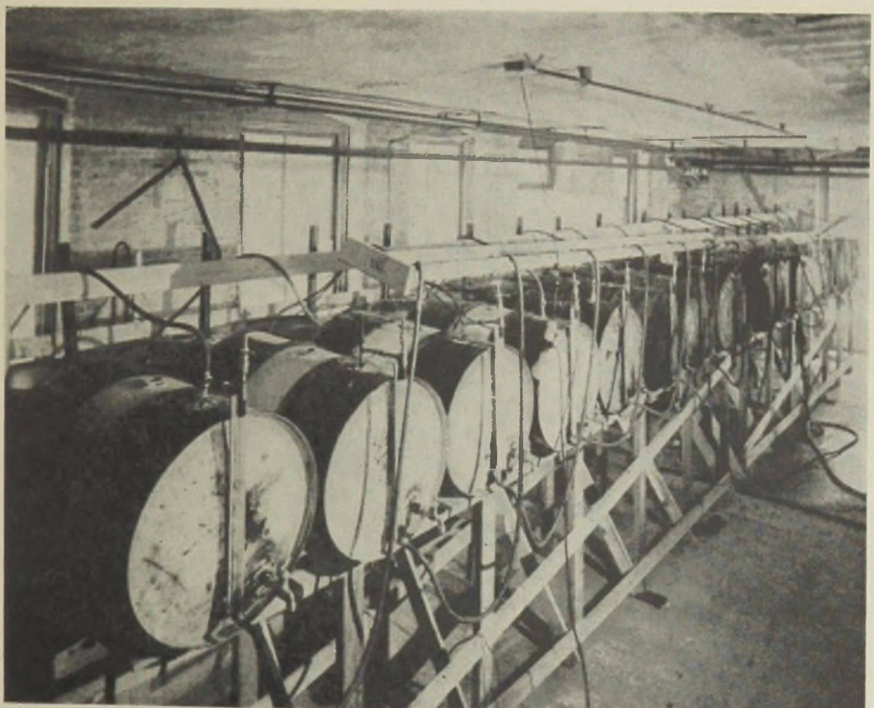


FIG. 2.—Gas collecting tanks.

Procedure

Before the experimental work was begun, it was necessary to examine all the tanks for leakage. This was done by adding water to the tanks with all fittings and valves closed, thereby compressing the air in the tank, causing the water in the gage glass to rise. If there were no leaks in a tank, the water level in the gage glass would remain constant; if the level fell, the tank leaked, and it was necessary to find and

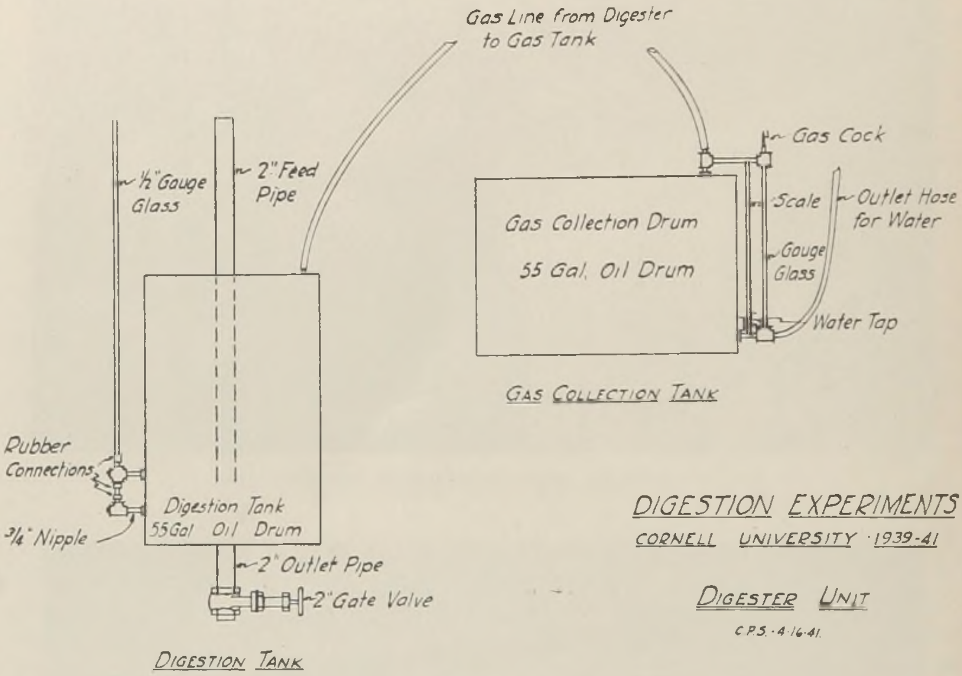


Fig. 3

repair the leak or replace the tank. When a unit was found to be gas and water tight, it was seeded with approximately 240 pounds of digested sludge.

Measured quantities of fresh sludge were added to the tanks until they functioned normally, at which time the sludge feeds were replaced by vegetable feeds in three of the five tanks. Before loading, the raw vegetables were sliced and put through a meat grinder. A sample of each vegetable was tested for total and volatile solids content. Water was added to the weighed portion of vegetable before adding to the tank in order to facilitate loading. For a time supernatant liquor was siphoned from the vegetable tanks and was used as the diluting medium, but this method was discontinued since it did not agree with practice where, in all probability, water would be the diluting medium.

Supernatant liquor was siphoned from the digester through the gage glass, but as this method was awkward another was tried whereby it was removed through a faucet attached to the upper tee-gage glass connection. This method proved to be much more satisfactory.

Digested sludge was withdrawn through a gate valve provided for this purpose in the bottom of the tank. Since the tank had a flat bottom and the volume of sludge removed was in the shape of an inverted cone, supernatant liquor was frequently discharged with the sludge when the rate of withdrawal was excessive. As a result, the solids content of the sludge was reduced as larger quantities of sludge were withdrawn. To correct this condition, hopper-bottomed tanks should be installed.

TABLE I.—*Feeding Schedule, October 14, 1939 to July 6, 1940*

Tank	Sludge										Vegetables	Potatoes	Carrots	Cabbage
Dates	Oct. 14–Oct. 18*	Oct. 19–Oct. 21	Oct. 24–Oct. 28	Oct. 31	Nov. 1–Nov. 18	Nov. 20	Nov. 21–Dec. 18	Dec. 19–Dec. 20	Dec. 21–Jan. 13	Jan. 16–July 6	Dec. 19–Dec. 26	Dec. 27–July 6		
16	3.50	3.50	4.20	7.50	7.00	8.50	7.78	7.00	10.50	9.25	—	—	—	—
15	3.50	3.50	4.20	7.50	7.00	8.50	7.78	7.00	10.50	9.25	—	—	—	—
4	3.50	3.50	4.20	7.50	7.00	8.50	7.78				Variable	1.42	—	—
2	3.50	3.50	4.20	7.50	7.00	8.50	7.78				"	—	3.06	—
1	3.50	3.50	4.20	7.50	7.00	8.50	7.78				"	—	—	3.88

* Alternate days. All quantities given are in lbs. wet weight added daily (6 times per week).

Gas was withdrawn from the tanks by filling them with water after the volume of the gas was measured under atmospheric conditions. All gas volumes were corrected to standard conditions (0° C. and 760 mm). Gas samples were collected at various times during the investigation

TABLE II.—*Summary of Materials Added To or Removed From Tanks*

	16		15		4		2		1	
	Total added to or removed in lbs. (1)	Volatile added to or removed in lbs. (2)	Total added to or removed in lbs. (1)	Volatile added to or removed in lbs. (2)	Total added to or removed in lbs. (1)	Volatile added to or removed in lbs. (2)	Total added to or removed in lbs. (1)	Volatile added to or removed in lbs. (2)	Total added to or removed in lbs. (1)	Volatile added to or removed in lbs. (2)
Seed Material—lbs.	235.08	7.048	234.00	7.348	238.73	12.868	243.99	8.393	247.38	8.065
Daily Loadings:										
Fresh sewage sludge	1850.91	48.395	1850.91	48.395	351.66	9.705	342.51	9.472	346.16	9.542
Cabbage									614.87	45.405
Carrots							471.09	43.341		
Potatoes					250.75	59.517				
Paper pulp	0.47	0.011								
Withdrawals:										
Supernatants:										
Fresh sewage supernatants	628.78	1.047	587.60	1.468	139.11	0.254	97.67	0.229	135.30	0.238
Composite supernatants					170.34	0.503	385.08	0.849	320.78	1.264
Digested sludges:										
Digested sewage sludge	315.76	10.745	167.59	6.179	28.64	1.013	40.38	1.481	36.54	1.381
Composite sludges					172.42	4.548	115.82	3.677	285.40	4.930
Emptying Tanks:										
Digested sewage sludge	359.35	8.532	532.22	11.705						
Composite sludge					438.78	5.725	386.96	6.248	673.40	14.362
Unaccounted solids—lbs.	35.130		36.391		70.047		48.722		40.837	
Gas produced in cu. ft.	560.93		532.57		635.92		559.81		503.96	
Cu. ft. Gas per lb. volatile material unaccounted for	15.97		14.63		9.08		11.49		12.34	
Carbon to Nitrogen ratio	20.9		20.9		29.21		24.14		16.32	
Number additions to tanks										
Sewage	212		212		52		51		52	
Vegetables					161		153		159	
Paper Pulp	1									

(1) Wet weight. (2) Dry weight.

and were tested for methane, carbon dioxide, carbon monoxide, hydrogen and oxygen. The Hempel and Orsat gas testing outfits were used in making the analyses. Nitrogen was determined by difference.

Upon completion of the study, the tank contents were removed. Water was added to the tanks to wash out thoroughly all solid material.

Each day's feed, either sludge or vegetable, was tested for total solids and volatile solids, in order to determine the amount of volatile material * added to the tank. These same tests were made on all supernatants and digested sludges removed from the tanks. All volatile materials consumed or unaccounted for were assumed to have gone into the production of gas.

Tanks 15 and 16, the control tanks, were seeded on October 11, 1939, with 234.00 lbs. and 235.08 lbs. of digested sludge, respectively, and tanks 1, 2 and 4 with 247.38 lbs., 243.99 lbs., and 238.73 lbs., respectively, on October 13, 1939. The feeding schedule for fresh sludge and vegetables is given in Table I.

Table II gives the pounds of material (wet weight) added to or removed from the tanks and volatile material added to or removed from the tanks during the feeding period, which extended from October 14, 1939, to July 6, 1940.

All tanks were operated from July 6 to August 21–24, 1940, during which time the gas was measured and withdrawn as was done during the feeding period although no material was added.

Results of the Investigation

Chatfield and Adams (4) report the following average compositions for the vegetables used in this investigation (Table III):

Table III.—*Composition of Vegetables*

Vegetable	Per Cent Water	Per Cent Protein*	Per Cent Fat	Per Cent Carbohydrate
Cabbage	92.4	1.4	0.2	5.3
Carrots	88.2	1.2	0.3	9.3
Potatoes	77.8	2.0	0.1	19.1

* Protein determined by multiplying N×6.25.

From these values it was possible to compute the approximate carbon and nitrogen contents of these vegetables and to compare the results with carbon and nitrogen values obtained by test. These results are presented in Table IV.

On the basis of this information the carbon to nitrogen ratios were computed. For the computed carbon and nitrogen values the C/N ratios were 14.22, 24.65, and 27.22 for the cabbage, carrots, and potatoes, respectively, and for the test carbon and nitrogen values the C/N ratios were 16.32, 24.14, and 29.21.

* Wherever volatile material is mentioned it will be on a wet solids basis unless otherwise noted.

Table IV.—*Per Cent Carbon and Nitrogen in Vegetables*

Vegetable	Computed*		Test	
	Carbon	Nitrogen	Carbon	Nitrogen
Cabbage	3.182	0.224	3.312	0.203
Carrots	4.739	0.192	4.225	0.175
Potatoes	8.754	0.321	9.700	0.332

* From data in Chatfield and Adams (4).

Comparison of moisture contents as given by Chatfield and Adams and those obtained in daily tests during the study show slight differences. These data are presented in Table V.

Table V.—*Per Cent Moisture in Vegetables*

	No. of Tests	Cabbage	Carrots	Potatoes
Chatfield and Adams	56	92.4	88.2	77.8
Straub	155	91.71	89.63	75.02

From Table II it will be seen that there were 9.542, 9.472, and 9.705 lb. of volatile material added with the fresh raw sludge and 45.405, 43.341, and 59.517 lb. of volatile material added with the fresh vegetables, giving vegetable to sewage sludge ratios of 4.75, 4.58, and 6.13, respectively, for Tanks 1, 2, and 4 containing cabbage, carrots, and potatoes in that order.

Solids Characteristics.—Table VI presents a summary of the fresh sludge and vegetable characteristics and shows that there was considerable variation in the per cent total solids and in the per cent volatile matter (dry solids basis) of the fresh sludge added to the digesters. The variation in the vegetables was not quite so great as in the fresh sludge, but the per cent solids decreased during the course of the investigation.

Table VII presents a summary of the supernatant liquor characteristics and indicates that the per cent total solids was higher in all cases for the composite (mixture of sewage sludge and vegetable) supernatant liquors than for the fresh raw sludges and controls, but the per cent volatile material (dry solids basis) was lower in all composite supernatant liquors. The pH of the composite supernatant liquors was higher (numerically, therefore, more alkaline) for the cabbage and potato tanks than in the controls and lower in the carrot tank. The per cent volatile material (dry solids basis) in the composite supernatant liquors of Tanks 1, 2, and 4 was less than 40 per cent and in the controls was approximately 47 per cent.

Table VIII presents the digested sludge characteristics. In all cases the per cent total solids was lower in the composite sludges than in the controls and digested sewage sludges drawn from Tanks 1, 2,

TABLE VI.—*Characteristics of Materials Added to Tanks*

Tank	Matl.	No. Samp.	Per Cent Total Solids (wet basis)			Per Cent Volatile Solids (dry basis)			Per Cent Volatile Solids (wet basis)			pH			Remarks
			Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	
16	Raw	212	3.42	19.37	0.53	76.84	99.60	10.44	2.647	18.403	0.133	5.78	7.2	5.2	208 pH tests
16	Pulp	1	24.44			99.45			24.31						
15	Raw	212	3.42	19.37	0.53	76.84	99.60	10.44	2.647	18.403	0.133	5.78	7.2	5.2	
1	Raw	52	3.50	5.53	2.20	80.83	85.09	71.59	2.832	4.620	1.849	5.94	9.05	5.2	50 pH tests
1	Cabbage	159	8.29	15.94	2.30	89.74	94.85	68.55	7.424	15.119	2.101				
2	Raw	51	3.51	5.53	2.20	81.02	85.09	71.59	2.846	4.620	1.849	5.94	9.05	5.2	50 pH tests
2	Carrots	153	10.37	18.55	1.99	91.00	99.73	68.06	9.476	17.487	1.809				
4	Raw	52	3.51	5.53	2.20	80.92	85.09	71.59	2.840	4.620	1.849	5.94	9.05	5.2	50 pH tests
4	Potato	161	24.98	52.20	5.01	93.99	98.82	70.73	23.533	49.329	7.875				

TABLE VII.—*Supernatant Characteristics*

Tank	No. Samp. Tested	Per Cent Total Solids (wet basis)			Per Cent Volatile Solids (dry basis)			Per Cent Volatile Solids (wet basis)			pH		
		Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
16	26	0.48	2.22	0.10	47.15	64.40	8.00	0.199	0.997	0.041	7.04	7.5	6.9
15	25	0.56	2.54	0.06	47.10	63.94	3.94	0.307	1.540	0.007	7.04	7.4+	6.9[1]
1	7	0.39	0.78	0.25	47.89	56.87	36.06	0.193	0.444	0.082	6.94	7.2	6.7
1*	13	1.00	1.79	0.45	39.61	64.25	12.70[5]	0.459	1.150	0.081[5]	7.09	7.5	6.7[2]
2	6	0.55	1.58	0.24	51.63	56.69	46.57	0.296	0.896	0.113	6.92	7.2	6.8−
2*	11	0.64	1.38	0.31	28.16	53.67	1.58	0.200	0.729	0.013	7.01	7.1	6.7[3]
4	6	0.33	0.45	0.24	54.56	67.39	40.56	0.184	0.276	0.136	6.98	7.2	6.9
4*	9	0.80	2.29	0.46	39.66	53.23	19.94	0.316	0.993	0.140	7.26	7.9	7.0[4]

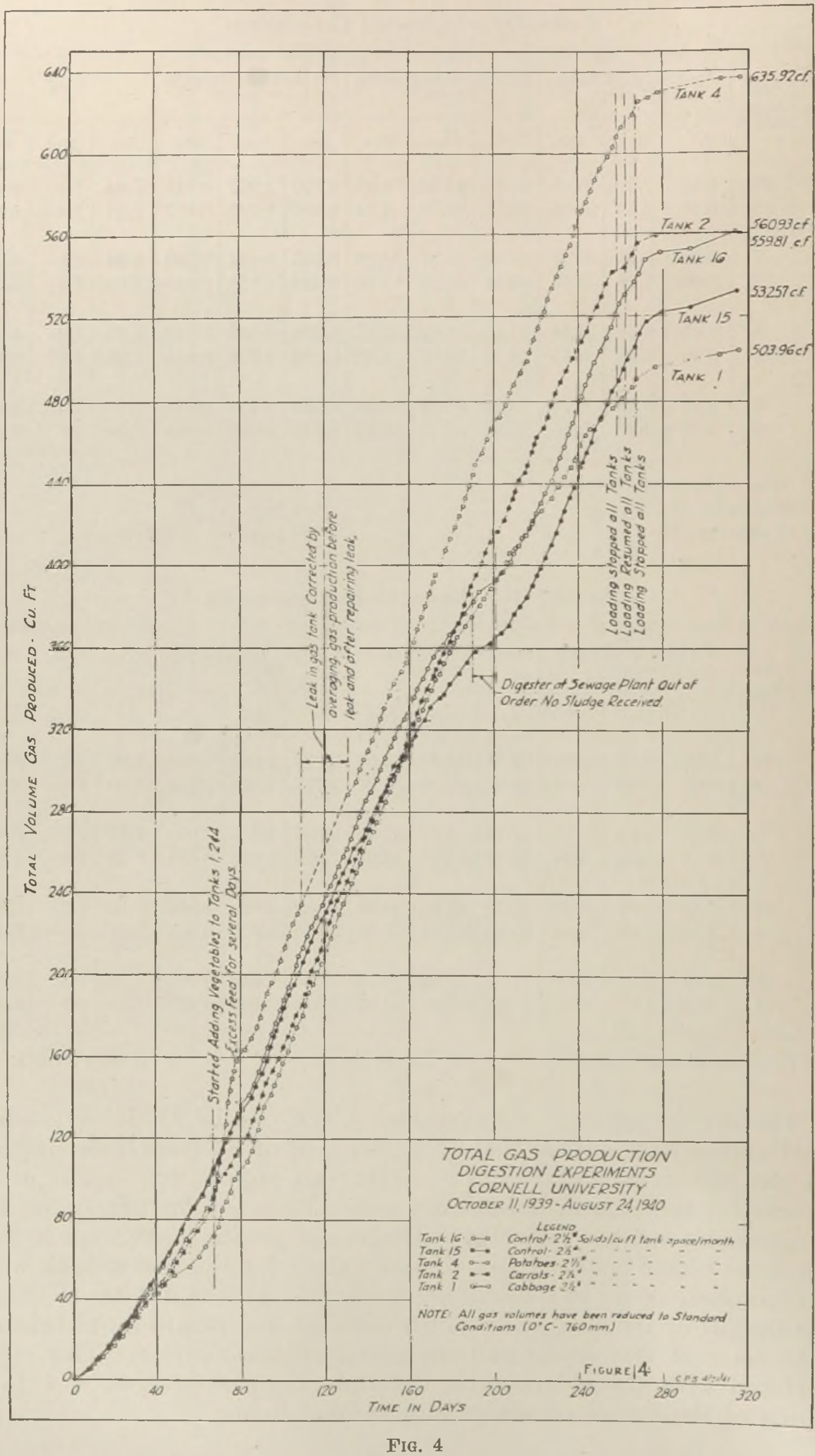
* After addition of vegetables.
[1] 23 tests for pH.
[2] 5 tests for pH.
[3] 8 tests for pH.
[4] 6 tests for pH.
[5] 11 tests for volatile solids.

TABLE VIII.—*Digested Sludge Characteristics*

Tank	No. Samp. Tested	Per Cent Total Solids (wet basis)			Per Cent Volatile Solids (dry basis)			Per Cent Volatile Solids (wet basis)			pH		
		Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.
16	12	6.06	9.69	3.66	58.91	74.92	53.96	3.627	7.26	2.071	7.00	7.3−	6.9
15	8	6.69	7.89	5.49	56.46	57.59	54.27	3.779	4.493	3.103	7.09	7.3−	7.0−
1	3	6.27	6.69	5.79	57.78	58.37	56.80	3.625	3.885	3.29	7.07	7.2	6.8
1*	10	3.15	6.38	0.80	59.59	65.05	42.94	1.883	4.116	0.491	7.10	7.4	7.2[1]
2	3	6.51	6.93	6.23	56.74	58.22	54.26	3.689	3.76	3.598	7.10	7.2	6.9
2*	4	5.23	6.02	4.48	60.98	65.45	57.29	3.164	3.450	2.932	7.04	7.2+	6.9
4	3	6.96	8.68	5.26	57.80	59.65	56.74	4.023	4.91	3.009	7.13	7.2	7.0
4*	7	4.38	6.71	1.66	59.34	62.64	54.95	2.616	3.921	0.912	7.38	7.8	6.9[2]

* After addition of vegetables. [1] 2 tests for pH. [2] 4 tests for pH.

and 4 before the addition of vegetables. The volatile solids (dry solids basis) values were approximately 60 per cent in the composite sludges. The controls were slightly lower, having an approximate value of 58 per cent for the volatile solids (dry solids basis). The pH values for the composite sludges from the cabbage and potato tanks were higher than those of the controls and similar values for the carrot tank were approximately equal to those of the controls. It was difficult to determine the pH of the sludges from the cabbage and potato tanks because of the color of the sludge and sludge supernatant liquor. This color interfered with the colorimetric determinations even after a 1 to 4 dilution of the sludge or sludge supernatant liquor.



TOTAL GAS PRODUCTION
DIGESTION EXPERIMENTS
CORNELL UNIVERSITY
October 11, 1939 - August 24, 1940
Legend
Tank 16 Control 2½# Solids/cu ft tank space/month
Tank 15 Control 2½#
Tank 4 Potatoes 2½#
Tank 2 Carrots 2½#
Tank 1 Cabbage 2½#
NOTE: All gas volumes have been reduced to Standard Conditions (0°C - 760 mm)
Total Volume Gas Produced - Cu. Ft.
Time in Days
Tank 4
Tank 2
Tank 16
Tank 15
Tank 1
635.92 cf
560.93 cf (16)
559.81 cf (2)
532.57 cf
503.96 cf
Started Adding Vegetables to Tanks 1, 2 & 4
Excess Feed for several Days
Leak in gas tank Corrected by averaging gas production before leak and after repairing leak.
Digester at Sewage Plant Out of Order No Sludge Received.
Loading stopped all Tanks
Loading Resumed all Tanks
Loading Stopped all Tanks
Figure 4

FIG. 4

Table IX, giving data taken from Table II, permits the computation of the reduction in volatile matter in each tank. From this table it is seen that the maximum reduction in volatile matter occurred in Tank 4 (potatoes), there being a reduction of 92.44 per cent. There was a reduction of 88.63 per cent in Tank 2 (carrots), 74.12 per cent in Tank 1 (cabbage), 80.46 per cent in Tank 16 (control) and 75.66 per cent in Tank 15 (control).

Table IX.—*Per Cent Reduction in Weight of Volatile Sludge Solids*

Tank	$a-b-c$*	$a-b$*	a	Per Cent Reduction	
				$\frac{a-b-c}{a-b}\times 100$	$\frac{a-b-c}{a}\times 100$
16	35.130	43.662	55.454	80.46	63.30
15	36.391	48.096	55.743	75.66	65.28
1	40.837	55.099	62.912	74.12	64.91
2	48.722	54.970	61.206	88.63	79.61
4	70.047	75.772	82.090	92.44	85.33

* a = seed + sewage sludge + pulp added in lbs. b = digested sludge + supernatant withdrawn in lbs. c = amount withdrawn at end of test in lbs. All weights are those of volatile dry solids in lbs.

An attempt was made to determine the amount of gas produced per pound of vegetable solids consumed by assuming that all the material withdrawn from the tanks, after vegetable addition had begun, was composed of vegetable and sewage sludge in the ratio equal to the amount of each in the tank during the entire loading cycle. On the basis of these assumptions and computations, it was found that in Tank 1, 11.39 cu. ft. of gas were produced per lb. of cabbage consumed; in Tank 2, 10.10 cu. ft. per lb. of carrots consumed; and, in Tank 4, 6.87 cu. ft. per lb. of potatoes consumed.

Gas Characteristics.—Cumulative gas volumes produced during the period of the investigation are shown in Fig. 4. In this figure total gas production in cubic feet is plotted against time. All gas volumes were reduced to standard conditions before plotting. The total gas volumes as recorded are lower than those would have been obtained in practice as the gas was collected over water. Carbon dioxide, and other gases to a lesser extent, are soluble in water and losses, therefore, resulted. A test was made of the water in the gas tank and it was found to be supersaturated with carbon dioxide. There was much corrosion in the tanks due to the formation of carbonic acid.

The quantity of gas produced per pound of volatile solids consumed in each tank is given in Table X, together with percentage production based on the amount of gas produced in Tank 16.

Referring to Fig. 4, one can see that Tank 1 was a little sluggish in gas production after the 40th day. The tank was examined for leaks at that time but none could be found and the tank was continued in operation. After the addition of vegetables on the 67th day, the tank

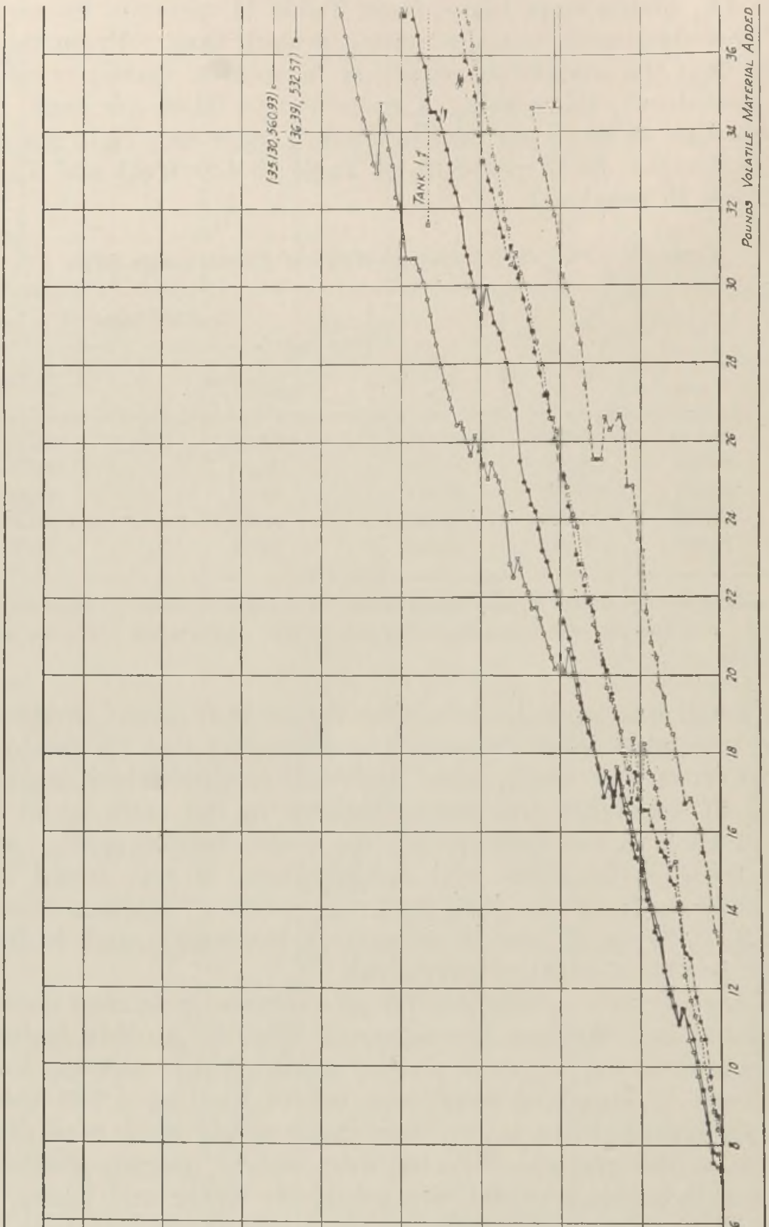

Pounds Volatile Material Added
Total Volume Gas Produced in Cu Ft
(35130, 560.93)
(36.391, 532.57)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
100
200
300
400
500
600
700
800

Fig. 5

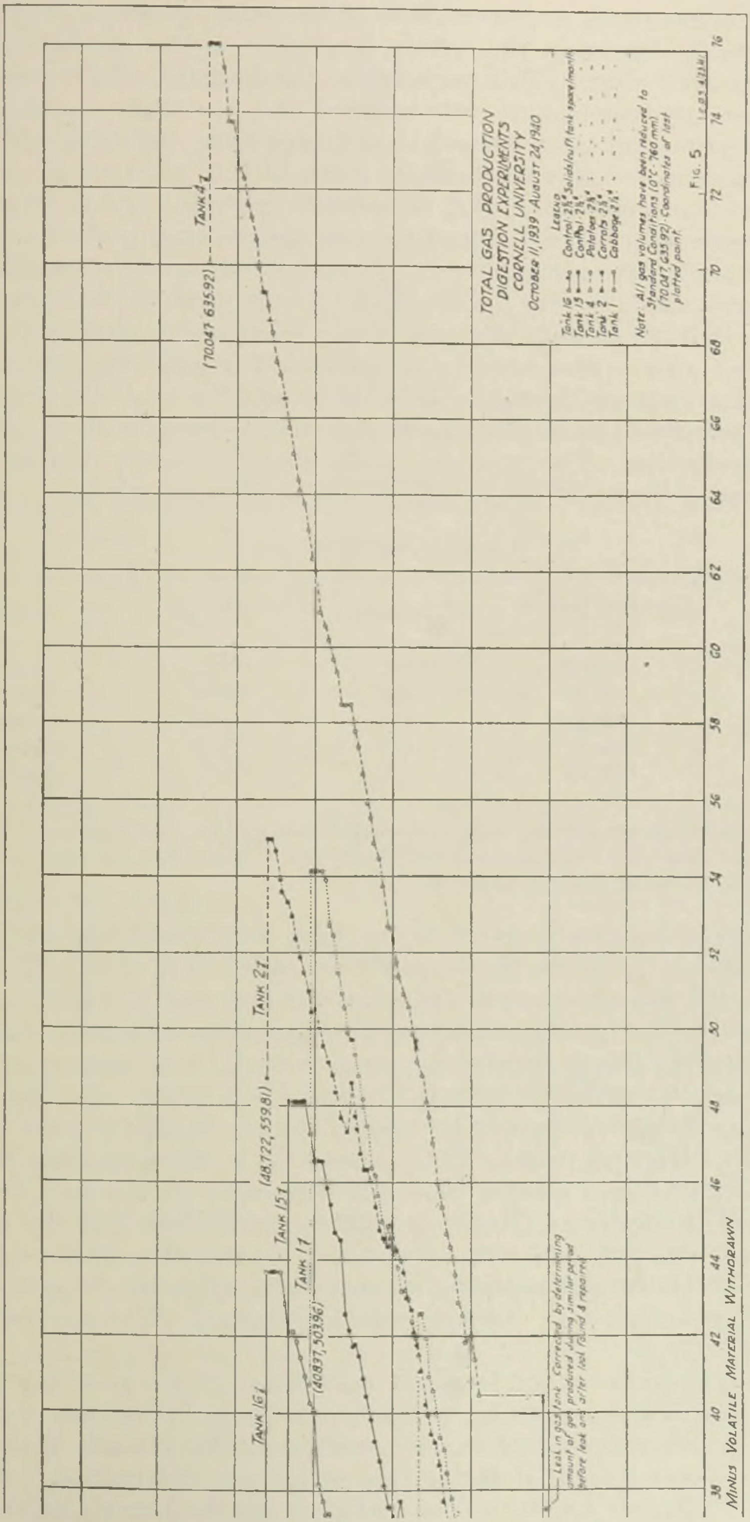


FIG. 5 (*Continued*)

seemed to come back to normal and to function properly. There was an obvious flattening in the curves for Tanks 15 and 16 between the 190th and 201st days. This was due to the fact that the digesters at the sewage treatment plant were clogged and no sludge was delivered to the experimental laboratory during this period. After this incident, it took about a week for the tanks to come back to normal.

Figure 5 represents a plot of volatile material added minus the volatile material removed from the tank against gas production. The abscissal scale gives the amount of volatile material in pounds that would have been present in the tank at any time if there were no volatile solids going into the production of gases or broken down in some other way. The curves are somewhat jagged but this is due to the way they are plotted. It will be noted that there are many points where there was a decrease in volatile material with an increase in gas production. This was due to the fact that more volatile solids were removed from the tank that day with digested sludge or supernatant liquor than were added to the tank with the fresh raw sludge or vegetables. In other places it will be noted that there was an increase in the gas volume with no apparent increase in volatile solids. This may be due to two reasons, first, the solids withdrawn balanced those added on that particular day and, second, there was gas production without the addition of any fresh volatile material. The latter condition is best seen toward the end of the investigation when all the tanks were continued in operation without the addition of more volatile solids. From Fig. 5 one can see that the slopes of the lines between the jagged portions are relatively uniform, indicating that the rate of gas production was constant. The slope of the line connecting the origin with the last plotted point in each curve gives the amount of gas produced per pound of volatile solids consumed. These values are given in Table X.

TABLE X.—*Gas Production*

Tank No.	Total Gas Produced cu. ft.	Gas Production*	Per Cent Gas Produced†	Remarks
16	560.93	15.97	100.0	Control
15	532.57	14.63	91.6	Control
1	503.96	12.34	77.3	Cabbage
2	559.81	11.49	71.9	Carrots
4	635.92	9.08	56.9	Potatoes

* Cubic feet of gas per pound of volatile material unaccounted for or consumed.

† Per cent production assigning a value of 100 per cent to Tank 16's gas production in cubic feet per pound of volatile material consumed.

The break in the curve for Tank 4 shown in Figs. 4 and 5 is due to the fact that a loss in gas production took place. When the leak was found, the tank was replaced with a new one. The amount of gas that would have been produced during this period was determined by taking a period of similar length before and after the leak was repaired and obtaining the average value of the volume of gas produced during this interval of time. This value was assumed to give the volume of gas that would have been produced during the period if no leak had developed.

In Table XI are given analyses of gas samples collected at various intervals during the investigation. It will be seen here that the addition of fresh vegetable solids to well seeded sewage sludge digestion tanks caused an increase in the CO_2 content and a corresponding decrease in the CH_4 content of the gas. There was little difference in the methane content of the composite gases from the three vegetable tanks, there being 56.0 per cent methane in Tank 1, 57.6 per cent in Tank 2, and 58.6 per cent in Tank 4. The corresponding CO_2 values were 39.0, 38.0, and 39.0 per cent. There seemed to be a reduction in the nitrogen content of the gas due to addition of pure vegetables.

Table XI.—*Results of Gas Analyses*

Tank	No. Samp.	CH_4	H_2	CO_2	O_2	CO	N_2
16	20	68.8[1]	1.1	26.6	0.2	0.2	3.2
15	17	69.5[2]	1.6	25.9	0.3	0.2	2.5
1	3	68.8	1.4	22.3	0.3	0.1	6.4
1*	13	56.0[3]	0.2	39.0	0.5	0.1	4.3
2	7	72.7	0.2	22.8	0.2	0.2	4.4
2*	16	57.6[4]	0.2	38.0	0.5	0.1	3.6
4	5	70.1	0.6	20.9	0.9	0.1	6.4
4*	16	58.6[5]	0.1	38.0	0.4	0.2	2.9

* After addition of vegetables.
[1] 17 tests for CH_4, H_2 and N_2.
[2] 14 tests for CH_4, H_2 and N_2.
[3] 11 tests for CH_4, H_2 and N_2.
[4] 13 tests for CH_4, H_2 and N_2.
[5] 12 tests for CH_4, H_2 and N_2.

Odor Control.—A very strong odor with a threshold number of 4000 was produced in the digestion of the cabbage. This odor could not be tolerated and to abate it six pounds of activated carbon were added, at one time, to that tank on April 13, 1940. This large application of carbon caused some condition in the tank (either a floating of the material, an increase in the viscosity of the material, or foaming) which resulted in the clogging of the gas line on several occasions immediately after the addition of the carbon. To correct this condition, it was necessary to draw off large quantities of digested sludge and supernatant liquor from the tank in order to lower the level of the material in it. On analysis, the total solids contents of the digested sludge and supernatant liquor had similar values, indicating a mixing of the tank's contents, possibly due to the action of the activated carbon. One gram of activated carbon was added to each daily dose of cabbage after April 13th. Carbon was added until June 1st. A metal chimney containing a one-foot layer of granulated carbon was placed over the feed pipe to control odors coming from the tank during this period.

After June 1st, ortho-dichlorbenzene was added to the tank instead of activated carbon to see whether it would control odors. One milliliter of ortho-dichlorbenzene was added to each day's feed of cabbage.

Both activated carbon and ortho-dichlorbenzene satisfactorily controlled the odors produced in the digestion of cabbage.

Conclusions

The following conclusions may be drawn from the investigation conducted on the digestibility of cabbage, carrots, and potatoes when added to heated, well seeded, separate sludge digestion tanks operated under the conditions described above:

1. The three vegetables studied digested satisfactorily.
2. No harmful effects upon the digestion were noted during the investigation period of 315 days.
3. There was a more complete breakdown of the volatile solids in the carrot and potato tank than of the volatile solids in the control tanks. The cabbage tank produced approximately the same value as the control tanks.
4. Potato skins do not seem to digest as readily as potato pulp.
5. The pH of the vegetable tank contents was as high or higher than the pH in the control tanks and was on the alkaline side.
6. The gas produced in the digestion of the vegetables contained a greater percentage of CO_2 than did the gas produced by the digestion of fresh sewage sludge solids, and there was a corresponding decrease in the per cent of methane in the vegetable gases.
7. Less gas per pound of volatile solids consumed was produced in the vegetable tanks than in the controls.
8. Digestion of cabbage was accompanied by the production of strong odors which were satisfactorily controlled by the addition of activated carbon or ortho-dichlorbenzene.

Acknowledgment

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EFFECT OF ACTIVATED SLUDGE PROCESS ON POLIOMYELITIS VIRUS *

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One of the major objectives in the design and operation of modern water and sewage treatment processes is directed toward adequate removal of pathogenic bacteria known to be responsible for transmission of disease by the water carriage route. Major operating attention is given toward this end in water treatment plants using surface and other bacterially contaminated waters. In sewage treatment, though often combined with other stream pollution problems, the responsibilities are similarly as great in this respect. This is particularly so in cases where the sewage plant is depended upon to eliminate what would otherwise be an excessive bacterial load on a water treatment plant using the same receiving stream as a water supply. Modern means of water and sewage treatment effectively remove disease-forming bacteria.

While there is no epidemiological evidence at the present time of the transmission of virus diseases by water, the demonstration of poliomyelitis virus in stools of patients and carriers and in sewage, by various investigators (1) (2) (3) (4) (5) (6) (7), and the thesis (8) (9) (10) (11) that the transmission of virus may be through the gastrointestinal tract, makes the question of the fate of virus in water and sewage treatment processes one of more than ordinary interest to both designer and operator.

The first study of a series on the effect of water treatment on poliomyelitis virus was submitted recently by the authors in the form of a preliminary report on the efficacy of individual water purification units (12). The data in this paper are a report on the effect of the activated sludge type of treatment on the same strain of virus.

Methods

General: Mouse-adapted poliomyelitis virus was used throughout these experiments. The virus suspension used was prepared from cords and brains of mice paralyzed in two or more extremities. The tissue of the animals was ground in refined silica, suspended in buffered broth, 1:5, and this material was added to the activated sludge mixture in an amount to give a dilution of 1:300. The heavy inoculum was used in order to show the effect of activated sludge under a severe load of the virus.

* This study was aided by a grant from the National Foundation for Infantile Paralysis, Inc.

The method of investigation consisted of observing the extent of removal of the virus by activated sludge under different conditions, designed to simulate the maximum and minimum activated sludge plant operating conditions usually encountered in practice, with respect to solids concentrations.

The activated sludge virus suspension mixture, consisting of 1 part virus suspension to 300 parts of mixed activated sludge liquor, was aerated for nine hours. Samples were then taken from the aerations units at 2 minutes, 3, 6, and 9 hours to represent different detention periods. These samples were settled and centrifuged and portions of the supernatant liquor were inoculated into mice. Concentrations of activated sludge in amounts of 1100, 2200, and 3300 p.p.m. were studied separately in the above described manner. The effect of aeration without sludge was also studied under similar conditions.

The activated sludge used in the experiment was obtained from the Ann Arbor activated sludge plant. The condition of the sludge that was used is shown by the following chemical and biochemical determinations:

Ash—16 per cent (dry basis).
pH of mixed liquor—6.8.
Bio-chemical oxidizing power—90 per cent removal of 5-day B.O.D. in 6 hours.
Suspended solids removal—95 per cent.
Nitrate—nitrogen produced—15 p.p.m.

Before introducing the virus suspension, the activated sludge was aerated in the laboratory for 24 hours.

Aeration Units.—The aeration units used in these experiments are shown in the diagrammatic sketch in Fig. 1. The unit appearing in the left of the figure was used in several of the early studies and check runs of this investigation. The air entered through the base of the unit into a carborundum ball which dispersed the air throughout the mixture. The degree of dispersion was sufficient to keep the mixture agitated so that all portions were constantly aerated. In the second unit the air was introduced through a tapered glass tube placed at the bottom of a liter glass cylinder. The end of the glass tube was narrowed to a small orifice allowing only a fine stream of air to be dispersed, sufficient in quantity to keep the sludge in suspension and circulation and to maintain aerobic conditions in the mixture.

The various concentrations of activated solids used in the experiment were obtained by concentrating from the aeration units of the plant.

Method of Sampling.—In collecting the samples at consecutive aeration intervals, the supernatant was removed aseptically by suction. The samples were then centrifuged to remove the coarser particles that otherwise could not be eliminated by the method used in collecting the supernatant liquor. Comparisons made between centrifuged specimens and gravity settled specimens showed a supernatant liquor of comparable quality. Centrifugation, however, speeded up this phase of the work.

Bactericidal Treatment.—In order to obtain an effluent free from bacteria that might cause complications and death in the animals, the supernatant liquor was treated with chlorine. The addition of chlorine in sufficient concentrations to destroy interfering bacteria was demonstrated not to affect the virus. The bactericidal process consisted of

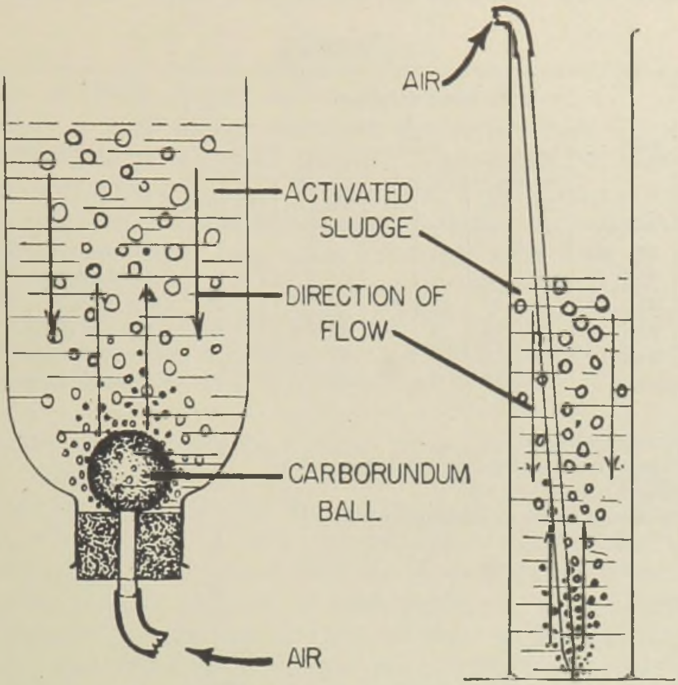


FIG. 1.—Activated sludge—aeration units.

treating the samples to be used for inoculation with chlorine in such quantity that 0.5 p.p.m. residual chlorine was present at the end of 10 minutes contact time. Residual chlorine was determined by the starch iodide method. All control and activated sludge samples were treated in the same manner.

