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THE TREATMENT OF "BEER SLOP" AND SIMILAR WASTES

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(505S6)

A Case of High Grade Effluent from Sewage Treatment Works (on Right), Entering Industrially Polluted Stream (Left). A Far Too Frequent Condition

THE TREATMENT OF "BEER SLOP" AND SIMILAR WASTES

By A. M. BUSWELL, Ph. D.*

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THE wastes from breweries and distilleries, commonly referred to as "beer-slop," are typical of a rather large group of industrial wastes for which a common method of treatment is in general applicable. In this group we would include wastes from breweries, distilleries, grain vinegar, cereal beverages (ovaltine), starch manufacture, creameries, meat packing, citrus fruit juice, pea, bean and corn canneries, and beet sugar; in short most of the industries which produce food and drink in a "ready to use" condition.

Nearly all of these industries use water for three purposes, (a) process water, which is relatively small in amount but when discharged carries several per cent ot organic matter; (b) wash water used to clean equipment, floors, etc., which is variable in quantity and may be of the approximate concentration of domestic sewage; and, (c) cooling or condenser water which is usually several time the volume of (a) and (b) but with proper piping it may be discharged in an uncontaminated condition.

This paper deals primarily with the treatment of "process water" or more properly "process by-product" in the case of certain industries such as creameries and citrus fruit juice bottlers. In the treatment proposed it is assumed that this concentrated waste (a) can be separated completely from (c) and more or less completely from the more dilute liquids composing the wash water (b).

The concentration (1, 3, 6, 7, 8) of these process liquors as shown in the tables below range from 1 per cent to 6 or 7 per cent total solids, of which the major portion is organic matter in true solution. The inorganic matter (ash) and settleable solids run considerably under 50 per cent of the total, and the oxygen consuming substances are almost wholly in solution.

With material of this sort the usual expedient of sedimentation produces relatively little improvement. The addition of chemical coagulents is likewise of limited benefit as far as oxygen demand reduction is concerned. The reason for this failure is apparent when we stop to consider that much of the organic matter in these wastes is in a state of true solution (i.e., like a salt solution or a sugar solution) and cannot be removed by coagulation. In this respect they differ from domestic sewage, for it has recently been shown[0] that passage through an "ultra filter" (i.e., a filter which will remove true colloids) will reduce the B. O. D. of ordinary sewage to zero. Substances in true solution are not removed by "ultra filtration."

The aerobic methods of treatment, trickling filters or activated sludge, may be employed to remove dissolved organic matter but the loading limits for good results are very low.[6] Rates of 10,000 to 50,000 gallons per acre per day are required for the undiluted wastes on trickling filters and aeration periods of 24 hours or more with high air consumption are required when the activated sludge process is used. The sludge produced tends to be light and feathery and settles poorly.

One of the most embarrassing characteristics of high organic wastes is the rapidity with which they become sour. Acetic, lactic and other organic acids develop in a few hours to give acidities of several thousand parts per million. In some cases these acids develop during the normal manufacturing process and the wastes as discharged are strongly acidic. Experience has shown that sour wastes cannot be treated by aerobic methods even at the low loadings given above. Neutralization must be employed and frequently dilution is necessary, water or domestic sewage being used if available. The necessary dilution ratios run from 1 to 10 to 1 to 100. Where the industry operates only a few months a year, broad irrigation or lagooning at the rate of 10,000 gallons per acre per day may be employed.

It is apparent then that ordinary sewage treatment methods applied to industrial wastes of this character require an outlay for plant and equipment which is a heavy burden on the industry. Some manufacturing plants, to handle their wastes in this way, would have to build treatment works capable of purifying the wastes from several million people.

Since the concentrations encountered are similar to those found in the sludge from sedimentation tanks it was early suggested that these wastes might be handled as sludge is handled, namely, by anaerobic or septic digestion. Attempts to accomplish this were unsuccessful due in most cases to the extensive and rapid production