Results

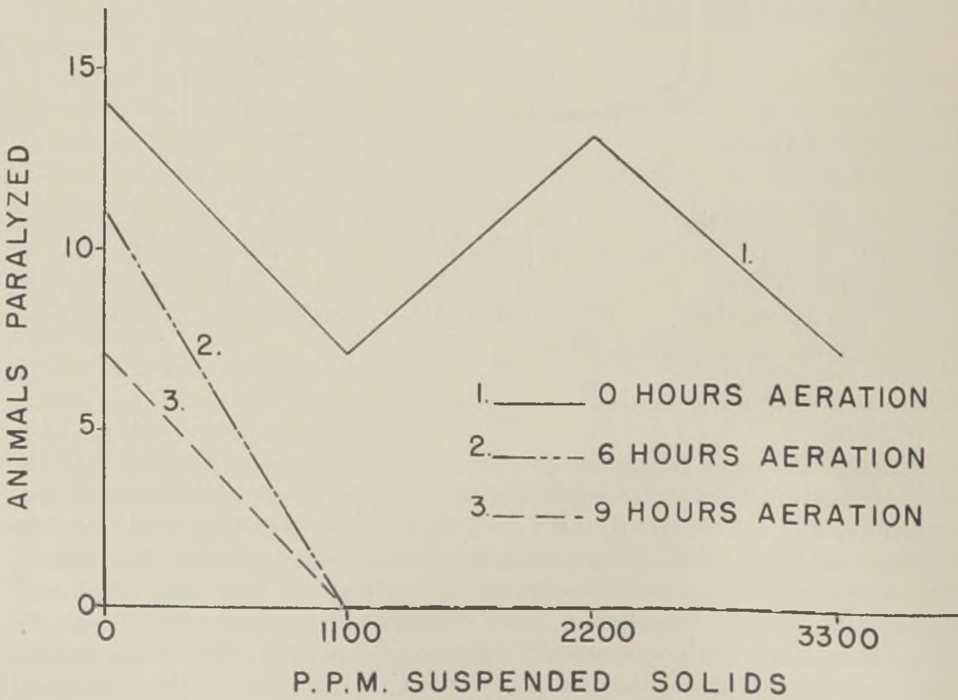
Paralysis in one or more mice in any group was indicative that the activated sludge did not completely remove the virus with which it was contaminated. Animals dying 1 to 3 days after injection could be considered to have died from trauma or interfering toxic substances. Those dying without showing paralysis, after the first animal in any group had become paralyzed, were considered to have died from the virus infection, with respiratory paralysis causing the death before paralysis was observed in the extremities. However, in the statistical interpretation of the results, non-paralyzed animals were counted as having succumbed to the virus only if the presence of the virus in each animal so dying was checked by subsequent passage.

The results of the study are shown in Table I and Graph 1. Four hundred and sixty mice were used in the final experiment with a total of 1150 animals used altogether for preliminary studies and check runs. Table I gives the results in the control and in the different activated sludge concentrations for three different periods of aeration. Three controls were used. Two of the controls (Nos. 1 and 2 in the table)

TABLE I

No.	Suspended Solids p.p.m.	No. Mice	Hours of Aeration									Miscellaneous
			0 hours			6 hours			9 hours			
			P	D	Dis	P	D	Dis	P	D	Dis	
1	0	30	24	6	—							Virus control 1–5 nonaerated
2	0	30	18	4	8							Virus control 1–300 nonaerated
3	0	90	14	6	10	11	10	9	7	3	20	Virus control 1–300 aerated
4	1100	90	8	12	10	0	6	24	0	1*	29	Activated sludge plus aeration
5	2200	90	13	5	12	0	3	27	0	1*	29	Activated sludge plus aeration
6	3300	90	7	6	17	0	1*	29	0	1*	29	Activated sludge plus aeration

P = Animals paralyzed.
D = Animals dying without developing paralysis.
Dis = Animals remaining alive.
* Virus not demonstrable in subsequent transfer.



GRAPH I

consisted of the original 1:5 braincord virus suspension and the 1:300 suspension; the latter equivalent to the dilution used in the activated sludge tests. These were injected into mice to determine the potency of the virus used. The third (No. 3) consisted of the 1:300 suspension which was aerated without activated sludge, to establish the effect of aeration without the effect of the sludge. Lines Nos. 4, 5, and 6, in the table represent the effect of different concentrations of activated sludge for different aeration periods.

Discussion

A study of these results shows that activated sludge in concentrations as low as 1100 p.p.m. removed the virus from the supernatant liquor, in a six-hour aeration period. The sludge in all amounts of 1100, 2200, and 3300 p.p.m. at 6- and 9-hour aeration periods removed the virus sufficiently from the liquor to make it non-infective when injected inter-cerebrally into mice. Several mice died in each group during the observation period without evidence of paralysis. These deaths were deemed due to trauma when the mice died within three days after inoculation. Other deaths, as indicated in Table I, were demonstrated as not being due to the virus, but probably of intercurrent infection.

It appears that the sludge without prolonged aeration had no great power for immediate adsorption of the virus. This is indicated by the series where fourteen mice of the control group of thirty animals were paralyzed, as against 8, 13, and 7 respectively in the similar groups that received virus after treatment with the three concentrations of sludges.

The mechanism of removal or destruction of the poliomyelitis virus in this process of sewage treatment is not clear at this writing. Further experiments are in progress to determine what proportion of removal is due to mechanical adsorption, to partial precipitation, or to virucidal or enzymatic activity of the sludge.

The effect of aeration without the presence of activated sludge is indicated in line 3 of Table I. Virus removal or inactivation may have been effected to some degree by prolonged aeration, since fewer animals became paralyzed in the group of 30 after 9 hours aeration in the absence of activated sludge.

Summary

Investigations were made of the effect of activated sludge, as used in a municipal activated sludge sewage treatment plant, on the removal or inactivation of a mouse-adapted strain of poliomyelitis virus. Virus suspensions of 1:300 were used in sludge concentrations of 1100, 2200, and 3300 p.p.m. solids, with aeration periods of 0, 6, and 9 hours.

The results showed that activated sludge in amounts as low as 1100 p.p.m., with six hours' aeration, removed or inactivated the virus to a sufficient extent to render it non-effective to mice when injected intracerebrally.

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ANAEROBIC DIGESTION *

III. ANAEROBIC DIGESTION OF UNDILUTED HUMAN EXCRETA

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The far eastern countries have for centuries collected and fertilized their fields with human excreta, but have only recently come to realize the public health significance of this practice. While these wastes are a major vehicle in the spread of intestinal diseases, it is estimated that to provide substitute fertilizers would cost China about $315,000,000 a year. As yet no adequate answer to this problem of the Orient has been presented.

In the United States, too, there is a call for the solution of the problem by means other than standard sewage treatment methods, in connection with the disposal of excreta from pail privies and in tight-vault and septic privies.

Anaerobic digestion of undiluted mixtures of urine and feces would seem to give an answer to both of these problems, but unfortunately such mixtures, unlike the solids separated from sewage, refuse to digest in a normal way, even though they are properly seeded and held for as long as a year. It is the purpose of this paper to show why such mixtures will not digest and how to initiate and maintain proper digestion.

Composition of Excreta

The average weight of human excreta produced daily varies greatly with age and sex. The estimated average daily per capita excreta production by the mixed population of the United States, as of 1930, is given in Table I, along with the average composition.

Table I (1).—*Average Production and Composition of Human Excreta* *

	Weight in Gms. per Cap. per Day	Total Solids per cent	Organic Matter per cent	Nitrogen per cent	Phosphoric Acid per cent	Potash per cent
Feces	86	22.8	19.8	1.00	1.10	0.25
Urine	1055	3.7	2.4	0.60	0.17	0.20
Excreta	1141	5.15	3.7	0.63	0.24	0.20

* Calculated on a basis of wet solids.

It is estimated from available published figures that the average Chinese produces only about 80 per cent as much excreta as the average

* This is the third of a series of papers based on two years of research at the Harvard Graduate School of Engineering. For the first and second papers see *This Journal,* 14, 1304 (Nov., 1942), and 15, 56 (January, 1943).

American and that the total nitrogen content is only 60 per cent as high. This is stated to be due to lower body weights and poorer protein diet.

Human excreta are rich in phosphoric acid and potash as well as nitrogen. On the basis of prevailing prices the yearly excretal production of an average American may be calculated to be worth $1.33 as a fertilizer. For a Chinese or Japanese the value is reduced to about $0.85. The fertilizer derived from human excreta is sufficient to care for the agricultural needs of the land in the Far East, but not in the United States. About 85 per cent of the fertilizer value of excreta is contained in the urine, and is therefore lost in the effluent of ordinary sewage treatment plants.

Standard Excreta

The make-up of the average composite of urine and feces from a mixed population called "standard excreta" is given in Table II.

Table II.—*Grams of Moisture, Solids and Nitrogen in 1000 Grams of Standard Excreta*

	Moisture	Total Solids	Organic Solids	Inorganic Solids	Nitrogen as N
Feces	58.2	17.2	14.9	2.26	0.75
Urine	890.5	34.2	22.2	12.0	5.55
Excreta	948.7	51.4	37.1	14.26	6.30

This standard excreta was prepared from urine and feces collected separately from members of the Harvard graduate school. The feces were finely ground and mixed and both the urine and feces were analyzed. They were then mixed on the basis of 5.55 grams of urine nitrogen to 14.9 grams of volatile fecal solids per 1000 grams of mixture.

Seeding, Gas Collection, and Chemical Tests

Digested Imhoff tank sludge was used for seeding at a 1:2 ratio to the weight of volatile solids. Most of the experiments were batch experiments conducted in four-liter Pyrex bottles. Five experiments were made with semi-weekly withdrawals and additions of solids.

Gas was collected and analyzed, and served as the main means of measuring the progress of digestion. Total and volatile solids were determined before and after digestion. These figures were found to have little significance because of the hydrolysis of urine and large losses on drying and ignition. Other tests were made for pH, total and ammonia nitrogen, bicarbonates (2) and volatile acids. All digestions were conducted at an incubation temperature of 25° C.

Separate Digestion of Urine and Feces

The experiments show that seeded feces (no urine present) digest as rapidly as seeded sewage solids but unseeded feces take over ten times as long to digest. An average gas yield totaling 500 liters, including

350 liters of methane, per kilogram of volatile solids added, was noted during the digestion of feces. In the digestion of the seeded feces, an initial pH of 6.9 to 7.0 would rise to 7.2 to 7.6 with only a slight tendency to drop during the first few days; otherwise digestion is essentially the same as that of sewage solids.

In the separate digestion of urine, the breakdown of urine into ammonium carbonate and bicarbonate is very rapid when the urine is adequately seeded and sufficient food is present to support the organisms responsible for digestion. The equation for the decomposition of urea is as follows:

$$CO(NH_2)_2 + 2\,H_2O \rightarrow NH_3 + HNCO + 2\,H_2O \rightarrow (NH_4)_2CO_3,$$
$$(NH_4)_2CO_3 + CO_2 \rightarrow H_2O + 2\,NH_4HCO_3.$$

When urine and feces are mixed the urine breaks down to form ammonium carbonate, but insufficient carbon dioxide is present for the production of bicarbonates. This results in a high pH of the mixture (8.6

TABLE III.—*Chemicals Employed in Inhibition Experiments with Seeded Feces*

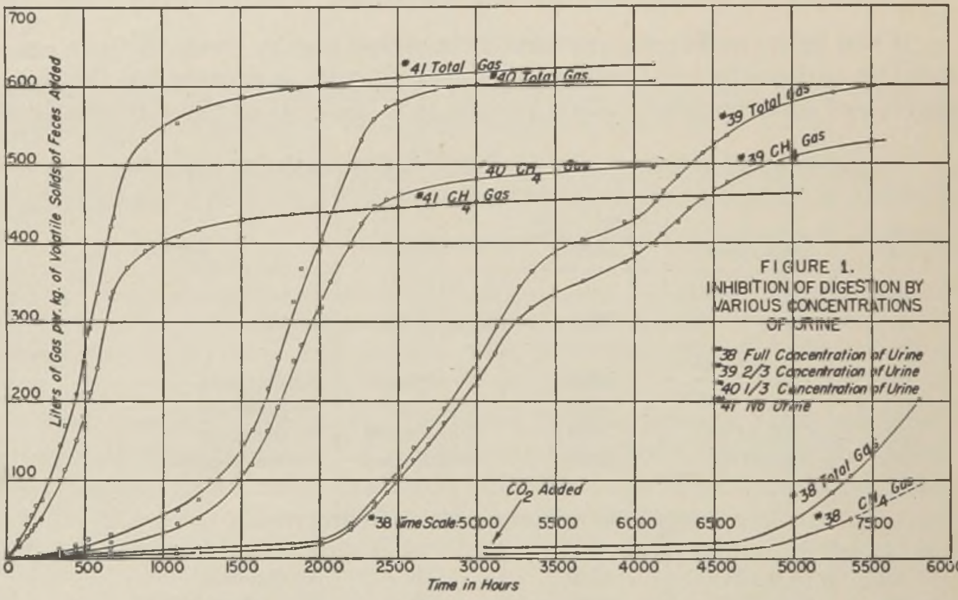
Experiment No.	Chemical Employed	Initial Concentration in Whole Mixture (p.p.m. as N)	pH Adjusted to:	Remarks
Series A (Pilot experiments in 250 c.c. bottles)				
(a)	Urine	3000	Unadjusted	No digestion
(b)	Urea	3000	Unadjusted	No digestion
(c)	$(NH_4)_2CO_3$	3000	Unadjusted	No digestion
(d)	NH_4HCO_3	3000	Unadjusted	Normal digestion
Series B (Full scale experiments in 4-liter bottles)				
(19)	$(NH_4)_2SO_4$	4280	7.0	No digestion
(20)	NH_4Cl	4280	7.0	25% rate of blank
(21)	NH_4HCO_3	4280	7.6	50% rate of blank
(22)	*$(NH_4)_2CO_3$	3960	8.7	No digestion
(23)	Na_2SO_4	4280‡	7.2	No digestion
(24)	NH_4NO_3	4280	7.0	No digestion
(25)	*$CO(NH_2)_2$	4280	7.9	No digestion
(26)	KOH for pH	0	8.2	Above pH 8.3–8.5 digestion almost stops
(27)	Blank	0	7.05	Digests rapidly
Series C (Full scale experiments in 4-liter bottles)				
(52)	NH_4HCO_3	0	Unadjusted	Rate = 107†
(57)	NH_4HCO_3	710	Unadjusted	Rate = 100
(58)	NH_4HCO_3	1420	Unadjusted	Rate = 105
(59)	NH_4HCO_3	2820	Unadjusted	Rate = 94
(60)	NH_4HCO_3	4260	Unadjusted	Rate = 81

* Later add 30 gms. sucrose and digestion goes on to completion.
† Rate = liters of total gas per kilogram vol. solids per hour.
‡ Figures as though Na ion were equal to NH_4 ion.

to 8.8) and completely stops methane digestion of the feces. Instead the feces are broken down slowly into "volatile acids." These in turn lower the pH (to around 7.6 to 8.0) but at the concentration present are in themselves very inhibitive, and the methane digestion remains at a standstill indefinitely.

Inhibition of Digestion by Various Ions

In order to determine the true cause or causes of the inhibition in the digestion of excreta, various pure chemicals were added to seeded feces. Table III gives the basic data, with remarks for three series of such experiments.



The results obtained from this study and those taken from other sources, as well, show that both urea and ammonium carbonate (4,300 p.p.m. as nitrogen) completely prevent the digestion of seeded feces but that the same strength of ammonium bicarbonate only retards the rate of digestion by 25 to 50 per cent (see Table III). Sulfate ion (1.4 per cent) in combination with either sodium or ammonium ion was found to be completely inhibitive even when the pH had been adjusted to 7.0. It is thought that ions such as ammonium and calcium are not so inhibitive as the stronger alkaline ions, sodium and potassium. A combination of ions from a weak base and a strong acid, or vice versa, is generally more inhibitive than that of ions from two strong or two weak bases or acids. Good methane digestion does not occur below pH 6.8 nor above pH 8.2.

Results of a series of experiments (38 to 41) with different concentrations of urine in seeded feces are shown in Fig. 1 and Table IV. Examination of this figure and table shows that the time of lag before digestion starts increases, and the rate of digestion decreases, as the urine concentration is increased. Concentrations of ammonia expressed as 1000 p.p.m. N remained almost constant during the time of digestion and were 5.4, 4.0, 2.5 and 0.9 for experiments 38 to 41 respectively. The critical urine concentration causing complete inhibition lies between 2,350 and 3,525 p.p.m. of urine nitrogen. The correlation between inhibition and either high volatile acids concentration or high pH is noticeable. The effect of added CO_2 in Experiment 38 should also be noted.

TABLE IV.—*Inhibition of Digestion by Various Concentrations of Urine Chemical Data*

Time in Hours	Volatile Acids 1000 p.p.m. as HAc				Bicarbonates 1000 p.p.m. as CO_2				pH			
	No. 38	No. 39	No. 40	No. 41	No. 38	No. 39	No. 40	No. 41	No. 38	No. 39	No. 40	No. 41
0	1.5	1.5	1.5	1.5	—	—	—	—	8.7	8.7	8.7	7.2
240	—	—	—	—	—	—	—	—	8.7	8.7	8.2	6.9
660	—	—	—	—	—	—	—	—	8.6	8.4	7.8	7.2
1280	6.6	7.2	8.0	0.4	13.1	9.7	4.2	4.2	8.6	8.3	7.4	7.2
1680	8.2	7.5	5.0	0.2	13.0	8.0	5.2	3.9	8.6	8.3	7.7	7.2
2330	11.2	7.5	0.6	0.1	13.0	8.0	6.9	3.7	8.5	8.1	7.9	7.2
3140	10.8	4.1	0.3	0.1	12.1	9.1	7.3	3.4	8.4	8.1	7.8	7.2
5060	9.8*	0.8	0.2	0.1	10.2*	10.2	7.5	2.8	8.3*	8.0	7.6	7.2
5080	—	—	—	—	—	—	—	—	7.6	8.0	7.6	7.2
5520	8.8	0.8	0.2	0.1	10.2	10.6	7.5	2.6	7.5	8.0	7.6	7.2

* CO_2 added.

Mixtures of seeded feces and various concentrations of ammonium acetate at different values of pH were used to study the inhibition of digestion by the accumulation of high concentrations of acetate during the storage of excreta. The results show that, at pH 7.2, 2000 to 4000 p.p.m. of ammonium acetate as HAc is not very inhibitive, but that an increase to 8000 or 10,000 p.p.m. reduces the gas production rate by 50 per cent and doubles the time required for 90 per cent digestion. If the ammonium acetate concentration is gradually increased to 13,000 p.p.m., the digestion rate is reduced to 5.5 per cent of normal. Given sufficient time (400 hours), however, a suitable flora is developed, and digestion proceeds normally. With 3000 to 6000 p.p.m. of ammonium acetate present, a progressive increase in pH above 7.6 causes more and more inhibition until at pH 8.2 or 8.3 the digestion is completely and permanently stopped.

The results of these inhibition experiments indicate that excreta can be digested with little difficulty if the ammonium carbonate, resulting from the rapid decomposition of the urine, can be converted into ammonium bicarbonate, or if the pH can be lowered. This may be accomplished by adding carbon dioxide in some form. The obvious way to accomplish this is to digest some carbon-dioxide-producing substance such as cellulose or garbage together with the excreta. Lowering the pH by addition of strong acids has been shown to be inhibitive.

Digestion of Carbon-Dioxide-Producing Substances

Before mixtures containing carbon-dioxide-producing substances were digested, the gas production of these added substances was determined. The gas produced from well-seeded sucrose, starch, and cellulose (filter paper) checked with Buswell's (4) general formula for the digestion of carbohydrates:

Table V.—*Digestion of Seeded Excreta with Carbon-Dioxide-Producing Substances*
Chemical Data

Time in Hours	Volatile Acids 1000 p.p.m. as HAc					Bicarbonates 1000 p.p.m. as CO_2					pH				
	No. 33 Cellulose	No. 34 Starch	No. 35 Sucrose	No. 36 Rice Straw	No. 37 Garbage	No. 33 Cellulose	No. 34 Starch	No. 35 Sucrose	No. 36 Rice Straw	No. 37 Garbage	No. 33 Cellulose	No. 34 Starch	No. 35 Sucrose	No. 36 Rice Straw	No. 37 Garbage
0	0	0	0	0	0	—	—	—	—	—	8.7	8.7	8.7	8.7	8.7
125	3.5	8.0	6.0	4.6	6.0	—	—	—	—	—	8.7	7.6	7.5	8.7	8.0
250	4.5	11.4	8.6	6.8	8.6	—	—	—	—	—	8.7	7.3	7.4	8.6	7.8
500	5.9	13.8	11.0	9.0	11.0	—	—	—	—	—	8.5	7.4	7.6	8.4	7.6
1800	9.5	16.0	14.6	12.0	14.0	12.0	9.2	9.5	11.0	8.6	8.5	7.4	7.6	8.0	7.4
2600	10.8	14.4	15.8	8.8	14.4	10.4	8.4	9.0	11.4	7.8	8.3	7.7	7.5	8.1	7.5
3500	13.0	3.5	12.0	3.2	6.4	8.0	14.0	10.5	13.5	11.0	8.1	8.1	7.8	8.1	7.8
4000	14.4	2.8	6.0	3.2	2.2	8.5	15.0	13.8	16.8	15.0	7.5	8.1	8.1	8.0	7.9
5500	3.8	0.3	1.0	0.6	0.5	10.0	16.0	15.2	15.6	15.2	7.9	8.1	8.1	8.0	8.0

$$C_nH_aO_b + \left(n - \frac{a}{4} - \frac{b}{2}\right) H_2O \rightarrow \left(\frac{n}{2} - \frac{a}{8} + \frac{b}{4}\right) CO_2 + \left(\frac{n}{2} + \frac{a}{8} - \frac{b}{4}\right) CH_4,$$

where C, H, and O have their usual chemical significance, and the subscripts refer to the number of the respective atoms in the molecule.

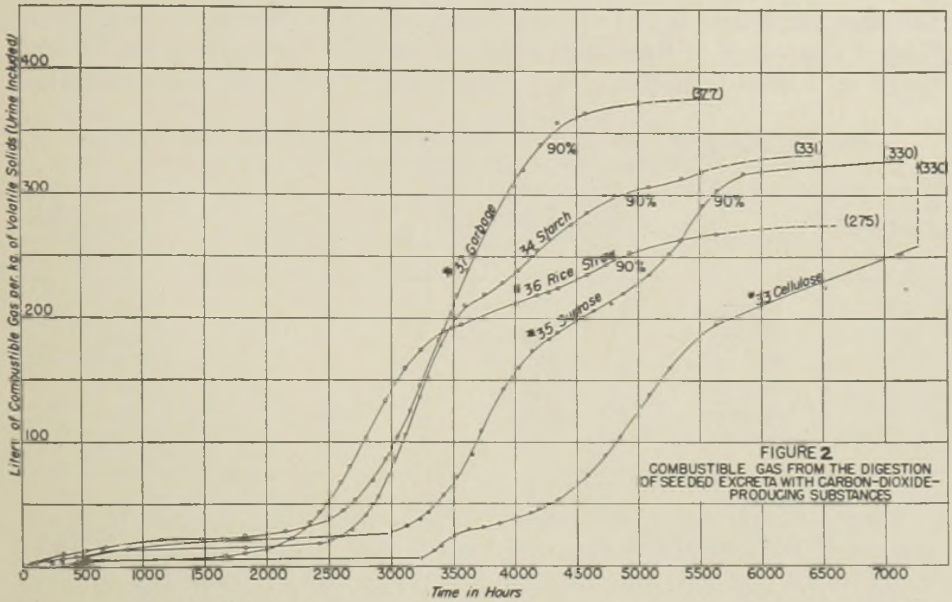
A synthetic garbage, made to standard specifications, produced 337 liters of CO_2 and 249 liters of CH_4. Rice straw produced 187 liters of CO_2 and 249 liters of CH_4. Urine was used to control the pH during digestion and a correction was made for the CO_2 absorbed by it. Rice straw digests at a rate about equal to excreta, but the other substances digest three or four times as rapidly.

Digestion of Excreta with Carbon-Dioxide-Producing Substances

(1) *Batch Experiments*

This series of five experiments was designed to study the effect of added carbon-dioxide-producing substances on the digestion of seeded excreta. Each four-liter bottle contained 2000 grams of the wet standard excreta and 1000 grams of digested sludge (1 part sludge to 2 parts standard excreta on the basis of volatile solids). The weights of added substances, calculated to produce just enough CO_2 to change all the nitrogen in the urine into ammonium bicarbonate, were as follows for these experiments:

Experiment 33—21.4 grams of cellulose.
Experiment 34—21.4 grams of starch.
Experiment 35—22.6 grams of sucrose.
Experiment 36—24.5 grams of rice straw (assumed to be 90 per cent cellulose).
Experiment 37—25.4 grams of standard garbage (assumed to produce 350 liters CO_2 and 350 liters CH_4 per kilogram of volatile solids).



The accumulative combustible gas is plotted in Fig. 2, and Table V gives the changes of pH, bicarbonates, and volatile acids during the course of digestion.

Table VI gives the maximum rate of digestion, the time required for 100 per cent digestion at this maximum rate, and the actual time required for 90 per cent digestion. Table VII sums up the theoretical and measured gas production and Table VIII gives the solids and chemical data before and after digestion. The gas data were calculated on the basis of liters of gas produced per kilogram of volatile solids in all the fresh material added, *i.e.,* urine, feces, and carbon-dioxide-producing substances. To compare these data with those for feces or sewage sludge, multiply these values by

$$\frac{\text{Total fresh volatile solids}}{\text{Total fresh volatile solids} - \text{urine volatile solids}},$$

or

$$\frac{2.869}{2.869 - 0.717} = 1.333 \text{ (figures from Table VIII).}$$

A lag of from 100 to 135 days occurred in each experiment before rapid gas production began. Inspection of the chemical results in Table V reveals the reason for this lag. High concentrations of volatile acids have accumulated and inhibit the digestive process. Digestion will proceed only after a flora has been developed which will work under these conditions.

Even after 100 to 135 days the rates of digestion in these experiments were much lower than when feces were digested alone. The maximum rate of digestion, the time required for 100 per cent digestion at this rate, and the actual time required for 90 per cent digestion are given in Table VI for each of these experiments. These rates must also be multiplied by 1.333 to compare them with those of feces and sewage sludge.

TABLE VI.—*Maximum Digestion Rate, Time for 100 Per Cent Digestion at Maximum Rate, and Actual Time for 90 Per Cent Digestion for Experiments 33–37*

Experiment No.	Material Added	Rate (max.) in Liters of CH_4/Day/Kg of All Fresh Solids Added	Time in Days for 100 per cent Digestion at Maximum Rate	Actual Time in Days for 90 per cent Digestion (Lag Included)
33	Cellulose	0.153	90	351
34	Starch	0.264	52	200
35	Sucrose	0.194	71	232
36	Rice straw	0.217	53	200
37	Garbage	0.263	60	175
Average		0.218	65	232

These solids figures are taken from Table VIII. To obtain a better idea of the actual time required for 90 per cent digestion, 135 days should be subtracted from the time given for Experiments 33 (cellulose added) and 35 (sucrose added), and 100 days should be subtracted from the time given for the others. The basis for this correction is that in actual practice the proper digestive flora would be built up and this lag of 100 or 135 days thus would be eliminated. For Experiment 37 (garbage added) this would mean that the actual time for 90 per cent digestion would be only 75 days. If digestion proceeded at the maximum rate, however, it would be 60 days. For some reason digestion in Experiment 33 (cellulose added) proceeded rather slowly, but in Experiment 36 (rice straw added), which is cellulose in another form, digestion proceeded rapidly.

All but Experiment 33 (cellulose added) produced the theoretical quantity or more of gas. In Experiment 33 gas was still being produced freely when the experiment was discontinued and there remained at that time 3680 p.p.m. of volatile acids as HAc. These on decomposing would produce 52.3 liters of CH_4 per kilogram of total fresh volatile solids. It is estimated that the remaining 25 liters would have been produced from the organic matter present.

The gas values in Table VII are calculated as liters produced per kilogram of total fresh volatile solids added. These dry volatile solids for each bottle were 29.2 grams of feces, and 21 grams of urine; to this must be added the dry volatile solids for cellulose, starch, etc., given above. Since the sums of these values were different in all cases except for Experiments 33 (cellulose added) and 34 (starch), the gas produced by the same weight of feces in each was slightly different. The total and combustible gas production values for feces in Table VII were converted from the values of 620.6 liters of total gas and 455.6 liters of CH_4 per kilogram of feces, at the end of 3700 hours in Experiment 41 (see Fig. 1 and Table IV). The feces used in Experiments 33 through 37 and in Experiment 41 were taken from the same batch.

The carbon dioxide absorbed by the urine was calculated to be just equal to that amount required to convert all the nitrogen present in the urine to ammonium bicarbonate.

TABLE VII.—*Theoretical and Measured Gas Production for Experiments 33–37* *

	No. 33 Cellulose	No. 34 Starch	No. 35 Sucrose	No. 36 Rice Straw	No. 37 Garbage
Total gas from feces	258	258	254	250	245
Total gas from CO_2-producing material	246	246	242	143	272
Total gas absorbed by urine	−123	−123	−121	−119	−117
Sum of total gas produced	381	381	375	274	400
Actual total gas produced‡	400§	435	432	335	480
CH_4 from feces	205	205	201	198	194
CH_4 from CO_2-producing material	123	123	121	82	160
Sum of CH_4 produced	328	328	322	280	354
Actual CH_4 produced‡	305§	331	330	275	377
Theoretical CO_2 produced†	53	53	53	−6	46
Actual CO_2 produced†	95	104	102	60	103

* Gas values are all in liters per kilogram of the sum of the fresh volatile solids added (V.S. used are not corrected for loss on drying).

† Total gas minus CH_4 gas.

‡ Taken from graph.

§ Has 52.3 liters added in for CH_4 produced by HAc still present.

It may be seen from Table VII that the theoretical and actual amounts of CH_4 produced were in very close agreement. However, in every case a great excess of CO_2 was produced. In most cases the amount actually produced was about twice the theoretical quantity. The same condition has been noted in all experiments where there have been long periods of inhibition due to high pH or to large concentrations of acetates present.

Table VIII gives the solids and chemical data, before and after digestion, for each of these experiments. The solids for each substance at the beginning are given in terms of the whole volume so that their sums will equal the solids for the whole mixture. To obtain the total or volatile solids present in the mixture for any experiment add the value given under cellulose or starch, etc., to the total of the solids in the feces, digested sludge, and urine. All values given in Table VIII are measured values and should be corrected for losses on drying.

Although such solids corrections were carefully made, percentage reduction results are much lower than are indicated by the weight of the gas given off, even when the weight of combined water in this gas has been accounted for.

TABLE VIII.—*Solids and Chemical Data Before and After Digestion Experiments 33–37*

Substance	Per Cent T.S. Measured	Per Cent V.S. Measured	HCO_3— as CO_2 p.p.m.	HAc p.p.m.	Ammon. N p.p.m.	Total N p.p.m.	pH
Feces at start	1.400	1.157	346	1310	155	640	6.7
Dig. slud. at start	0.950	0.495	2890	120	75	455	7.7
Urine at start	1.640	0.717	0	270	170	3785	6.5
Total at start	3.990	2.369	3236	1700	400	4880	
Cellulose (start)	0.712	0.712	(Experiment 33)				
Starch at start	0.712	0.712	(Experiment 34)				
Sucrose (start)	0.752	0.752	(Experiment 35)				
Rice Straw (start)	0.998	0.815	(Experiment 36)				
Garbage (start)	0.895	0.847	(Experiment 37)				
Exp. 33 at end	3.23	1.45	14,300	3680	(4600)*		8.1
Exp. 34 at end	3.63	1.60	15,700	870	(4600)		7.95
Exp. 35 at end	3.34	1.47	15,200	800	(4600)		8.05
Exp. 36 at end	4.78	2.85	15,650	600	(4600)		7.95
Exp. 37 at end	3.11	1.56	14,800	800	(4600)		8.00

* Ammonia values at end are averages of the five experiments.

In conclusion, with respect to the time required for digestion, it may be stated that, although batch digestion of carbon-dioxide-producing substances and excreta is not the answer to the excreta digestion problem, the fact that digestion takes place at all is very encouraging. This observation now directs our attention to digestion with continuous dosing to remove the initial lag caused by high pH and the presence of acetates. A description of a series of continuous-dose or semi-weekly-addition experiments follows:

Digestion of Excreta with Carbon-Dioxide-Producing Substances

(2) *Semi-Weekly Additions*

In this series of experiments the same carbon-dioxide-producing substances were used as were used in the batch digesting experiments describd in the preceding pages. At the start each bottle contained only digested sludge. Twice a week, part of the contents of the bottle was removed and the proper weight of excreta and carbon-dioxide-producing substance was added to keep the weight constant. Four-liter glass aspirator bottles were fitted with special 1-inch rubber tube openings to aid in dosing the ground rice straw and cellulose.

Calculations of the correct weight of semi-weekly additions and subtractions were based on an assumed 50-day period for complete digestion of the excreta. Since each bottle was started with 3500 grams of digested sludge, the semi-weekly weight added was $3500 \times 7/2 \times 1/50 = 245$ grams. The weight of the material removed was lower by the calculated weight of the gas produced during digestion.

The fresh excreta added were made up slightly weaker than usual, with 14.9 grams of volatile solids of urine in 1107 grams instead of 1000 grams of wet mix. The reason for this was the use of a batch of weak urine. The weights of the excreta and carbon-dioxide-producing substances added and the digested mixture removed are given in Table IX.

TABLE IX.—*Weights of Materials Added and Removed Semi-Weekly in Experiments 28–32*

Experiment	Wt. of CO_2-Producing Substances Added in Grams		Weight of Wet Excreta Added in Grams	Weight of Dig. Mix Removed in Grams
	Dry V.S.	Wet T.S.		
Exp. 28 (+ cellulose)	2.23	2.23	245	244.5
Exp. 29 (+ starch)	2.23	2.23	245	244.5
Exp. 30 (+ sucrose)	2.35	2.35	245	244.6
Exp. 31 (+ rice straw)	7.45	9.54	245	250.7
Exp. 32 (+ garbage)	2.85	12.77	245	254.6

The gas produced by each semi-weekly dose upon complete digestion is given in Table X. These gas-production values are expressed in liters per kilogram of all the volatile solids added per week (urine included), and are the constants used in all further theoretical computations of weekly gas production.

TABLE X.—*Gas Produced from Semi-Weekly Dose by Complete Digestion Liters per Kilogram of All Volatile Solids Added per Week*

Experiments	Wt. of V.S. Added Weekly in Grams	CH_4 Produced by Excreta Added per Half Week (Ge)	CH_4 Produced by CO_2-Producing Substances Added per Half Week (Gs)
Exp. 28 (+ cellulose)	16.62	86.8	55.7
Exp. 29 (+ starch)	16.62	86.8	55.7
Exp. 30 (+ sucrose)	16.82	85.5	54.8
Exp. 31 (+ rice straw)	27.06	147.0*	....
Exp. 32 (+ garbage)	17.86	80.7	85.0

* Ge + Gs.

Chemical tests were run on the material removed semi-weekly for pH, ammonia nitrogen, bicarbonate, and volatile acids. Total gas was recorded from time to time and gas analyses were made on all gas removed.

Mathematical Formulation of Theoretical Gas Production with Semi-Weekly Feedings and Withdrawals

In order to study digestion as it progresses we must first formulate the theoretical progress of the reactions in these semi-weekly addition experiments. The formulation theory can be divided into two parts:

The first part is a formulation based on the actual dosing rate and a digestion rate assumed to be constant. By this method the theoretical potential gas remaining and the rate of theoretical gas production can be computed for any week. The gas rate curve can also be integrated into a summation gas curve that will give a good approximation of the expected total gas produced at the end of the experiment.

Before any general formula may be derived for the theoretical gas production of a periodic withdrawal and feed digestion experiment certain assumptions should be made clear. First, we shall assume that the withdrawals are made only after complete mixing, and before the fresh material is added. It is also necessary to assume a constant rate of digestion for the added material, that is, a constant gas production per unit weight of digestible material remaining.

The following symbols will be used in our further discussion of the mathematics of this derivation:

T = assumed time for total digestion = 50 days.

t = time between doses of fresh materials or between withdrawals of digested material = $3\frac{1}{2}$ days = $\frac{1}{2}$ week.

$a = t/T$ = fraction of total material added each $\frac{1}{2}$ week.

b = fraction of total material digested each $\frac{1}{2}$ week, or rate of gas production.

a_1 and b_1 = $(1 - a)$ and $(1 - b)$ respectively.

G = gas produced at end of time T, or by 100 per cent digestion of a single dose.

W = total weight of the digesting mass (remains almost constant).

$w = W \, x \, a$ = weight of fresh volatile solids added in each dose.

u = weight of digested material withdrawn = w − weight of gas produced by W.

g_1, g_2, g_3, etc. = gas produced during the 1st, 2nd, 3rd, etc. weeks.

P_1, P_2, P_3, etc. = total potential gas remaining in bottle at the end of the 1st, 2nd, 3rd, etc. weeks (this equals the potential gas included in the weights u).

Figure 3 shows diagrammatically the mechanics of digestion during periodic withdrawals and feedings. The case presented here is the more general of two described in the author's thesis. To conserve space most of the steps in the derivations must be omitted.

Withdrawals and feedings are made twice a week, but gas evolved and potential gas remaining are computed only once a week. If the experiment is started by making a withdrawal and a feeding, the total potential gas at the beginning equals that produced by 100 per cent digestion of a single dose, or

$$P_0 = G.$$

The potential gas remaining at the end of the first week (see Fig. 3), P_1, equals that at the beginning, P_0, minus that lost as gas during the first half week, bP_0, minus that removed at the middle of the week, $(1 - b)P_0a$, plus that added at the middle of the week, G, minus that lost as gas during the second half of the week, $(1 - b)P_0(1 - a)b + Gb$, minus that removed at the end of the week, $(1 - b)^2P_0(1 - a)a + (1 - b)Ga$, plus the potential gas added at the end of the week, G, or

$$P_1 = P_0 - bP_0 - (1 - b)aP_0 + G - (1 - b)P_0(1 - a)b - Gb - (1 - b)^2P_0(1 - a)a - (1 - b)Ga + G.$$

By substituting $a_1 = (1 - a)$ and $b_1 = (1 - b)$, and simplifying the equation, we obtain

$$P_1 = P_0a_1^2b_1^2 + G(1 + a_1b_1).$$

By the same reasoning the general equation may be written:

$$P_n = P_{n-1}a_1^2b_1^2 + G(1 + a_1b_1). \qquad (1)$$

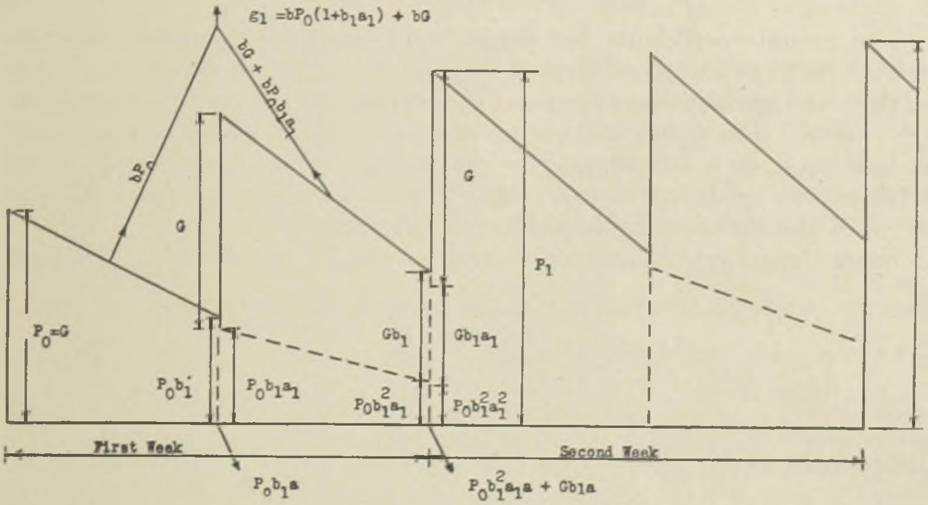


Fig. 3.—Sketch of the mechanics of digestion during periodic withdrawal and feeding. (Case 2 where the rate of digestion is faster than the rate of feeding.)

Note:
a = Per cent removal per half week
b = Per cent digestion per half week
$a_1 = 1 - a$
$b_1 = 1 - b$

Developing this equation into a geometric progression, and obtaining the sum of its terms, P_n is found irrespective of preceding terms:

$$P_n = G\left(1 - \frac{1 + b_1a_1}{1 - b_1^2a_1^2}\right)(b_1^2a_1^2)^n + \frac{1 + b_1a_1}{1 - b_1^2a_1^2} \times G. \qquad (2)$$

When $a = b = 0.07$, this becomes:

$$P_n = 7.41\,G - 6.41\,G\,(0.748)^n. \qquad (3)$$

Consider next the gas evolved during each week. Referring again to Fig. 3, it is seen that the gas evolved during the first week, g_1, is that evolved during the first half of the week, P_0b, plus that evolved during the second half of the week, $Gb + P_0(b_1a_1)b$, or

$$g_1 = P_0b + P_0(b_1a_1)b + Gb.$$

Generalizing, we may write:

$$g_n = P_{n-1}b(1 + b_1a_1) + Gb. \quad (4)$$

Substituting the value of P_{n-1} from equation (2) and simplifying, the equation for the gas evolved during any week may be obtained:

$$g_n = bG\left(1 + \frac{1 + b_1a_1}{1 - b_1a_1}\right) - bGb_1a_1\left(\frac{1 + b_1a_1}{1 - b_1a_1}\right)(b_1{}^2a_1{}^2)^{n-1}. \quad (5)$$

When $a = b = 0.07$, this becomes

$$g_n = 1.037\,G - 0.837 \times (0.748)^{n-1}. \quad (6)$$

The actual coefficients for equation (5) may be computed for the various carbon-dioxide-producing substances. The digestion rates for cellulose and garbage were assumed to be about 35 per cent per half week or $b = 0.35$. For starch and sucrose the rate is assumed to be 50 per cent per half week, or $b = 0.50$, and for rice straw the rate is almost the same as for excreta or $b = a = 0.07$. These rates are obtained from the gas curves of the carbon-dioxide-producing substances.

From the general equations (2) and (5) the following table is derived:

TABLE XI.—*Weekly Theoretical Gas Production Values for Semi-Weekly Withdrawal and Feeding Experiments*

Digesting Material	Cellulose or Garbage	Starch or Sucrose	Excreta Case 2
Value of a	0.07	0.07	0.07
Value of b	0.35	0.50	0.07
Equation no.	4	4	4
g_1	0.910 G	1.233 G	0.200 G
g_2	1.456 G	1.733 G	0.410 G
g_3	1.655 G	1.840 G	0.569 G
g_4	1.728 G	1.864 G	0.687 G
g_5	1.755 G	1.869 G	0.775 G
g_6	1.765 G	1.870 G	0.841 G
g_7	1.768 G	1,870 G	0.890 G
g_8	1.770 G	1.870 G	0.927 G
g_9	1.770 G	1.870 G	0.955 G
g_{10}	1.770 G	1.870 G	0.976 G
g	1.770 G	1.870 G	1.037 G

Computation of the Measured Theoretical Rate of Gas Production from Actual Potential Gas Remaining in Semi-Weekly Withdrawal and Feeding Experiments

Although the preceding formulas apply when the free material added digests at the assumed rate, a short period of inhibition or a reduced or an accelerated rate of digestion would completely upset the relation between time and gas production.

To obviate these difficulties, a step-by-step tabulated computation was derived by which the potential gas remaining in the bottle could be computed. The theoretical rate of gas production for any time is then found from the potential gas remaining at the time. The potential gas remaining takes into consideration all additions and subtractions of fresh and digesting material calculated as potential gas, as well as the loss of potential gas by escape, as actually measured. Only theoretical rates at any time can be calculated and not the total production. However, a check on the total gas produced is obtained at the end, for the potential gas remaining should be reduced to zero. It follows that the theoretical rate at the end should also be zero.

Different rates of digestion are assumed for the excreta solids and the carbon-dioxide-producing substances, and separate account is kept of their accumulated potential gas and weekly gas productions. The digestion rates are the same as those previously listed.

The same symbols are used as before except that g_m equals the measured gas produced during each week. Also the subscripts e and s denote that the symbol with which they are connected refers only to excreta or to carbon-dioxide-producing substances respectively.

Referring to Fig. 3, it is seen that if the recorded gas is to replace the theoretical gas in a formulation, the potential gas remaining at the end of any week must equal:

$$P_n = P_{n-1}[1 - b_1a(1 + b_1a)] + G(2 - b_1a) - g_m. \qquad (7)$$

Referring to Fig. 3 again, it is seen that the theoretical gas produced for any week is

$$g_n = bP_{n-1}(1 + b_1a_1) + bG. \qquad (8)$$

Now, by substituting the values of the coefficients into these general formulas, and tabulating each week individually, the values of P_n and g_n may be calculated. The actual gas produced during the week, g_m, is used in these calculations. This method has the disadvantage of requiring a great deal of additional work in tabulated computation. An error in the assumed rate, however, or a variation in the actual rate of digestion from the theoretical rate will not affect the time-rate relation. This is due to the fact that the potential gas remaining, and therefore the gas production rate curve, are both computed from the gas actually given off and not by the theoretical amount that should be given off. This rate curve cannot, however, be integrated into a summation curve.

Results and Conclusions

Of the five experiments conducted, only three are presented here in Figs. 4, 5, and 6. The pH values and the concentrations of ammonia, bicarbonate, and acetate are plotted at the top of each figure. The times when withdrawals and feedings were made each half week are indicated. The actual rate of methane and carbon dioxide gas production during each week and the summation of the methane produced are plotted. Three theoretical methane gas curves, two rate curves and one summation curve are included. One of these is a plot of the measured theoretical rate of methane production. The meaning of this term is explained in the immediately preceding section. This rate is derived by multiplying the actual potential gas present as excreta and cellulose,

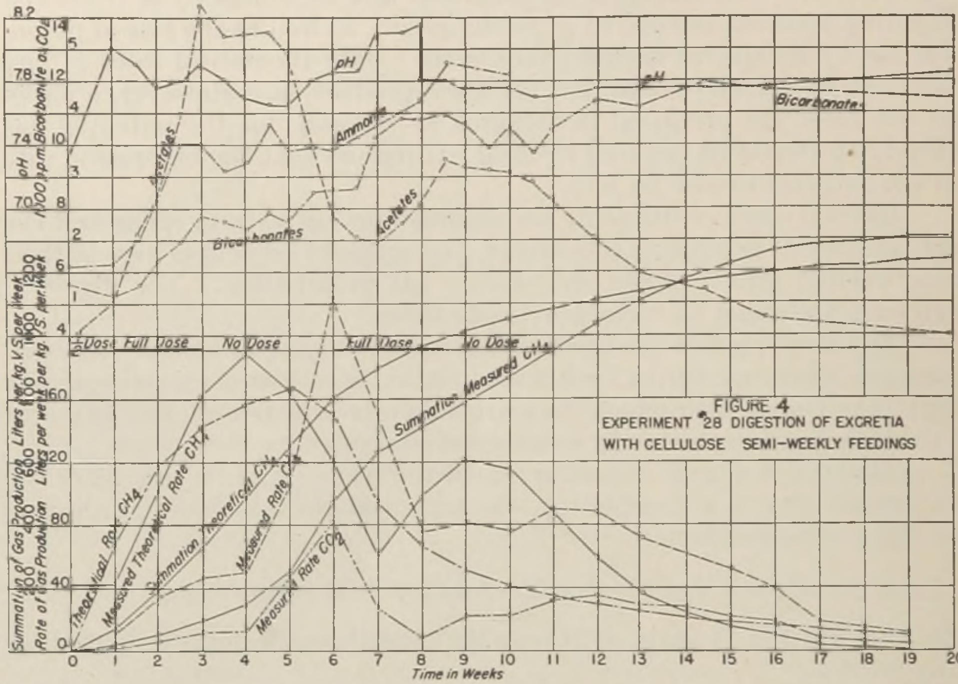


FIGURE 4
EXPERIMENT #28 DIGESTION OF EXCRETIA WITH CELLULOSE SEMI-WEEKLY FEEDINGS

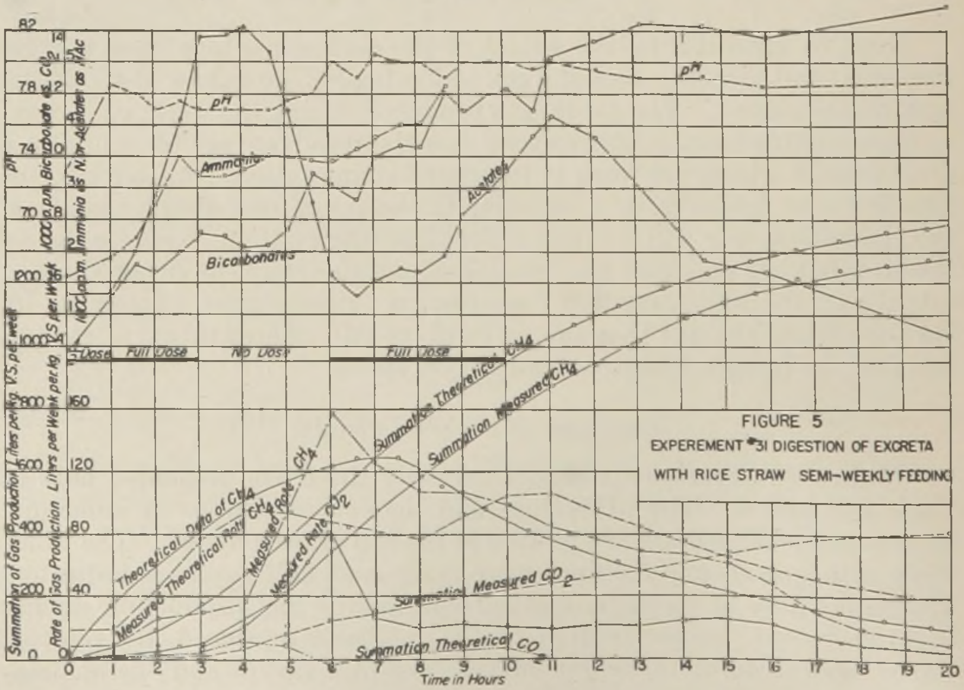


FIGURE 5
EXPEREMENT #31 DIGESTION OF EXCRETA WITH RICE STRAW SEMI-WEEKLY FEEDING

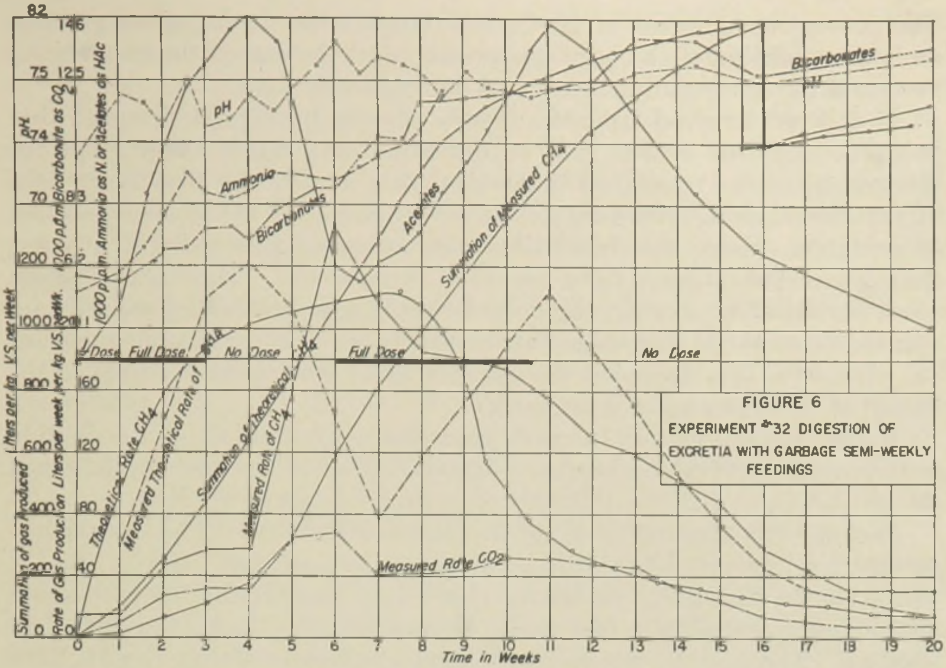


FIGURE 6
EXPERIMENT #32 DIGESTION OF EXCRETIA WITH GARBAGE SEMI-WEEKLY FEEDINGS

etc., by the theoretical rate of digestion of each substance. If this rate is higher than the actual rate, it indicates that digestion is proceeding at a lower rate than that assumed, and the potential gas as undigested solids is accumulating more rapidly than it should. On the other hand, if the actual rate is greater than this measured theoretical rate at any time, this indicates that digestion has been accelerated beyond the assumed rate, and the potential gas as undigested solids is disappearing more rapidly than had been assumed.

This curve should approach or reach zero at the end of the experiment, because if the material is digested the potential gas remaining at the end will be zero; therefore, the measured theoretical rate should also be zero.

The other two theoretical curves have no connection with the actual amount of gas produced. The first part of the rate curve is equal to the sum of g_n from excreta and g_n from carbon-dioxide-producing substance in equation 5, with the correct values of a and b substituted. The latter part of the rate curve is unimolecular. Here again the gas produced from the excreta and the carbon-dioxide-producing substance are kept separate during calculation and added before plotting. To simplify computation, the periods of no dosing were assumed to be filled in by the periods of dosing, or the same total weight of material was assumed to be added continuously at the regular rate from the beginning of the experiment. This curve could have been computed for the actual dosing schedule, but any period of deviation of the actual rate from the theoretical rate would completely disarrange the relation between the rate and the time, losing the advantage of this extra work.

The present assumption of no discontinuity in the dosing gives as close an approximation of the total gas produced at the end of the experiment as would the curve following actual dosing conditions.

It will be observed from the results plotted in Figs. 4, 5, and 6 that in every case the actual rate of digestion was much lower than the theoretical or the measured theoretical rate during the first few weeks of the experiment. This inhibition accompanied a rapid accumulation of acetates. Since this inhibition was becoming increasingly greater, dosing was discontinued for a period of three weeks. During this three-week period of no dosing, the actual rate of gas production rapidly increased beyond the measured theoretical rate. The measured theoretical rate, however, decrased during this three-week period, because the potential gas remaining decreased.

Rapid gas production in every case was accompanied by a reduction in the concentration of acetates. The digestion of the acetates lessened the inhibition and allowed digestion to proceed more rapidly.

Dosing was continued after the three-week rest. The actual gas production began to be retarded, but not so seriously as before. As the graph shows, the rate of measured theoretical gas production rose again at this point and after a few weeks became greater than the actual production. The acetates accumulated again, but more slowly than before.

These facts seem to indicate that digesting conditions are better later than they are during the first few weeks of each experiment, but that they are not good enough to prevent excess accumulation of undigested solids. The accumulation of acetates is believed to be due to too rapid feeding. The breakdown of cellulose, starch, etc., and excreta into acetates is without doubt more rapid than the break-down of the acetates into gas. If new material is added faster than the methane digestion will proceed, acetates necessarily accumulate. After they have accumulated beyond a certain point, they themselves become inhibitive and further reduce the rate of gas production.

After dosing was discontinued for the second time (see graphs) the measured theoretical gas production rate decreased until it became equal to or less than the actual rate. At the end, the measured theoretical gas production rate dropped to zero or near-zero, indicating that the accumulated potential gas had disappeared or was disappearing, and that digestion was completed or would be completed shortly. The reduction of acetates to a low concentration, the rise in the bicarbonate concentration and in the pH, are all indicative of completed digestion. In most cases the summation of the actual gas produced agrees rather well at the end of the experiment with the theoretical gas produced.

It is important to discover the maximum rate at which a mixture of excreta and cellulose, starch, etc., can be added continuously and still produce good digestion. This rate can be approximated in several different ways, but the only accurate test would be to try a rate of feeding sufficiently low for good digestion and gradually to increase it until digestion was inhibited. Lack of time in the author's experiments prevented the actual test, but an approximation of the rate was made. Referring to Fig. 6, we see that, after 11 weeks, the actual gas production rate was equal to the measured theoretical rate; therefore digestion was proceeding normally. During these 11 weeks, 5 weeks of dosing have been carried on. The required rate of dosing, then, would be only 5/11 (about 45 per cent) of that assumed. This rate is thought to be low because with a lower continuous dosing rate the flora developed could probably digest the material more rapidly than when the conditions are constantly being changed, and time is lost in the development of a new flora.

Another approximation may be made for the maximum continuous dosing rate from the ratio of the actual gas production rate to the measured theoretical rate immediately after dosing is discontinued for the second time. At the end of 8½ weeks (in Fig. 4) this would be 78/110, or 71 per cent and at the end of 9 weeks it would be 82/121, or 67 per cent. The safe maximum dosing rate is probably between 65 and 70 per cent of the assumed rate. This would raise the assumed detention period from 50 days to 72 to 77 days, or about 2½ months.

In the digestion of garbage with excreta (Fig. 8) the ratio of the actual rate to the measured theoretical rate of gas production at the end of 11 weeks was 155/224, or 69 per cent. For rice straw and excreta (Fig. 5) at the end of 11 weeks the ratio was 85/107, or 79 per cent. For starch with excreta (not included in the graphs), at the end of 12 weeks the ratio was 107/127, or 84 per cent.

It seems safe to assume that digestion proceeds without any difficulty if dosages are made semi-weekly at such a rate that the period of detention is 72 to 77 days. A reduced dosing rate may be required at first until the proper flora is developed. Digested sludge or some other suitable seeding material would of course be required at the beginning.

A higher ratio of carbon-dioxide-producing substances to urine nitrogen would probably produce better results because digestion would take place at a lower pH. However, when sufficient carbon-dioxide-producing substance is added to produce enough carbon dioxide to convert all the urine nitrogen to ammonium bicarbonate, digestion proceeds as described in the preceding paragraphs. Experiments 38 through 41 (described on page 682) contain seeded feces with various concentrations of urine present. They show that digestion will proceed, though at a much lower rate, when insufficient carbon dioxide is produced to convert all the ammonium carbonate to bicarbonate.

Although semi-weekly dosing experiments require a great deal of work and the results are difficult to analyze on a theoretical basis, certain valuable information can be obtained from them. It is impossible to obtain rapid digestion in a batch-digesting experiment when excreta and cellulose, starch, etc., are mixed, because of the inhibition, due first to high pH and then to an accumulation of acetates. In order to show that digestion is possible in a relatively short period of time, some kind of continuous dosing experiment is necessary. Several experiments should be run at different dosing rates to obtain the most useful information.

Effect of Digestion or Storage of Excreta on the Life of Pathogenic Organisms

The author's experimental work on the longevity of pathogenic organisms was limited to the coli-aerogenes group. It was desired to learn whether any correlation existed between their longevity and the condition of digestion. The results of the experimental work with other pathogens have been studied from the literature. The experimental and reviewed results may be briefly summarized as follows:

The death rate for the bacteria in the coli-aerogenes group is about the same in sewage sludge as it is in feces and excreta. The death rate, r, at 25° C., is 10 to 15 per cent per day, or the rate constant, k_e, is 0.12 to 0.16 per day.

The temperature coefficient, Q, for the coli-aerogenes group is computed to be 1.04 per degree Centigrade.

Conditions which inhibit digestion, such as high pH, or the presence of high concentrations of the $SO_4^=$ ion, seem also to increase the death rate of the coli-aerogenes group.

The most resistant Rawlins strain of *Bacillus typhosus*, according to Ruchhoft's work (5), dies at about twice the rate of the coli-aerogenes group. This death rate is greatly affected by temperature changes, Q being equal to 1.22 per degree Centigrade change. At 10–15.2° C., the Rawlins strain is estimated to be reduced 99.999 per cent in 66 days, or $K_2 = 0.175$.

From the reviewed literature it would be safe to say that in stored excreta (feces and urine) with a pH of 7.8 to 8.2 and an average summer temperature of 20° to 22° C. (68° to 72° F.) ascaris would probably not live longer than two or three months (6) (7) hookworm ova not over two or three weeks (8), and *Bacillus typhosus, Bacillus paratyphosus,* and *Bacillus dysenteriae* from 2 to 14 days (5) (9) (10). In the spring and fall (average temperature 15° to 17° C.) these periods should be about doubled, and in the winter (average temperature 8° to 10° C.) these periods should be multiplied by four or five.

Since digestion of excreta in the summer requires from 60 to 80 days, it is apparent that the digested material would be free from viable hookworm ova and pathogenic bacteria. The ascaris infestation would probably be reduced to from 0.1 to 1.0 per cent of the original. In other seasons, digestion requires a longer time and will, it is believed, cause approximately the same degree of sterility for the same degree of digestion.

Engineering Problems Involved in the Digestion of Excreta

All the experiments made in this study of excreta digestion were "bottle experiments." The excreta, rice, straw, and garbage digested were finely ground. The excreta used in the experiments were limited in their origin (American male university students). Only one temperature (25° C.) was used throughout the study. Confirmation of these data with larger and wider-scale experiments would be necessary before a well-founded design of a large excreta disposal plant could be undertaken. However, certain estimates can be made from the present data which will enable the engineer to design an experimental plant, or will give him a rough idea of the requirements for a full-scale plant.

All the estimates are based on the assumption that rice straw or garbage will be added to the excreta to aid digestion.

The weight of excreta produced per 1000 average persons in the United States per day is estimated at 2,525 lb. (40 cu. ft.). The Oriental production is only about 80 per cent of this amount.

The weights of garbage or rice straw needed per 1000 people in the United States per day are 76.8 lb. dry volatile solids of rice straw (98.5 lb. damp) or 29.4 lb. dry volatile solids of garbage (131.5 lb. wet). The average American city produces about 500 lb. wet garbage per 1000 people per day. In the Orient the amount needed is estimated at 60 per cent of these values.

The maximum time required for the digestion of excreta and a carbon-dioxide-producing substance, with continuous dose conditions, is estimated to be about 75 days at 25° C. and 135 days at 15° C.

The digestion tank capacity per 1000 population would then be $75 \times 40 = 3000$ cu. ft. at 25° C. or 5400 cu. ft. at 15° C. This may be reduced by 20 per cent in the Orient.

The gas production per 1000 population per day is estimated to be 651 cu. ft. methane and 95 cu. ft. carbon dioxide when rice straw is used, and 487 cu. ft. methane and 101 cu. ft. carbon dioxide when garbage is used to aid digestion. Oriental quantities are estimated at 60 per cent of these values. The value of this gas produced per 1000 population per day is estimated at $1.04 and $0.781 for rice straw and garbage respectively. The digested sludge from 1000 population per day is estimated to be worth $3.65 as fertilizer. Oriental values are estimated at 60 per cent of those quoted here.

Digestion tank design would vary somewhat from standard sludge digestion tanks. A deep, trapezoidal tank divided down the center by a vertical baffle with openings at the bottom and top is suggested. A horizontal ¼ in. mesh screen about one-third of the way up is called for. As the excreta reaches the plant a fine screen is used to separate the urine from the feces. The urine enters the digestion tank at the top while the gas-producing feces and the garbage or rice straw are fed in below the horizontal screen. Carbon dioxide produced bubbles up and is absorbed by the slowly downward-moving urine so that its urea content has been converted into $Ca(HCO_3)_2$ by the time it reaches the actively digesting material below.

In the second compartment the digested sludge would be drawn off at the lower end and the stabilized urine removed at the top.

The control of digestion is aided by the same tests employed during the digestion of sewage sludge. These checks include determination of pH, volatile acids, solids reduction, gas production, and bicarbonates. Solids reduction has been shown to be a rather poor check in excreta digestion because of the high percentage of volatile solids in the urine, the hydrolysis of the urea, and the relatively large losses of the solids. The rate of gas production and the per cent methane it contains offer convenient checks on the operation. The volume of gas expected per weight of material added can be calculated from formula (5). The per cent methane should exceed 75 or 80 per cent during good digestion.

Probably a good index to proper digestion of excreta is the concentration of acetates. While digestion is not greatly inhibited by concentrations of acetates under 4000 to 5000 p.p.m. as HAc, an accumulation of over 2000 to 3000 p.p.m. is generally accompanied by poor digestion.

A high bicarbonate concentration indicates that the urine ammonia is in the form of stable bicarbonate and not unstable acetate. The possible bicarbonate concentration is largely dependent on the ammonia concentration. Therefore the expected concentration cannot be stated unless the concentration of the urine nitrogen is known. If the nitrogen concentration in the urine is normal (5550 p.p.m.), the expected bicarbonate concentration should lie between 12,000 and 15,000 p.p.m. as CO_2.

A pH above 7.8 to 8.0 is indicative of insufficient or poorly digesting carbon-dioxide-producing substances. Normal digestion of a mixture of excreta and carbon-dioxide-producing substance takes place at about pH 7.6 to 7.8. The state of digestion cannot be judged by pH alone, but a knowledge of both pH and acetate concentration enables one to predict the condition of a digesting mixture. To have a more certain means of control, bicarbonates should also be determined and the amount and quality of the gas produced should be measured.

An accumulation of excess acetates should be treated by a short rest period, or a decrease in the dosing rate, or both. Adequate seeding and a period of slower digestion are needed at the beginning. The digested end product should settle rapidly, leaving a clear effluent, which may have a strong odor, though it should not be offensive.

Acknowledgment

The experiments described in this article were carried on, at the Harvard Graduate School of Engineering, under Professor G. M. Fair, whose consultation in the work is gratefully acknowledged.

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SURVEY OF SEWAGE RESEARCH PROJECTS—1943

Part II *

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

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

I. Problems Under Investigation

Research activities concerning sewage and waste treatment and stream pollution in the United States are undoubtedly affected by the war. Nevertheless, the listing of projects under study indicates that a considerable amount of work is under way and actively prosecuted. In the May issue (page 466) some 98 projects were listed; 30 additional projects are given in Table I. In the tabulation the 128 problems have been grouped under three main headings, but under each heading the types of problems have been segregated as much as possible.

An examination of the problems reveals that 70 deal with sewage treatment, 41 with industrial wastes and 11 with stream pollution. Grouping of the problems reveals the following number of problems on sewage and industrial waste research:

Sewage	No. of Problems
Sludge digestion	12
Sludge dewatering	7
Sludge disposal (fertilizer)	4
Supernatant liquor treatment	4
Scum and grease removal	6
Activated sludge treatment	7
Filtration	5

It is evident that problems connected with sludge treatment, occupying one-third of all dealing with sewage treatment, are most intensively studied. This may be the result of widespread adaptation of digestion which brings problems to the fore. Considerable interest is manifested in effective methods for removal of scum and grease, which undoubtedly deserves further experimentation.

The relatively low number of problems under study pertaining to activated sludge and trickling filters is somewhat surprising.

The number of problems under study pertaining to industrial wastes treatment is rather large and is indicative of the trend in stream pol-

* For Part I, see *This Journal,* 15, 466 (May, 1943).

TABLE I

Supplementary List of Problems Under Investigation

Sewage

No.	Title of Project	Description	Investigator, Organization
99	Inventory	Continuing inventory and statistical study of sewerage works in the United States.	S. R. Weibel, U. S. P. H. S., Cincinnati, Ohio.
100	Sewage Flows	Study of sanitary sewage flows from a large industrial plant.	Russell S. Smith, U. S. P. H. S., Cincinnati, Ohio.
101	The Effects of Various Treatment Processes on the Survival of Helminth Ova and Protozoan Cysts in Sewage	The fate of ova and cysts of parasites of public health importance is being studied following their introduction into experimental sewage treatment units of various types.	Eloise B. Cram, Nat. Inst. of Health, U. S. P. H. S., Bethesda, Md.
102	Grease	Determination of quantities of grease under different operating conditions.	Gladys Swope, North Shore San. District, Waukegan, Ill.
103	Oxidation-Reduction Studies	Oxidation-reduction potentials developed in sewage and sewage acti vated sludge mixtures.	W. Allen Moore, C. C. Ruchhoft, U. S. P. H. S., Cincinnati, Ohio.
104	Flora and Fauna	Comparison of the flora and fauna of Guggenheim sewage treatment process with that of activated sludge.	J. B. Lackey, U. S. P. H. S., Cincinnati, Ohio.
105	Filters	Comparison of the biota of biofilters and slow rate trickling filters.	J. B. Lackey, U. S. P. H. S., Cincinnati, Ohio.
106	Chemical Treatment of Sewage	Effect of various types of chemicals on sewage purification in Imhoff tanks.	Gladys Swope, North Shore San. District, Waukegan, Ill.

Industrial Wastes

No.	Title of Project	Description	Investigator, Organization
107	Sulfite Wastes	Water purification studies on waters polluted with sulfite pulp mill digester wastes.	C. R. Scott, Tenn. Valley Auth., Wilson Dam, Ala.
108	Reclamation of Sulfite Pulp Liquors	A study to develop uses for sulfite liquors and to prevent their discharge to a stream.	Castanea Paper Co., Johnsburg, Pa.
109	Treatment of Corn Canning Wastes	A study on the effectiveness of seasonal waste water storage, complete treatment with fractional regulated discharge.	Blue Mountain Canneries Inc., Martinsburg, Pa.
110	Tannery Waste	Studies on tannery waste and its effect on sewage treatment.	Gladys Swope, North Shore San. District, Waukegan, Ill.
111	Study of Wool Scouring and Dye Waste Disposal	To determine suitable method of waste treatment.	James Lees & Sons, Inc., Bridgeport, Pa.
112	Studies of Munitions Wastes	Field studies of the volume and character of wastes that may be expected from munitions plants of various types: TNT, smokeless powder, tetryl, nitroglycerine, small arms ammunitions manufacturing.	Russell S. Smith, U. S. P. H. S. Stream Pollution Investigation, Cincinnati, Ohio.

TABLE I—(*Continued*)

Industrial Wastes (continued)

No.	Title of Project	Description	Investigator, Organization
113	Laboratory Study of Possible Methods for the Treatment of TNT Wastes	To find a more economical treatment than evaporation.	Stuart Scholt, C. C. Ruchhoft, Stephen Megregeian, U. S. P. H. S., Stream Pollution Investigation, Cincinnati, Ohio.
114	Waste Problems of the Iron and Steel Industries	Study to develop ways and means to dispose or recover acid pickle liquors.	W. W. Hodge, Mellon Institute of Research, Pittsburgh, Pa.
115	Separation of Coal Dust	Study on separation of fine coal solids in beaker wash waters, resulting from coal preparation.	Evan Evans, Chairman, Coal Com. and Gen. Man., Lehigh Navigation Coal Co., Lansford, Pa.
116	Oil Field Brines	Disposal of oil field brines in relation to stream pollution.	L. Schmidt, Bur. of Mines, Petroleum Exp. Station (in co-operation with Kansas State Bd. Health).
117	Gas House Waste Studies		Gladys Swope, North Shore San. District, Waukegan, Ill.
118	Oxidation Studies	Determination of the rates of oxidation of various organic materials and industrial wastes.	G. R. Scott, Tenn. Valley Auth., Wilson Dam, Ala.
119	Trickling Filters	Effects of certain industrial wastes on trickling filters.	J. B. Lackey, U. S. P. H. S., Cincinnati, Ohio.

Stream Pollution

No.	Title of Project	Description	Investigator, Organization
120	Stream Pollution	Preparation of a report covering the sources of pollution and conditions of the major tributaries of the Tenn. River system.	G. R. Scott, Tenn. Valley Auth., Wilson Dam, Ala.
121	Organisms in Streams	Comparison of the flora and fauna of streams in clean and polluted regions.	J. B. Lackey, U. S. P. H. S., Cincinnati, Ohio.
122	Stream Organisms	Effects of munitions plant wastes on stream organisms—fish, plankton.	J. B. Lackey, U. S. P. H. S., Cincinnati, Ohio.
123	Indicator Organisms	Studies of indicator organisms appearing in streams receiving specific trade wastes other than munitions wastes.	J. B. Lackey, U. S. P. H. S., Cincinnati, Ohio.
124	Stream Organisms	Effects of certain industrial wastes from synthetic rubber and chromium plants on stream organisms.	J. B. Lackey, U. S. P. H. S., Cincinnati, Ohio.
125	The Cause of Blooms in Lakes	Sewage, trade wastes or other causes?	J. B. Lackey, U. S. P. H. S., Cincinnati, Ohio.
126	Fish	Studies of the effect of phosphorus on fish.	G. R. Scott, Tenn. Valley Auth., Wilson Dam, Ala.

TABLE I—(*Continued*)

Analytical Methods

No.	Title of Project	Description	Investigator, Organization
127	Dissolved Oxygen Determination	Application of the Hatfield photometer to dissolved oxygen determination.	Gladys Swope, North Shore San. District, Waukegan, Ill.
128	Problems in the B.O.D. Determination of Some Industrial Wastes	A study of the differences encountered in determining B.O.D. on oil wastes, small arms waste containing copper, sulfite paper wastes and TNT wastes.	C. C. Ruchhoft, Stephen Megregian, U. S. P. H. S., Cincinnati, Ohio.

lution abatement. A grouping of the problems under study is interesting:

Industrial Wastes	No. of Problems
Sugar and fermentation	5
Paper wastes	7
Textile and dyes	6
Pickling liquors	6
Acid wastes	4
Laundry wastes	4
Canning, tannery, etc.	4

The problems appear to cover rather uniformly a variety of industries. No doubt the increase in industrial activity caused by the war has some effect on the type of problem studied, but actual war industries, producing mainly acidic wastes, are represented by only a few projects. The great majority of projects pertain to problems which will remain in peace time.

The stream pollution problem may be divided into two parts: (1) surveys, (2) stream organisms. The number of surveys under way appears to be limited to two streams. Comparatively little is known about the effect of industrial wastes on the flora and fauna of streams. It is significant therefore that a number of problems are listed designed to increase the fund of information.

Of the 128 problems under study only 6 deal with analytical methods. Of these, 4 pertain to B.O.D. determinations and 2 to dissolved oxygen determinations. Either all other analytical methods and procedures are accurate enough and so well standardized that no improvement is possible, or investigators have so many other and more pressing problems that attention cannot be given to analytical methods. It should be kept in mind that the listing of problems under study is probably far from complete, because the committee is still to hear from several research and larger treatment plants laboratories where investigations are actively conducted.

II. PROBLEMS REQUIRING INVESTIGATION

Considering that the extended activities of the Research Committee have only recently been inaugurated, that the time allotted to obtain

Table II

Problems Requiring Investigation

Sewage

No.	Title of Project	Description	Suggested by:
1	Purification by Storage	The effect of prolonged storage upon sewage and industrial wastes.	Metcalf and Eddy, Boston, Mass.
2	Development of More Efficient Sedimentation Tanks in Sewage and Industrial Waste Treatment	Increasing the efficiency of sedimentation to get a greater removal of settleable and suspended solids.	Conn. State Water Com., Hartford, Conn.
3	Flow Distribution	Study on distribution of flow in various types of settling tanks to determine optimum detention, most efficient inlets and outlets, proper baffling, etc.	N. J. Agr. Exp. Sta., Dept. Water and Sewage Research.
4	Flocculation of Colloids and Small Suspended Particles in Sewage Effluents	When sewage effluents are discharged into waterways—particularly salt water—a flocculation of the smaller particles takes place. A determination of the feasibility of accomplishing this in the treatment plant would be desirable.	Conn. State Water Com., Hartford, Conn.
5	The Concentration of Ammonium Bicarbonate Increases During Sludge Digestion	To what extent does the concentration of the bicarbonates of calcium and sodium take place during sludge digestion.	A. L. Genter, Baltimore, Md.
6	Scum	A study of methods of controlling scum accumulations in sewage sludge digestion units.	W. H. Wisely, Urbana-Champaign San. Dist., Urbana, Ill.
7	Scum	A study of the influence of water supplies high in hardness in the formation of excessive scum accumulations in sewage sludge digestion units.	W. H. Wisely, Urbana-Champaign San. Dist., Urbana, Ill.
8	Supernatant Liquor	Additional studies on the treatment and disposition of supernatant liquor from separate sludge digestion units.	W. H. Wisely, Urbana-Champaign San. Dist., Urbana, Ill.
9	Digester Heat Losses	Studies of heat losses through the concrete walls of buried sludge digestion tanks in and out of ground water.	Metcalf and Eddy, Boston, Mass.
10	Trickling Filters	Factors affecting the unloading of standard and high rate trickling filters over a period of years.	Metcalf and Eddy, Boston, Mass.
11	Loading of Standard and High-Rate Filters	To obtain independently sufficient and reliable data irrespective of type of equipment.	P. Henderson, Ass. Eng. Oklahoma State Dept. of Health.
12	Treatment Effect of Recirculation on High-Rate Trickling Filters	Determination of the treatment limits.	Conn. State Water Com., Hartford, Conn.
13	Activated Sludge	Tapered loadings in the activated sludge process.	Metcalf and Eddy, Boston, Mass.
14	Lime Requirements of Sludge Used as Fertilizer	Continuous application of sewage sludge has a tendency to make soil acid. What are the lime requirements; when should lime be applied.	N. J. Agr. Exp. Station, Dept. Water and Sewage Research.

TABLE II—(*Continued*)

Industrial Wastes

No.	Title of Project	Description	Suggested by:
15	Byproduct Recovery	The use of anion-exchange resins for the recovery of byproducts from industrial wastes.	Metcalf and Eddy, Boston, Mass.
16	Settling of Sewage-Industrial Wastes Mixtures	Effect of various industrial wastes on the rate of settling of suspended solids.	N. J. Agr. Exp. Station, Dept. Water and Sewage Research.
17	Industrial Wastes Equalization Tanks	Effect of slow and fast mixing on the equalization of mixed industrial wastes.	N. J. Agr. Exp. Station, Dept. Water and Sewage Research.
18	Milk Wastes	Efficient, simple and economic method of disposal of small milk plant wastes.	J. H. Ruge, U. S. Dept. Agr., Dunidin, Fla.
19	Industrial Alcohol Waste Treatment		L. F. Warrick, Wisc. State Bd. of Health, Madison, Wisc.
20	Sulfite Liquors	Treatment of sulfite liquors from the manufacture of wood pulp.	Metcalf and Eddy, Boston, Mass.
21	Synthetic Rubber Waste Treatment		L. F. Warrick, Wisc. State Bd. of Health, Madison, Wisc.
22	Treatment of Wastes from Rubber Reclaiming and Possibly Synthetic Rubber Plants	The removal of chemicals, alkalis and dissolved materials for satisfactory discharge into streams.	Conn. State Water Com., Hartford, Conn.
23	Treatment of Dyeing and Finishing Wastes from Textile Industries	Chemical precipitation processes are now in use, but more work is necessary to develop processes which will remove, to a high degree, the B.O.D. or O.C. constituents and the color from dyes.	Conn. State Water Hartford, Conn.
24	Treatment of Wastes from Steel Mills	The removal of iron and acids from wastes by processes applicable to the smaller plants, prior to discharge of effluents into waterways. The very large plants may recover the acids and iron oxide, or produce copperas and other products.	Conn. State Water Com., Hartford, Conn.
25	Dewatering of Sludges from Chemical Precipitation Treatment Processes on Metallurgical and Textile Wastes	The development of dewatering processes so that the sludges can be satisfactorily handled for final disposal.	Conn. State Water Hartford, Conn.
26	Refinery Wastes	The disposal of refinery wastes is active in certain districts in the mid-continent area. Although facilities are available as far as laboratory and field equipment is concerned, lack of funds has prevented starting the problem.	L. Schmidt, Bur. of Mines, Petroleum Exp. Station.

Table II—(*Continued*)

Stream Pollution

No.	Title of Project	Description	Suggested by:
27	Self-purification of Streams Following Sewage and Industrial Waste Pollution	The rate of self-purification taking place in New England streams under various conditions and limits. A great deal of work has been done in the Middle West by the U. S. P. H. S.	Conn. State Water Com., Hartford, Conn.
28	Effect of Salt Water Upon Organisms of the *B. Coli* Group in Sewage Effluents	A determination of the rate of which the germicidal effect takes place and the degree of dependability would be a desirable contribution.	Conn. State Water Com., Hartford, Conn.
29	Beef Tape Worm	Sewage disposal in relation to the beef tape worm. Although it is probable that primary sewage plant effluents can contribute to the incidence rate of *Cysticercus bovis* infestation, more evidence is necessary. What degree of treatment is necessary to remove the tape worm egg from sewage.	Geo. W. Marx, Dir. San. Eng. Div. Arizona State Dept. of Health, Tuscon, Arizona.

Analytical Methods

No.	Title of Project	Description	Suggested by:
30	B.O.D. Determinations	The development of a technique for the B.O.D. determination which will more accurately measure the effect of concentrated wastes upon a stream.	G. R. Scott, Tenn. Valley Auth., Wilson Dam, Ala.
31	Conversion Effect on Volatiles During Combustion	In various types of sewage sludge what is the approximate relationship between: (a) the actual organic matter present and the volatile matter determined by the ordinary method of combustion, or (b) the actual inorganic compounds present and the ash produced and determined by combustion?	A. L. Genter, Baltimore, Md. P. D. McNamee, Sewage Treatment Plant, Dis. of Columbia.

information was relatively short, that many persons who have problems were not acquainted with the activities and that pressure of work is unusual, the response has been most gratifying. In Table II, the title of the project, description of the project and the person or organizations suggesting the problems, are listed under the same general headings as are the projects under investigation. Of the 31 projects suggested, 14 pertain to sewage treatment, 12 to industrial waste treatment, 4 to stream pollution and 2 to better methods.

It is of particular interest to note that a number of problems suggested are concerned with fundamental principles in sewage and wastes treatment. The fact that nearly as many problems requiring investigation deal with industrial waste treatment as with sewage treatment is further evidence of the trend in the whole question of stream pollution abatement. Very few of the suggested problems dealing with industrial waste treatment emphasize the necessity of by-products recovery. It would appear that those suggesting the projects rather shy away from recovery and are more concerned with proper treatment. If recovery can be accomplished, so much the better, but it is not a prerequisite.

This first attempt to collect and list research projects under investigation and requiring study may be considered successful. When the work of the Research Committee was extended in this direction, the possibility of success was doubtful. It is believed that the listing of work under way will stimulate investigations and prevent needless repetition. The listing of problems requiring study undoubtedly will aid and direct investigation. Several of the projects suggested can be studied only at places where specialized equipment or specifically trained personnel is available. Some of those who have suggested projects such as the problems connected with alcohol and rubber wastes will be interested to know that work has been authorized to be undertaken as soon as arrangements can be made by the United States Public Health Service, and others are already actively under way.

The Research Committee is ready to receive suggestions of work to be done and call attention to the problems by personal contact and publication. Anyone who has problems which are of general interest and cannot be solved for any reason, can make use of the facilities of the committee. The committee shall be glad to be of assistance to find an investigator equipped to handle such problems, but cannot take the initiative to perform the work or guarantee that study will be undertaken.

THE OPERATOR'S CORNER

Conducted by W. H. WISELY, Executive Secretary*
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SEWAGE SLUDGE FOR VICTORY GARDENS?

Is there likelihood of transmission of disease through the use of sewage sludge as a soil conditioner for vegetable gardens? Sewage works operators everywhere have been faced with this question many times in the past few months because of the Victory Garden movement and the shortage of commercial fertilizers.

Tanner, in an extensive review of the literature (*This Journal*, **7**, 611 (July, 1935)), reports that typhoid and dysentery bacteria may survive for extended periods when placed in soil, although most of the work to which he refers appears to be based on pollution of the soil by *undigested* sewage solids. Ruchhoft (*This Journal*, **6**, 1054 (November, 1934)) shows that *undigested* activated sludge may contain *B. typhosus* and should be handled with discrimination. Wright, Cram and Nolan (*This Journal*, **14**, 1274 (November, 1942)) report studies on samples of sewage and sludge at all stages of treatment, including sludge from air drying beds, and show evidence that the use of sewage sludge as fertilizer may serve to disseminate ova of several intestinal parasites.

The Committee on Sewage Disposal of the American Public Health Association, in a most comprehensive report (*This Journal*, **9**, 861 (November, 1937)), concluded that:

"From a hygienic standpoint, heat-dried activated sludge and heat-dried digested sludge appear safe for any reasonable use in agriculture or horticulture. Digested sludge, air-dried, appears safe for such purposes if used like manure and plowed in, when preparing for a crop, and if care is taken not to apply such sludge thereafter on root crops or low-lying leafy vegetables which are eaten uncooked. Thorough digestion and air-drying, as well as storage of the air-dried sludge, afford a sufficient protection. The Committee knows of no case of sickness traceable to the use of digested sludge or activated sludge."

In at least one city, there has been some objection raised by local physicians to the use of air-dried, digested sludge on Victory Gardens. If such objections become open and widespread, is it not likely that a public prejudice will develop, resulting eventually in a greatly reduced demand for sewage sludge regardless of the manner of use? Perhaps it will be best to avoid overzealous exploitation and follow a relatively

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cautious policy in our recommendations to sludge users, since, after all, there is much more to be learned about the survival and viability of pathogenic bacteria and other disease organisms after passage through ordinary sewage treatment processes. Heat-dried sludge, of course, need not be considered subject to such limitations.

It has been the writer's practice to suggest the use of sludge (digested and air-dried) on vegetable gardens *only* when it is spread over the ground surface in the fall and spaded in before the garden is planted, with an admonition not to use *any* sludge where raw-edible vegetables are to be grown. Furthermore, all domestic sludge users are directed to sections of the stock pile where the sludge is at least a year old, even though it is realized that the fertilizing qualities of such sludge may have been depreciated during storage. Where a supply has been requested by a farmer, for use on field crops, there has been no hesitancy about furnishing sludge directly from the drying beds. The precautionary comments to Victory Gardeners appear to be "good psychology" in that the user feels he is being given unprejudiced advice while the "seed of discretion" has been planted in his mind.

Remember that there is as yet no case history of disease transmitted through sludge fertilizer. Let us make sure that no such case is ever recorded!

W. H. W.

PROTECTION OF SEWAGE WORKS IN WAR TIME

Discussion * led by
P. A. Sanitary Engineer William T. Ingram,
U. S. Public Health Service, Assigned to 9th
Regional Office of Civilian Defense

Mr. Ingram:

I consider it very much of a privilege to be here today to act as a leader in what I feel to be one of the most important discussions to be held at this series of meetings.

I believe we should think of this as being a discussion of the war-time activities of sewage works men. There are two phases we can consider in dealing with war activities; one is the broad phase dealing with planning normal procedure, normal operation, possible war construction and things of that sort. We have been discussing those during this meeting. They constitute the broad field we are carrying on under normal conditions. There is another, at this time more important part of the program to be considered: that of specific activities and their relation to the war. We are in a paradoxical situation. We are being asked to assume more responsibility and at the same time, are being curtailed in personnel due to the war. We are afraid, perhaps, to do too much because we may spread ourselves too thin. But we must

* From program of Fifteenth Annual Fall Meeting of the California Sewage Works Association, Los Angeles, September 22, 1942.

also evaluate the harm that may be done if we don't do the work that is necessary. With that as foreword, I would like to proceed with a few preliminary remarks which may serve to guide the discussion.

As you all know, the literature concerning sewage works protection is incomplete at the present time. There are many articles in connection with civilian defense work, but sewerage seems to be among the lesser subjects mentioned. We all know the weak link is the one that will break, and if sewerage is the weak link and it breaks, all of the work otherwise applied is of less value.

You are familiar with the organization of the State and local defense councils. There is an operating organization (of a local citizens defense corps) in almost every city. It is observed from our work with the citizens defense corps, that there is an interest in sewerage. This interest is reflected in the departments of the cities through the public works, the utilities, fire, police, and public health departments, the city engineering staff, and the various private utility companies. Through this group of departments we get the work done, or hope we get the work done. That is the ultimate aim of our effort.

In order to orient this discussion, I have outlined briefly a number of points which I considered important and which require some consideration and thought. Therefore in order to orient our effort we should divide our thoughts in terms of (*a*) before the emergency, (*b*) during the emergency, and (*c*) after the emergency—and work from those captions through the details.

Before the Emergency

It is rather hard to set a dividing line of thought under this caption. I am going to call on many of you here to discuss as many of these points as you feel you would like to in order that we may have the sense of this group as to what is being done at this time in the sewage works field. It must be realized that many of the points may be logically included under any or all of the captions.

1. We have first, and perhaps fundamentally, a basic study of the treatment works. One of the primary concepts we need to work on in consideration of this particular item is that we can anticipate illogical behavior. We don't know what the civilian population is going to do when we have an emergency. We can only guess; but our guessing should be intelligent—based on probabilities and experience. We need maps of sewers, and areas of critical use in order to know their location and relationship with other activities concerned with the war effort. Concentrations of industry and population may affect the sewerage system.

2. We need to know something of the security of our system and treatment works. Protection against sabotage is not easy. I would suggest that each one of you pretend you are the saboteur—that you are going to sabotage your system and treatment works. Apply that plan and you will be doing what the saboteur plans to do. He is intelligent and knows what he is doing. He will do probably the very thing

you figure out, and possibly a little more. Put yourself in that position first, then come back to your present position and say, "I am going to protect against that plan of sabotage as far as I am able to, if the structure is worth protecting."

3. We need to protect against physical damage such as fragmentation and blast. Evaluate your structure piece by piece. If any part of it can be eliminated without impairment of the operation of your works, then you need not worry about that part, but if any part is vital to your system, you do need to worry.

4. Anticipate heavier loads on the system because of war activities. Either volume or strength, or both, are likely to be increased. We need to think of the possible damage caused by stream pollution, the health hazards, and any other dangers attendant upon the expansion of a municipality and its functions in the sewerage field, due to increased population and increased industrial activity. Such increases bring problems which we haven't had to face before on the same scale. These are not normal problems. The improvements may be urgent. The question of how money, materials, supplies, and labor may be made available to make necessary changes, requires some very intelligent thought.

5. We need to know that the personnel that is working on the sewerage system can be trusted. One individual can do a tremendous amount of damage if he is allowed to do what he would like to do if he is in the employ of the enemy. You need to identify your men in responsible jobs so others may know they have the right to do what they are doing.

6. Prepare to train personnel. We must be prepared for the possibility of situations arising when regular employees enter the service and new, inexperienced men come in. Accident hazards are increased and damage to the system may be caused by new employees. In many small cities, if the operator should be injured during a bombing incident, there would be no one to take his place. We should have relief operators and auxiliary men who are well enough trained to take over in event of necessity. These may be volunteers or perhaps part-time employees.

7. Administrative organization is one of the most important things in the whole war effort as I see it. There must be coordination between all departments and all services of the cities' defense forces. Such coordination must be worked out, with every man working participating, if the Civilian Army is to function at the time it is needed.

We must utilize the manpower on the basis of maximum efficiency. Avoid duplication of work, and dual responsibilities. Recently I had occasion to discuss the latter point with a superintendent of a water plant who had been assigned to an air-raid listening post. Now is the time to correct such inconsistencies in the defense plan.

8. Financial and legal problems are multiplied under war conditions. It becomes necessary in the interest of speed to sacrifice many rights and privileges which are proper and justified in normal procedures. Some of the legal and financial difficulties can be anticipated if careful attention is given to defense planning. There will be no time for discussing technicalities while bombs are falling.

The Emergency Period

1. How and when will repairs be made? Are they going to be made after or during the damage? Should they be temporary or permanent? Repair crews should know their work, so that maximum repairs can be made in minimum time. There has been a little experience in California on the type of thing that can be very real to all of us. You all remember the recent floods when the sewerage system of San Bernardino was torn out of the river-bed and for a number of days the sewage was carried down the side of the street in a ditch. Until that ditch was constructed the sewage was running all over the pavement. We have to draw on those experiences we know about, and allow our imagination to go ahead from there and think of damage that may be caused. . . . In England it has been suggested that if one thinks of the damage that can be caused, multiply by two and add a safety factor, one may be approximating the damage that may be caused in the actual disaster.

2. We have to operate the system as well as repair it. Increased water use for fires, and tremendous amounts of water for decontamination service, may be expected. Decontamination water is as dangerous as the original vesicant gas in many instances. Broken water pipes will contribute water to a combined system or storm drain. Do we have by-passes that can be operated if necessary?

Are we going to have stoppages in the sewer system which will cause backing up of sanitary sewage into basements or houses or in the streets? If sanitary sewage or polluted water gets out of bounds, who is to be notified? The Health Department has a real interest in protecting the health of the people at all times. Notification of health authorities or co-operation therewith is a necessity in time of emergency.

3. We need to think of the use of the sewage laboratory in a little different terminology than we do ordinarily. Can it be used by other agencies?

4. During emergencies we have community sanitation to worry about. In congested areas it is necessary perhaps to build public latrines in the streets or in the neighboring parks or wherever there may be open ground, to keep the community reasonably sanitary during emergencies when water and sewer lines are broken and normal functions cannot go on.

5. We need to think of the possibility of interchange of equipment, materials, and personnel—when and where needed. Perhaps the bombing incident is of such magnitude that the local crews cannot handle it. Then we like to feel we can call on our neighbors to help us take care of that situation.

After the Emergency

1. There are going to be a tremendous number of financial and legal problems develop. They should have been considered as much as possible ahead of time, but naturally some will have been overlooked. Everything possible should be accomplished between the first and second incidents, to smooth the way for more efficient procedure.

2. We should analyze the shortcomings of our plans. We shouldn't say everything is perfect. We can't possibly plan every detail of an emergency; there are bound to be some things left out. But we can apply a critique to the damage and to the plan of operation and the next incident will find us better prepared.

3. Last, but not least, is the task of reconstruction. This will have to be accomplished with whatever materials are available and may require many substitutes. Ingenuity will be required to complete the work.

I would now like to call on a few of those present who have been working on this problem of protection of sewage works in war time. I would like to hear from Mr. Kennedy and then Mr. Randall to discuss this from the viewpoint of the City of Long Beach.

MR. KENNEDY (City of Long Beach):

The matter of civilian defense has been given most serious consideration in Long Beach, probably intensified by the experience of some ten years ago. Following the earthquake, an organization was set up which continued as such until the present Council of Defense was authorized, when it was a comparatively simple matter to switch the original set-up over to the present plan.

The matter of protection against sabotage for war emergency involving damage to sewers and pumping stations, et cetera, had not been seriously considered before Captain Ingram visited our city a short time ago, and following Captain Ingram's suggestion, we are making a survey intended to locate and protect those points of the lateral sewer outfall system and pumping stations which may be considered as vulnerable in the event of a raid. Also, it is proposed to seal, or otherwise protect manholes against opening by unauthorized persons. The necessity of such protection was brought very forcibly to our attention a month or so ago, when one of our pumping stations was completely disrupted—whether by accident or sabotage is not yet known.

So far as general repairs are concerned, I will leave that matter to my associate, Mr. Randall, who, as a member of the Defense Council, is more familiar with the plans covering activities of the Public Service Department.

However, from an actual standpoint, and to care for emergency calls, our unit has set up a plan and has organized, in addition to the regular crews, several emergency crews made up largely of City employees whose duty it is to move on the "Blue" and to report to their respective headquarters which are located at strategic points throughout the city. These crews will be used in any emergency and, though a part of the Demolition Unit, will not function in other than emergency work.

Other crews made up of volunteers and led by men who are well qualified to carry on, have been organized. These, also, are to be located at strategic points throughout the city so that in the event of an incident in their locality they will proceed immediately to carry on their work, supplemented, if necessary, by crews from other districts. These crews will report on the "all-clear" signal and are expected to handle all demolition and emergency construction of any nature.

While I hope that we may never be called upon to function in actuality, I would like to report that we are ready.

I will ask Mr. Randall to carry on from here and to give you an idea of preparations which are being made to cover general repairs.

Mr. Randall (City of Long Beach):

Mr. Chairman, Mr. Kennedy and I came here to listen and not to talk. We had fully hoped that we would learn many things that would aid us in the various troubles we are having in regard to the coordination of our defense effort.

Our biggest trouble has been in trying to eliminate duplication of effort. Almost every city in California has a condition which is pretty hard to counteract. In most instances, the power companies have their own trained personnel which they naturally feel are the most competent to make any emergency repairs necessary. In fact, in some instances they refuse to allow any other personnel to "monkey with their stuff."

This same situation applies to other privately-owned utilities. Originally, Long Beach contemplated combination crews, but it was found that the utilities departments and companies did not believe that the combination crews would accomplish the results they hoped to obtain. Frankly, in Long Beach we do not feel that we have the positive answer to this problem yet.

As far as sanitary sewers and storm drains are concerned, the original OCD information that came to us in July, 1941 threw the sewers and storm drains into the Utilities Division of the Defense Council. As you know, in almost every city the sewage disposal, as well as the storm drain system, is a part of the engineering department or the department of public works. The information we received about the first of 1942 indicated that the sanitary sewer and storm drain system should be a part of the Public Works Division. The most recent information we have received indicates that they should be back in the Utilities Division. While it is realized that the information which is received from the OCD is intended only as a guide, frankly we still do not know where the OCD feels is the best place for emergency work on these facilities.

Due to the fact that we were unable to create these fairly large emergency combination crews which might handle problems occurring on all types of utilities, our emergency set-up has eliminated the use of such a crew, leaving the matter entirely to the utilities company involved and making it their problem and responsibility to repair any damage occurring to their own facilities. We have, however, included what we consider to be a "flying squadron" for more or less first-aid work or reconnaissance in the area. They would only be able to accomplish temporary repairs in order that the situation could be controlled.

Following this type of emergency service, it is intended that these crews revert strictly to Demolition and Emergency Construction units.

Nothing which has been stated or explained above is intended to convey the impression that the fullest spirit of co-operation between any of the utilities departments or companies has been lacking. In fact, the reverse is true.

Mr. Rawn (Los Angeles County Sanitation Districts):

Mr. Randall has asked how to iron out some of the duplication stumbling blocks in civilian defense work. There won't be any real answer to this until, in my opinion, we get into the thick of a situation which will call for great effort on the part of those engaged in civilian defense. In the meantime it seems basic to me that our forces of the civilian defense organization must carefully plan and chart their position in the whole picture; know pretty well what moves to make; the source of their information; the sequence of events essential to sewerage maintenance and repair following sabotage or bombing; and then proceed in straight lines as far as possible to do the job efficiently and well without particular reference to the multitude of activities which will be going on about us. This does not imply a lack of cooperation; certainly it will be necessary to plan procedure in such a manner that a minimum of interference with the functions and duties of other agencies will be had. The thing I am trying to imply here is that the doing of the job when the time becomes critical is the basic thing and those charged with the responsibility of sewage works know far better than any one else what to do and how to do it in connection with their own line of endeavor.

I would like to picture what occurs to me as a possible happening in sewer maintenance in this area following a bombing. In the first place, there is probably no place in the world where the area's economy is so thoroughly connected with petroleum products development as here in Southern California. The metropolitan district is thickly underlain with a vast number of pipe lines carrying petroleum products ranging from crude oil to the most volatile type of casing head gasoline. I am aware of certain intersections in the area where not less than thirty (30) pipe lines criss-cross—most of them carrying petroleum oils and gasoline. It is conceivable that if an area is bombed and the utilities in the street are disturbed, that the sewer will have flowing in it a large quantity of gasoline or oil. It is also very likely that incendiary bombs or explosives will be used at the same time so that the oils and gasolines will be ignited. This is not a far-fetched visualization of what may transpire, because during the earthquake of 1933 lines conveying casing head gasoline were ruptured at or near the trunk sewers of the County Sanitation Districts, and inspection the following morning disclosed that not less than twelve miles of large diameter sewers were filled with the gasoline fumes. Gasoline was being pumped from the sewer into the treatment plant and the whole lower end of the system was a potential bomb. Venting this gasoline from the line was quite a problem. It was accomplished safely, but had there been any fire in or near the sewer at the time the results would have been appalling. It isn't necessary for the sewer lines to be broken to admit casing head gasoline. I have seen the flow from a broken pipe line seep through the soil and pass into a sewer through the brick manhole walls in sufficient quantity to completely destroy the sewer were fire applied to the explosive mixtures.

There is one thing that the sewerage authorities may anticipate with complete confidence, and that is that whenever disaster overtakes anything that has a connection with the sewerage system, and there is something which needs to be gotten rid of, it will be emptied in the sewer—and it won't make any difference what it is, just so it will flow. In time of disaster we must be prepared to flood our lines first to put out fires and then protect ourselves and our treatment works afterwards.

Mr. Cortelyou (City of Los Angeles):

The subject is one of very great interest to all of us, and involves a great responsibility.

As to the conflict or disorganization which has been said to exist in the matter of handling repairs to sewers or storm drains, in thinking of our own setup in Los Angeles, I do not believe there is such a condition. I believe our basic plans of operation do not involve conflict of authority or any lack of organization. As to whether or not sewers and their repairs should be handled by the utilities, as is mentioned in the OCD instructions on public works,—it is a matter of no great concern as far as the Government is concerned. The purpose is to have the matter attended to appropriately. I understand that the OCD is not greatly concerned with observation of their manual to the exact letter, but wish to be sure an organization is set up which will perform the function. In Los Angeles the public utilities division of the Citizens Defense Corps does not handle anything but public utilities such as water, gas, electricity, telephones, ammonia lines, etc., and does not handle sewers or storm drains. The repairs to the latter are a function of the public works division, and it is planned to use, and we are organized to use, our regular employees and equipment, with the addition, as may be required, of volunteer labor from the A. F. of L. and C. I. O., and also that of various contractors. I do not anticipate confusion or duplication of effort in Los Angeles.

Like every other city, we have been greatly concerned since Pearl Harbor as to possible sabotage or air raid damage to our sewerage system. One of the great problems in repairing damage to sewers is the matter of by-passing the flow so repairs can be made. We have been concerned for a number of years with the matter of constructing by-passes for repairs or earthquake, but when the war came along we made a critical examination again and found our available by-passes pitifully inadequate. We have therefore undertaken a campaign of construction of by-passes. We pointed out several locations to the Bureau of Engineering and recommended that plans be prepared, and that the Council be asked to appropriate money for construction by contract. Also, we set up tactical problems ahead of time as to exactly what we would do under certain emergencies, and our Sewer Maintenance Division has studied them and prepared solutions, somewhat as a military organization would work out their problems in advance. We assumed that the outfall sewer would be bombed, made plans and a bill of materials of what would be needed and where to get the materials for reconstruction,—and handled it clear through to complete reconstruction.

One problem in Los Angeles, where the water supply may be exceedingly limited in fire fighting, is to give assistance to the Fire Department in the matter of water supply. Several lakes in parks have outlets through storm drain systems for purposes of draining those lakes. These have all been noted with our Fire Department and studies made so this water may be used in case of failure of the regular supply. In this connection we have also worked with the Fire Department, giving them maps of our main trunk sewers, so that sewage may also be used in great emergency by means of dams at the outlets at manholes and putting the pump suction at about half way between the top of the impounded sewage and the bottom of the manhole.

Another problem is the possibility of use of sewers or storm drains by saboteurs to damage defense industry plants. Within the boundaries of Los Angeles there are many defense plants critical to the war effort. We have studied that problem, and Captain Ingram has worked with us, giving us the benefit of his advice.

We have 3000 miles of sewers, 800 miles of storm drain, and about 60,000 manholes, which creates an enormous problem of protection. We have therefore had to take some practical approach to the problem so that we might at least be within the bounds of reason. We have reached the tentative determination that it is not probable, in most cases, that saboteurs would attempt to use sanitary sewerage systems for damaging plants. The sewers are generally full of flowing liquid, and the space above is filled with gas. This, combined with the high velocity of the sewage, makes it seem very improbable that a saboteur would attempt to enter a sewer. We have, however, considered that saboteurs might be tempted to use storm drains. We are making a careful study of 24-inch or larger storm drains, and through cooperation with the local Army officers, are making a study of those lines in relation to defense plants. The question is: how close should a storm drain be to a defense plant before it might conceivably be used for entering and firing some high explosives? We have taken a figure of 50 feet from the storm drain to the wall of the actual building as a reasonable limit. Then, how far up or down stream along that line should we attempt to protect it? What protection could be given? We are planning to provide protection by sealing manhole covers. The question has been raised as to the various methods of sealing those covers to prevent access. Welding has been suggested, but we understand that has not been found very successful in San Francisco. Bolting is another possibility, but nuts must be left exposed on top, and a saboteur may easily remove those in a reasonably short time. We have given consideration to the method used by us in silencing "noisy" covers by sealing them with asphaltic concrete of low penetration, about 30–40 or 40–50, which would be poured hot. It does make a manhole cover difficult to remove,—practically requires a blow torch to heat it. We are also experimenting with cement grout, but this does not appear promising.

In this connection I might say we have requested our Police Department to warn all of their patrol cars to be on the lookout for persons who may be attempting to enter the manholes within the streets. They have issued orders to all officers to be on the alert and demand proper identification from any persons seem tampering with manhole covers.

Mr. Frickstad (City of Oakland):

What I might say would closely parallel Mr. Cortelyou's remarks. We are making the same study he is making. Los Angeles has many large sewers and numerous culverts carrying creeks under the streets. We have precisely the same types of structures and thus our problem is the same as that of Los Angeles, although of lesser magnitude.

The subject of possible destruction of sanitary sewer raises some embarrassing questions: If such destruction should take place at an important intersection or under a railroad, it would be impossible to open a temporary channel and at the same time keep open lines of communication. We have not given much attention to this as yet, although I think it is one of the most likely things that might happen.

As to closing manholes against saboteurs in critical areas, that seems to be a puzzling problem. We have tried various recommended schemes of grouting with cement and with sulphur-silica compound and they do not create any obstruction to anyone who wants to enter. In test cases, grouting delayed our crew not more than a minute. We have a large sewer passing through a shipyard. In that case the length of large sewer outside of the yard is relatively short with only a half dozen manholes on it. We are planning to cast a layer of concrete inside the manholes under the covers, leaving a 6-inch opening for inspection purposes. That means a compressor will be required to open the manhole for any purpose whatever, which would be a difficult and noisy operation for a saboteur. It will also involve considerable inconvenience if our own crew must enter the sewer, but we do not regard this seriously as to this small group of manholes, inasmuch as we may not have to open more than one or two in a year. We have found no other practical method by which unwelcome visitors may be kept out and at the same time our own men may have reasonable access to the manholes, and therefore for the present will limit this type of activity to the most critical areas.

Mr. Frank Rossi (City of Modesto):

The gentlemen preceding me covered this field very thoroughly. It is true there are yet a considerable number of problems to be ironed out concerning protection of sewerage and water systems. My problem is primarily water supply at the present time. However, it has certain problems in common with the sewerage systems, such as pumping plants, pipe lines, etc. Perhaps I should give you a little better idea of the organization that we are setting up in Modesto at the present time, and not particularly the zones covered by the State subcommittee on water supply.

The problems are somewhat different in your coastal area than in our inland cities. We are more interested in the possibility of damage from saboteurs than we are from direct or aerial bombing. We may only be confronted with one attack rather than a series of attacks. What we are doing may be of some value to you gentlemen. All of our cities are not operated on the same principle. That is one of the things we must consider when formulating an organization to protect our utilities, as the authority of the departments is varied. I will try to give you a brief outline of our procedure in organization: There is a considerable overlap of authority in these organizations. We find it to be true especially when men appointed to the various units are sometimes appointed on as many as five or six committees outside of our regular organization. Normally they should be where they are employed. You have to have all of the departments of the city coordinated properly to get the best results. We have started to organize the entire city.

Modesto is the County seat of Stanislaus County. It has been combined with the Stanislaus County civilian defense control station. Many of the City department heads direct their operations from the control station. This simplifies the procedure. First the air-raid warden reports the cause of damage to the telephone operators at the control station; messengers transmit it to the dispatchers who relay it to public works, utilities, fire or police departments. The units we are particularly interested in protecting are the water and sewerage systems. Our orders come under the public works dispatcher, and he transmits them to the city utility control center; they are then out of the hands of the civilian defense authorities. We have one unit organized into sanitary and laboratory control, headed by the health department inspector. The water system is broken down into three units: one unit for pumping plants, one for large repair jobs, and one for services of a small nature. The repair shops are equipped with all types of machinery and operated by city mechanics. That group may be called for through the public works city control center. Our sewer system and street department have been combined as one unit and operate under the Street Department. They are organized with their crews, cleaning rods, compressors and other equipment for proper control in case of emergency.

We are having the same problem with storm sewer manhole covers that many other cities are experiencing. Sanitary pumping and water units are being guarded by constant and regular inspections as a prevention against sabotage.

The problem we had in coordinating all these different men and departments was not easy. We have accomplished our goal by calling in the department heads and familiarizing them with the procedure. We discussed the problem as to when the guards should report at the pumping plants. After some discussion it was determined that, perhaps due to the trouble in traveling during a blackout, they should be called to their posts on the first, the "Yellow," alert. They should go to their stations and remain there until given the "All Clear" signal. This will be rather hard on the guards. It won't be pleasant, for there may be many times they will report to their stations and nothing further will happen. But this is war! We are all conscious of the fact that we'll have to make sacrifices. When it does happen, we'll be ready.

Mr. Hoskinson (City of Sacramento):

Protective procedure at Sacramento has included closing of all plants to visitors and placing the water plant under armed guard, using time-check on their patrol and requiring regular calls to a central point as a further check on their movements. Provision is made for an investigation by police squad car in event regular reports are not received at the central point. Sewage pumping plants are kept locked at all times, and at one station which is isolated, windows and doors are heavily screened and barred. Protective lighting up to limits allowed, and in accordance with coast dim-out regulations is provided at all plants. Procedure for sealing vital manholes has been started along the lines of suggestions received through Major Arnold's office. Trials have been made of manhole sealing by use of lead-sulfur compounds and cement grout. We have also heard that sealing by hot lead is very effective. Present experience has not developed the best manhole seal.

Water and sewer departments cooperate in the weekly drills on test incidents, sending both water and sewer trucks to locations of incidents where such service is indicated. The local Master Plumbers Association and Plumbers Local Union have volunteered their help for emergencies and cooperate in defense drills. In case of bombing or special call, plumbers report at five (5) separate strategically located assembly points from which they move to incident locations as ordered or await pickup by city truck. Equipment of the Master Plumbers Association has been listed with the city for use in emergency. All local Unions show a good spirit of cooperation in the city defense effort.

Mr. May (City of Palo Alto):

Before we started this discussion today, I did not think there was much of a sewer problem. We are a small community and we do not have any nearby defense industries. The only possibility of attack probably would come from a stray bomb. We never considered the sewers. We thought if the plant were damaged, we could make a ditch and drain the sewers into the natural channel. But today I can see it is not as simple as that at all. When I get back I think we will follow your outline and see what we can do.

Mr. Goudey (Los Angeles City Water Department):

I happen to be on the national committee of the Sewage Works Federation. The final report of that committee will come out about a month from now. I don't believe most of us receive seriously enough the advice that was given us in the opening part of this paper. We have lost a lot of our personnel and are going to lose more. I don't believe one-third of the people here, who are going to be in the services a year from now, took that to heart. It is a serious situation. It is our responsibility to see to it that the duties of the sewage plant operators are outlined so that adequate help can be obtained. The industries have ordered their personnel sections to find out what jobs in their particular industries can be turned over to women. The water departments have made surveys to find out what jobs can be turned over to women. Power departments are doing the same thing, even as it applies to linemen, power poles, etc. Women are going to operate water pumping plants. I'm not talking through my hat—I'm telling you what representatives from Washington are telling critical industries and utilities. So why shouldn't the Sewage Works Associations figure out what jobs in the matter of sanitation and sewage disposal can be turned over to women? Obviously we won't say they should do the actual repair work. You need a woman who has a list of the names of plumbers; who is familiar with the plans of the sewer system, and who can operate sewage pumping plants. Women can be used in the operation of sewerage works, whether on a volunteer or paid basis. If the war keeps up you will find out this statement means something that we should seriously consider.

Operators should be studying the change in the character of sewage due to wastes from war industries and particularly from chromium plating plants. Sewage can become toxic from chromium. England has found a number of high-grade treatment plants completely upset by the toxic chromium wastes contributed to the sewage. Perhaps you don't know you have a plating plant in your town. It should bear investigation.

At the Santa Cruz convention I outlined a number of tests which the sewage treatment plant operators could make to determine poisons and war gases in sewage. That paper was not well received because it was given before Pearl Harbor. After Pearl Harbor a number of the members said I was perhaps right. I still say the sewage plant operator should make those simple key tests which were recommended in that paper. They are still standard and still tell us the group war gases. Each operator should know at least how to make those tests should such an occasion arise.

I think the time has come when sewage treatment plant operators should clearly keep in mind what degree of treatment is absolutely essential from a health standpoint, as contrasted with more complete treatment during peacetime. When the times get tough it might be necessary to disregard any repairs to that part of the plant which does not need to operate from the health standpoint. The operator should know the minimum degree of treatment to protect health and safety and not expend large sums of money to restore for peacetime treatment during war.

If our large reservoirs become contaminated by gases, they will be dumped into storm drains and sewers. War gases in general are toxic and will tend to destroy biological processes at treatment works. If we are going to protect ourselves from all these angles, it becomes a man-sized job. I think we should be prepared. It will take much time, thought, energy—but very little money.

Mr. Kennedy (San Francisco):

I think it is important that the public be informed on problems of sewage treatment and their relationship to public health under emergency conditions as differing from normal conditions. Under conditions of disaster, sewage may be turned into open ditches or street gutters. The public will have to be informed of the sanitary significance of sewage so discharged. The principal problem to be met in sewage treatment is the unanticipated load from industrial plants which have been established under the War Emergency. One of these in my experience has requested plant service for wastes containing a high chlorine residual. It was recommended that this waste be turned into a storm drain since it has no health significance. Wastes that are toxic must be diverted from treatment plants, and people will have to be made aware of the fact that such diversion is necessary. In the design and operation of sewage works for emergency conditions we must distinguish between the things that have definite health significance and those which are desirable under normal conditions. Those wastes which are not of themselves dangerous to health may be diverted to storm drains or natural channels with only the creation of local nuisance.

MANAGEMENT OF SLUDGE DIGESTERS *

By E. J. M. Berg

Superintendent, Sewage Treatment Works, San Antonio, Texas

I hope you permit me to approach this subject in my own hesitating and methodical way. I like to reduce each problem to its simplest principles, consider the fundamental laws of nature to be applied in its solution, and express these facts mathematically if it is possible to do so. Some learned man said that we do not really know anything, unless we can express and measure it mathematically.

Sludge digestion is a phase of sewage treatment and disposal. The sewage plant operator receives a liquid that is objectionable because of its appearance, its odor, its solids content, and its potential liability to spread disease. It is his job to dispose of this liquid in an unobjectionable way. This is usually impossible to do properly unless the sewage is treated first to remove or at least minimize its objectionable characteristics. Ordinarily it is more advantageous to remove the sol-

* Presented at 25th Annual Water Works and Sewerage Short School, February 15–17, 1943.

ids from the liquid, to the extent that this can be done economically, and then to treat the liquid and the solids, or sludge, separately.

Examination of this sludge will reveal that it may contain as little as 2 per cent or possibly as much as 10 per cent solids. Of these solids, as much as 80 per cent may be organic material.

These two facts determine the problem of sludge disposal. The high water content means that a large volume of sludge must be handled. So removal of water is one part of the problem. The use of sand drying beds immediately suggests itself. Gravity and sunshine are two willing servants. But unfortunately colloidal conditions prevent ready separation of the water from the solids, and the decomposition of the organic matter taking place during the drying time will cause serious nuisance. So nuisance-free destruction of the organic matter is the other part of the problem.

Digestion overcomes both difficulties. The fermentation process going on in the digester changes the colloidal condition so that the water separates readily from the solids. The organic materials are decomposed gradually, and the danger of odor nuisance decreases as this decomposition progresses. Hence a properly digested sludge will drain promptly, and, as the odor-producing material is reduced, the danger is much less or practically nil.

Broadly, this odor-producing organic material entering a digester consists of fats, proteins and carbohydrates. Of these three the fats are most readily digested, forming fatty acids, together with other products which need not interest us now. The proteins and carbohydrates decompose much more slowly forming ammonia and other products that need not concern us here. What we are interested in is the fact of the active fat decomposition and formation of acids, which, if it is not overtaken by the slower decomposition of the protein and carbohydrate material, will cause acid conditions in the digester. Such an acid condition will still further hamper the decomposition of the other material, and, as it frequently is quite erratic and violent, will cause foaming, one of the worst troubles of the operator.

Let us visualize what happens in a digester that has been freshly filled with the proper mixture of partly digested and fresh sludge, to which no additional sludge is added and from which none is drawn. As has been said, the fats will begin to decompose first, causing the formation of fatty acids, and a corresponding drop of the pH of the contents. Later on, when digestion of the proteins and carbohydrates begins, ammonia will be produced. This neutralizes the acids, and the pH rises and, ordinarily, in a properly functioning digester, a neutral or even a basic condition will be reached and maintained.

Investigation has shown that this digestion is the result of bacterial action. It is also known that different types of bacteria decompose different types of food. In addition we know that bacteria decomposing carbohydrates and proteins do not flourish in an acid medium. We also know that all this activity decreases as the temperature decreases, but that the fat-splitting bacteria apparently can work at a lower temperature than the bacteria decomposing protein and carbohydrates.

Let us now see how this knowledge is used in the actual operation of a digester.

Knowing that the decomposition of the sludge solids is due to bacterial action, it is evident that if digested sludge is added to the fresh sludge going into a new digester, a much smoother action can be expected. Similarly, all incoming sludge should be thoroughly mixed with the contents of an established digester. It is evident that the amount of fresh solids to be added depends not only on the amount of partly digested solids in the digester, but also on the amount of decomposition of the organic material to be attained. Knowing that the contents should be at least neutral, it is easily seen that the pH changes furnish a good indicator of the condition inside a digester. Unfortunately these conditions may not be uniform throughout the tank; in addition it is much safer to prevent a tank from becoming acid, than to hope to correct it after the acid conditions have developed.

From what has been said, it is evident that a new digester will pass through an acid stage, unless a large amount of semi-digested material is available and mixed with it. Usually this is not the case. It is much safer then to load the tank slowly and not to expect it to take the designed load till the acid stage is passed. Addition of lime is often advised to cure or prevent acid and foaming conditions. I think it is much wiser for a man to dine more wisely and less well, than to rely on milk of magnesia.

After a digester is established, how big a load can it carry? The designer may state that it can take a daily load of so many gallons of so many per cent sludge. If actual performance bears out his statement in your case, you are to be envied. But even then sludge consistency varies; the amount depends on changes in sewage flow and sewage strength.

To answer this question, let us review what the digester is expected to do.

We expect the digested sludge to drain promptly and without odor nuisance. It is our experience that sludge having a pH of 7.1 or even 6.9 will dry promptly if the organic matter has been decreased to 65 or 60 per cent, that is if the ash content is at least 35 per cent, and not necessarily more than 40 per cent. Carrying digestion above 40 per cent is a waste of digestion time in San Antonio, where the sewage plant is out in the country. This 35 to 40 per cent sludge still gases on the beds, resulting in a friable sludge that permits better air and water circulation. The ash content of the digested sludge is important, therefore, so far as nuisance-less drying is concerned. It should never drop below 35 per cent; in fact, we try to keep it between 38 and 40 per cent. If it drops below 35 per cent, the digester is left alone for about a week. This means that certainly no sludge is drawn, and, if at all possible, no sludge is added.

If a digester is properly established, it is possible to determine mathematically how many gallons of sludge may be drawn without unbalancing it.

Assume that 5,000 gallons of 4 per cent solids and 20 per cent ash primary sludge are added daily; how much digested sludge can be drawn without depleting the supply for seeding left in the digester, if the digested sludge is 6 per cent solids and 40 per cent ash? The calculation is based on the assumption that no ash is lost in the digestion process. Of course some is lost in the supernatant, and its amount can be determined, as will be shown.

The incoming sludge has an ash content of 8⅓ times 5,000 times 0.04 times 0.2 or 333 lb. Hence an amount of digested sludge having 333 lb.

FIG. 1.—Four of the new open sludge digestion tanks at San Antonio, Texas.

of ash can be drawn. As the ash is expected to be 40 per cent, the amount of solids to be drawn is given by the proportion 100% : 40% as x : 333 or 832 lb. The sludge is 6 per cent solids, hence the weight of liquid to be drawn is given by the proportion 100% : 6% as x : 832 or 13,866 lb. This amounts to 1,666 gallons. We see that an addition of 5,000 gallons of raw sludge means a withdrawal of only 1,666 gallons of digested sludge; there is a reduction of 3,334 gallons, due to the decomposition of organic material. To replace the sludge drawn, 5,000 gallons of fresh sludge must be added, and this means a displacement of 3,334 gallons of supernatant, if we forget that a certain amount of water is used up in the production of gas. If the supernatant has 1,000 p.p.m. solids of 40 per cent ash, the supernatant ash will amount to 8⅓ times 0.0033 times 0.4 or 10 lb. This is only 3 per cent of the ripe sludge ash, and may seem negligible. For safety's sake it would be better to draw less sludge than calculated till the pH determination as well as the increase in ash shows that performance is definitely basic.

The foregoing calculation can also be used to determine digester volume, at least approximately. It is seen that a daily addition of 5,000 gallons results in a daily withdrawal of 1,666 gallons; hence 3,334 gallons of daily storage is needed. If it is expected that the needed organic reduction is attained in 50 days, which is a fairly safe figure with a heated digester, then a volume of 50 times 3,334 gallons or 166,700 gallons must be provided.

A word of warning. These calculations are based on sludges of a certain consistency; if the sludge is lighter in solids, which is more likely to happen than not, these volumes will be altogether different. Hence, I still say that as far as digester volume is concerned, abundance is of primary importance. I am in complete agreement here with the army cook who was asked by the inspecting colonel what is the most important quality of army food. The answer promptly given was that it must be abundant.

The digester operator also has to contend with the problem of scum and the disposal of digester supernatant.

Apparently scum is the result of grease that remains at the top of the digester and is not properly seeded, in combination with paunch manure, hair and straw from the slaughter houses. Scum should be prevented by proper digester construction and mechanical equipment. The advocates of floating covers claim that if scum-forming material is kept submerged it will digest, and hence no scum cover can form. Inasmuch as we know that grease digests readily, I believe that they are right. That is why I say that scum should be prevented by proper construction and mechanical equipment. If a digester is not so equipped, the sludge surface should be lowered by drawing sludge from the bottom, and then breaking the scum cover with a fire hose. This is hard and dangerous work because of the presence of gas and the loss of the sludge drawn certainly upsets digestion. We have tried drawing out all the supernatant and then refilling the tank with excess activated sludge. Of course, the tank so treated must be left alone for a week or so to allow digestion of the large amount of new sludge to become properly started. This does some good. But still I say, scum should be prevented; it can hardly be cured.

In the problem worked out above, it was shown that the addition of 5,000 gallons of fresh sludge resulted in the displacement of some 3,300 gallons of supernatant. Theoretically this goes to the primary clarifier to be mixed and settled with the fresh sewage. If the digester functions properly neither the amount of suspended solids nor the B.O.D. load introduced should produce any ill effect, theoretically. If we were returning all of the supernatant to the primary tanks, it would increase the suspended solids load about 7 per cent and the B.O.D. load about the same. The actual effect on aerobic treatment is far out of proportion to the effect the above figures would lead one to believe. This is probably due to the anaerobic state of the supernatant and probably also to the amount of NH_3 and H_2S it contains. Laboratory experiment has convinced me that a moderate amount of aeration followed by short settling decreases the suspended solids as well as the B.O.D. load very much indeed. If I had to design a plant, I would certainly make provision for aeration and settling of the supernatant. I would also want to take the proper precautions to prevent possible odor nuisance that might result from such aeration.

I do not think that I should touch the topic of multiple digestion. It would be only a repetition of what other men who have had actual experience with such installations have published in articles and books. I will only state that apparently multiple digestion has a very appropriate place in the larger plants.

Let me summarize briefly the conclusions to be drawn from this study:

1. A new digester should be seeded with digested sludge if possible.
2. If this is impossible, foaming is to be expected; but this can be greatly reduced by not bringing the tank up to capacity till past the acid stage.
3. Rest the digester when the pH of the contents drops below 6.9 or 7.0, or when the ash approaches 35.0 per cent.
4. Mixing the fresh sludge with the partly digested contents, *i.e.*, "circulating the contents," promotes digestion.
5. Concentrate the primary sludge as much as possible to decrease the amount of overflow.
6. Digester capacity can be increased by drawing sludge as early as it will dry properly.
7. Apply a little mathematics to the digester operation; it rationalizes the procedure.

TRICKLING FILTER OPERATION AS PRACTICED AT CORPUS CHRISTI *

By S. L. Allison

Superintendent, Sewage Treatment Plant, Corpus Christi, Texas

The filters at Corpus Christi, as originally constructed, were 165 feet in diameter with a depth of 7 feet of limestone. The underdrains consisted of 4 inch slotted top Dickey tile laid at right angles to a central trough that divided the filter bed into two parts. This trough was blind at one end and terminated in a box outside the filter wall. Each row of drain tile had a 1¼-inch pipe insert set 1 inch above the flow line of the tile, and extended through the outer wall. These pipes were not set to line up with the tile, but were pointed to the center or axis. This made it impossible to use them for any purpose except breathers. Being only one inch above flow line, it did not take a very heavy flow to make each pipe insert a discharge line for the filter effluent; and thereby preventing ventilation.

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After these filters were built up and seemed to have reached their best operating condition, a check was made of their efficiency for a number of months, after which the pipes through the outer walls were closed, and no change in the filter efficiency was observed.

The distributors were single arm, motor driven, revolving at a constant speed regardless of the flow. The orifices were arranged with adjustable aluminum plates. This made it possible with the aid of baking pans to adjust for any dosage rate per square foot. A flat pan 5 inches wide was bolted below the orifices and along the entire length of the arms to spread or fan-out the discharge.

Considerable difficulty was encountered at first to maintain any set discharge rate, because orifice plates were made of aluminum and the chloride content of our sewerage varying from 1,500 to 3,500 p.p.m. caused the aluminum to disintegrate rapidly. This was assumed at first to be erosion and the plates were increased from 1/16-inch thickness to 3/16-inch. The heavier plates helped somewhat, but only by extending the time for re-adjustment a few weeks and showed the aluminum being acted upon by the chlorides. Brass plates were then made by hand and proved entirely satisfactory and by the aid of wooden plug gauges, various changes in dosing rates were tried in weekly periods.

Taking the overall B.O.D. reduction through the filters, as adjusted when set into operation, averaging 78 per cent, we gradually increased this B.O.D. reduction to an average of 90 per cent. This was not accomplished entirely by changing the distribution although much work was done on the distributors needlessly before we discovered another contributing operation factor that affected the reduction ability of the filters.

For almost two years the primary clarifiers were not equipped with baffles to permit floating matter to be skimmed; floating matter was carried over the weirs and deposited on the filters, causing them to pond if kept in continuous operation for more than five days. Resting or stopping one filter each day and cleaning the orifices every hour prevented the ponding.

After a period of operation in this manner we found that the morning B.O.D. reduction would often be about 14 per cent lower than the afternoon or night reduction, and accounted for wide variations in the daily reduction. Samples taken at 4 P.M. were highest and more consistently above 85 per cent. From this variation we discovered that resting or stopping a filter for even one day resulted in a reduction of its efficiency for a period of from 3 to 5 hours of more than 50 per cent.

Baffles and skimmers on the primary clarifiers to maintain continuous operation and a few more changes in distribution gave us a more uniformly high reduction, in fact, a careful three weeks check using composited samples averaged 94.6 per cent overall reduction of the B.O.D.

We found that continuous operation or dosing was necessary for a high average reduction, as well as a good coverage or fanning-out the distributor discharge, so that it would cover the entire surface of the stone, increasing the dosage rate gradually until it was about 25 per cent heavier on the outer 10 feet of the distributor arm over the first 10 feet near the center.

During the next two years the load on the plant increased until it was more than 50 per cent above the designed capacity making it necessary to enlarge the plant. This heavy overload decreased the efficiency of the clarifiers, but the B.O.D. removal remained constantly around 90 per cent.

Enlarging the plant added a 100-foot diameter clariflocculator, a flocculator to precede the two original primary clarifiers, a detritor, a two-stage digester, and one 85-foot final clarifier.

FIG. 1.—View of the trickling filters at Corpus Christi, Texas. One of the final clarifiers in foreground.

The only change in the filters made was changing the distributors to two compartment arm, reactionary distributors capable of handling three million gallon per day each. The 14-inch feeder lines from distribution box to distributors and the 14-inch effluent lines to secondary clarifiers were not changed. As the influent line has a 3.4-foot head and effluent 0.9-foot head, a flow above 60 per cent of distributor capacity floods the bottom of the filters. During storm flows, a stream of water can be seen pouring out a crack 4 feet from the top of the filter.

A check of filter efficiency during times when lower half of the filters were flooded showed 86 to 88 per cent reduction, but the filter effluent B.O.D. would be 20 p.p.m. or under, in fact, just about the same as during normal operation. The apparent loss in reduction per cent was due to a low raw sewage B.O.D. caused by rain water dilution.

During peak loads our filters are flooded to a depth of more than 6 inches at the outer edge. Our highest B.O.D. reductions are obtained by putting the dissolved oxygen in the settled sewage before it starts through the stone, and letting ventilation or filter breathe, if possible. An activated plant proves that good aerobic condition can and does exist with 2 p.p.m. of dissolved oxygen and our flooded filters giving good consistent results, prove ventilation can be dispensed with.

Our original distributors were motor driven and proved continuous operation was needed for high constant efficiency. The new reactionary type, not being able to operate during the low night flow, proved this also as the B.O.D. reduction averaged about 80 per cent.

We cut a 1000 g.p.m. sewage pump into the sludge lines from the final settling tanks and returned this through the plant, thereby furnishing sufficient flow to keep the distributor in motion at all times, and the B.O.D. reduction went up to ninety odd per cent.

This 1000 g.p.m. return from the sludge pockets also aided in turning out a good effluent by reducing the suspended solids during peak loads. Our clarifiers are Dorr Sifeed, with effluent from filters entering at the center and directed downward by a circular baffle. As oxidized humus is very near zero buoyancy and has a tendency to floc, these floc would be caught in the under flow of the baffle and redistributed, but the 1000 g.p.m. displacement at the bottom or sludge pocket, assists in the downward movement of the flocculated humus.

Another idea resulted in saving 350 pounds of chlorine per day by utilizing this 1000 g.p.m. return. The Corpus Christi plant is arranged for pre- and post-chlorination with electrical control chlorinator to vary the dosage according to the flow. To get satisfactory odor control, which is absolutely necessary as the plant is located only eight blocks from the center of the city, 850 pounds of chlorine was required and results were not very satisfactory. Every sewage plant operator knows that slimes build up rapidly and heavy slimes mean considerable odors, and chlorine is one of our best slime inhibitors. The pre-chlorine line was shut off and all chlorine solution was diverted to the filter effluent distribution box ahead of the final clarifiers. A dosage of 500 pounds per day gave a residual of 1 to 1.5 p.p.m. over the weir of the final clarifiers at eight o'clock in the mornings. The clarifiers cleaned up over night and did not have to be touched for months.

Dosage rate is governed by residual at the weir during peak flows. As contact time during peak flows is more than two hours, a 0.2 p.p.m. residual was found to be ample for presumptive *B. Coli* tests using 10 cc., 1 cc., and 0.1 ml. dilutions. These dilutions showed no positives except for the occasional positive upsets that are often encountered even on potable water supplies.

This means a high residual is built up in the finals during low flows at night, and the 1,000 g.p.m. return displaces the raw sewage in the flocculators and primary clarifiers with final effluent containing a high chlorine residual, before morning peak flows start to dilute it.

No residual is found in the primary clarifiers at eight o'clock in the morning, but slimes are white and entire primary contents are milky in appearance. This milky discoloration is due to a chlorine reaction with the digester supernatant and always occurs when the residual in the final effluent return is 1 p.p.m. or above, and only in the primary receiving the digester supernatant. We can almost always check the raw sludge pumps every morning by the color of the clarifier effluent. The final clarifiers can also be checked visually for residual at 8 A.M., as they have a clear greenish-blue color when residual is above 1 p.p.m.

This, no doubt, seems to be a waste of chlorine to carry this apparently high residual, but the benefit derived from it actually saves 350 pounds of chlorine per day, gives far better odor control, cuts cleaning work on clarifiers more than 50 per cent and reduces sliming in effluent line to the ship channel thereby giving this outfall line a greater carrying capacity and also, the refinery using our effluent has been able to reduce their chlorine demand about 75 per cent.

Another benefit derived and very useful for filter plants near residential districts is psychoda fly control. Continuous operation reduces the fly trouble markedly; and whenever interruption of distributors is necessary for repairs or painting, raising the chlorine dosage from 50 to 100 pounds a day or two prior to the interruption, so that there will be a carry-over from the primaries to the filters, results in a total absence of flies which are usually present when filter stone dries.

IMPROVING EFFICIENCY OF SEDIMENTATION OF SEWAGE *

By J. M. Jones

Chemist, Sewage Treatment Plants, Houston, Texas

After I had agreed to discuss this subject, and had given it some thought, I began to realize that here was a problem that should be discussed by a designing engineer. A designing engineer might be able to obtain sufficient priorities to purchase the material necessary to enlarge your sedimentation tank, so as to increase the sedimentation detention time from one and three-quarter hours to two and one-half hours. Without this adequate settling time capacity in your sedimentation unit, good results cannot be expected.

But we should not always blame poor sedimentation results on inadequate capacity until we have checked some of the following points:

If your Imhoff cone test shows that your unit is not removing fifty five to sixty per cent of the suspended matter in the sewage, and yet

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your detention time figures on an average of one and a half to two hours, it may be that your tank is exhibiting a very common ailment—"short circuiting." One of the most common causes of poor removal of settleable solids is short circuiting through the sedimentation tank. This is brought about by improper distribution of flow and poor baffling at the inlet and outlet ends. The extent of this short circuiting will vary with the flow rates reaching the unit, and its nature will vary with the physical conditions of the settling tank. Your first duty then would be to find the extent and nature of this shortcoming by using dyes,

FIG. 1.—Overloaded primary sedimentation tank—a prime example of "floating sludge."

salt, or other measurable chemical material placed in the tank inlet to show paths of short circuiting and stagnation. Baffles can be placed in the tank at locations that will distribute the sewage flow more uniformly over the tank cross-section. This is, of course, a trial and error method, but it may be quite effective in obtaining improved settling results.

If the tank shows no evidence of short-circuiting, then you should check into your sludge removal routine. A good index to this fault is "floating sludge." Floating sludge may be caused by improper procedure in the withdrawal of sludge from the sludge sumps. If the sludge is drawn too rapidly from the sumps, a large part of the material in direct contact with the sump slopes may not move rapidly enough to the outlet to be removed. The remaining sludge decomposes, and rises to the surface of the tank. The settling of sludge on parts of the clarifier mechanism and flat horizontal sections of the tank also causes trouble. The ideal method of sludge removal is slow, continuous operation of the clarifier mechanisms with continuous removal of the settled sludge. This procedure will, of course, be limited to the larger plants because it requires a uniform quantity of settled sewage solids to prevent the withdrawal of excessive amounts of liquid with the sludge.

If your sludge removal procedure proves to be satisfactory, and you are convinced you are maintaining clean tanks, then you should check

FIG. 2.—Chemical mixing hopper used in feeding chemical coagulants at an overloaded sedimentation tank.

into the chemical qualities of the sewage. Septic sewage and industrial wastes will often give trouble in the sedimentation tank. Sewage that is septic before it reaches your plant will be in a state of anaerobic decomposition, and the suspended matter in the sewage will likely bear minute gaseous decomposition products of this anaerobic action. This attached gaseous globule will have just enough buoyant effect on the suspended particle to cause it to rise to the surface and give the "floating sludge" condition mentioned; or it can so retard the particle's natural settling rate that, even though it does not appear on the surface of the tank, it is carried out with the tank effluent. We all know that sewage becomes septic only through prolonged detention in the absence of sufficient oxygen. So our problem of eliminating septic sewage as it reaches the plant becomes a problem of rapid transportation of the sewage from its point of origin to the treatment plant. In some cases however, even with properly designed sewerage systems, the sewage may become septic in hot weather. In such cases, it is necessary to locate the point where septic decomposition begins, and introduce a sterilizing agent such as chlorine to retard the anaerobic decomposition.

Industrial wastes will sometimes disrupt the normal settling efficiency expected from a sedimentation unit. The easiest remedy for this is to prohibit the discharge of the material into the sewers. This procedure will be possible, however, in only a few cases. If the waste must be treated, you must often resort to chemical precipitants. Industrial wastes exist in such a variety of compositions that it is impossible to recommend any one chemical or procedure for the treatment of them. The chemicals commonly used as coagulants at present are ferric chloride, ferric sulfate, chlorinated copperas, and alum. These are used alone or in conjunction with lime or acid. Very recently, bentonite has been recommended as a coagulant for sewages and industrial wastes, and a treatise on its use may be found in the December, 1942 issue of *Water Works and Sewerage* magazine. One thought must be kept constantly in mind if you do resort to chemical coagulants as an aid to sedimentation. Your problem has now become, besides one of purely physical clarification, a problem of proper chemical combinations between the coagulant chosen and the sewage or industrial waste. Consequently, to obtain maximum efficiency, a procedure of close supervision and chemical testing must be followed at all times.

I have attempted to discuss the more important aids in improving the efficiency of sedimentation of sewage. Any one or all of these suggestions, and others that I know come to your mind, may prove ineffective; in this case, your problem, no doubt, is one for the designing engineer.

BARK FROM THE DAILY LOG *

March 3—The first call by Uncle Sam, via the Selective Service System, reached our plant to-day when our relief operator received orders to report for his physical examination. The man hunt (for a replacement) is on!

Anybody want a job?

March 6—Rolled the main entrance road into the plant, "black-topped" last summer, to counteract heaving from frost action during the past winter.

High suspended solids in the filter effluent offer the first evidence that seasonal unloading of the trickling filters has begun.

March 10—More work! Received appointment to the Sanitation Committee of the Illinois State Council of Defense.

* Notes from 1942 diary kept as part of the records of the Urbana and Champaign (Ill.) Sanitary District.

March 11—Six weeks ago, a lady phoned that her expensive denture had been lost in such fashion that we might expect to find it at the sewage treatment works. She was advised at the time that the only chance we might find it would be during the removal of the grit accumulation in our screen chamber, a chore performed about four times yearly, and she was promised that a diligent search would be made the next time the chamber was cleaned. Her weekly phone calls since would have prevented our forgetting this obligation, even though we had made adequate note of it.

No, we did not find the false teeth today when we cleaned the screen chamber. Instead, the climax of this anecdote comes in the lady's reply when we phoned to let her know that our search had been unsuccessful. Said she, "Thank you so much for your trouble, but I'm just glad you didn't find them. They cost so much that I felt I had to do everything I could to get them back, but now I can order a new plate made without worrying about it. I'm so relieved!"

Spent the evening studying psychology.

March 12—Due to the location of one of the city dump grounds adjacent to our property, continuous warfare must be waged against rats. A total of 150 pellets of ground meat containing red squill and wrapped in paper were distributed at centers of rat population about the plant. A score card was placed on the plant bulletin board for recording purposes, each operator being instructed to mark up victims as he finds and disposes of them.

March 13—First use of the A-10 preference rating allowed under the original Order P-46. Rating used on an order for a replacement part for a clarifier mechanism. (After raising the preference rating twice as allowed by subsequent amendments to P-46, the part was finally delivered on December 4, 1942.)

March 16—Windy March outdid itself today by bringing a tornado through central Illinois. The brunt of the storm struck less than five miles east of us, resulting in five fatalities and causing much damage to rural property.

The first and only time we have seen the plant barometer hit bottom!

March 24—Visited by representatives of the Public Work Reserve relative to the development of a post war construction and improvement program. (A short time later, PWR relapsed into obscurity and nothing more was heard from the local office. Although we have a post-war program, complete with construction plans and specifications, we consider it most unfortunate that the functions of PWR were discontinued.)

March 26—"Bellyache" in Imhoff Tank No. 4 results in headache for us! Unsettled recently, the tank has been out of service the past ten days for rest, but this evening it suddenly began foaming over the gas vent walls (42-inch free-board). Probably due to favorable digestion conditions brought about by warm weather this month.

April 6—Imhoff Tank No. 4 returned to service at half load—apparently in good condition.

April 14—Plant visited by Safety Inspector of State Factory Inspection Division. The first of his two recommendations, i.e., the provision of a transparent eye shield at the shop grinder, was obviously justified and was immediately provided. Vigorous protests were raised, however, to the second recommendation that pipe handrails be provided completely around the Imhoff tanks and on both sides of all cross walkways. Our main argument stressed the fact that such handrails would make it physically impossible to perform adequately the daily skimming and occasional manual removal of gas vent scum which is required to keep the units in satisfactory operating condition. The inspector was not convinced until he was shown a photograph taken at another plant equiped with such handrails, in which an operator was pictured while skimming from a precariously perched plank outside the railing.

Outcome of the discussion (and subsequent correspondence) is the overhead cable safety belt suspension which was installed at the end walkways. The safety belt is hitched to a sliding ring around the overhead cable, enabling the worker to move along the walkway without fear of falling into the tank. The operators dislike the arrangement, however, because the cable interferes with manipulation of the skimmer.

April 25—Enroute via plane to Bakersfield, California, to meet with the California Sewage Works Association.

April 29—Back from sunny California, ready to second everything the Los Angeles County Chamber of Commerce has to say about that beautiful state and to add a few paragraphs about California hospitality as extended by the C. S. W. A. An extremely profitable and pleasant trip!

May 10—Glad to welcome a representative of the company which manufactured our sewage pumps, for a conference about the rumbling noise which has developed at the thrust bearing of the 5.5 m.g.d. unit. Investigation disclosed that vibration was originating at the impeller, probably due to cavitation, and was transmitted up the shaft to the thrust bearing. Since both the impeller and shaft are of obsolete design, a rebuilding job is indicated.

Another post-war project!

May 16—Noticed that there are unusually large amounts of snail shells and fewer earthworms in the trickling filter humus during this unloading season. These small shells are very troublesome in the gas vent scum.

May 26—More inspections lately! This time it's the Illinois Inspection Bureau looking for fire hazards. Found none.

May 30—The bulletin board shows that at least 46 of the 150 red squill pellets distributed on March 12 have claimed a rodent. Gives us a "ratting average" of .307 for the known victims—not bad, eh?

INTERESTING EXTRACTS FROM OPERATION REPORTS

FINDLAY, OHIO (1942)

By Ben H. Barton

Chief Operator

Supernatant Liquor Lagoon.—The disposal of digester supernatant overflow has become an acute problem in the sewage treatment plant in the City of Findlay. Lagoon facilities were provided in July 1941 by construction of a 6-inch pipe line from the digester to the abandoned river channel. This space is now almost filled with overflow liquor and the coming summer will present new problems in digester overflow liquor disposal. About 1,000 cubic yards per month are being added to the present lagoon, which, on the basis of dry solids, amounts to about 22 cubic yards per month. It is impossible, however, to dry the material. Some clear water can be decanted to the river from time to time but this is increasingly difficult. The impounded material is neither liquid or solid. It was the intention at the start of using the lagoon to eventually compact the area with coarse fill when its usefulness as a lagoon was ended. This would gradually force out the water and salvage the swampy area for some useful purpose.

Extension of the present lagoon into the low ground in a southerly direction would provide space for impounding another year's digester overflow. This would require construction of a decanting chamber over the existing sewer manholes. Such extension may meet with objections from an esthetic viewpoint but the filling of the area would be an eventual improvement to Rawson Park.

Activated Sludge vs. Bio-Flocculation.—In spite of the increased cost of treatment per million gallons of sewage treated and increased cost per capita per month in 1942 over the two preceding years; the plant efficiency has brought about a decrease in the cost of removal on a B.O.D. basis. This is directly due to the use of the activated sludge process in its entirety during the year 1942, whereas both preceding years were lessened in efficiency by use of the Bio-flocculation process.

Bio-flocculation was employed to reduce the sludge volumes. The difficulty in sewage treatment arises from the fact that the higher the plant efficiency becomes, the more sludge there is to dispose of, by whatever means may be at hand. Shortage of sludge disposal facilities will likely decrease the plant efficiency in the year 1943 as it has done in the past. This situation was rather exhaustively covered in previous reports. The same conditions described in those reports still hold and will maintain until some comprehensive means are provided to alleviate the overloaded digestion and sludge disposal devices.

The strength of the sewage treated combined with the volume received has been computed into population equivalent. This has consistently increased from 38,200 in 1940 to 48,000 in 1941 and 52,625 in the year 1942. The designing engineers computed the plant would be serving 25,000 in 1940 with a volume of flow of 4.0 million gallons per day. In 1950 the estimate was 30,000 population with a flow of 4.6 million gallons per day. The ultimate capacity was computed to be 35,000 population at 5.1 million gallons per day in 1960.

Sludge Concentration Needed.—A most significant item is the decrease in the per cent of dry solids in the raw sludge pumped to the digester. With an average for the year of 4.3 percent there were fewer solids in the volume of sludge than in either 1940 or 1941. This percentage dropped to 2.5 per cent average for the month of December, 1942.

Sludge concentration tanks have been suggested as desirable or some equally practicable means of thickening the sludge before discharging into the digesters. Studies have been made on the several possibilities of acquiring a thicker sludge and the original idea of concentration in separate tanks designed for that purpose has survived without any considerable competition by other methods.

The writer approached technicians in several other city sewage treatment plants with the suggestion that they make a more or less comprehensive test upon the methods outlined. Those technicians who have completed the tests, while their plant characteristics are not entirely similar, have confirmed the findings at the Findlay sewage treatment plant. This method has been discussed since 1936 and no municipality has yet granted its technicians the necessary structures to carry on a plant scale study. However due to the recent investigations one plant may conduct a series of tests on large enough scale to determine the practicability of strata decantation, both with and without thermal phases.

In the Findley plant it is proposed to concentrate raw sludge enroute to the digester and to concentrate supernatant liquor in the same manner in tanks constructed in duplicate and alternated in their respective uses. The obvious advantages of concentration are:

1) Reduce raw sludge volume.
2) Increase digester detention.
3) Produce more gas for power, heat, etc.
4) Eliminate digester supernatant problems.
5) Produce salable digested sludge.

Manipulation of Aeration Tanks.—Attention is directed to the method employed in adjusting aeration periods. Adjusted aeration consists of alternating the two tanks at eight-hour intervals or for eight-hour periods. One is referred to the "working" tank and the other is referred to as the "idle" tank. The means of changing tanks is to close the outlet valve leading to the final tank. This builds up a "head" on the idle tank making the water depth greater than that of the "working" tank, thus diverting the larger portion of the common air supply to the shallower or working tank receiving the primary treated sewage.

Summary of 1942 Operation Data at Findlay, Ohio

Item	1942 Average	
Sewage flow treated	2.295	m.g.d.
Per capita	115	g.p.d.
Green garbage ground	5250	lbs. per day
Screenings removal	1.0	c.f. per m.g.
Grit removal	2.0	c.f. per m.g.
Detritor detention period	2.1	min.
Analytical data:		
5-day B.O.D.—raw sewage	405	p.p.m.
Primary effluent	121	p.p.m.
Removal	70.2	per cent
Final effluent	21	p.p.m.
Removal	94.7	per cent
Suspended solids—raw sewage	427	p.p.m.
Primary effluent	90	p.p.m.
Removal	78.1	per cent
Final effluent	11	p.p.m.
Removal	97.3	per cent
Primary sedimentation—detention	3.1	hrs.
Skimmings removal	0.9	c.f. per m.g.
Activated sludge—detention	5.5	hrs.
Adjusted detention (see test)	3.9	hrs.
Applied air	0.69	c.f. per gal.
Mixed liquor solids	1420	p.p.m.
S. I. (Mohlman)	151	
Final effluent dissolved oxygen	4.9	p.p.m.
Return sludge ratio	25.9	per cent
Return sludge solids	5116	p.p.m.
Final sedimentation—detention	2.8	hrs.
Sludge digestion:		
Raw sludge quantity	9060	g.p.d.
Per m.g. sewage	3943	gal.
Solids content	4.3	per cent
Volatile content	73.5	per cent
pH	6.3	
Digestion temperature	92.3	deg. F.
Digestion time	69	days
Digested sludge—per m.g. sewage	840	gal.
Solids content	4.5	per cent
Volatile content	53.4	per cent
pH	7.9	per cent
Supernatant liquor—per m.g. sewage	3090	gal.
Solids content	1.97	per cent
Volatile content	58.1	per cent
pH	7.8	
Gas production (waste not included)	9413	c.f.d.
Operation costs—per m.g.	$28.14	
Per capita per year	$ 1.11	
Per 100 lbs. 5-day B.O.D. removed	$ 8.66	

This method of aeration is used only during low-flow periods and when the flow rate increases the other or idle tank is promptly put into service. The object is to shorten the aeration period, reduce surge flows and loss of floc over the final tank weirs. The experience of six months of such operation has been such that the procedure is recommended to plants which have too much air, or where power required to compress air can be saved. The alternation of tanks at eight-hour intervals provides some degree of re-aeration or re-activation of the activated sludge. Loss of floc from the final tank has been negligible under adjusted aeration. Further study is contemplated.

Gas Engine Overhaul During Gas Shortages.—Engine operation was interrupted during January and September for overhauling and valve grinding. The rest of inoperative time was due to shortage of gas. At the end of the year, it appears advisable to arrange overhaul periods during that time when gas supply can be expected to be short because of flood periods in the Blanchard River, rather than to shut the engine down and waste gas while operating a blower on purchased power. Had such arrangement been effective in 1942 the percentage of operation would have exceeded 90 per cent for the year.

Garbage Quantities.—The records show that the garbage grinder operated a total of 117.5 hours in the year 1942. The number of grindings per day averaged 2.1 and the average time per grind was 10.8 minutes.

By no means all of the city's garbage was received at the sewage treatment plant, much was fed to hogs by local gatherers and an unestimated amount was hauled from the city by commercial concerns to Toledo and Lima. The data per capita are therefore unreliable. However the received amount was equal to 7.986 pounds per capita per month or 0.261 pounds per capita per day. This is at considerable variance from the figure of one-half pound per capita per day of green garbage.

The "free-lance" garbage collectors co-operated with the plant personnel in commendable manner as has been past experience. There were numerous phone calls from their customers regarding lack of service as some collectors dropped out of this not too pleasant business to take other jobs which indicates that garbage collection may become a city problem. It would seem that the sewage treatment plant is entitled to some revenue for garbage disposal in fairness to those who do not avail themselves of it but must help pay for it.

MUSKEGON HEIGHTS, MICHIGAN (1942)

By R. A. Anderson

Superintendent

Industrial Wastes Create Problems.—Industrial waste interference with the operation of the sewage treatment plant was again experienced during the entire year.

Inspection at the John Wood Company showed that oil was being discharged from the rustproofing and de-greasing unit and that the soda ash process, used for recovery of excess paint, was toxic. All of their trade wastes were removed from the sanitary sewer during the summer. The soda ash and bonderite wastes were discharged to a sand pit at the rear of the factory and the rustproofing wastes were connected to the storm sewer. This sewer discharges into the stream, above the treatment plant, at Broadway Street. The waste causes no discoloration of the stream but occasional patches of floating oil are noticeable.

The discharge from the cyanide unit at the Shaw Crane Works was changed to the storm sewer. The waste soluble oil remains connected to the sanitary system.

Operations at the Norge Company gradually slowed down and ceased entirely for several months during the summer while they were changing to war production. They are now using a strong sodium dichromate solution for processing plastic material but the waste from this unit is discharged to the storm sewer. An anodizing unit, using chromic acid, was installed and connected to the sanitary system. The sewage and sludge at the treatment plant was analyzed for chromium and indicated that about one-half pound of chromium was received per day. This waste aggravated conditions at the plant to a noticeable degree but was not the main cause of activated sludge difficulty. The Norge has recently removed this waste to the storm sewer.

A green colored waste was traced to the Williams Sausage Company and was caused by bile from slaughtered animals. This waste consists of the usual type of slaughter house waste such as paunch manure, blood, grease, etc., and amounted to about 5,000 gallons per day. At first we were confused by other trade wastes being received and considered this waste was too small an amount to cause any difficulty. Our difficulty with the activated sludge had started the latter part of 1941 and investigation showed that slaughtering of animals by this company had started at that time. A study of the plant records showed that the per cent volatile matter had increased from 65 per cent to a point where it now remains between 80 to 85 per cent. E. Hurwitz states that slaughter house waste in amounts as low as one per cent will disturb activated sludge operation and also that any sewage with a high organic content will invariably cause operating difficulties. The company has been ordered to install a grease trap and also a holding tank to distribute the flow of waste over a longer period of time.

Effects of Industrial Wastes.—Difficulty was experienced with the operation of the activated sludge during the entire year. Suspended solids and B.O.D. removal was poor due mainly to a lack of sufficient air for the aeration tanks. There was little or no oxygen present and the sludge settled too rapidly, easily became septic, and, at times, gave off considerable odor. The sludge had a tendency to float in the final settling tanks almost continuously until prechlorination of the raw sewage was begun. There has been no odor or floating sludge since Nov. 1st. However, the oxygen residual still remained low and during December one-half of the primary effluent was diverted to the rock filter and from there to the sand filters. Until larger aeration equipment can be obtained it is planned to continue bypassing 25 per cent or more of the primary effluent to the rock filter and sand filters with the improved effluent of the aeration tanks being discharged directly to the stream. This method should provide a much better final effluent.

Chlorination and Chemical Precipitation Experiments.—Experiments were conducted with chemical precipitation using lime, ferric chloride, alum and activated carbon.

Lime and ferric chloride was added to the raw sewage for a few days but this treatment made conditions much worse.

Lime and alum and alum alone was then tried on the raw sewage and the effluent from the final aeration tank. A small amount of improvement was noted in the primary tanks but none was noticeable in the final settling tanks. The General Chemical Company then advised that the use of alum on a sewage of high organic content was impractical. About twenty tons of alum was used in the experiment.

Two tons of activated carbon was added to the raw sewage and another ton was later added to the return activated sludge. This chemical reduced odors to a large extent but did not improve other conditions.

It was then decided to try chlorination of the raw sewage to reduce odor and prevent floating sludge in the primary tanks, of which a considerable amount passes into the aeration unit, and also to reduce the effect of organic solids upon plant treatment.

A temporary building was constructed beside the grit basin for housing the chlorine and chlorinator using materials left over from the construction of the water filtration plant. A portable chlorinator was loaned from the Muskegon Filtration Plant and chlorine in ton containers was purchased from the Muskegon Sewage Treatment Works.

Chlorination was begun on October 26 with the chlorine being applied to a short submerged sewer connecting the grit basin with the primary tanks. All odor due to septic sludge throughout the plant was eliminated. A large amount of grease is removed daily from the primary tanks and very little floating sludge appears. No floating sludge has been observed in the final settling tanks. For about a week after chlorination was started a greasy scum floated off the final settling tanks. There has also been a very marked improvement noted in the filtration through the sand filters. However, no reduction in the oxygen demand has been noticed.

Recommendation was made that a portable chlorinator be purchased for the Utility Department and the City Council has authorized the purchase.

Miscellaneous Maintenance Problems.—The special hard finish paint applied to the H-weirs in the final settling tanks during 1941 scaled and dropped off completely. This may have been caused by a strong shot of acid which was received shortly after the painting was completed. The heavy coating of pitch paint applied in the aeration tanks just seemed to dissolve and disappear. No acid waste was received after this paint was applied. The damp-proof red paint, manufactured by the Rustoleum Corp., Evanston, Illinois, was unaffected in both of

Summary of 1942 Operation Data—Muskegon Hts., Michigan

Item	1942 Average
Estimated connected population	15,000
Sewage flow	1.18 m.g.d.
Per capita	79 g.p.d.
Screenings removal	2.3 c.f. per m.g.
Grit removal	5.8 c.f. per m.g.
Organic matter content	45 per cent
Analytical data:	
Suspended solids—raw sewage	305 p.p.m.
Primary effluent	134 p.p.m.
Activated sludge effluent	69 p.p.m.
Rock filter effluent	62 p.p.m.
Sand filter effluent	6 p.p.m.
5-day B.O.D.—raw sewage	357 p.p.m.
Primary effluent	193 p.p.m.
Activated sludge effluent	52 p.p.m.
Rock filter effluent	38 p.p.m.
Sand filter effluent	9 p.p.m.
Activated sludge—aeration period	6.3 hrs.
Applied air	0.47 c.f. per gal.
Mixed liquor solids	900 p.p.m.
S. I. (Mohlman)	100
Return sludge ratio	41.1 per cent
Return sludge solids	4300 p.p.m.
Waste activated sludge	24,000 g.p.d.
Sludge digestion data:	
Raw sludge quantity	7580 gal. per m.g.
Solids content	3.56 per cent
Volatile content	77.5 per cent
Dry solids loading (per c.f. per month)	1.44 lbs.
Volatile solids loading (per c.f. per month)	1.11 lbs.
Gas production (per capita)	1.56 c.f.d.
Per lb. dry solids added	8.86 c.f.
Per lb. vol. solids added	11.82 c.f.
Per lb. vol. solids digested	16.62 c.f.
Digested sludge quantity	1780 gal. per m.g.
Solids content	7.0 per cent
Volatile content	49.9 per cent
Digestion temperature	87 deg. F.
Supernatant liquor quantity	6754 g.p.d.
Solids content	0.22 per cent
Volatile content	54.7 per cent
pH	7.6
Operation costs—per m.g.	$33.20
Per capita connected	$ 0.95

the tank units. This paint has been used for the past four years and cannot be commended too highly for metal parts where corrosion and abrasion are severe.

The cover on one of the transformers was partly raised and snow blowing inside the transformer during a heavy snowstorm caused an electrical short and fire requiring the services of the fire department to extinguish.

After the water cooling lines had been removed from the return activated sludge pumps severe scoring of the pump shaft at the stuffing box resulted and two water seal pumps were purchased from the Chicago Pump Company. One unit is attached to the two Fairbanks-Morse pumps while the other unit serves the Scru-Pellor pump. The performance of these units appears to be satisfactory.

A prolific weed growth appeared on the rock filter which defied ordinary means of removal. A weed killer solution was purchased from the C. Dolge Company and used with very good results.

CRITERIA FOR DETERMINATION OF ESSENTIAL SANITARY ENGINEERS IN PUBLIC HEALTH SERVICES

Important rulings in regard to the assignment of sanitary engineering personnel between civilian and military services have recently been issued by the War Manpower Commission—a definitely progressive step toward eliminating the uncertainty on the part of many individuals in the sewage works field as to their personal status in the war effort. Captain C. W. Klassen of the Sanitary Corps, formerly Chief Sanitary Engineer of the Division of Sanitary Engineering of the Illinois Department of Public Health and now assigned to service with the Committee on Sanitary Engineering of WMC, has furnished the following material for the guidance of individual sanitary engineers and administrative officials:

"*General Considerations*

It is realized that methods of rendering health services and the requirements for the safeguarding of the public health differ throughout the country. Sanitary engineering activities and needs, in particular, may vary with the climate, location, population, and in terms of war industries, military centers, and other situations connected with the war which create such problems. Especial consideration may have to be given to those situations, but sanitary engineers under thirty-eight years of age, except in special cases, should normally be released for military service—their places to be taken by older persons and by those not eligible for service in the Armed Forces.

Definition of the term 'Sanitary Engineer'

For the purposes of the Procurement and Assignment Service of the War Manpower Commission, the professional occupational designation 'sanitary engineer' shall apply to a graduate of an approved scientific or engineering school * (1) who is designated a sanitary or public health engineer by the state, county, or municipal health department in which he is employed; or (2) who has fitted himself for suitable training, or study, and by experience to conceive, design, construct, operate, direct, and manage engineering works developed, as a whole or in part, (*a*) for the protection and promotion of the public health or (*b*) capable of injuring the public health.

Ability to identify, evaluate, and explain, in terms of their sanitary or public health implications, those factors connected with engineering works that will prevent injury to health or that will promote health, in addition to ability to conceive, design, construct, operate, direct, and manage such works, shall constitute the basis of differentiation be-

* In exceptional circumstances, eight years of suitable experience and study that give evidence of the acquisition of proficiency in the fundamental engineering sciences as well as in engineering technique may be considered equivalent to graduation from an approved scientific engineering school.

tween individuals qualified as sanitary engineers and individuals qualified only as civil, mechanical, electrical, mining, or chemical engineers.

Essential Sanitary Engineering Positions

The following positions are considered essential to the safeguarding of civilian health. Additional positions may be defined by the responsible agency and submitted for consideration and approval to the War Manpower Commission.

A and B refer to state health departments.

C. In an organized Municipal, Metropolitan, or District Water Supply or Sewerage Service the following positions shall be consdiered essential; the duties to be defined by the administrative head of the water supply or Sewerage Service and filed with the War Manpower Commission:

1. Population under 500,000
   - Position D 1 The full time sanitary engineer in charge of sanitary engineering services.
2. Population 500,000–2,000,000
   - Position D 1 The full time sanitary engineer in charge of sanitary engineering services.
   - Position D 2 One assistant sanitary engineer.
3. Population 2,000,000–4,000,000
   - Position D 1 The full time sanitary engineer in charge of sanitary engineering services.
   - Position D 2 One assistant sanitary engineer.
   - Position D 3 One assistant sanitary engineer.
4. Population above 4,000,000
   - Position D 1 The full time sanitary engineer in charge of sanitary engineering services.
   - Position D 2 One assistant sanitary engineer.
   - Position D 3 One assistant sanitary engineer.
   - Position D 4 One assistant sanitary engineer.

Essentiality of Individual Sanitary Engineers in Health Agencies

Individual sanitary engineers will be considered essential to civilian health protection and shall, therefore, not be cleared by the War Manpower Commission for service with the Armed Forces except with the written consent of the administrative authority of the Public Health Agency as follows:

Individuals who:

(a) Occupy one of the essential positions listed above.
(b) Have been full time employees of the Health Service for at least two years.
(c) Meet the War Manpower Commission's definition for sanitary engineers.

EXCEPT IN SPECIAL CASES, SANITARY ENGINEERS UNDER THIRTY-EIGHT YEARS OF AGE SHOULD BE RELEASED FOR MILITARY SERVICE."

Information To Be Submitted

Municipality (District, Metropolitan area, etc.) .... State ....
Population ....

ESSENTIAL SANITARY ENGINEERING POSITIONS

Referring to the criteria for essential positions (Section D) list those under particular class according to population.

State duties of each position and name of person occupying position, his age, number of years employed, and whether he meets the sanitary engineering definition of the War Manpower Commission.

Example:

1. Under 500,000

D 1 The full time sanitary engineer in charge of sanitary engineering services. Duties:

Position filled by .... Age ....
Years employed in Municipality (District) .... He (does, does not) meet the War Manpower Commission definition for Sanitary Engineer.

Note: If the individual is less than thirty-eight years of age and qualified for military service, a statement should accompany that no person above this age is available and qualified to fill the position.

NEW SEWAGE WORKS PRIORITIES ORDER

Under date of July 5, 1943, the War Production Board has issued an amended Order P–141 covering maintenance, repair and operation supply requirements of public sanitary sewerage facilities. The new order greatly simplifies procedures and the various limitations on deliveries and inventories and assigns a preference rating of AA–1 to maintenance, repair and operating supply orders. The amendment of P–141 and improvements to sewerage project priorities are to be credited to A. M. Rawn, Vice-President of the Federation, who has been serving as Consultant to the Government Requirements Division of WPB for several months.

The Federation Secretarial office is arranging to make a separate mailing to all Active, Corporate and Associate Members of the amended Order P–141 with copies of other orders and instructions pertinent to our field. It is expected that the mailing can be accomplished before the end of July.

WAR PRODUCTION BOARD

Part 3209—Public Sanitary Sewerage Facilities—Maintenance, Repair and Operating Supplies

[Preference Rating Order P-141, as amended July 5, 1943]

Part 3209 is hereby amended by changing the title to read "Public Sanitary Sewerage Facilities—Maintenance, Repair and Operating Supplies."

Section 3209.1 is hereby amended to read as follows:

§ 3209.1 *Preference Rating Order P-141*—(a) *Definitions.* For the purpose of this order:

(1) "Operator" means any individual, partnership, association, corporation, governmental corporation or agency, or any organized group of persons, whether incorporated or not, located in the United States, its territories, or possessions, engaged in or constructing facilities for the purpose of engaging in, the operation of a public sanitary sewerage system or a public sanitary sewerage system combined with a storm sewerage system, whether or not such operator has applied the preference ratings herein assigned.

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

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

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

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

(6) "Operating supplies" means:

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

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

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

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

(9) "Calendar quarterly period" means the several three months of the year commencing January 1, April 1, July 1, and October 1, or the operator's customary accounting period closest to such period.

(10) "Inventory" means all new or salvaged material in the operator's possession, unless physically incorporated in plant, without regard to its accounting classification, excluding, however, material which is segregated for use in additions and expansions specifically authorized under paragraph (e) (2) of this order or by an operative preference rating order or certificate issued by the War Production Board.

(b) *Preference ratings.* (1) A preference rating of AA-1 is hereby assigned to orders to be placed by an operator for material to be used for maintenance or repair, and for operating supplies.

(2) To orders to be placed by an operator for material required for construction of sewer pipelines, manhole structures and pumping stations and equipment and appurtenant works (but not including sewage disposal or treatment plants or plant equipment) to serve a rated project, the lowest rating assigned to such project is hereby assigned, subject to the provisions of paragraph (e) (2) hereof.

(c) *Controlled materials*—(1) *Steel and copper.* Subject to the quantity restrictions contained in paragraph (f) of this order, any operator requiring delivery of any controlled material, except aluminum, for maintenance, repair or operating supplies, may obtain the same by placing on his delivery order the certificatoin required in paragraph (e) (1) (i) hereof. An order bearing such certification shall constitute an authorized controlled material order.

(2) *Aluminum.* (i) Any operator requiring aluminum in any of the forms or shapes constituting a controlled material, for essential maintenance, repair or operating supplies, where the use of other materials for the purpose is impracticable, may obtain the same from a controlled materials producer or from a distributor specifically authorized by the War Production Board to engage in the business of receiving aluminum for sale or resale, in an amount not to exceed 100 pounds from all sources during any one calendar quarterly period by placing on his delivery order the certification required in paragraph (e) (1) (i) hereof. An order bearing such certification shall constitute an authorized controlled material order.

(ii) Any operator who requires aluminum in any of the forms or shapes constituting a controlled material, in amounts aggregating more than 100 pounds from all sources during any one calendar quarterly period for use as essential maintenance, repair or operating supplies where the use of other material for such purpose is not practicable, may apply for an allotment of the amount thereof in excess of 100 pounds during any one calendar quarterly period by letter addressed to the Aluminum and Magnesium Division, War Production Board, Washington, D. C., Ref: P-141. The letter should contain substantially the information called for by paragraphs (d) (1) to (6) of Supplementary Order M-1-i, as amended March 10, 1943. If the application is granted, the applicant will receive an allotment number or symbol and may place an authorized controlled material order by endorsing an order with such allotment number or symbol and the certification prescribed in paragraph (e) (1) (i) hereof.

(d) *Restrictions on use of symbol and ratings.* (1) The allotment symbol and preference ratings hereby assigned shall not be used by an operator or supplier to obtain deliveries of scarce material, the use of which could be eliminated without serious loss of efficiency by substitution of less scarce material or by change of design.

(2) The preference ratings assigned by paragraph (b) (1) hereof for maintenance, repair and operating supplies shall not be used to obtain any item included in Lists A, B, or C of Priorities Regulation No. 3.

(e) *Application and extension of ratings; application of CMP allotment symbol*—(1) *Certification.* (i) The AA-1 rating assigned by paragraph (b) (1) of this order and the CMP allotment symbol MRO-P-141 may be applied by an operator to deliveries of material for use in maintenance, or repair, or as operating supplies only by use of a certification in substantially the following form:

Preference Rating AA-1, CMP Allotment Symbol MRO-P-141. The undersigned purchaser certifies, subject to the penalties of Section 35 (A) of the United States Criminal Code, to the seller and to the War Production Board, that to the best of his knowledge and belief the undersigned is authorized under applicable War Production Board regulations or orders to place this delivery order, to receive the item(s) ordered for the purpose for which ordered, and to use any preference rating or allotment number or symbol which the undersigned has placed on this order.

....
Name of operator

....
Signature of designated official

Such certification shall be signed manually or as provided in Priorities Regulation No. 7.

(ii) The ratings assigned by paragraph (b) (2) of this order may be applied by an operator to deliveries of material for use in construction of sewer pipelines, manhole structures and pumping stations and equipment and appurtenant works (but not including sewage disposal or treatment plants or plant equipment) to serve rated projects, by use of the certification provided in Priorities Regulation No. 3 as amended (or the alternative standard form of certification provided in CMP Regulation No. 7): *Provided,* That approval of the construction of such facilities has been granted pursuant to paragraph (e) (2) hereof.

(2) In addition to the requirements of paragraph (e) (1), no operator shall apply the preference ratings assigned in paragraph (b) (2), or segregate material from inventory for the uses described in such paragraph, or accept delivery of material for such uses, until he has first obtained authorization by the War Production Board after filing application at the place prescribed for filing application for authorization to construct the project. If the rated project to be served is or will be owned by Federal Public Housing Authority or if such project is constructed pursuant to an order in the P-55 series, or by an order in the P-19-h series issued to Federal Public Housing Authority as builder, such application for authorization shall be made on Form PD-545. In all other cases, such application, unless otherwise directed, shall be made on Form WPB-617 (formerly PD-200).

(3) The ratings assigned by this order may be extended by a supplier in the manner provided in Priorities Regulation No. 3, and CMP Regulation No. 3.

(4) An order for material other than controlled material, bearing a rating assigned or extended in accordance with this paragraph (e) and a CMP allotment number or symbol, shall have the same status as a rated order bearing a CMP allotment number under all applicable CMP regulations. Such number or symbol shall constitute an "allotment number or symbol" for the purposes of CMP Regulation No. 3.

(f) *Restrictions on deliveries, inventory and withdrawals*—(1) *Deliveries and withdrawals.* No operator shall, during any calendar quarterly period, accept delivery of any material or withdraw from inventory any material, to be used for maintenance or repair or as operating supplies or for any other purpose (except material to be segregated for use in additions and expansions specifically authorized under paragraph (e) (2) of this order or by an operative preference rating order or certificate issued by the War Production Board), the aggregate dollar value of which shall exceed the aggregate dollar value of materials used for maintenance or repair or as operating supplies, during the corresponding calendar quarterly period of the year 1942, or at the operator's option, twenty-five per cent of the aggregate dollar value of materials used for said purpose during the operator's fiscal year ending closest to December 31, 1942.

(2) *Inventory.* No operator shall, at any time, accept delivery of any material if the operator's inventory will, by virtue of such acceptance, be in excess of a practical working minimum.

(3) *Exceptions.* The provisions of paragraph (f) (1) of this order are subject to the following exceptions:

(i) An operator who, during the calendar year 1942 (or fiscal year ending closest to December 31, 1942), used for maintenance, repair, and as operating supplies, materials of the aggregate value of not exceeding $1,000 and whose estimated requirements for materials to be used for maintenance, repair and as operating supplies during any calendar year (or corresponding fiscal year) do not exceed $1,000 may, during such year, exceed the quantity restrictions prescribed by paragraph (f) (1) of this order. If the actual requirements of material for maintenance, repair and operating supplies for such year should prove to be in excess of $1,000, such operator shall not accept any deliveries of material or withdraw from inventory any material to be used for maintenance, repair or as operating supplies if such deliveries or withdrawals, when taken together with other deliveries or withdrawals within such year, would, in the aggregate, exceed $1,000. In such case the operator may apply for specific authorization to exceed such quantity restrictions pursuant to the provisions of paragraph (f) (4) hereof.

(ii) An operator may, in any calendar quarterly period, increase scheduled deliveries, and withdrawals of material required for maintenance or repair or as operating supplies over the limits prescribed in paragraph (f) (1) of this order, in proportion to the increase in the load on the system during the preceding calendar quarterly period of the year 1942 corresponding to the calendar quarterly period in question, determined by a measurement of the average daily flow for the two comparative periods: *Provided,* That in determining the average daily flow of sewage, any flow of surface storm water which enters the system shall not be taken into account.

(iii) An operator may, in any calendar quarterly period, accept deliveries of material or make withdrawals from inventory of material, necessary for the maintenance or repair of the operator's property or equipment which is damaged by acts of the public enemy, sabotage, explosion, or fire or by flood, storm or other similar climatic conditions: *Provided,* That if the restrictions of paragraph (f) (1) are exceeded because of such deliveries or use, a full report thereof shall be made within thirty days after such delivery or withdrawal, to the War Production Board.

(iv) An operator may, in any calendar quarterly period, accept delivery of material, having, in the aggregate, a dollar value of not more than the dollar value of material of the same class taken from the operator's inventory for delivery to other persons authorized to accept delivery under applicable regulations of the War Production Board but only if, and to the extent that, such taking has reduced the operator's inventory of material below a practical working minimum.

(v) An operator may, during any calendar year (or his fiscal year), withdraw from inventory, material, having, in the aggregate, a dollar value of not more than the dollar value of usable material of the same class salvaged from plant during such year.

(vi) The provisions of paragraph (f) (1) and (f) (2) shall not apply to fuel or to chemicals for sewage treatment.

(4) The War Production Board, on its own initiative, or on application of any operator by letter, in triplicate, addressed to the Government Division, War Production Board, Washington, D. C., Ref: P-141, may modify the limitations on practical working minimum inventory, and on scheduling or accepting deliveries, or on use or withdrawals, set forth in this paragraph (f).

(g) *Restrictions on construction of sewerage facilities.* No operator shall construct any sewerage facilities, including but not limited to sewer pipelines, manhole structures, pumping stations, sewage disposal or treatment plants and connections, and no operator shall, in case of contract construction, accept deliveries of material for such purposes except as follows:

(1) An operator may construct an addition to, or an expansion of, sewerage system or works, other than buildings: *Provided,* That such addition or expansion shall not include any work order, job or project in which the cost of material shall exceed $1,500 in the case of underground sewer pipeline addition or extension, and $500 in the case of any other addition or expansion: *And provided,* That no single construction project shall be subdivided into parts in order to come below these limits: *And further provided,* That in making house connections or extension of line to serve premises, no iron or steel pipe shall be used except the minimum quantities required in making necessary connections.

(2) An operator may construct sewer pipe lines, manhole structures and pumping stations and equipment, and appurtenant works (but not including sewage disposal or treatment plants or plant equipment) to serve rated projects in which the cost of material is in excess of the dollar limits prescribed in paragraph (g) (1) hereof, if, but only if, the construction of such facilities is authorized by the War Production Board pursuant to the provisions of paragraph (e) (2) hereof.

(3) An operator may construct sewage disposal or treatment plants and any sewerage facilities other than those referred to in paragraphs (1) and (2) of this paragraph (g), only pursuant to specific authorization by the War Production Board, by the issuance of an order in the P-19 series or other applicable order, pursuant to application on form WPB-617 (formerly PD-200), or in such other form as may be prescribed.

(h) *Sales of material from inventory.* Any operator may sell to another operator material from seller's inventory in excess of a practical minimum working inventory: *Provided,* That (1) a preference rating of AA-5 or higher assigned by this order or by any preference rating certificate, or (2) a specific direction issued by the War Production Board, is applied or extended to the operator selling such material.

(i) *Audits and reports.*

(1) Each operator and each supplier who applies the preference ratings or allotment symbol hereby assigned, and each person who accepts a purchase order or contract for material to which a preference rating or symbol is applied, shall submit from time to time to an audit and inspection by duly authorized representatives of the War Production Board.

(2) Each operator and each such supplier shall execute and file with the War Production Board such reports and questionnaires as said Board shall from time to time request, subject to approval by the Bureau of the Budget as required under the Federal Reports Act.

(3) Each operator shall maintain a continuing record of inventory and of segregated material in his possession and all material used by him for maintenance, repair or as operating supplies.

(j) *Communications to the War Production Board.* All reports required to be filed hereunder and all communications concerning this order shall, unless otherwise directed by the War Production Board, be addressed to the War Production Board, Government Division, Washington, D. C., Ref: P-141.

(k) *Violations.* Any person who wilfully violates any provisions of this order or who, in connection with this order, wilfully conceals a material fact or furnishes false information to any department or agency of the United States, is guilty of a crime and, upon conviction, may be punished by fine or imprisonment. In addition, any such person may be prohibited from making or obtaining further deliveries of, or from processing or using material under priority control, and may be deprived of priorities assistance.

(l) *Revocation or amendment.* This order may be revoked or amended at any time as to any operator or any supplier. In the event of revocation, deliveries already rated pursuant to this order shall be completed in accordance with said rating, unless the rating has been specifically revoked with respect thereto. No additional applications of the ratings to any other deliveries shall thereafter be made by the operator or supplier affected by such revocation.

(m) *Applicability of regulations.*

(1) Preference Rating Order P-141 is issued in lieu of Preference Rating Order P-46 in so far as it affects public sanitary sewerage systems as defined in paragraph (a) (1) hereof and any reference in any order or regulation of the War Production Board to said Preference Rating Order P-46 shall constitute a reference to orders in the P-141 series.

(2) This order and all transactions affected hereby, except as herein otherwise provided, are subject to all applicable regulations of the War Production Board as amended from time to time, *Provided,* That none of the provisions of CMP Regulations No. 5 or No. 5A shall apply to operators as defined in paragraph (a) (1) hereof, and no such operator shall obtain any material under the provisions of either of said regulations.

Issued this 5th day of July 1943.

War Production Board,
By J. Joseph Whelan,
Recording Secretary.

TIPS AND QUIPS

Worn sprockets in sludge collector and bucket elevator mechanisms are regularly salvaged at the Minneapolis-St. Paul Sanitary District by building up the worn parts with a hard gear bronze. A sheet metal template, conforming to the original shape of the sprocket, is used by the welder as a guide in restoring the proper contour. A weld rod of 31T hard bronze has proven successful and grinding of the rebuilt sprocket has been considered unnecessary as any rough areas are found to "wear in" very quickly.

In discussing this practice, Chief Engineer George J. Schroepfer suggests that a harder metal such as Stellite might be better adapted to restoring grit chamber collector sprockets.

* * *

Superintendents of sewage works employing women laboratory technicians may be interested in the suggestions offered by the George S. May Business Foundation:

> "All you have to do in order to get effective production from women workers is to select them carefully; assign them to the work for which they are best fitted; train them; house them properly and provide social recreations and adequate wash and rest rooms; don't work them over 48 hours per week, nor require them to lift over 35 per cent of their body weight; re-engineer plant operations to their lesser strength and stature; dress them safely and neatly; provide day nurseries for their children; pay them as much as you pay men on similar jobs; arrange for transportation where plant is isolated, especially at night; supervise them properly, and play them peppy music."

Well?

* * *

Another digester gas explosion—this time at the Fargo, North Dakota treatment works where a terrific blast and fire occurred about 1:30 A.M. on April 27. The report of this mishap contained in the April issue of *Official Bulletin* (North Dakota Water and Sewage Works Conference) does not furnish details of the cause of the explosion, except that a gas leak must have developed in the main control room. Extensive damage to the roof of the building and to motors and equipment will prevent operation of the plant for some time.

* * *

From *News Broadcast* of the New York State Sewage Works Association:

WANTED—Sewage Plant Operator. Leading community on Long Island desires operator over 80 years of age and with at least six dependent children. Applicant must be allergic to defense industries. Opportunity for right man to clean up on this job. Good salary plus various reclamation concessions. Box X.Y.Z.

* * *

Many operators save wear and tear on their vocal cords by making available a printed leaflet for distribution to sludge users and prospective users. The brief but complete leaflet used with success at the Aurora (Illinois) Sanitary District is reproduced herewith:

Aurora Sanitary District

INSTRUCTIONS FOR USING SLUDGE FERTILIZER

SLUDGE is the earth-like remainder left from the solids removed from Aurora sewage after the objectionable part has been removed by scavenger bacteria.

SLUDGE is a fibre-filled soil rich in humus. It is about equal to barnyard manure for general use.

Average Analysis (Dry)

Humus	35 to 40%
Nitrogen	2 to 3%
Phosphorus	1 to 2%
Growth Hormones	Present

The ideal soil contains 20% sand, 40% clay and 40% humus. Most local soils are deficient in humus, which *SLUDGE* can supply. *SLUDGE* will break down a clay soil and close up a sandy soil, causing either to be more workable (friable) and hold water longer for plant use.

SLUDGE is generally free from weed seeds and is practically odorless, although it may have a slight musty odor after a rain and before it has been worked into the soil. None after.

SLUDGE may be used on lawns, flower gardens, trees and shrubs. It should *not* be used, however, in vegetable gardens in which vegetables eaten uncooked are grown. It is best to spread it over the area to be treated in the fall and spade it into the ground in the spring.

SLUDGE should not be mistaken for a balanced fertilizer but it is well worth hauling and application to the ground. There is no charge for *SLUDGE*. It is free for the hauling.

Application

Garden and flower beds—3 to 5 inches should be spaded well into the ground.

New lawns—3 to 4 inches should be worked well into the seed bed before seeding. As much as one (1) cubic yard per 100 square feet may be used to advantage in proportions up to ⅓ to ½ of the soil volume.

Existing lawns—About 1 inch should be raked into the grass roots and in bare areas.

Trees and shrubs—Use as "mulch" around roots.

Note: Always mix sludge into the soil. Most seeds will not germinate directly in sludge.

WALTER A. SPERRY, *Supt.*

A recent release * by the U. S. Department of Labor indicates that a large percentage of industrial accidents result from plant housekeeping. The bulletin states:

"Cram all the accidents that happen from poor housekeeping into one picture and you have—

Men tripping over loose objects on floors, stairs and platforms;

Hit by falling objects or improperly piled or supported materials;

Slipping on greasy, wet or dirty floors;

Running against poorly piled or placed materials;

Piercing their feet or hands on projecting nails;

And the climax, a fire starting in rubbish or oil-soaked clothes and spreading beyond control through flammable or readily combustible materials scattered about needlessly."

Made up as a safety sign, this summary of accident causes might bring about more individual attention to plant housekeeping by employees!

* * *

First Victory Gardener—"Do you use sludge on your radishes?"
Second Victory Gardener—"Nope. I like salt much better!"

* * *

MAKE PLANS NOW!

Second Wartime Sanitation Conference

Federation of Sewage Works Associations

Chicago, Illinois

October 21–23, 1943

* Special Bulletin No. 10.

Editorial

YR. EDITOR'S THOUGHTS IN BLACK AND WHITE

Now that the May issue's in the mails, I must plan the July issue. That article from Snell—will I get the drawings in time? At last, I have something from Pennsylvania—remember that visit with Siebert last summer re TNT wastes? Sorry Ted Moses wasn't there. How lucky that Duke Donaldson sent me that paper by Dr. Setter just in time for this issue and so much to the point of the discussions I have had lately with Sam Greeley on Gordon Fair's studies of recirculation of mixed liquor, as reported in Logan's thesis. I wish we had more experimental data on parallel operation of standard activated sludge and tapered aeration, stage feeding, etc. Sawyer didn't do so well with stage feeding at Two Rivers, but maybe all plants might not have so much short-circuiting. Well, Dick Gould's ideas on design are stimulating and, with Greeley's collaboration, Hunt's Point ought to be the culmination of new ideas on design of activated sludge plants. Back to the Journal—

I'm glad we can have a good section on research in July. There's Doc. Rudolfs' paper on sludge concentration—he has certainly been the lifesaver of the research section of the Journal for many years. I'm glad Miller sent me Straub's paper just at the right time—July is always the low point and I still wonder what sort of an issue it will be—pretty slim, I guess. I should have boiled down Snell's paper, but can't spare a day for that—it would be a real job.

Well, Pete came through with a fine "Corner" and I am happy that the Texas and California operators get a lot of space (their states have a lot of space). Gladys has a big abstract section and that will help.

Galley proof is coming in fast—I hope the next editor will have a better proof reader than I am. Giles' diagrams will have to go in, as is, no time to hold up page proof. I'm glad I don't have to wait on the censor for approval of page proof any longer. Good enough, page proof on ads is here. I'll take the page proof to Texas with me and read it on the train. Hope we can find some way to make those plants work down there. What else is going on? Wonder if they'll have an interesting time at Ann Arbor on August fifth? Sawyer must be hard at work on those Madison lakes. Lackey ought to be able to give me papers on his work up there and on those plants down in Texas. But back to Madison—Warrick should have that bulletin out now on the cooperative work on high-rate filters. I wrote several letters to Walton about it in March, but guess I'll have to wait until the report comes out and abstract it.

Are we all ready for the Convention? Our last committee meeting was good. Sorry Gilcreas couldn't get Dr. Maxcy to come. Am glad

George Martin suggested the Saturday morning Operators' Conference, with good practical topics, so the operators won't leave before the banquet Friday night.

Gladys and I must immediately get ready for the manufacturers' section in the September issue. Want to try two-column setup—see how it reads—those articles in the Journal of Psychology indicated that the two columns will be much easier to read than our present long lines.

Must write that chapter for Dr. Grinter's book. Must arrange Saturdays at the ordnance and aniline works. Maybe I'll have a Saturday at home next month for what's left of the victory garden, and to catch up on those double-crostics in the Saturday Review of Literature. Ho-hum, it will be nice to have more time next year—only two more issues to get out. What a relief, after fifteen years.

Hope our Committee on grease salvage will take less time later. How am I going to write that paper on industrial wastes before the Convention? I must check up on those manuals on fertilizer, air diffusion and sewers—Niles, Wirts and Brooks—we ought to publish one of them this year, if possible.

How fortunate that Rawn and Klassen got their stuff to Wisely so it will appear in this issue. Rawn is doing a lot for us and George Schroepfer has been steering affairs well. Well, Texas was pretty hot—105 officially yesterday, but these air-conditioned trains are fine. Now I must write this editorial and put the July issue to bed.

F. W. Mohlman

Proceedings of Local Associations

MISSOURI WATER AND SEWERAGE CONFERENCE

Eighteenth Annual Meeting

Hannibal, Missouri, November 9–10, 1942

The meeting was attended by approximately 100 members and although this was a smaller attendance than usual we considered it a good representation in view of the transportation difficulties.

At the business meeting, held Monday evening, November 9, 1942, a committee was appointed to formulate rules and regulations for honoring the most outstanding member of the Conference each year. The meeting was conducted as usual, including discussion of the papers rendered, trips of inspection, and concluded with a banquet and entertainment.

Papers on sewage treatment were presented on Tuesday morning and were as follows:

"Historical Developments of Sewage Treatment" by George S. Russell.

"Laboratory Methods in Sewage Treatment" by Robert Campbell.

"Industrial Wastes in Springfield, Mo." by George L. Loelkes.

"Effect of the War on Water and Sewage Chemicals" by Harry Daum.

W. A. Kramer, *Secretary*

NEW ENGLAND SEWAGE WORKS ASSOCIATION

Fourteenth Annual Meeting

New Haven, Connecticut, May 26, 1943

The New England Sewage Works Association held its spring conference and annual meeting at the Hotel Garde in New Haven, Conn., on Wednesday, May 26, 1943. Seventy-eight members and guests were registered for the meeting.

The morning session was called to order by President Roscoe H. Suttie at 10:30 A.M. The reports of the Secretary-Treasurer were accepted. Mr. Joseph A. Muldoon, Chairman of the Committee on Salaries for Sewage Plant Operators, submitted a progress report to the members of the Association. No recommendations were given.

The following slate of officers was selected to serve for the year 1944:

President: Joseph A. Muldoon, Bridgeport, Conn.
First Vice-President: Frank L. Flood, Boston, Mass.
Second Vice-President: George H. Craemer, Hartford, Conn.
Directors: Charles H. Copley, Hamden, Conn.; Charles G. Richardson, Providence, Rhode Island; Edward Wright, Boston, Mass.
Secretary-Treasurer: LeRoy W. Van Kleeck, Hartford, Conn.

The first paper was on "Inlet and Outlet Design for Sedimentation Tanks" which was presented by J. Henry L. Giles, Senior Sanitary Engineer, Conn. State Department of Health. There was considerable discussion of this paper.

The above paper was followed by a symposium on Post War Planning, led by Morris M. Cohn, Sanitary Engineer, Schenectady, New York. Mr. Cohn presented a short paper and his remarks were followed by considerable discussion by the members.

The luncheon was served at 12:30 P.M. Present at the head table were Professor Roscoe H. Suttie, President, Mr. John Golden, Director of Public Works of the City of New Haven, Mr. C. A. Emerson, Consulting Engineer of Havens and Emerson, Doctor William W. Peter, Associate Professor of Public Health, Yale University, who presented a luncheon speech on "Fighting With China," Doctor Adolf Nichtenhauser, Mr. Joseph A. Muldoon, First Vice-President, Mr. Frank L. Flood, Second Vice-President, and Mr. L. W. Van Kleeck, Secretary-Treasurer.

Unfortunately, Mr. Julius W. Bugbee, dean of sewage treatment plant operators, was not present to receive his certificate of life membership in the Association. Announcement was made and the certificate will be forwarded to him.

Tribute was paid to the memory of Paul Martzell, who passed away on October 30, 1942, and who had been chief operator of the Grass Island sewage treatment plant in Greenwich since its construction in 1917. A colored photograph of Mr. Martzell in his flower garden was passed among the group and Mr. Joseph A. Doman, Sanitary Engineer for the Greenwich Department of Public Works, read a Memoriam.

Mr. John Golden spoke briefly concerning the New Haven sewage treatment program and welcomed the members and guests of the Association to his city.

During the luncheon, Doctor Peter had displayed over 30 models carved in wood of life in China. A number of slides of China were also shown in connection with his talk.

In the afternoon, First Vice-President Joseph A. Muldoon presided. The subject for discussion was "Operation of Sewage Treatment Plants in War Time." This was a round table at which operators and engineers exchanged viewpoints. Mr. Charles Emerson of Havens and Emerson then spoke briefly on the construction and special features of the Boulevard sewage treatment plant in New Haven. The members then visited the Boulevard sewage treatment plant which was the closing event of this meeting.

LeRoy W. Van Kleeck, *Secretary.*

NEW YORK STATE SEWAGE WORKS ASSOCIATION

Annual Spring Meeting

Rochester, New York, June 4–5, 1943

The Annual Spring Meeting of the New York State Sewage Works Association was held in Rochester, New York, on June 4 and 5, 1943, with headquarters at the Seneca Hotel. Approximately 100 members and guests were registered. It was considered that this attendance, even though somewhat less than usual, was satisfactory, considering the present travel restrictions and the fact that most members now have considerable extra work due to participation in war activities.

General arrangements for the meeting, as well as arrangements for the entertainment, were made by the Genesee Valley Section of the NYSSWA, who acted as hosts for the meeting.

On Thursday evening, June 3, the Executive Committee of the NYSSWA held its usual dinner meeting. Present at this meeting were Edward J. Smith, President; K. C. McKeeman, William H. Larkin, William D. Denise, George W. Moore, W. L. Malcolm, members of the Executive Committee; C. George Andersen, representative of the NYSSWA on the Federation Board of Control; A. S. Bedell, Secretary-Treasurer; J. C. Brigham, Asst. Treasurer; and A. W. Eustance, Asst. Secretary.

Following a brief business meeting on Friday morning, June 4, the technical session was opened with a paper by J. T. Howson, plant operator, Westfield, New York, entitled "Standard Rate Filter Operation Experiences at Westfield, New York." In this paper Mr. Howson explained operating difficulties at his plant and how they were corrected. In concluding his paper, Mr. Howson stated that B.O.D. reduction in the plant means little to a local taxpayer, but that exhibits of samples of the sewage at various stages of treatment showing improvement in the several stages, plus a clean plant with well-kept grounds, mean much more; and that such a demonstration makes for a well-satisfied taxpayer and will aid in improving the status of the operator in his community.

This paper was discussed by Carl Bernhardt, District Engineer, State Department of Health, Jamestown, New York; and in his discussion, he pointed out the need of B.O.D. tests to determine efficiency of a plant and the need of cooperation between village and industries to solve the industrial waste problem at sewage plants.

In a further discussion of Mr. Howson's paper, Newell L. Nussbaumer, Consulting Engineer of Buffalo, New York, discussed operating conditions at District No. 5 plant in Cheektowaga, a plant vitally affected by war industries and war housing developments. Mr. Nussbaumer stressed the necessity of consultation between plant operator and designing engineer in order to straighten out operating difficulties.

Considerable discussion from the floor followed Mr. Howson's paper, with Morris Cohn, William Ryan, and S. E. Kappe participating.

A paper not originally scheduled on the program entitled, "Emergency Repair to Gate Valve on Force Main," was given by C. George Andersen of Rockville Centre. This interesting paper tells how one community solved the problem of repairing a valve without dewatering the force main. This paper was presented with the explanation that this type of paper was desired from operators for competition in the Kenneth Allen Award, a paper showing work and study over and above that needed for the actual operation of the plant. Mr. Andersen is Chairman of the Kenneth Allen Memorial Award Committee.

The last paper in the morning session was given by Edwin C. McKeeman of Freeport, New York, entitled "Operation of Freeport, Long Island, Sewage Treatment Plant Before and After Improvements." Improvements to this plant included a sludge concentrating tank to concentrate sludge prior to discharging sludge to digestion tanks. This device eliminates excess supernatant liquid from the digestors and results in improved operating conditions in the plant. Considerable discussion followed this paper, with particular reference to use of sludge as fertilizer on gardens.

Entries submitted in the Gadget Contest were on view in the ballroom. A total of five legitimate entries were received and one entry, a "Rube Goldberg" affair, was submitted in fun. The number of entries was somewhat less than usual, probably due to transportation difficulties, although the quality of the entries was up to par.

At the noon luncheon on Friday, the members were welcomed to Rochester by a member of the City Council and were urged to see the famous display of lilacs at the city park. Other guests from the city of Rochester were W. N. Roberts, Commissioner of Public Works; and John V. Lewis, Deputy Commissioner of Public Works. The presentation of the Rating Award to the operator submitting the best report on the operation of his plant for the preceding year was made by A. W. Eustance, Chairman of the Rating Committee, to Edward J. Smith, Operator of the Niagara Falls sewage treatment plant. In his presentation, Mr. Eustance pointed out that this was the first year that the President of our Association, during his term of office, has won this award. Following this presentation, Lt. William T. Harter, USNR, U. S. Naval Training Station, Sampson, New York, gave an interesting talk on the Sampson Naval Training Station, its building and its functions. Following his talk, Lt. Harter conducted a question and answer discussion with Warrant Officer Andrew W. Pucota, also from the Sampson Naval Training Station, bringing out in this discussion the highlights of his career in the Navy which included participation in both the present and the last World Wars.

The afternoon technical session was opened by Glenn D. Holmes, Consulting Engineer, Syracuse, New York, who spoke on "Post-War Planning—Syracuse and Onondaga County." Mr. Holmes stated that post-war planning in Syracuse and Onondaga County is not a program to list or to make plans for all conceivable projects which may be invented to make work after the war, but a real plan, looking well into the future, for the lasting benefit of the entire area. To develop such a plan, three groups have been set up: the Research and Planning Group, the Ways and Means Group, and the Public Participation Group. Various agencies of the city and county are also cooperating in this work. In closing, Mr. Holmes quoted a recent statement by Mayor Kennedy of Syracuse, "Three important things must be kept in mind: first, that the initial concern of our country be to win the war; second, that post-war planning be kept within the bonds of common sense; third, that what is planned be within our means."

The next paper, read by Uhl T. Mann, Superintendent, Sewage Plant at Cortland, N. Y., was jointly prepared by him with James T. Lynch, Superintendent, Sewage Plant, Auburn, N. Y., and entitled "Rotary Vacuum Filtration of Sludge and the Effect of the War on Operation." This paper compared the operation of the two plants, one of which filters raw sludge and the other, digested sludge. The effect of the war on operation was expressed by the following five items: (1) Increased load due to wartime industry, (2) loss of personnel, (3) difficulty in obtaining equipment and repair parts, and restrictions on necessary new work, (4) increased cost for lower grade filter cloths, and (5) increased cost of chemicals.

A scheduled paper entitled "Stream Organisms as an Index of Effective Reduction in Oxygen Demand" was not given due to the absence of the author, G. E. Burdick, Jr., of the New York State Conservation Department.

A paper entitled "The Operation and Maintenance of Sewage Pumps" was given by Glenn Searls, Supervisor, Sewage Treatment Plants, Rochester, New York.

Following Mr. Searls' paper, there was considerable discussion of all the afternoon papers, which had been postponed until the end of the session. N. L. Nussbaumer and Morris Cohn both discussed Mr. Holmes' paper on post-war planning. This discussion brought out the need of completing now detailed plans and specifications for those portions of the master plan which will be scheduled for immediate construction after the war, but delaying the detailed plans and specifications for later projects, particularly those which would be influenced by change in population or similar changes, until the project is being considered for construction.

Mr. Cohn also made an announcement concerning the Rating Award from the Federation, advising that he favors the present rating plans of the NYSSWA and hopes that the Federation will adopt a similar plan.

The informal banquet and entertainment was held Friday evening and this banquet was well attended.

The Saturday morning program opened with a Sunrise Breakfast, at which time the winners of the Gadget Contest were announced.

First place was won by J. D. Slough of Wellsville for his entry of a magnetic valve for use in compositing a sewage sample. Second place went to H. D. Hutchison of Newark, whose entry was a sludge blanket finder. Third place was won by A. E. Martin of the town of Tonawanda for his entry of a visible gas pressure indicator. Mr. Martin also exhibited a scum burner and a portable carbon-dioxide testing equipment.

The Saturday morning Round Table on "Questions and Answers on Wartime Operation of Sewage Plants" was conducted by Morris Cohn, Sanitary and Testing Engineer, Schenectady, New York. In his opening remarks, Mr. Cohn stated that most of the present sewage plant operators are experiencing for the first time the impact of war on sewage treatment, since very few of the operators in 1917 are still operating sewage plants.

Mr. Cohn listed twelve points where the war impact may affect sewage treatment plants, their operation and operators: (1) Increase or decrease in sewage flow due to shift of population *to* centers of war work and *from* points of non-production. (2) Increase of sewage flow due to concentration of men-in-training, tributary to public sewer systems. (3) Change in rate of flow throughout the day or throughout the week, due to changed life habits of community dwellers, and the round-the-clock operation of industries that formerly made a strong point of the 40-hour week. (4) Change in composition of sewage due to the production of industrial wastes, in unusual quantity or quality. (5) Effect of war shortage on the "3 M's of Operation"—Men, Materials and Mechanisms—the men to operate the works; the materials and supplies with which to perform operations and maintenance, and the machines *with which* or *by which* to perform our functions. (6) The tradition-blasting employment of women in actual sewage works operation tasks, as women on the production line have changed manufacturing to "femufacturing." (7) Increased cost of operation due to commodity costs and demands of labor for increased pay. (8) The effect of restrictive orders and priorities upon plant enlargement, revision, reconstruction or construction. (9) The swing of public opinion and national demands towards the utilization of sewage sludge as a fertilizing material; the use of gas for power production; and even the conservation of fish-food by pollution prevention. (10) Protection against sabotage and bombing damage by blackout, protective lighting and fencing, training, camouflaging, etc. (11) The improvement of supply-and-manpower relationships between communities situated "in the same boat" of war emergency conditions. (12) The need for "looking ahead" to the post-war period when scarce materials will become abundant, when labor shortages will become labor surpluses, and when the unfinished problems of sewage treatment stand a real chance of becoming completed in the first decade after victory.

Following Mr. Cohn's opening remarks, A. M. Rawn, Vice-President of the Federation of Sewage Works Associations and Chief of the Sewage and Sanitation Section of the Governmental Division of the War Production Board, addressed the group, discussing briefly his activities on this board and the general philosophy behind the changes in procedures due to the transfer of sewerage matters from the Utilities Section of the Power Branch to the Sanitation Section of the Governmental Division. Mr. Rawn indicated that after two months' intensive work he believed they had worked out a new Sewerage Preference Order which when promulgated will greatly simplify procedures in securing priorities in the future.

Mr. Rawn also stated the criteria governing new construction. (1) Is the work essential to public health and safety? (2) Is it essential to the war effort? These criteria must be applied in making application for priority assistance, and if application can prove that the work is essential for either or both of the above reasons, favorable action will undoubtedly be taken by the WPB. New construction must, however, follow wartime construction standards. Address all communications for priority assistance to Governmental Division, WPB, and underline "Sewerage." In preparing an application, study list of critical materials given in "Critical Construction Materials Design Guide," WPB, Conservation Division.

Major J. H. Brewster, U. S. Public Health Service, Office of Civilian Defense, next addressed the group on the subject of civilian defense, pointing out the lack of organization, particularly on the part of inland communities in preparing for any reconstruction of sewage facilities necessitated by enemy action or sabotage. Most communities have been depending on contractors for this work, but contractors are not now available. This work is important because, in most instances, sewers will have to be repaired before work can be commenced on water mains. Major Brewster urged that we come out of our state of complacency and get the municipalities to study this problem to determine how they could rehabilitate sewer systems, if necessary, and plan for the temporary disposal of sewage. In stressing the importance of this, Major Brewster explained the amount of damage to be expected even from a token raid.

In a further discussion of this problem, Major Brewster advised that he didn't feel that this was the time to make big expenditures on camouflage, but we should know how to do this work, if necessary. In his office, Mr. Francis Keally, a camouflage specialist, is available at all times for consultation. Since the chances of direct enemy action decrease as we start coming out on top in this war, sabotage will become more frequent. Right now we are at that point and can look for acts of sabotage. Major Brewster advises, therefore, that we should have at least a paper set-up for repairs of sewerage systems and facilities, with selected personnel properly identified, registered, etc., ready to act if the occasion necessitates.

In further discussion of wartime problems at sewage plants, Mr. McKeeman of Freeport noted that laundry wastes have increased considerably in his community since several commercial laundries have closed. Another noticeable result of the war is the reduction of the quantity of grease reaching the sewage plants, due in part to grease salvage and in part to limited quantities of fats available.

Time did not permit a complete discussion of Morris Cohn's twelve points on the effect of war on sewage treatment, but the items discussed were interesting and to the point.

The next meeting of the New York State Sewage Works Association will be held in conjunction with the meeting of the Sanitary Section of the A.S.C.E. in New York City in January, 1944.

A. S. BEDELL, *Secretary*

OHIO CONFERENCE ON SEWAGE TREATMENT

Seventeenth Annual Meeting

Mansfield, Ohio, June 23, 1943

The seventeenth annual meeting of the Ohio Conference was held on June 23, 1943, in the Mansfield-Leland Hotel. The total registration was eighty-five.

The officers for 1943–44 were elected as follows: *Chairman,* R. F. Snyder, Massillon; *Vice-Chairman,* J. R. Turner, Mansfield; *Secretary-Treasurer,* D. D. Heffelfinger, Alliance.

The meeting opened with a round table discussion of the topics: "War Time Effects on Treatment Plants," led by T. C. Schaetzle; "Problems of Sampling and Sampling Methods," led by C. D. McGuire; "Activated Sludge," led by J. R. Collier; and "Sludge Handling and Disposal," led by G. E. Flower.

Papers presented were:

"Problems of Plant Operation and Coordination" by Walter E. Gerdel.

"War Time Planning of Federation of Sewage Works Associations" by W. H. Wisely.

"War Time Problems in Sewage Treatment from the Consulting Sanitary Engineer's Viewpoint" by F. C. Tolles.

"Present and Post-War Planning of the State Department of Health" by F. H. Waring.

"Sewage Treatment Problems at Military Installations and Cooperation Between Military and Civil Authorities on Joint Treatment Problems" by Lt. Col. B. F. Hatch.

"Latest War Production Board Priorities Information" by A. M. Rawn, Engineer-Consultant, War Production Board.

A banquet was held in the evening at which time greetings were received from the Honorable William J. Locke, Mayor of Mansfield. Dr. G. E. Symons, associate editor of *Water Works and Sewerage,* spoke on "Sewage Treatment Processes and Comparison of Results Obtained." Mr. L. H. Enslow, editor of the same journal, discussed the recent rulings of the War Manpower Commission as regards the disposition of sanitary engineers between military and civilian activities.

W. H. WISELY, *Federation Secretary*

PACIFIC NORTHWEST SEWAGE WORKS ASSOCIATION

Ninth Annual Meeting

Bellingham, Washington, May 6, 1943

Because of war time conditions this meeting was planned for the evening only, of May 6, 1943. The dinner and meeting were held in the Leopold Hotel.

The dinner preceding the meeting was so well attended that all who desired to join the group were unable to do so because of lack of space and service facilities which could not be expanded to provide for the unexpectedly large number in attendance.

Following the dinner hour, the meeting was held in an assembly room and was called to order by President R. E. Koon, who explained that Secretary-Treasurer Fred Merryfield was now overseas as a Captain in the U. S. Engineer Corps, and that Archie H. Rice, who had served for Captain Merryfield since January, had just received a commission as Second Lieutenant, U. S. Engineer Corps, Sanitary Branch, and was leaving immediately for training camp.

After these announcements the following program was presented:

"Sewage Treatment at Army Camps" by R. E. Ramseier.

"Preparation for Post-War Construction" by L. R. Durkee, Assistant Regional Director, Federal Works Agency, Seattle, Washington.

"The Aims and Progress of the Federation" by George J. Schroepfer, President, Federation of Sewage Works Associations, St. Paul, Minnesota.

Mr. R. E. Ramseier, Senior Sanitary Engineer, Office of the Division Engineer, U. S. Engineers, Salt Lake City, Utah, presented an interesting and informative paper, but because of war time restrictions he was unable to leave a copy with the Association or to permit its publication.

Mr. Durkee spoke relative to the necessity of early planning for post-war construction of sewer system improvements and sewage treatment works. He emphasized the belief that local agencies must take the initiative in this regard and not wait for the Federal Government to provide funds or other incentives for such action.

Mr. Schroepfer confined his remarks mainly to a discussion of operations of the Federation, its accomplishments and future plans.

A brief business meeting was then held.

As a consequence of the sudden departure of Lt. Rice, Acting Secretary-Treasurer, there was no official report from the Secretary-Treasurer. President Koon stated verbally that there was a balance in the treasury of $65.25 as compared with $75.96 on May 1, 1942, as reported at the last annual meeting. There were 60 members who had paid dues for 1943 as of May 5, 1943 and 13 additional payments were made at this annual meeting, making the total membership 73 for 1943.

There were 56 members and guests in attendance at the Bellingham meeting.

The following officers were elected for the ensuing year:

M. S. Campbell, *President*
C. V. Signor, *1st Vice-President*
C. M. Howard, *2nd Vice-President*
W. P. Hughes, *Secretary-treasurer*
C. D. Forsbeck, *Director*

FLORIDA SEWAGE WORKS ASSOCIATION

Third Annual Meeting

West Palm Beach, Florida, June 9–12, 1943

The Florida Sewage Works Association in co-operation with the Florida State Board of Health and the Florida Section of the American Water Works Association held a Short School in Water and Sewage Treatment at West Palm Beach on June 9, 10, 11 and 12.

Just short of two hundred operators from water and sewage plants of the army, navy and various municipalities registered for the course. The meetings were held at the West Palm Beach Water Company. The program, so far as sewage treatment was concerned, was as follows:

"Operation and Maintenance of Water and Sewage Pumps" by Captain deWolf.

"Hydraulic Flow Measurements—Simple Mathematical Problems in Water and Sewerage" by Captain Taylor.

"Sewage Treatment Processes" by Joe Williamson, Jr.

"Operation of Primary Treatment Plants" by Captain Scott.

"Operation of Trickling Filter Plants" by G. W. Ferguson.

"Operation of Activated Sludge Plants" by representatives of activated sludge equipment manufacturers.

"Operational Problems of Sewage Treatment Plants" by H. I. Kurtz.

"Operation and Maintenance of Automatic Pump Control Equipment" by Mr. Ward.

The commanding officer of Morrison Field, which is located at West Palm Beach, invited the entire group to inspect the water and sewage plants at Morrison Field. This trip was taken at 3:00 on Friday afternoon.

The entire group held a dinner at the George Washington Hotel on Friday evening at which time the Extension Division of the University of Florida gave out special Short School attendance certificates to all who had attended the first three days.

The Florida Sewage Works Association held its annual business meeting on the evening of June 9. In the absence of President Drew, Vice-President Fiveash of Fort Lauderdale presided. Director Joe Williamson, Jr., who had attended the Cleveland meeting, made an interesting report. An interesting discussion relative to the voluntary certification of sewage plant operators developed and as a consequence a three-man committee was appointed to investigate and prepare such a plan, using the voluntary water works operators certification plan as a guide. This committee was instructed to have its report ready for the next annual meeting. A standing committee was also appointed whose duties are "to investigate and carry on any needed research on problems of sewerage and sewage treatment peculiar to Florida." Fifteen new members were obtained of whom seven also joined the Federation by subscribing to the *Journal.*

1943–1944 Officers

President—Chas. E. Fiveash
Vice-President—J. B. Miller
Secretary-Treasurer—J. R. Hoy

J. R. Hoy, *Secretary*

Reviews and Abstracts

CALIFORNIA SEWAGE WORKS JOURNAL

Volume 15 (1943)

A Sanitary Survey of Sewage Pollution of the Surf and Beaches of Santa Monica Bay

By Elmer Belt, M.D., pp. 27–39

Pollution reaching the shores of all cities along Santa Monica Bay has increased at an alarming rate, with mounting danger of epidemics, and increasing filthiness of the beaches. The Los Angeles region has the third greatest population concentration in the United States, and the sewage from this population is for the most part dumped into the sea at Hyperion Beach. The outfall sewers are overtaxed, and because of seams which have developed in the north outfall this sewer is bypassed into Ballona Creek at Culver City during high storm flows. Permission for this was granted by the California State Board of Public Health, and the need of this step brought the problem to the attention of the authorities. Permission to operate the sewage plant and outfall at Hyperion Beach is granted only on a yearly basis, on the stipulation that Los Angeles City take steps to modernize the sewage disposal plant. This study was undertaken to bring the whole problem to the public.

Sewage Disposal Works.—The Hyperion sewage plant is located opposite the city of El Segundo, slightly south of the center of the bay shoreline. It is a screening plant, with large bar screens in the intake, and 10 revolving screens, 10 ft. by 12 ft., with slots 2 in. by $\frac{2}{32}$ in. Each screen has a capacity of 33 cu. ft. per sec. except two in which the capacity has been increased about 50 per cent by changing the slots to $\frac{3}{32}$ in. width. Ordinary excess flows are bypassed around the screens to the outfall, and excessive flows are bypassed ahead of the intake to the beach. The outfall extends 5,000 ft. into the ocean where the water is about 54 ft. deep. There are several breaks on the line, two of them quite large; one is at mid-tide line where the sewage discharges up through the sand at peak flows, and the other about 400 ft. off shore.

Field Investigations.—Field investigations and studies were carried on throughout the year 1942. The purpose of the investigation was:

1. To obtain information as to the amount and condition of sewage debris on the beaches and surf,
2. To study operating conditions of the sewage plant,
3. To observe the condition and operation of the outfall,
4. To make a detailed study of wind and weather, and air and ocean temperatures,
5. To observe and record all types of ocean currents, and factors influencing them,
6. To obtain samples of surf and polluted sand, and to isolate intestinal bacteria, and
7. To record the size and geographical distribution of the crowds at the beaches.

Regular observations were made at 17 stations located along the shore of the bay for a distance of approximately 16 miles. Each station was inspected at least twice a week, and samples of the surf were collected for culturing once a week. The sewage plant was inspected at each trip and conditions of operation and amount of bypassing noted. A complete report of the study is being prepared by the State Department of Public Health.

Relationship of Wind, Ocean Surface Currents and Spread by Sewage Debris.—Records were kept of the direction and velocity of the wind during every hour of the day throughout the year, and these were correlated with the direction and strength of ocean currents.

The natural current in the bay is not over one-tenth of a mile per hour in calm weather and often is practically zero. Observations indicate that in calm weather there is no movement in a north or south direction, movements being in- or off-shore, depending on the tide. Winds were the most important factor in creating currents that deposited sewage debris on the beaches.

Laboratory Work.—Samples were collected in sterile 4-oz. bottles suspended from a 20-ft. pole extended out into the surf. A total of 45 to 47 samples were cultured for *Escherichia Coli* at each station during the year. Mixtures of sewage debris and sand were also collected, and 10 cc. portions of the polluted sand ground in a sterile mortar and mixed with 10 cc. of sterile water. These samples were cultured in the same amounts as were the surf samples. At least two of such samples were collected at stations 5 to 15, inclusive, during the year. All such cultures were positive for *Escherichia Coli* in amounts from 24 to 110 plus per cc.

The following table shows results of cultures from surf samples at all stations.

Number of Coliform Bacteria per Cc.	Stations																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10 or more	1	2	1	2	13	11	23	36	#	41	33	25	20	10	12	5	10
6 to 10	1	1	1	3	13	8	4	4	#	4	7	8	8	5	7	7	4
Less than 6	11	17	15	19	18	17	10	7	#	2	7	13	19	23	18	16	15
0 in 1 cc. of sample	34	27	30	23	3	11	19	0	#	0	0	1	0	9	10	19	17
Total	45	45	45	46	47	46	47	47	#	47	47	47	47	47	47	47	46

Note: On three occasions 10 cc. of sample was cultured from each station. All 10 cc. samples were positive for *Escherichia Coli* at every station. Stations 10 to 17 are north of outfall.

Sewage outfall: Samples not regularly cultured. *Escherichia Coli* found 100,000 to 1,000,000 per cc.

All samples were cultured in duplicate tubes of 1 cc., 0.1 cc., and 0.01 cc. It is noted that the greater number of samples having 10 or more coliform bacteria per cc. came from stations north of the outfall. This conforms to the fact that the southwest wind is present in sufficient velocity most of the year to create surface currents.

Degree of Pollution in Surf.—Because of the high coli count in samples from the surf at the outfall it was not considered necessary to make regular cultures from these samples. At the time cultures were made of samples from this station maximum dilution cultures were made from samples from the two stations nearest the outfall (stations 8 and 10). Two samples each at stations 8 and 10 and one at station 10 contained 2,000 *Escherichia Coli* per cc., one sample each at stations 8 and 10 contained 1,000 coli per cc., and the remaining samples contained 500 coli per cc. or less. It was noted, however, that the count falls, even in grossly polluted surf at a distance of a mile or more from the outfall. A series of survival tests were made and the results indicated a regular death rate of *Escherichia Coli* in natural sea water that rapidly reduced its numbers in a few hours time. However, a few survivors were found viable in cultures several days after the samples were obtained. The table below shows the decrease in *Escherichia Coli* in sea water stored at room temperature. The figures represent the maximum dilution of the sea water in which *Escherichia Coli* were isolated.

Hours:	Immediate	4	8	12	16	20	24	48
Station 8	1/500	1/100		1/10		1.		1.
Station 10	1/1000	1/500	1/100		1/10		1.	1.

Coli counts in excess of 110 per cc. were found in the surf nine miles from the outfall in spite of this bacteriological action of sea water. Examination of the polluted surf indicated that most of the sewage bacteria were transported in very fine particles of tissue or fuzz-like debris.

Epidemiology.—Thousands of people use these beaches every month. Organizations opposed to spending money for a new sewage treatment plant have argued that no serious illness has been traced to bathing in the surf. An epidemiological survey of the Los Angeles area would be extremely difficult. However, certain knowledge was gained from the survey. Three life guards had to leave their jobs for varying periods of time because of serious dysentery. A number of frequent users of the beach gave histories of acute diarrhoea after swimming in the polluted surf. Doctors along the bay state they are kept busy with cases of dysentery, the numbers being in proportion to the numbers of swimmers. The incidence of bacillary dysentery, paratyphoid fever, and poliomyelitis is higher in Los Angeles than elsewhere in the state in proportion to population.

Protection of Sewage Works in War Time

Discussion led by William T. Ingram, pp. 40–51

This discussion covers thoroughly problems in connection with the protection of sewerage systems and sewage treatment works against sabotage and bombing. A review of the discussion appears in the March, 1943, issue of *Sewage Works Journal,* pages 329–331.

Shore Pollution Reduction at San Francisco

By Charles Gilman Hyde, pp. 52–61

This paper was published in *Sewage Works Journal,* 15, 3 (January, 1943).

Problems of Disposal of Peach and Tomato Wastes from the Largest Cannery in the West

By Grover L. Walters, pp. 62–63

At Fullerton, canning and juicing plant wastes have been a factor in the problem of sewage disposal affecting the Joint Outfall Sewer System of Orange County. The largest canning plant of the west is located here. This plant handles peaches and tomatoes, with a 1942 pack of 747,000 cases of peaches, and an estimated pack of 1,000,000 cases of tomatoes.

An understanding was reached between the city and the cannery officials whereby the wastes entering the sewers will be reduced to a minimum. The plant is also to install and operate as soon as possible pre-treatment devices to remove excessive amounts of suspended solids. It appears that treatment by other than mechanical means will not be necessary. Due to material shortages it has not been possible to build the plant and an attempt was made this season to remove the entire cannery flow from the city sewers.

The flow is now passed to a wet well and then pumped through fine rotary screens. Screened effluent could be pumped to a tract of land of 120 acres owned by the cannery, or diverted to the sewers. At the start of the peach canning season the inlet to the sewer was stopped off and the entire flow pumped to the land. The area was not properly prepared for ponding and some adjoining land was flooded. The cannery then used a nearby flood control channel as a means of disposal but vigorous complaints soon forced the discontinuing of this practice. During the balance of the season such flows as cannot be absorbed by the acreage will be taken into the city sewers.

Characteristics and Treatment of Potato Dehydration Wastes

By Harold Farnsworth Gray and Harvey F. Ludwig, pp. 64–70

This paper was published in *Sewage Works Journal*, 15, 71 (January, 1943).

Ventilation of Large Sewers in the City of Los Angeles

By H. G. Smith, pp. 71–79

An inspection trip made through the North Outfall sewer in 1936 disclosed the fact that very serious corrosive action was taking place due to gases generated by the sewage. Repair was felt impractical and chlorination, successful in other outfalls, was too costly, considering the high flows and the condition of the sewage. Ventilation had been recommended for a sewer, since abandoned, by Dr. Rudolph Herring, over 40 years ago. An experimental ventilation plant was installed in 1938. This plant was located on the lower section of the outfall and is described in a paper published in the March, 1939, issue of *Sewage Works Journal.*

The section ventilated by this plant was about 6 miles in length, extending from the Hyperion screening plant to a syphon under Centinela Avenue. The outfall is semi-elliptical in section, 10.5 ft. by 12.3 ft., and was built of unreinforced concrete, lined with cement jointed tile. A blower was used which delivered about 22,000 cu. ft. of air per minute. Air was admitted to the sewer through apertures in 14 manhole covers over a distance of about three miles.

Results were quite gratifying. The interior walls became dry and the cement joints, which previously had the consistency of putty, became hard and firm. Cement blocks placed at a number of points in the sewer after ventilation was started showed no indication of deterioration after several years. The exhausted air had a hydrogen sulfide content of 16 p.p.m. and a relative humidity of 100 per cent.

The plant was operated until October, 1941, when extensive repairs to the engine became necessary. A new plant has been constructed at the middle of the six mile section and is nearly completed. There are two blowers, each rated at 22,000 cu. ft. of air per minute at a static pressure of 15 in. water. The blowers discharge to two wood stave stacks, 27 in. in inside diameter and throttled to 18 in. at the outlets which are 80 ft. above the ground. The stacks are provided with vermiculite filled silencers. Outlet velocities will be over 200 ft. per sec.

In the spring of 1938 complaints on odors from an area adjacent to another section of the outfall were received. Investigation showed that a new syphon, made necessary by river channel improvements, had shut off free flow of gas and air up and down the sewer, and that the gas flooded back through laterals and found an outlet by way of roof vents. The first method tried to relieve the situation at this point consisted of venting the gas through a hot spot induced by burning commercial gas. Odors were destroyed but not enough gas could be removed from the sewer. Accordingly, it was decided to install a blower plant, using a high velocity in the stack discharge.

At this station satisfactory conditions were obtained as regards odors when the stack height was increased to 60 ft. and the stack velocity was maintained at 150 to 160 ft. per second. However, noises created by air leaving the stack were very objectionable until a silencer was installed, using vermiculite as the absorbing medium. A permanent station was placed in operation in October, 1941. Satisfactory conditions are obtained by operating the blowers a few hours in the morning and again in the afternoon.

Another ventilating station was installed on a sewer where violent explosions had occurred from time to time. The area served is largely industrial, and at times liquids were discharged that later gave off explosive gases. The equipment consisted of a blower of 2,500 cu. ft. per minute capacity at 12½ in. water pressure. The stack height was 40 ft. when the station was built but this was later increased to 70 ft. Almost from the start of operation complaints were received because of odors. It developed that odors were produced intermittently, with no evidence of odor between appearances. Tests indicated that these "bursts" carried as high as 120 p.p.m. of hydrogen sulfide.

Tests were then made on eliminating odors by means of chemical sprays. These tests led to the construction of four brick towers adjacent to the blower station. Each tower was four feet square and 10 feet high, and was equipped with wooden covers. By means of ducts gases were passed up and down through these towers while being sprayed. The liquid was pumped from the bottom of the towers to a regenerating tank. It was found that complete mixture of spray and air was necessary for efficient removal of odors. Many different chemicals and mixtures were tried. At present a combination of a small quantity of chlorine and soda ash in water is being used.

San Bernardino Sewage Plant Revisions

By David H. Currie, pp. 80–83

Location of a government depot near San Bernardino necessitated either enlarging the city sewage works or the building of a separate plant by the Government. An agreement was reached, under the terms of which the Government paid the city a lump sum for the enlargement of the plant and the disposal of the sewage from the depot for a period of 50 years.

The existing plant consists of four Imhoff tanks, two trickling filters, a chlorine contact tank, and sludge beds. The Imhoff tanks provided a detention period of 1.24 hours, design basis, and a sludge storage capacity of 2 cu. ft. per capita. The trickling filters were designed for 3,000 persons per acre-foot, and the design of the drying beds was 0.5 sq. ft. per capita.

In the design of the plant extensions it was decided to expand the capacity of the present plant to the limit of the capacity of the filters. Construction and alterations are now under way. A pre-aeration unit is provided which is designed for a period of two hours. This is followed by primary clarification with an overflow rate of 800 gallons per sq. ft. per day.

Changes are being made in the trickling filters whereby the rate of application will be decreased and the time of application correspondingly increased. The filters have a volume of 752,000 cu. ft. With a loading of 10 lb. B.O.D. per 1,000 cu. ft., and 50 per cent removal by pre-aeration and primary clarification, the filters have sufficient capacity to serve 85,000 persons. Secondary clarification will be provided with the same overflow rate as the primary units.

The Imhoff tanks are being revamped to provide two 2-stage digesters. The volume will be about 2¼ cu. ft. per capita. The primary digesters will be heated.

Operators' Symposium, pp. 84–96

There were four topics for discussion; Sludge Gas Meters, Sludge Heating Coils, Digester Scum, and Pump and Motor Standards. During the discussion on heating coils it was suggested that data bearing on the rate of heat transfer be collected by the operators and turned over to the chairman of the Design Committee for study.

The committee on standards for sewage pumps, motors, and controls submitted standard specifications for purchase of such equipment. The specifications are to be accompanied by a data sheet showing the quantity, head, and other pertinent data. Any modification to the specifications are also to be noted on this data sheet. There was some discussion of the principal items of the specifications.

T. L. Herrick

TESTING STATION ON IPIRANGA SEWAGE. ACTIVATED SLUDGE

By J. P. J. Netto

Bull. Dept. Water and Sewage, Dept. Public Works, Sao Paulo, Brazil.
Year 6, No. 14, pp. 22–30 (1942)

This is a description in Portuguese of tests on sewage made at Ipiranga with the activated sludge process in a plant handling about 2,600 cu. m. per day (687,000 gal. per

24 hr.). The plant consists of a primary settling tank (period about 1.5 hr.), three aeration tanks, and a secondary settling tank (period about 2 hr.). The settling tanks are equipped with straight line mechanisms. The excess sludge daily is about 1 per cent of the effluent.

The aeration tanks are of the spiral flow type, 3 m. (9.85 ft.) wide and 4 m. (13.12 ft.) deep, inside dimension. The deflectors at the top are small, inclined at 40 to 45° with the horizontal. There is a single line of diffuser plates, of Norton make, with a permeability of 34. The rate of application of air varied from 0.5 to 1.2 cu. m. per sq. m. of diffuser area (1.64 to 3.94 cu. ft. per sq. ft.). The quantity of air used varies from 4 to 12 liters per liter of sewage (0.54 to 1.62 cu. ft. per gal.). The oxygen required by the activated sludge varies from 8 to 14 p.p.m. per gram of sludge with a contact period from 2 to 6 hours.

In the tests, about 8 liters of air were used per liter of sewage (1.08 cu. ft. per gal.) with varying aeration periods of 2.4 or 6 hours. Ingersoll air compressors were used, at 5.6 to 6 lb. per sq. in. pressure, with a maximum possible of 8 lb. The return sludge is about 20 per cent of the volume in the aerators. The dissolved oxygen in the aeration tanks varied from 1.7 to 5.4 p.p.m.

Chemical treatment was also tried, applying sulfate of alumina to the influent of an Imhoff tank. Experiments were also made with a Dorr flocculator and settling tank. About 50 p.p.m. of coagulant were used. The Dorr tank showed a higher efficiency in removal of settling solids.

Langdon Pearse

MELBOURNE AND METROPOLITAN BOARD OF WORKS

Annual Report Year Ending June 30, 1942

This Board controls both the water supply and sewerage of the Melbourne Metropolitan area in Australia. The total number of water services was 302,361 and the population served was 1,200,373. The estimated sewer services were 286,473, with a population of 1,137,297. There were 783 factories. The water consumption for the year averaged 71.97 Imp. gal. (86.4 U. S. gal.) per cap. per day.

Early in 1942 practically all regular sewerage construction work stopped. Considerable construction work has been done for the Commonwealth and the U. S. Army.

The working expense for sewerage was £232,157 (about $753,000).

There are two small treatment plants, serving about 7,100 and 560 people, respectively. The sewage farm receives the bulk of the flow. The annual rainfall has averaged 18.22 inches over 48 years.

The profit on sheep raising was a record. About 66,000 were sold. The Commonwealth Government has continued the ban on the sale of cattle from the farm for human consumption, in the face of a beef famine in Southern Australia. About 10,000 cattle are normally carried. Horses were also boarded. Over 500 acres were sown to wheat and oats. The expense of the farm was £129,000 (about $418,000), whereas the income was about £115,700 (approximately $375,000), mostly from sales of sheep.

War conditions have increased the difficulty of carrying on.

About 681,000 night soil cans were collected, cleaned, and disinfected.

The occurrence of hydrogen sulfide in the main sewers and the outfall is a problem on which tests are being made. Single-stage filters are being tried.

(*Note:* The Australian pound is figured at $3.24.)

Langdon Pearse

BIRMINGHAM, TAME AND REA DISTRICT DRAINAGE BOARD

28th Annual Report. Year 1941–1942

The annual report reflects the war conditions in Great Britain. The population of the main sewerage district is 1,264,629. The sewage flow is 48.32 (Imp.) m.g.d., or 57.984 m.g.d. (U. S.), of which 41 (Imp.) m.g.d. passes through the Tame Valley Works.

Shortage of labor and declining efficiency hinder operation. In the year ended Dec. 31, 1941, 82,269,424 cu. ft. of sludge digestion gas was used, generating 3,753,957 units of electricity through 11 gas engines totaling 2,370 H.P. The fuel value of the gas was equivalent to over 4,500 tons of coal. The total annual cost per rated tenement was 10 shillings, 6 pence (approximately $2.12).

The increasing interest of farmers in sewage sludge has led to cooperation with the Rothamsted Experimental Station in field experiments, comparing various sludges in different amounts with and without the addition of sulfate of ammonia. The entire experimental field received a dressing of potash and superphosphate.

For sedimentation, rectangular tanks with cross baffles were believed desirable, although not cleaned mechanically. Mixing of sewage occurs in sedimentation tanks. Some equalization of flow is secured by using two weirs set at different levels, to impound sewage at high flows and release at low flow. At Coleshill, a mechanical scraping device is used to clean rectangular tanks 230 ft. long. For activated sludge, final settling rates of upward flow up to 8.5 ft. per hr. are considered satisfactory in circular tanks with mechanical cleaners. At Yardley, no sludge is lost in the effluent at 12.5 ft. per hr. upward flow velocity. A circular settling tank with tangential inlet (showing 100 p.p.m. suspended matter in the effluent) was found inferior to the upflow tank (showing 19 p.p.m. suspended matter in the effluent).

Langdon Pearse

CONTINUOUS FLOW SEDIMENTATION IN THE TREATMENT OF SEWAGE

By L. B. Escritt

Institute of Sewage Purification (Nov. 27, 1942)
Surveyor, 101, 433–37 (1942)

This is a review of sedimentation data and practice in the United States, Great Britain, and Canada, from 1904 to date. The author starts with the Hazen theory (which I am told was derived by Hazen largely from observations on the behavior of sand particles in a glass of water on his desk) that the depth of a tank had no effect upon sedimentation, but that the size of a particle which could be settled depends on the surface area of the tank, and states—

Practice Flow Rate	Area Settling Tank
British Max. 3 times D.W.F.	1 sq. ft. per 200 or 300 Imp. gal. (240 to 360 U. S. gal.) per day D.W.F.
	Varies from 200 Imp. gal. for primary to 450 Imp. gal. for humus.
U. S. practice	
(Metcalf and Eddy) shows—	
300 Imp. gal (360 U. S. gal.) per sq. ft. per day for granular solids.	
600 Imp. gal. (720 U. S. gal.) per sq. ft. per day for tanks 5 ft. or more in depth.	
800 to 1,000 Imp. gal. (960 to 1,200 U. S. gal.) per sq. ft. per day for humus tanks.	

Following an academic discussion of settlement of particles, turbulence, and detritus settlement, grit chambers are considered with the possibility of obtaining constant velocity channels. They should be of sufficient length to give storage for detritus. At Mogden, England, the design calls for a horizontal velocity of 1 f.p.s. and a falling velocity of 0.1 f.p.s. Detritus does not flocculate.

Flocculation is the clinging together of small particles and collecting into larger, thus increasing the falling velocity. Reference is made to the studies of Fischer, Hurley, Gehm, and Keefer. Eddies which form around the inlets should be dissipated. Various horizontal velocities of flow (suggested by Temple, Metcalf and Eddy, Babbitt and

Schlenz, Imhoff, Fuller and McClintock, and Smith) range from 50 to 600 ft. per hour for preliminary settling. Metcalf and Eddy and others suggest 30 to 40 ft. per hr. for final settling in activated sludge works.

Benas suggests 0.8 ft. per sec. as optimum for flocculation.

The author states that horizontal velocities may produce vertical velocities in the order of one-tenth the horizontal velocity.

Theoretical detention periods are discussed but the practical comparison relates to a pyramidal upward flow tank, where short circuiting occurred.

Detention periods are discussed. English practice is to design works on the basis of a maximum rate of flow equal to 3 times the D.W.F. Thus the minimum period is one-third of the term of hours D.W.F. In some cases one-half the normal day solids arrive during 6 hours peak flow. English practice (Royal Commission) is 10 to 15 hr. D.W.F. for primary tanks. American practice for percolating filter plants varies from 1½ to 6 hr., with 1½ to 2½ hr. in recent work for primary tanks and 1 to 1½ hr. for the humus tanks. English practice may provide a capacity of 6 hr. D.W.F. for final settling of activated sludge because of the volume of returned sludge. In American practice, from 20 min. to 1½ hr. in preliminary tanks, and from 1½ to 2 hr. in final tanks, are used in the activated sludge process. The Ministry of Health believes at least 4 hr. D.W.F. capacity is required. In recent works English tank capacities are 3 times American practice.

The design of Dortmund, pyramidal, and two-stage sedimentation tanks are considered. Balancing tanks are mentioned, largely unknown in American practice.

Removal of sludge by hand is yielding to various forms of mechanical designs, suitable for circular or rectangular tanks.

The pitch of pyramidal bottoms in England is about 60° with horizontal. In American practice 1.75 in 1 or steeper is common. The discharge of sludge from a tank by gravity is used when practicable.

Inlet channels need attention to prevent deposit of grit or heavy material.

Elasticity of design is desirable to meet varying conditions.

(*Note:* This article is of interest to show the English point of view, under conditions radically different from those in the United States. The author omits all mention of handling eddy currents in final activated sludge settling tanks and the work of Zack, Eddy, and others in that field.)

LANGDON PEARSE

THE YARDLEY SEWAGE DISPOSAL WORKS OF THE BIRMINGHAM, TAME AND REA DISTRICT DRAINAGE BOARD

By F. C. VOKES AND S. H. JENKINS

J. Institute Civil Engineers, 65–84, No. 2, 1942–43 (Dec., 1942)

The Yardley Works, handling about 60,000 population, was the first in Great Britain to use sludge gas in a gas engine for power. Extensions of the settling tanks and trickling filters have been made from time to time. Since 1936, acid trade wastes have increased the ponding on the filters. In 1937, temporary treatment was installed, adding ground quicklime to the crude sewage, followed by aeration. Such devices are now included in the extensions, which also include bio-flocculation ahead of the filters. The plans call for a plant adequate for 200,000 people, including (1) screening plant and detritus tanks; (2) plant for adding lime and aerating the sewage for iron removal; (3) sedimentation tanks; (4) bio-flocculation plant; (5) new distributors; (6) additional humus tanks; (7) enlargement of sludge digestion plant and sludge drying beds; (8) plant for generating power from sludge gas.

Sewage passes through 6-inch openings, in bar screens, then 2-inch. Two detritus tanks, for maximum flow 36 Imp. m.g.d. (43.2 m.g.d. U. S.), with velocity 1 f.p.sec. One tank is for use up to 3 D.W.F.; then two between 3 and 6 D.W.F.

To remove iron salts lime is added by dry feed, followed by aeration in three unit tanks, with total capacity 17 min. D.W.F.

Sedimentation in one stage is provided by three rectangular horizontal flow tanks, each 230 ft. long by 60 ft. wide, and 10 ft. deep, with a floor pitch of 1 in 200 ft. towards inlet end, where there are deep hoppers. A gantry crane, electrically driven, draws a scraper the length of the tank, towards the hoppers. On the return the scraper is lifted, serving to skim the floating material to a channel at the outlet end.

Bio-flocculation handles settled sewage up to 9 (Imp.) m.g.d. (10.8 m.g.d. U. S.), in six unit tanks, having a total capacity of 1.71 D.W.F., and reconditioning tanks of equal capacity. The tanks have a series of channels 20 ft. wide by 60 ft. 6 in. long, with water depth of 10 ft. over diffusers. Each flocculation tank is supplied with a reconditioning tank.

Three centrifugal pumps with a total capacity of 37 per cent D.W.F. return activated sludge to the reconditioning tanks. The four settling tanks are 44 ft. diameter, with bottom sloped at 30° to center, equipped with electrically driven scraper.

The old distributors have been replaced by new distributors, self-propelled, capable of handling 4.25 Imp. m.g.d. per acre (5.1 m.g.d. U. S. per acre). The average effective depth of the filter is 5 ft. 3 in., filled with ¾ to 1½ in. quartzite.

The new humus tanks are circular, upward flow type, with electrically-driven scraper working to sludge outlet at center.

The crude sewage (after aeration and liming) receives the humus and excess activated sludge. The sludge digestion is two-stage. There are ten primary tanks, each 61 ft. 4 in. long by 31 ft. 4 in. wide; overall depth 16 ft.; sludge depth 14 ft. 6 in.; equipped with floating steel gas collector. Ten primary tanks have a total capacity 283,000 cu. ft.; five secondary have a total capacity 306,000 cu. ft. The combined capacity for 200,000 persons is 2.95 cu. ft. per capita. There are no gas collectors on the secondary tanks.

Part of the gas is used to generate electricity, part to heat the sludge in the primary tanks. Alkaline liquor from the secondary tanks is heated in a heat exchanger to pass into the primary tank.

The power house contains 3-cylinder gas engines, one at 150 B.H.P., the other, 118 B.H.P.

The reconstructed works went into service in November, 1938. The D.W.F. increased each year: 4.6 Imp. m.g.d. (5.52 U. S. m.g.d.) in 1938; 5.9 Imp. m.g.d. (7.08 U. S. m.g.d.) in 1939; 6.2 Imp. m.g.d. (7.44 U. S. m.g.d.) in 1940. The crude sewage has a B.O.D. of 250 p.p.m., with an alkalinity of 120 p.p.m. (normal would be 300 p.p.m.). The pH frequently ranges between 3 and 4 for short periods between 8 A.M. and 9 P.M. On an average, 50 p.p.m. of iron are present in the sewage, with a maximum day of 275 p.p.m. The iron is removed from the sewage-surplus activated sludge-sludge liquor mixture by 50 p.p.m. lime between 8:30 A.M. and 4:30 P.P.M. The sewage is aerated throughout the 24 hours, with a 17-minute period on the D.W.F. The air diffusers show no signs of clogging.

The new settling tanks show an improvement.

Results in P.P.M.

	1938 Before Extension		1939 After Extension	
	Crude	Tank Effluent	Crude	Tank Effluent
4 hr. Ox. Absorption	125	89	120	57
Suspended Solids	299	56	313	35

In 1939 the tank floors were scraped twice daily; the hoppers desludged three times a week. The sludge contained 5.7 per cent solids.

At the Minworth Works, bio-flocculation for one hour doubled the effective capacity of the trickling filters.

At Yardley, the sludge in the flocculation tanks has been held at 4–6 per cent by volume (on one hour settling). The return sludge ranged from 6.6 to 18.5 per cent. If the return sludge exceeds 60 per cent in volume after settling one hour, bulking may occur suddenly. The detention periods in four months of 1940 were 1.46 hr. on sewage mixture and 6.4 hr. in re-aeration tanks. In 1939 the following results were obtained by bio-flocculation:

Results in P.P.M.

Determination	Settling Tank Effluent	Settling Tank Effluent after Bio-Flocculation and Settling
Ox. Absorption, 4 hr.	57	40
B.O.D.	109	81
Suspended Solids	35	18
Iron as Fe	18.6	8.8

The flow treated in 1939 was 6.6 Imp. m.g.d. (7.92 U. S. m.g.d.). The excess activated sludge on a dry basis was 9.98 tons per 24 hours. The air used averaged 0.315 cu. ft. per Imp. gal. (0.262 cu. ft. per U. S. gal.). On D.W.F. the average was 0.353 cu. ft. per Imp. gal. (0.294 cu. ft. per U. S. gal.). In the flocculation tanks 0.140 cu. ft. air per Imp. gal. (0.117 cu. ft. air per U. S. gal.) was used, and in the re-aeration tanks 1.202 cu. ft. per Imp. gal. (1.002 cu. ft. per U. S. gal.). The nominal detention periods were 1.55 hr. in the flocculation tanks; 10.49 hr. in the re-aeration tanks.

Since the extension went into operation, ponding on the trickling filters has disappeared.

The improvement in the settled effluent of the trickling filters is shown:

Results in P.P.M.

Determination	Before Extension 1938	After Extension 1939
Ox. Absorption, 4 hr.	26.0	14.2
B.O.D.	36.0	22.8
Ammoniacal N.	42.9	24.6
Oxidized N.	5.2	19.4
Suspended Solids	18	9.0

In 1939, the bio-flocculation effluent was applied to the filters at the rate of 120 Imp. gal. (144 U. S. gal.) per 24 hr. per cu. yd. of media, without ponding. The effect of dosing at increased rates with various liquors is shown:

Liquor Filtered	Imp. Gal. per Cu. Yd. per 24 Hr.	Bed	Ox. Absorp. 4 Hr. P.P.M.		Oxidized N. P.P.M.
			Influent	Effluent	
Tank effluent	185	A	40	9.8	30.9
	185	B	40	9.7	29.3
Tank effluent	170	A	52	14.4	20.4
	340	B	52	18.8	16.5
Bio-flocculation	145	A	44.5	10.7	18.3
Effluent	290	B	44.5	18.6	5.9

The yearly volume of sludge increased in cu. yd. 79,509 in 1938; 117,955 in 1939; in tons dry solids 2,987 to 5,066.

In the first stage of digestion a temperature of 70 to 78° F. is held.

Year	Digestion Capacity		Yield of Gas	
	Primary	Secondary	Cu. Ft.	Per Lb. Organic Matter
1938	48	52	32,491,000	7.2
1939	32	35	35,272,000	4.8

The gas contains 684 B.T.U. per cu. ft. and is free from hydrogen and hydrogen sulfide. Digestion reduces the organic matter by 64 per cent. The volume of the sludge is reduced 65 per cent. The air dried sludge occupies 11 per cent of the volume of the crude sludge. The air drying beds contain 50,000 sq. yd. (4 persons per sq. yd.) divided into units of 0.5 acre. These are filled to a depth of 18 inches and require 92 days for drying in the summer and 267 days in the colder months. Each bed is used twice a year. The dried sludge, containing 58 per cent moisture, is dumped.

Langdon Pearse

CITY OF JOHANNESBURG, ANNUAL REPORT OF CITY ENGINEER

Year Ending June 30, 1942

By E. J. Hamlin

The report is brief, owing to war conditions.
The average flow at the sewage works was as follows:

Works	Imp. Gal.	U. S. Gal.
Antea	369,100	442,920
Bruma	2,059,000	2,470,800
Cydna	1,171,000	1,405,200
Delta	2,213,000	2,655,600
Klipspruit	7,679,300	9,215,160

At Bruma, flat-bottomed tanks were remodelled by the use of pre-cast concrete hopper bottoms. At Delta, the separate sludge reconditioning unit, with a capacity up to 8 hr. detention, makes available a large volume of sludge to meet peak loads. The rising of sludge in the final settling tanks ceased. The addition of fine silt to the activated sludge is being tested to keep the density above 0.5. The supernatant liquor from the digestors is now settled before return to the incoming sewage, the solids being discharged to the drying beds. 940,063 kwh. was produced from 29,626,000 cu. ft. sludge gas.

At Klipspruit, preparations are being made to recirculate effluent at night. The crude grease from the sewage is to be acidified, and the recovery washed and steam distilled.

The B.O.D. test is given up as a routine procedure, in favor of the relative stability test.

Langdon Pearse

NINTH ANNUAL REPORT ON SEWAGE DISPOSAL, CITY OF JOHANNESBURG. 1940–1941

By E. J. Hamlin and H. Wilson

The operating data on the five works were:

Works	Mil. Gal. per 24 Hr.		Notes
	Imp.	U. S.	
Antea	0.432	0.478	
Bruma	1.902	2.282	Additions under way.
Cydna	—	—	Additions in hand.
Delta	1.861	2.233	Centrifugal pumps replace air lifts on sludge.
Klipspruit	7.222	8.666	Additions under way.

The recovery of grease from sewage is being studied. In general, research has been stopped by depletion of staff by war conditions. Notes on the comparative study of sizes and types of media with and without special ventilation zones in a 6-ft. and a 12-ft. deep filter are appended by A. H. Meyling. Two experimental filters, each 100 ft. diam., were used, divided into 12 radial sectors. Various arrangements were tried, with stone ranging from 1 to 1½ in., up to stone 2½ to 3 in. Dosing was by rotating sprinkler arms.

In both depths of filter the sectors provided with ventilation zones gave the best results. One zone (in the middle) is preferable to two zones (on the third points). With adequate ventilation the 12-ft. is preferred to the 6-ft.

In a second appendix E. J. Hamlin discusses the improvements at the Klipspruit Works. In the flow distribution tanks a hopper bottom was used. This tank fed 16 settling tank units. The sewage at Johannesburg contains a great deal of grease. The floating scum in a tank is hosed to an outlet, and washed to the sludge main. Compressed air jets are also used in round tanks. A reversible type of sand filter is under construction to handle the primary filter effluent. This serves both as humus tank and sand filter. When a mat of humus has formed, the flow is reversed, using filtered effluent from other units. At the same time, a squeegee traverses the top of the filter to push the mat to the channel leading to the humus draw-off.

Langdon Pearse

THE MAINTENANCE, OPERATION AND CONTROL OF SEWAGE TREATMENT PLANTS

By E. J. Hamlin

Trans. So. African Soc. Civil Engrs. (1942)

Overloading at the Delta Works at Johannesburg led to bulking in the activated sludge plant. A reactivation unit has been built on the return sludge. Usually the proportion of raw sewage to the returned activated sludge is 3:1. In South Africa the maximum flow is 3 times the average flow. The result has been an increase in the nitrates in the plant effluent up to a high monthly average of 28 p.p.m. Fine soil is added to the sludge whenever the sludge density is too low.

At Cydna there is a different problem, because of a high peak flow, 3½ times the average daily flow. A balancing tank has helped, by storing excess peak flow.

At Klipspruit, a flow dividing tank has been added to divide the flow uniformly among the unit settling tanks.

The removal of scum has also been studied. The efficiency of removal is greater in circular tanks with a series of air jets around the periphery of the tanks, with additional perforated radial pipes running to the collecting pipe at the center. The air holes all point to the center of the tank.

The Hamlin reversible filter has also been tried. The tests were also made on two experimental filters, each 100 ft. diam., one 6 ft., the other 12 ft. deep (see 9th Ann. Rep. on Sewage Disposal, City of Johannesburg).

Other experiments were made on settling in a Dortmund tank 25 ft. diam. and a primary settling tank at Bruma. A very low degree of efficiency may be improved by additional draw-off channels.

LANGDON PEARSE

DEWATERING, INCINERATION, AND USE OF SEWAGE SLUDGE

A SYMPOSIUM

Proc. Amer. Soc. Civil Eng., 69, 41–104 (January, 1943)

DEVELOPMENTS INDICATED BY EXPERIENCE AT BUFFALO, N. Y.

BY C. R. VELZY

The Buffalo sewage treatment works, designed for a population of 750,000, provides primary treatment with chlorination. The sludge disposal facilities include short period digesters, vacuum filters, and sludge incinerators. Lime and ferric chloride are used to condition the sludge prior to filtration.

The sludge digestion tanks have a capacity of one cu. ft. per capita, design basis. There are four tanks, each 90 ft. in diameter and 27.5 ft. deep at the side walls.

Dewatering equipment includes three vacuum filters, each with a filtering area of 500 sq. ft. There are three sludge incinerators with a design capacity of 100 tons of sludge cake, based on 70 per cent moisture content. The flash drying system is employed, using hot gases from the furnace in the drying circuit. Vapor from the drying system is passed through a preheater, thence to the furnace for destruction of odors. Oil or gas may be used as auxiliary fuel.

In the conditioning of sludge prior to filtration some studies have been made on details of the mixing tank. It appears that a short period with proper speed of the mixing paddle, without baffles, is best. However, more work is needed before definite conclusions can be drawn. There has been a tendency away from automatic devices for feeding chemicals and toward equipment that provides easy manual control.

Studies have been made on various types of cloth for use on the vacuum filters. Canton flannel has been found best as regards operating results and general economy. Sash cord has been found a satisfactory substitute for the bronze strips originally used in the application of the cloth to the drum. The wire screen on the surface of the filter drum became badly coated with lime scale after about two years of operation. This scale was removed by use of muriatic acid in the filter tank.

In the operation of the drying and incineration system the principal problems have been due to abrasion. During the first year of operation, during which time oil was used as auxiliary fuel, scale formed on the preheater surfaces. After using gas exclusively as fuel, scale formation has ceased and abrasion has become a problem.

Abrasion has been severe in the flash dryer. During the early months of operation replacement of bars and rings was necessary after about two months of continuous operation. Reducing the speed increased the life to about five months. Changes in method of assembly have resulted in easy replacement of worn parts and re-use of some of them.

Wear has been severe also in the induced draft fan and at bends in pipe lines and ducts. In the latter case the use of concrete wear backs at the bends has proved a very satisfactory solution. Wear in the fans limited the life of the blades to about two months. Hard surfacing of the blades by arc welding proved too costly. Ribbing of the blades with hard material was as effective as complete surfacing and much less costly. Moving the fan to the clean side of the cyclone was the real solution. One unit in this location has operated for more than a year without showing appreciable wear.

Abrasion in the fly ash cyclone has been less severe but has required attention. Some success has been had through the use of gunite, though better results would have probably been realized if a more suitable aggregate, such as trap rock, had been available. Probably some form of concrete, or some ceramic material, will be found to be more satisfactory than steel.

Operating results for three years of operation are given in the following table.

Description	Period [a]		
	1938–39	1939–40	1940–41
Moisture in raw sludge, per cent	96.54	93.38	92.77
Moisture in digested sludge, per cent	87.8	89.87	90.89
Volatile matter in raw sludge, per cent	57.6	56.4	62.9
Volatile matter in digested sludge, per cent	41.5	42.9	47.5
Chemicals used per 100 lb. dry solids,			
Ferric chloride	2.31	3.10	2.93
Lime (CaO)	9.25	11.62	11.21
Moisture in sludge cake	61.8	62.2	63.1
Volatile matter in sludge cake, per cent	38.8	38.1	42.9
Filter rate in lb. dry solids per sq. ft. per hr.	—	7.58	6.77
Incineration, total furnace hours	—	9,231	10,278
Dry solids burned (1,000 lb.)	13,559	23,525	23,226
Solids burned per furnace hour	—	2,550	2,260
Gas used for incineration, cu. ft. per lb. dry solids burned	—	1.30	1.23
Average daily gas production (1,000 cu. ft.)	—	476	516
Heat content of sludge cake (B.t.u. per lb.)	—	3,790	4,320

[a] July 1 to June 30.

The total flow for the year 1940–1941 was 51,262 million gallons. The total quantity of dry solids (including grit) was 18,300 tons. Unit costs were as follows:

Total cost of treatment, per million gallons	\$ 8.25
Cost, not including pumping and chlorination, per million gallons	\$ 5.97
Cost of treatment, per ton of raw solids	\$23.50
Cost, not including pumping and chlorination, per ton raw solids	\$16.70
Cost of solids disposal, per ton of raw solids	\$ 9.38
Cost of solids disposal, including only direct costs and maintenance and repairs, per ton of raw solids	\$ 7.07

Vacuum Filters Used in Primary Sludge Dewatering

By Ralph E. Fuhrman

The sewage treatment plant of the District of Columbia provides primary treatment, with digestion, elutriation, and vacuum filtration. Sludge cake is hauled from the plant by rail. There are four vacuum filters with filter areas of 500 sq. ft. each, which, with the auxiliary equipment, have sufficient capacity to handle the sludge in five eight-hour days. Ferric chloride is used as conditioning agent. Equipment for addition of lime is provided but thus far it has not been used.

In the operation of the plant it was found that large quantities of fine sand passed the grit chamber, settling eventually in the elutriation mixing tanks, in which air is used to accomplish the mixing. This sand accumulated until practically no mixing was attained. From this it appeared that mixing of the sludge and wash water was of minor importance. In one tank the inlet and the outlet were connected by a length of 12-in. pipe, thus reducing the time of travel from 15 to 20 minutes to about 20 seconds. It appears that the mixing within the pipe was sufficient. Plans are being made to try a similar scheme in the other mixing tank. If successful, the problem of handling this fine sand will have been eliminated by passing it on through to the vacuum filters.

In the operation of the vacuum filters it has been found very important that the filters be washed thoroughly after every operating period. Analyses of discarded filter cloths have revealed 52 per cent iron salts. Reclamation of cloths has been attempted, using a one per cent solution of oxalic acid in the filter pan. The drum was allowed to turn in the solution for a 24-hr. period. With one cloth the life was increased about 30 per cent by this method. With a cost of $120 per cloth the hourly cost of service was reduced from $0.23 to $0.18.

Trouble with fungus growths on the filter cloths has been encountered each summer during the week-end shutdowns. This has been remedied by saturating the cloths with a 100 p.p.m. solution of copper sulfate whenever the plant is to be shut down for periods longer than 16 hours. Before this procedure was adopted some cloths gave very short periods of service. The minimum has been 32 hours and the maximum 899 hours. During the calendar years of 1940 and 1941 the minimum life was 227 hours, the maximum 682 hours, and the average 408 hours.

It has been shown that without elutriation approximately three times the quantity of ferric chloride now used would be required. The following table presents an economic study of the value of elutriation.

Item	Description	Amount
1.	Construction cost of elutriation unit, including mechanical equipment	$40,500.00
2.	Patent rights	12,000.00
3.	Total investment (Items 1 and 2)	52,500.00
	Fixed charges on elutriation facilities:	
4.	Complete unit, amortized over 20 years at 3 per cent (0.037 times Item 1)	1,498.50
5.	Interest on investment (0.03 times Item 3)	1,575.00
6.	Total per year (Items 4 and 5)	3,073.50
	Operating cost for the fiscal year ending June 30, 1941:	
7.	Labor and supervision	2,496.00
8.	Materials and supplies	163.00
9.	Electrical energy	252.00
10.	Total for year (Items 7, 8 and 9)	2,911.00
11.	Total annual cost, operation and fixed charges	5,984.50
12.	Reduction in ferric chloride required	17,000.00
13.	Value of elutriation in dollars per year (Item 12 minus Item 11)	11,015.50

From this table it appears that the elutriation unit will pay for itself in four or five years. In this evaluation it is assumed that ferric chloride would be the sole conditioning agent were elutriation not practiced. No account is taken of the probable greater filter yields obtained with elutriated sludge, nor is account taken of the effect of elutriation on the life of filter cloths.

In the following table are presented data on the operation of the elutriation equipment and the sludge dewatering plant. Data are for the fiscal year ending June 30, 1941.

Analysis of elutriated sludge:

Specific gravity	1.03
Per cent solids	6.5
Volatile matter in solids	44.4
Ratio of wash water to sludge volume	3.8
Alkalinity, p.p.m.	
Digested sludge	3,364
Elutriated sludge	450
Effective wash water ratio (based on alkalinity)	7.5

Sludge dewatering plant operation:

Days of dewatering	220
Filter hours	4,705.1
Tons of cake produced (wet)	23,770.0
Solids in cake, per cent	28.9
Filter yield, lb. dry solids per sq. ft. per hour	5.9
Ferric chloride used,	
Tons	218.54
Per cent, dry basis	3.18

The costs of sludge disposal were as follows:

Ferric chloride	$ 8,500
Other operating costs of elutriation and dewatering	23,313
Railroad shipment of cake	20,929
Total	$52,742

Unit costs of sludge disposal were:

Description	General Operating Costs	Ferric Chloride	Sludge Disposal	Total
Per ton of sludge cake	$0.98	$0.36	$0.88	$2.22
Per ton of dry solids in cake	3.40	1.23	3.06	7.69
Per million gallons sewage treated	0.59	0.21	0.53	1.33

None of the above costs include the cost of sludge digestion.

Possible Economies in Sludge Disposal Practice

By George J. Schroepfer

The sludge disposal equipment at the Minneapolis-St. Paul plant was placed in operation in July, 1938. The treatment provided at this plant includes grit and screenings removal, and sedimentation. Provision is made for chemical treatment and effluent filtration in the summer months. The sludge disposal processes include concentration, dewatering on vacuum filters, and incineration. There are six vacuum filters, each with an area of 500 sq. ft. The incinerators, three in number, are of the multiple-hearth type with eight hearths. Each unit is 22.25 ft. in outside diameter.

The following table shows a comparison of filtration and incineration data by years.

Description	1938[a]	1939	1940	1941[b]
Sewage treated, m.g.d.	88.9	102.9	104.2	111.9
Suspended solids, raw sewage, p.p.m.	240	285	300	315
pH-value of concentrated sludge	6.0	5.8	5.8	5.7
pH-value of conditioned sludge	11.7	11.6	10.5	10.0
Total solids, per cent:				
Raw sludge	7.15	7.79	8.07	8.11
Thickened sludge	9.02	9.13	9.34	9.35
Filter cake	35.0	34.7	35.2	35.5
Volatile solids, filter cake, per cent	52.1	59.7	59.8	58.8
Suspended solids, filtrate, p.p.m.	315	260	165	135
Filter cake production, wet tons daily	172.0	303.3	308.3	305.7
Filter cake production, dry tons daily	58.6	103.3	108.4	108.6
Filter rate, lb. per sq. ft. per hr., dry	5.50	4.73	4.29	3.90
Period in conditioning tanks, minutes	13	12	10	9
Conditioning chemicals, per cent dry basis:				
Lime as CaO	10.3	5.68	4.76	3.81
Ferric chloride	3.17	2.10	1.92	1.60
Incineration power, kwh. per ton dry solids	18.5	17	17	14
Incineration, fuel oil, gal. per ton dry solids	3.7	2.3	2.5	1.5

[a] July to December, incl., 1938. [b] January to October, incl., 1941.

Attention is called to the planned reduction in filter rate from 5.50 lb. per sq. ft. per hour to 3.90 lb. per sq. ft. per hour, which ties in with the progressive reduction in the use of chemicals.

Costs of filtration and incineration for the same years are shown below.

Description	1938[a]	1939	1940	1941[b]
Filtration cost:				
Operation	$47,428.74	$92,177.80	$76,568.91	$60,744.22
Maintenance	2,990.74	6,932.35	5,306.02	5,706.86
Total	50,419.48	99,110.15	81,874.93	66,451.08
Incineration cost:				
Operation	19,233.60	32,393.09	35,697.84	27,007.48
Maintenance	1,808.60	4,691.93	14,524.63	13,522.59
Total	$21,042.20	$37,085.02	$50,222.47	$40,530.07
Dry solids disposed of, in tons	10,248.0[c]	37,703.0[c]	37,319.0	31,347.0
Costs per ton dry solids:				
Filtration	$ 4.92	$ 2.64	$ 2.19	$ 2.12
Incineration	2.05	0.99	1.34	1.29
Total	$ 6.97	$ 3.63	$ 3.53	$ 3.41
Cost, entire project:				
Collection, treatment and sludge disp., per ton dry solids	$ 15.40	$ 7.98	$ 8.18	$ 8.25
Cost of chemicals per ton dry solids:				
Lime at $9.30 per ton (CaO)	$ 0.96	$ 0.53	$ 0.44	$ 0.35
Ferric chloride at $39	1.24	0.82	0.75	0.62
Total	$ 2.20	$ 1.35	$ 1.19	$ 0.97
Cost of chemicals to filter 110 tons dry solids per day	$ 242.00	$ 149.00	$ 131.00	$ 106.70

[a] July to December, incl., 1938. [c] Includes conditioning chemicals.
[b] January to October, incl., 1941.

Improvements in Filtration and Incineration

Improvements and operating goals as they apply to this project should be mentioned briefly. Improvements effected at this plant should be regarded as possibilities for investigation as they might apply to a different plant.

Concentration of Sludge.—The concentration of sludge is controlled to a large extent at the sedimentation tanks. A further concentration is accomplished at the concentration tanks. In 1941 the average solids content of the sludge drawn from the sedimentation tanks was 8.11 per cent. This was increased to 9.35 per cent in the concentration tanks.

Conditioning of Sludge.—Air mixing is used in the conditioning tanks, and it was found that better results were obtained by increasing the number of points through which air is admitted and by reducing the violence of the mixing. Baffling was modified to create a twisting path, both vertically and horizontally. Improved dispersion of the chemicals was obtained by the installation of riffle boards for both lime and ferric chloride.

Filter Mediums.—At this plant an 8-oz. Canton flannel cloth is used. Cloths have been used for 800 hours in experimental investigations, but it is not economical to use them this long with the type of sludge obtained here. Newer cloths require less chemicals for the same yield. Use of cloth has been restricted to 350 hours even though they may still be in good structural condition. However, a longer period of use has been recently adopted because of the increased cost of cloth.

Plant scale tests have shown that there is a 2½ per cent loss in yield for each additional 100 hours of cloth use. These results apply to a 4-hour interval between washings. With longer intervals the yield with low chemical dosage falls off quite rapidly with older cloths. Results of tests made to determine the economical life of cloth are given below. They are based on present costs of cloth, $0.235 per square yard.

	Life of Cloth, Hours							
	100	200	300	400	500	600	700	800
Wire and Cloth	$ 36.00	$18.00	$12.00	$ 9.00	$ 7.20	$ 6.00	$ 5.15	$ 4.50
Chemicals	73.00	75.50	78.00	80.00	82.00	84.00	86.50	89.00
Total	$109.00	$93.50	$90.00	$89.00	$89.20	$90.00	$91.65	$93.50

In washing filter cloths it has been found that better results are obtained by shifting the sprays so that they impinge almost at right angles to the drum. Analysis of binding material found in a number of cloths after 300 hours to 400 hours' service was found to be about 60 per cent calcium carbonate and 20 per cent grease. At present prices it appears economical to use acid baths, using one to two carboys of hydrochloric acid and an inhibitor in 600 gallons of water. Such treatment is used after about 350 hours of service, and increases the life to 500 hours to 600 hours. Such treatment also removes deposits of calcium carbonate from the screens and splines of the filters which had previously been removed by sand blasting and other mechanical means.

Frequent washings of filters have been found economical. Intervals of 24 hours or longer between washings, used in the early months of operation, were reduced to 8 hours and then to 4 hours, the present practice. These frequent washings have had a marked effect on chemical requirements and because of its importance the staff of the District has developed a method of washing while the filters are in service, either continuously or at intervals. The method has not been incorporated to date (1942) because of priorities on necessary materials, but a description is felt justified. The wash-water pipe and nozzles would be located just below the take-off plate and the washing operation confined to the section between cake take-off and the point of submergence in the sludge. A trough located below the nozzles would carry spent water through the overflow box.

Incineration.—In May, 1941, the preheater was removed from one of the incinerators. This resulted in a reduction in power requirements from 17 kwh. per ton of dry solids to

5.5 kwh. Six months' operating experience on this unit has justified similar changes on the other units. It is estimated that this will save $12,000 annually or about 33¢ per ton dry solids in incineration operation and maintenance costs.

Fuel oil consumption has been reduced to 1.5 gallons per ton of dry solids. This is used for heating up, cooling down, and maintaining temperatures in units not in operation. Duct work has been installed so that heat available in units in operation can be used for these purposes.

Effect of Filter Rate on Cost of Filtration

During early months of operation filter rates of 8 to 10 lb. per sq. ft. per hour were maintained, using approximately 3 per cent ferric chloride and 10 per cent lime, dry basis. These rates have been gradually reduced. In October, 1941, the rate was 3.55 lb. per sq. ft. per hour and the chemical dosage was 1.23 per cent ferric chloride and 3.0 per cent lime. The reduced chemical dosage was not entirely due to the reduction in filter rate as other improvements were accomplished at the same time. However, a plant scale test of one day duration showed similar results, as shown in the following table along with routine plant results.

Description	No. of Filters Used (Test on Plant Scale)			Average Results, by the Periods:			
	6	4	3	1939	1940	1941	Oct., 1941
Filter Rate, Lb. per Sq. Ft. per Hour	3.00	4.60	6.15	4.73	4.29	3.90	3.55
Cake Thickness (1/32 In.)	5	8	12	8	7	7	6
Chemical Requirements, Per Cent							
Ferric Chloride	0.89	2.33	2.35	2.10	1.92	1.60	1.23
Lime as CaO	2.63	5.03	7.55	5.68	4.76	3.81	3.60

Studies indicate that, considering maintenance and operation costs only, a rate of about one lb. per sq. ft. per hour is most economical. With fixed charges figured at 6 per cent, a 2 lb. rate is indicated. Based on a tonnage of 110 tons dry solids per day at this plant a reduction of from 7 to 2 lb. per sq. ft. per hour would save about $125 per day in maintenance and operation costs. One additional filter would save about $5,000 annually in maintenance and operation costs, which would pay for the additional investment in two to three years.

Relative Costs of Filtration and Incineration

A study of the costs of filtration and incineration will show that the larger portion of the costs arise from filtration. At this plant, in spite of filtration costs being markedly reduced, they are still about twice the incineration costs. At other plants the difference is greater still. Future development will likely tend to reduce or eliminate filtration costs. One or two small plants have been incinerating liquid sludge for some time. In 1935, when making studies of the type of sludge disposal for this plant, the writer concluded that if the moisture content of the sludge could be reduced to 85 or 90 per cent, vacuum filtration could be economically dispensed with, assuming suitable equipment available for incinerating such sludge. Experiments have been started in which a portion of liquid sludge will be added to the filter cake in the incinerators to explore the possibilities of this procedure.

Filter Rate Index

The term pounds per square foot per hour does not furnish an accurate measure of the number of square feet of filtering surface utilized in a given period. The speed of the drum is changed frequently and these changes affect the actual area used. Knowing the number of turns and the tonnage produced in a given period of time, an accurate filter rate can be computed.

Use of Sewage Sludge as Fertilizer

By LeRoy W. Van Kleeck

In his paper "The Preservation of Domestic Wastes for Use on the Land," the eminent agricultural scientist of England, Sir Albert Howard, observes that the West has "lost direction" in dealing with problems of waste disposal. He notes that in the East the farmers for 40 centuries, the Chinese in particular, have returned all wastes to the soil. Vegetable and animal residues are mixed and converted into a humus before being added to the land, so that the soil is not overworked by having to decay this material and grow a crop at the same time.

In a discussion of this paper Arthur J. Martin states that the sanitarian is wasteful in disregarding the food cycle established by nature. Plant food is squandered and we attempt to maintain the fertility of the soil by means of artificial manures. The value of the humus in manures is overlooked in considering the nitrogen, phosphorus, and potassium content.

Use of Liquid Sludge Versus Dewatered Sludge

Objections to the use of liquid sludge are:

1. The large quantity of fluid bulk that must be transported unless pipe lines can be laid,
2. Difficulties of uniform application,
3. Likelihood of objectionable odors, and
4. The possibility of pathogenic organisms being present.

While liquid sludge does contain fertilizer constituents which are lost in the drained water in the dewatering process, the dewatering and storage of sludge are encouraged as additional safeguards against transmission of infection. No cases of sickness have been traced to the use of properly conditioned digested or activated sludge.

Use of Raw Sludge as Fertilizer

The use of raw primary sludge as fertilizer is not recommended because:

1. It is odorous,
2. It has a higher grease content than digested sludge and is not readily assimilated by the soil,
3. It tends to bring about early and persistent soil acidity, particularly if it has been conditioned with iron salts,
4. Industrial wastes in the sludge may poison the soil,
5. It is a potential carrier of disease unless highly limed in conditioning, and
6. It is not humified for soil use.

Sir Albert Howard states, in respect to the last objection, that unless the formation of humus from animal and vegetable wastes takes place before its incorporation into the soil the development of the crop will be interfered with.

Activated Sludge

Raw or heat-dried activated sludge has a much higher value as fertilizer than primary or secondary sludge because of its higher ammonia content and its higher availability. Much of the fertilizing value is lost on digestion. The analysis of Milwaukee sludge is as follows:

	Per Cent, Dry Basis
Nitrogen	6.2–6.5
Available phosphoric acid	2.5–2.75
Potash	0.5–0.75

Dewatered Digested Sludges

A comparison of primary digested sludge and related materials is shown in the following table.

Substance	Percentage by Weight, Dry Basis		
	Nitrogen	Phosphoric Acid	Potash
Digested sludge[a]	1.7 (total)	1.5	0.15
Manure[b]	1.97 (total)	1.29	1.96
Horse manure	0.7 (available)	0.11	0.45
Sheep manure	1.8 (available)	1.25	3.0
Commercial potato fertilizer	5.0 (total)	8.0	7.0

[a] Average of samples from a number of sewage plants in Connecticut.
[b] Supposedly a mixture of animal wastes.

In addition to the fertilizing values shown by the chemical analyses, sludges may have other characteristics of value as a soil conditioner. About 50 per cent of the dry weight of sludge may be humus. Most of the organic matter in digested sludge is humus except for the ether-soluble fats. Sludge is not an all-purpose plant food, but its application improves the texture of the soil. Its value should be judged by the results it produces in plant growth.

Application of Digested Sludge and Hygienic Considerations

Sludge may be applied as a top dressing or it may be spread and plowed or forked into the soil. Pulverizing the sludge cake enhances its application as a top dressing. It is best not to plant vegetables to be eaten raw, root crops, or those growing close to the ground in soil recently fertilized with digested sludge, unless the sludge has been stored for at least a month.

The following suggestions have been made for the application of digested sludge:

For orchards	10 tons wet sludge cake per acre
For grass	10 to 20 cu. yd. per acre
For vegetables, shrubs, and flowers	20 to 60 cu. yd. per acre

Fortifying Digested Sludge

Dried sludge can be mixed with chemicals and a balanced fertilizer obtained. Such mixtures should be applied to the soil in smaller amounts than indicated above. The following formula is suggested for general use:

Sludge (dry basis)	360 lb.
Ammonium sulfate	25 lb.
Acid phosphate (20 per cent)	50 lb.
Muriate of potash	15 lb.

Use of Sludge as Fertilizer

Sludge is well adapted for use on lawns, golf courses, pastures, meadows, and flower and vegetable gardens. It has been found beneficial for trees. Sludge has been used in citrus groves for many years with good results.

When used continuously sludge tends to acidify the soil, due to the breakdown of greases and fats. Corrective measures must be taken every three or four years where the crop requires a neutral or near neutral soil.

At most plants sludge is given away or used as fill. The commercial value of sludge can be considered as roughly equal to the cost of manure in that locality.

Why Digested Sludge Has Not Been More Widely Used as a Soil Conditioner

From the standpoint of many there is no doubt an objection to sludge on esthetic grounds, and to fear of producing odors. There now appears little objection from the health standpoint to properly digested, dried, and stored primary sludge and heat-dried activated sludge. Odors may be encountered through the use of manures if applied before thoroughly rotted.

Another reason is the lack of promotion at many sewage plants. In some cases this is no fault of the operating personnel but is caused by a lack of time. The principal function of a plant is the prevention of nuisance from raw sewage and not the sale of fertilizer.

Also, there is a lack of information among laymen on the proper application of sludge and its limitations. Many potential users do not appreciate the humus value of this material.

In many plants it is found more practical or economical to dispose of sludge cake by means other than as fertilizer. Storage facilities and equipment for handling sludge as a fertilizer material is apt to prove costly.

Experience of Chicago, Illinois, in the Preparation of Fertilizer

By William A. Dundas and C. P. McLaughlin

The present sewage load of the Sanitary District of Chicago is from a population of approximately 4,000,000 plus an industrial waste load equivalent to the sewage from about 3,000,000 additional persons. Practically all of the sewage is treated at four main plants. The Calumet, North Side, and Southwest Works utilize the activated sludge process, and the West Side Works provides Imhoff tank treatment with open air drying beds for drying digested sludge. Waste-activated sludge is dewatered, dried, and processed for fertilizer or incinerated at the Calumet and Southwest Works. Waste sludge from the North Side Works is pumped to the Southwest Works for disposal. The Calumet and Southwest Works were designed for daily averages of 40 tons and 375 tons, respectively.

Intensive studies of mechanical dewatering, heat-drying, and incineration were undertaken in 1931. An experimental plant with a capacity of 20 tons dry solids daily by dewatering, drying, and incineration was placed in service in 1932. By February, 1934, this plant was remodeled to develop the flash system as applied to the drying of sewage sludge and to incineration by burning in suspension.

In preparing activated sludge for fertilizer or burning its moisture must be reduced from about 97 per cent to between 5 and 10 per cent. With 5 per cent moisture in the dried sludge 64,561 pounds of water must be removed for each ton of solids. Such a quantity of water is best removed by a combination of filtration and heat-drying.

Ferric chloride is probably the best coagulant for conditioning activated sludge. It is the main item of expense in dewatering. Close control is required and the proper quantity will vary from day to day, with a seasonal swing. It appears that the amount required may be related to the volatile content of the sludge. The ferric chloride should be dosed continuously, mixed thoroughly with the sludge, and filtered as quickly as possible. Checks should be made at frequent intervals to determine the amount required for best operating results.

The filtration rate for a compressible substance like activated sludge does not increase in proportion to the pressure because the increased pressure decreases the size of the voids between the particles, thereby restricting the flow of water. Finer particles are carried by the liquid into the voids until the density increases to such extent that the passage of air and water ceases. In some cases the cake will crack and relieve the pressure, making further extraction of water impossible.

Filter operating costs on a percentage basis at the Sanitary District of Chicago are as follows:

Item	Calumet	Southwest
Ferric Chloride	40	55
Labor	21	23
Power	8	8
Filter cloth and wire	2	3
Maintenance	29	11

The life of the filtering medium is largely a function of time rather than tonnage output. Cloths are subject to rotting and frequently the life is determined by a deposit of iron oxide on the back of the cloth. A long-nap woolen blanket is used at the Sanitary District, and such cloth gives a life of about 3½ months. The life of winding wire is about the same as that of the cloth and no attempt is made to reuse it. Wooden backing has been used on a number of filters at Chicago and it appears that it may prove more economical than woven wire, which has not been satisfactory.

Heat-Drying

In drying, it is necessary to heat the sludge to the saturation temperature corresponding to the pressure in the system and to supply the latent heat of vaporization to the moisture. The fundamental factors necessary for economical and efficient drying, free from nuisance, to prepare sludge for efficient combustion or for use as fertilizer are:

(1) Maximum surface exposure,
(2) Thorough agitation of the wet material,
(3) Temperature potential of gas,
(4) Velocity of drying gas,
(5) Responsive and flexible temperature control,
(6) Deodorization of gases vented from drying operation,
(7) Instantaneous water removal, and
(8) Preservation of fertilizer qualities.

Flash drying is a continuous operation in which sludge in a finely divided state is dried instantaneously in a hot gas stream. In the Chicago installations the drying medium, superheated water vapor, enters the system at a temperature of approximately 1,100° F. and a velocity of 5,000 ft. per min. Sludge cake from the filters is mixed with previously dried material in such proportion to give a feed containing 40–60 per cent moisture. The mixture is introduced into the hot gas stream ahead of the cage mill, where the sludge is broken up into small particles thus affording maximum surface exposure. Cyclone separators are used to remove dried sludge from the system. Part of the vapors from the separators is reheated by means of a vapor heater which transfers heat from products of combustion from the furnace, and the balance, waste vapor, is passed to the furnace for destruction of odors. Dried sludge is burned in suspension in the furnace or withdrawn from the system for use as fertilizer, in which case an auxiliary fuel is used.

Heat may be carried directly by furnace gases to the drying system or transferred from furnace gases to water vapor, as at Chicago, or to air. Use of air entails lower efficiencies as it is another medium that must be heated from room temperature to stack temperature, and it supplies oxygen which might cause fires.

The rate of evaporation depends on the temperature of the drying medium, the size of the sludge particles, and the rate of removal of water vapor. Evaporation is higher with higher vapor temperature, *i.e.,* greater temperature differentials between the sludge and vapor. With small sludge particles the rate is higher as more moisture is in contact with the hot vapor. The relative velocity between the material and the drying medium must be great enough to remove instantly vapor released from the sludge.

Dried sludge has a tendency to heat and burn spontaneously when stored in large quantities over a period of time. This tendency depends on the fineness, moisture content, and the initial temperature. It is indicated that the moisture should be below 10 per cent, the material should be as free from dust as possible, and the temperature at the time of storing should be below 100° F. At Chicago, sludge is screened, cooled in water-jacketed conveyors, and part of the dust removed before loading into cars.

Combustion

The chemistry of the combustion of sewage sludge does not differ greatly from that of other solid fuels. The elementary substances encountered in either case are oxygen, nitrogen, hydrogen, carbon, sulfur, and combinations of them. Of these, carbon and hydrogen are the most important combustible substances found in sludge.

Liberation of hydrocarbon compounds is largely responsible for odors produced in the drying and burning of sludge. The ignition temperatures of these compounds lie between 1,100° and 1,200° F. Since the complete combustion of these compounds produces water vapor and carbon dioxide, both odorless, all gases and vapors resulting from the drying of sludge should be heated to at least 1,300° F. to insure complete destruction of odors.

Since the ignition temperature of combustible substances is well above the boiling point of water, the material is thoroughly dry when ignition and combustion take place. A large lump of sludge may ignite and smolder while moisture is driven off from the interior. This is inefficient combustion and may produce odors unless enough auxiliary fuel is burned to maintain temperatures high enough to ignite the combustible gases emitted and dissociate any noncombustible compound of an offensive nature. Sludge must be thoroughly dry if efficient combustion free from objectionable odors is to be obtained.

The air required to supply oxygen for combustion of various fuels may be easily calculated. This figure will vary widely with different materials when expressed as quantity of air per pound of fuel. Expressed as requirements per 10,000 B.t.u., a close agreement will be found. This figure for the theoretical air requirement is 7.5 lb. per 10,000 B.t.u. From this standpoint it appears a simple matter to supply the proper amount, but this is not the case. The air supplied must be as near the theoretical requirements as possible, and must be admitted in such manner that there is sufficient turbulence to insure intimate contact with all combustible substances.

Power Generation at Southwest Works

The annual costs of steam generation at this plant are chiefly the fixed costs on the steam generating equipment and the cost of fuel. Another advantage is the ample supply of plant effluent available for use as condensing water at a head sufficient for gravity flow.

There are four steam generating units in which dried sludge and pulverized coal can be burned together in suspension. Each unit has a capacity of 110,000 lb. of steam per hour at a pressure of 425 lb. per sq. in. and a maximum temperature of 725 to 750° F. In addition each unit can supply sufficient heat to remove up to 49,000 lb. of water per hour from sludge in the drying units.

T. L. Herrick

IMPROVED FINAL SETTLING TANKS AT BOWERY BAY

By Richard H. Gould

Civil Engineering, 13, 279 (June, 1943)

The Bowery Bay sewage treatment works of the City of New York has an installed capacity of 40 m.g.d. Treatment facilities include screens, grit chambers, preliminary settling tanks, aeration and final settling tanks, sludge concentration tanks, and digestion and storage tanks. Facilities for secondary treatment were placed in operation in the spring of 1942.

There are two four-pass aeration tanks of the spiral flow type. Provisions for step aeration are included, with sewage introduced at the head end of each pass. After the first few weeks of operation the first pass has been used for re-aeration of sludge, with sewage added at the head end of the last three passes in equal increments.

Return sludge is held at about 40 per cent of the sewage flow so that the solids concentration in the first pass will be low enough at all times to permit maintenance of dissolved oxygen. The dissolved oxygen is held at about 1 p.p.m. in the first pass and at about 3 p.p.m. at the end of the last pass.

Design of Final Settling Tanks.—The final settling tanks at Bowery Bay, it is believed, are different from any before constructed. It appears that heretofore the aim has been to secure maximum concentration in the tank. This means long periods in the tank with resulting loss of oxygen. The function of the tank should be to separate the activated sludge from the effluent and return the sludge to the aeration tanks as quickly as possible.

In a settling tank, activated sludge tends to flow along the tank bottom and form a fairly level blanket. Hydraulic flow must be depended upon to remove this sludge. It appears that the heavier mixture of sludge and water creates a current along the bottom away from the influent end. At the effluent end it is deflected upward and the direction reverses along the surface. During this circuit the solids are separated from the liquid.

It has been customary in the design of rectangular tanks to locate the sludge outlet at the influent end, thus forcing the natural flow against the direction of movement of the scraper flights. This results in a longer time for sludge removal, particularly as regards sludge from the far end of the tank. At Bowery Bay the sludge outlet was located at the effluent end of the tank. Suspended solids removal has been good with high overflow rates. Dissolved oxygen tests on sludge as withdrawn have shown positive results on numerous occasions. The sludge entering the aeration tanks usually has a dissolved oxygen content of 1 p.p.m. or more.

Measurement of Currents in Final Settling Tank.—Velocity measurements have shown currents ranging from 5 to 10 ft. per min. along the bottom of the tank toward the effluent end. The scraper mechanism was designed for a velocity of 3 ft. per min. Thus it appears that the function of the flights is limited to removal of deposits that might lodge on the floor. The number of flights might well be reduced.

Tests have also shown a return current along the top of the tank. The effluent weirs at Bowery Bay are located along the sides of the tank for about 40 per cent of the distance from the effluent end. While results have been satisfactory, the effluent weirs will probably be located at the influent end of the tank in the next design.

Savings in Gross Tank Capacities.—It appears that this type tank, in combination with "step aeration," makes possible a saving in gross tank capacities. Tankage provided per million gallons daily sewage flow at Bowery Bay is only 57 per cent of that at the Wards Island plant.

Operating results at the Bowery Bay plant for the period May to December, inclusive, 1942, are as follows:

Suspended solids, p.p.m.	
Raw	197
Primary effluent	141
Final effluent	12
Aeration effluent	1,600
Return sludge	3,980
5-day B.O.D., p.p.m.	
Raw	145
Primary effluent	107
Final effluent	15
Per cent volatile, ret. sludge	69.5
Sludge index (Donaldson)	0.69
Flow, m.g.d.	32.5
Return sludge, per cent	45
Aeration period, hours *	2.5
Final tank detention period, hr.	1.8
Final tank overflow rate, gallons per sq. ft. per day	858
Air, cu. ft. per gallon	0.59

* Based on conventional aeration tank.

T. L. Herrick

SOIL AREAS CORROSIVE TO METALLIC IRON THROUGH ACTIVITY OF ANAEROBIC SULFATE REDUCING BACTERIA

By R. L. Starkey and K. M. Wight

American Gas Association, 25, 223–228 (May, 1943)

The anaerobic corrosion of iron pipes by the agency of sulfate reducing bacteria is discussed. The reaction most favorable for the development of these bacteria and consequent corrosion is between pH values of 6.0 and 8.0. The theory for the mechanism of corrosion of iron under anaerobic conditions, as advanced by Wolzogen, Kuhr and Van der Vlugt, is based on the principle that corrosion is caused by bacterial action which results in the depolarization of the system. Depolarization of the hydrogen in the cathodic areas is effected by the bacteria which reduce sulfate under anaerobic conditions. The sulfide formed in turn reacts with some of the anodic ferrous iron producing ferrous sulfide. Evidence obtained by previous investigations supports this theory. The essential conditions for this bacterial corrosion to proceed are (1) anaerobic conditions, (2) presence of organic matter, (3) favorable pH value, and (4) presence of sulfates. The series of events that lead to the corrosion are as follows: Sulfate-reducing bacteria develop under anaerobic conditions in the presence of certain types of available organic matter reducing the sulfates to sulfides which react with the iron surface to produce ferrous sulfide. Once the bacterial cells are present in abundance they are able to utilize hydrogen for sulfate reduction. One of the sources of this hydrogen is the cathodic hydrogen. Thus the removal of cathodic hydrogen and consequent depolarization of iron systems are dependent upon the organic matter to produce the bacterial cells. Corrosion might result from the combined action of hydrogen sulfide and the depolarization. In cathodic protection corrosion through depolarization would be entirely blocked.

The investigations reported in this paper were undertaken to develop a field method to differentiate corrosive from noncorrosive soil conditions. Anaerobic conditions can be determined from the observations of the topography and land drainage. There is no suitable field method for determining the abundance of readily available organic matter. Sulfate content of the soil would not be expected to show any regular correlation with corrosion. The estimation of the number of sulfate reducing bacteria for the differentiation of the corrosive and noncorrosive soils has no value. The pH value of the soil is important in detecting corrosive areas. Redox potential offers a suitable measure of the corrosive character of the soil since under anaerobic conditions the sulfide and the ferrous iron would bring about a drop in the potential. Experiments showed that soils kept under aerobic condition had a high potential (450–560 mv.) even when 1 per cent organic matter and some sulfates were added. The same soil kept under waterlogged conditions had a greatly reduced potential (about 100 mv.) even without the addition of organic matter or sulfates. When subsoil was used the potential dropped only slightly due to waterlogging. The relatively few field soils of known corrosiveness tested showed that where corrosion occurred low potentials existed. It is tentatively suggested that potentials lower than 200 mv. indicate conditions favorable to corrosion, potentials from 200 to 400 mv. are intermediate and indicate moderately corrosive condition, and potentials higher than 400 mv. are not corrosive. Other factors such as seasons of the year play a part in the potentials of the soils. The potentials are lowest during the spring and highest in late summer.

Potentiometric titrations of soils were also attempted to determine the amount of reducing materials. The oxidizing agent used was .01 N $KMnO_4$. The results obtained by this method were similar to those obtained by the determination of the potential of soils. Soils kept under aerobic conditions required very little permanganate while soils kept under anaerobic conditions required 10 to 50 times as much permanganate to raise the potentials to the same levels as the aerobic soils.

H. Heukelekian

PROCEEDINGS OF THE TWENTY-FOURTH TEXAS WATER WORKS AND SEWAGE SHORT SCHOOL

FEBRUARY 9–13, 1942

Operating Experiences at a Biofiltration Plant, by H. D. McAfee, p. 81.

This plant is located at Camp Wolters, Texas, and consists of primary clarifiers, trickling filters each of which has a depth of 3 ft., final settling tank, and stage digestors. Recirculation is curtailed each day since the plant was underdesigned for peak flows. Short interruption of recirculation has little effect on quality of effluent. However, final effluent has been unsatisfactory since it contains little dissolved oxygen and has a high B.O.D. and solids content. Grease content of raw sewage (100 p.p.m.) may be blamed. Another operating difficulty has been the breeding of large numbers of filter flies.

Operating Experiences and Laboratory Results of the Sewage Treatment Plant, Camp Wallace, Texas, by J. H. Menefee, pp. 82–85.

The plant consists of a lift station, screen chamber, two Dorr Clarigesters, sludge drying beds, biofilters, recirculation pumps, two final clarifiers, and chlorination equipment. The primary filter effluent is split and part is pumped back to the screen chamber, the remainder going to the secondary filter. Secondary filter effluent flows to the final clarifiers. A portion of the final clarifier effluent is returned to the secondary filter while the remainder is chlorinated as it enters the plant effluent sewer. Sludge from the final clarifiers is returned to the screen chamber. Suspended solids removal has averaged 84.2 to 92.1 per cent and B.O.D. removal from 86.5 to 91.9 per cent. Recirculation ratio varied from 0.76 to 2.58. Average raw sewage loading to filters in pounds per cubic yard per day varied from 3.09 to 6.85. The amount of grease in the sewage was above design expectations.

Experience with Sewage Treatment Plants, by Lt. H. K. Orgain, p. 85.

The plant which serves Foster Field, Victoria, Texas, employs the Hays process. The plant is handling up to 165 per cent of the design flow with B.O.D. and suspended solids reductions in excess of 95 per cent. Grease has given trouble. Improper plate adjustment affects the operation of the contact aerators.

The Infiltration Problem, by K. F. Hoefle, pp. 86–88.

Data are presented which indicate a 20 to 98 per cent average daily flow increase during wet weather in certain Dallas, Texas, sewer districts. The additional flow is derived from poorly constructed house laterals. Rain water enters through broken pipe or connections and through faulty joints. Tile sewers may be crushed by excessive trench load. This can be avoided by increasing the pipe's load carrying ability by the construction of a concrete cradle. Excessive infiltration cannot be stopped in existing sewers but can be prevented in new installations if proper care is taken during construction.

Bituminous Jointing Materials, by S. W. Freese, pp. 88–90.

The principal advantages claimed for bituminous sewer jointing materials are that they provide joints which are water-tight, root-proof, and alkali-proof and flexible. Several Texas cities have successfully made bituminous jointing material as follows: Mix any standard asphalt (98 per cent soluble in carbon bisulfide, penetration 55) with sufficient "cement mill lime dust" or Portland cement, incorporated hot, to produce a specific gravity of 1.6. Asphalt to cement ratio is usually 1:1.25–1.5. The cost of bituminous joints is slightly greater than the cost of cement joints but the cost of the joints represents only about 1 per cent of the cost of the sewer line. When using bituminous materials the principal causes of defective joints are improper heating of jointing material and failure to clean the joints before pouring.

Use of Concrete Pipe in Sewer Systems, by Wm. Pralle, pp. 90–92.

The city of Houston, Texas, began an investigation of concrete sewer pipe in 1923. As a result of this investigation it was concluded that it would be satisfactory to use concrete sewer pipe provided that it was manufactured according to A.S.T.M. specifications and city requirements. Permeability of the pipe rather than porosity or density may be the criterion of resistance to deterioration. Permeability is affected by the cement and water content of the concrete.

Discussion of Use of Concrete Pipe in Sanitary Sewage Systems, by R. V. Andrews, pp. 93–94.

A summary of experiences with concrete sewer pipe at Fort Worth, Texas. Little difficulty with deterioration of concrete sewers has been encountered.

Sewer Cleaning Equipment Required for the Maintenance of the Sewer System, by C. G. Levander, pp. 94–96.

A discussion of various special tools and equipment used in sewer cleaning.

Design of Sewage Treatment Plants to Facilitate Operation, by H. L. Dabney, pp. 96–99.

A plant should be located so that it is not subject to flooding. The arrangement should be such that the plant operator can see the main units from the laboratory. A safe adequate water supply should be provided. Cross connections should be avoided. Landscaping the plant site should be a part of the contract.

The screenings drying platform should be equipped with a drain. Valves in Imhoff tank sludge draw-off lines should be located outside the tank. Facilities for rodding the sludge draw-off lines are a necessity. If secondary treatment is by trickling filters, a fine screen should be provided at the outlet to remove floating debris which would clog the filter distributor nozzles.

Provision for measuring the depth of sludge in the digestors should be made. Careful attention should be given to safety features.

Sewage Treatment as Applied to Army Camps, by F. M. Veatch, p. 100.

A brief review of Army policy and experience as regards sewage treatment.

Sludge Processing and Utilization, by E. B. Besselievre, pp. 100–103.

The primary objective of the handling and processing of sewage sludge is the rapid disposal of the sludge without nuisance. A secondary consideration is the capture of valuable by- or end-products of sludge solids. A new development in sludge disposal is "flash drying" which involves drying the sludge particles while in suspension in a stream of hot gases. The dried sludge has a moisture content of from 5 to 8 per cent. If desired the dried sludge may be incinerated. In systems employing flash drying only during months when fertilizer is required and incineration during the balance of the year the operating cost is about $1.27 per ton.

Sludge Processing and Utilization, by Wm. E. White, pp. 103–104.

The city of Houston, Texas, operates a plant for the disposal of raw activated sludge which consists of equipment for mechanical sludge filtration and heat drying of the dewatered cake for the production of saleable fertilizer. There is no difficulty in disposing of from 2,000 to 2,200 tons annually of this product whose bulk sale price averages about $12.00 per ton. Natural gas is used for drying at the rate of about 20,000 cubic feet per ton of dried product. Ferric sulfate is used as a sludge conditioner. The following data are typical of Houston's experience with raw activated sludge. Conditioner requirements: 3 per cent of ferric iron in terms of the weight of dried product; rate of filtration, 1 lb. of dry solids per sq. ft. per hour; water content of filter cake, 82 per cent; average cotton filter cloth usage, 1.5 sections per ton.

The two dryers used at Houston are of the rotary kiln type. Total power requirements are 310 kwh. per ton of dried product.

Sludge Processing and Utilization, by Alfred H. Proessler, pp. 105–106.

The sludge digestion equipment at the City of Austin sewage treatment plant consists of two batteries of Dorr multi-digestors. The digested sludge is dried on open beds. Several attempts have been made to feed alum into the sludge discharged to the beds in order to decrease the drying time but thus far no quantitative results have been obtained. The total value of dried sludge sold in 1941 was $1,250. The nitrogen content of the sludge averages 3 per cent. The sludge cake from the drying beds is ground by means of a Jeffrey swing hammer rock crusher.

Keeping Records of Sewage Treatment Plant Operation, by Lewis Dodson, pp. 106–109.

A complete set of operating records is necessary for three reasons. (1) The operator has a daily check on himself. (2) The sanitary engineer will need this information when called in for advice. (3) Records may prove invaluable in court in case of a law suit. An outline of essential records is presented.

Keeping Records of Sewage Treatment Plant Operation, by Jack M. Jones.

Suggestions for maintenance of daily operating records are presented.

The Use of Sewage Plant Effluent for Industrial Purposes, by S. L. Allison, pp. 110–111.

Increasing industrial water requirements may force the use of sewage plant effluents for industrial water supply. The Bethlehem Steel Corporation is spending over one million dollars in order to utilize the effluent of a Baltimore sewage plant as a source of water for industrial use. The degree of sewage treatment required depends on use of water in industry.

Let's Take a Look, by R. M. Dixon, pp. 112–118.

A discussion of the problems encountered by a sewage treatment plant superintendent and a plea for more initiative on the part of superintendents and operators.

The Sewage Treatment Problem in Rural Sections, by Joe B. Winston, pp. 118–120.

Many sanitation problems have been encountered in small communities subjected to the impact of large population increases due to war activities. These problems have in general been solved as a result of cooperation between public service agencies and individuals.

Progress in Certification of Sewage Treatment Plant Operators, by E. J. M. Berg, pp. 120–123.

At present three operators hold A certificates, 34 hold B certificates, and 312 hold C certificates. There are approximately 750 men working as full- or part-time operators.

Experiences with the Temple Sewage Treatment Plant, by N. E. Trostle, pp. 123–124.

A description of the plant and summary of plant operating experiences.

Classification of Industrial Wastes and Their Possible Effects Upon Sewage Problems, by Herman K. Clark, pp. 124–126.

Industrial wastes may be classified according to the nature of the raw products used and the materials involved in processing them. If significant amounts of industrial wastes are discharged into a public sewer system and no allowances are made for them trouble may be expected. Each industrial waste problem must be considered individually.

Industrial Wastes as an Administrative and Financial Problem of Cities, by W. S. Mahlie, pp. 126–129.

No generally accepted policy appears to exist in the United States relative to the admission of industrial wastes to the municipal sewerage system, but before any waste is admitted to a sewerage system a careful study should be made of the quantity and character of the waste. The key-note of successful treatment and disposal of industrial wastes is cooperation between industry and the city. It is the author's opinion, with some reservations, that it is better and more economical to treat all industrial wastes and domestic sewage in one central or municipal plant. Industrial wastes are usually more amenable to treatment after dilution with domestic sewage. Industry should assume the cost of treating its wastes either in the form of a service charge or on some other equitable basis. Treatment charges should be based on both quantity and strength.

Experiences with Oil Field Wastes, by J. C. Oliver, pp. 129–132.

Pollution of the Neches River with salt water resulted in a suit by riparian owners against some 155 East Texas oil field operators. The trial was postponed to allow the operators time to develop a plan for pollution abatement. This plan advocated the construction of impervious storage pits for the brine. All salt water produced on the oil leases operating under this general plan was to be stored until its release was authorized. A few operators refused to accept the plan and as a result were required by a district court to refrain from further polluting the Neches River. The court of civil appeals upheld this decision. At present there are some 26,000 producing oil wells in the East Texas field and some 6,000 are located on the Neches River watershed. Of the 6,000 wells 700 produce salt water in quantities ranging from a few barrels up to 600 barrels per day. The chloride content averages 40,000 p.p.m., and some 80,000 barrels of brine are produced on the Neches watershed each day. About 35,000 barrels per day are disposed of by injection back into the Woodbine sands. The remainder are disposed of by the controlled dilution plan. In general cooperation has been excellent, and the oil operators, realizing the seriousness of the situation, have taken steps to provide for sub-surface disposal of the brine. A salt water injection company has been organized and incorporated for $2,000,000. In addition to providing for brine disposal, injection will increase the life of the field by retarding the rapid decrease in bottom hole pressure.

Chrome Wastes in an Activated Sludge Plant, by W. N. Wells, pp. 132–133.

Activated sludge failed to settle satisfactorily and poor treatment efficiency was obtained at the North American Aviation Company's plant at Grand Prairie, Texas. Aeration tanks had a yellow appearance caused by chromate wastes. Chromate ion interferes with the dissolved oxygen and ortho-tolidine tests, erroneously high results being obtained. Due to the inhibiting effect of chromate on bacterial life, B.O.D. values in the presence of this ion are low.

Paul D. Haney

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"Three Years' Treatment of Sewage at Celina, Ohio," by Paul A. Uhlmann, pp. 13–17.

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LOCAL ASSOCIATION MEETINGS

Association	*Place*	*Date*
Canadian Institute on Sewage and Sanitation	Niagara Falls, Ontario	Oct. 28–29, 1943
Central States	Chicago, Illinois (Sherman Hotel)	Oct. 21–23, 1943
Federation of Sewage Works Associations	Chicago, Illinois (Sherman Hotel)	Oct. 21–23, 1943
New England	Boston, Mass. (Parker House)	Sept. 22, 1943
North Carolina	Not selected	Nov. 1–3, 1943
North Dakota	Grand Forks, N. D. (Ryan Hotel)	Oct. 5–7, 1943
South Dakota	Mitchell, S. D.	Sept. 15–16, 1943
Rocky Mountain	Denver, Colorado	Sept. 16–17, 1943

THE SECOND CHICAGO CONVENTION

FOURTH ANNUAL CONFERENCE IN CHICAGO TO STUDY WAR AND POST-WAR OPERATING CONDITIONS

Sanitation activities under wartime conditions will keynote the Fourth Annual Conference of the Federation of Sewage Works Associations, to be held in Chicago on October 21–23, preliminary plans for which have been announced by F. W. Gilcreas, Chairman of the Program Committee.

Of special interest to operators, municipal officials and manufacturers will be the appearance of A. M. Rawn, recently appointed engineering consultant to the War Production Board, who will define priorities procedures for those engaged in sewerage construction, operation and maintenance activities. Mr. Rawn, who is Vice-President of the Federation, will explain the details of making applications for ratings, and will be available to answer specific questions.

Wartime and Post-War Plans

Personnel, maintenance and operating experiences in municipal plants under present conditions will be outlined by a group of speakers representing all sections of the country.

Another session of the Conference will be devoted to sewage disposal practice and problems in Army camps, the handling of industrial wastes under emergency conditions, and the relation of sewage treatment to the transmission of virus diseases.

With a view toward future developments, the Conference will provide an opportunity for a discussion on postwar activities. This will be conducted by Morris M. Cohn, assisted by representatives from municipalities, states, consulting firms and manufacturers.

The Conference will conclude with an "Operators' Round Table," sponsored by the Central States Sewage Works Association, which is acting as host to the national group. Practical topics will be discussed.

Details of the manufacturers' exhibits, which will be limited in order to preclude transportation difficulties, are being formulated by Arthur T. Clark, Secretary-Manager of the Water and Sewage Works Manufacturers Association, Inc.

Under the direction of George J. Schroepfer, President of the Federation, the following committees have been appointed:

Convention Management

F. W. Mohlman, *Chairman;* Norval E. Anderson, Vice-Chairman; O. T. Birkeness, K. V. Hill, H. E. Schlenz, Frank Lovett, Fred G. Nelson, Arthur T. Clark, Langdon Pearse, Mrs. Langdon Pearse.

Local Finance

O. T. Birkeness, *Chairman;* Norman Dawson, Paul E. Langdon, W. H. Wisely.

Hotel Arrangements

Fred G. Nelson, *Chairman;* Paul O. Richter, G. J. Rettig.

Registration

K. V. Hill, *Chairman;* E. Hurwitz, W. W. Mathews, John R. Palmer, John C. Mackin.

Manufacturers

Frank Lovett, *Chairman;* Milton Spiegel, G. C. Karr.

Entertainment

H. E. Schlenz, *Chairman;* Paul E. Langdon, C. C. Abplanalp, Clinton Inglee.

Exhibits

Arthur T. Clark (*Ex-Officio*).

Local Host

Langdon Pearse, *Chairman.* (Chairman to select other members.)

Ladies Entertainment

Mrs. Langdon Pearse, *Chairman.* (Chairman to select other members.)

Publicity and Attendance

Edward J. Cleary, *Chairman;* Morris M. Cohn, Linn H. Enslow, W. S. Foster, A. Prescott Folwell, F. W. Mohlman.

Program

F. W. Gilcreas, *Chairman;* F. W. Mohlman, Rolf Eliassen, R. S. Phillips, E. W. Steel, Carl Green, F. M. Veatch, Jr., F. S. Friel, C. C. Larson.

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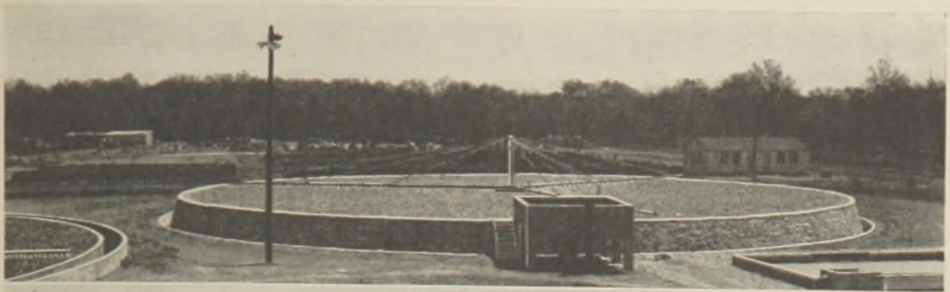

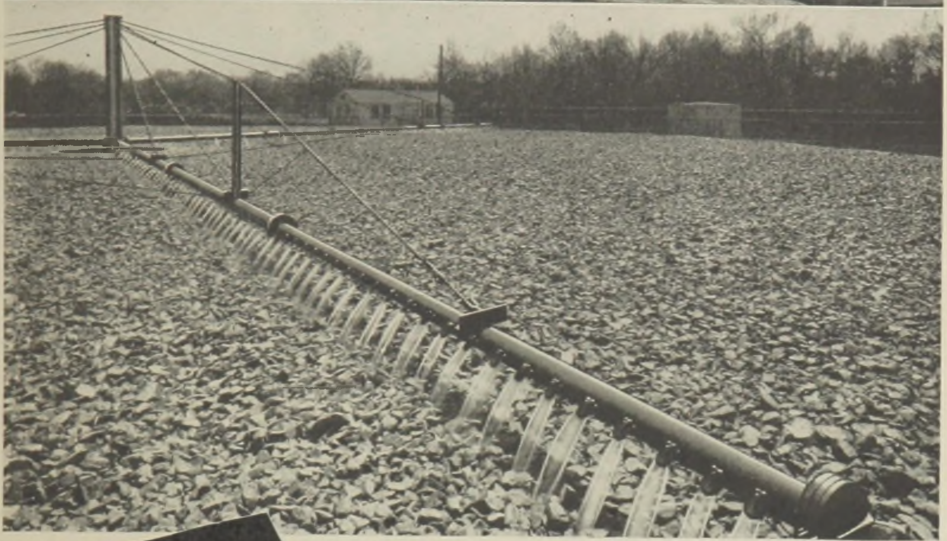

Hair-Splitting Exactitude . . .

Zeiss Toolmaker's Microscope being used for checking dimensions of newly purchased tap against accurate thread form standards.

TO 1/100,000 OF AN INCN !

PRECISION DIMENSIONAL CONTROL ASSURES ACCURACY AND LONG LIFE

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A human hair is approximately 3/1000 (.003) of an inch thick. Imagine, if you can, splitting a hair into 300 equal parts and being able to measure each individual subdivision. This graphic example is used to illustrate the almost infinitesimal dimensional measurement that is accomplished every day in the Standards Department of the Pittsburgh Equitable Meter Company.

This department, which developed out of the normal demand for manufacturing accuracy in volume production, was originally installed in 1937 and has been greatly expanded since. Many of this company's achievements in handling wartime projects would have been impossible without the dimensional exactness that is provided through our Standards Department. *We have recently been awarded the "A" rating of the Army Air Forces for quality control.*

Accuracy in the performance of meters made in large production is of necessity dependent upon the accuracy of the tools, jigs and gages that guide the machining and assembly procedures. The hair-splitting exactitude to which these manufacturing appurtenances are held by Standards control assures an accurately made and fitted product, capable of a long and useful life.

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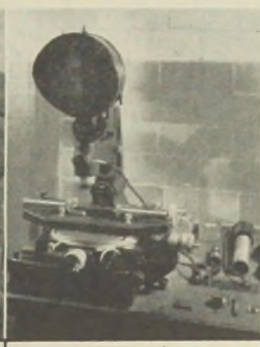
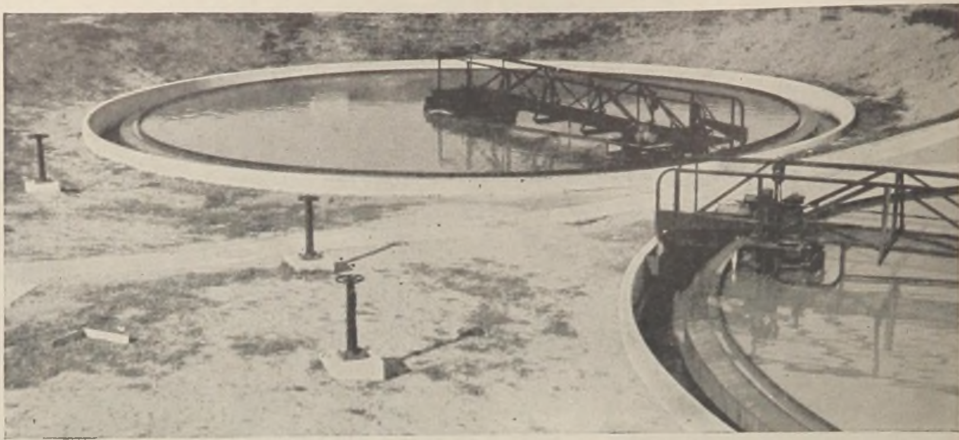


The Zeiss Toolmaker's Microscope in use checking a production part for

Pratt and Whitney Measuring Machin

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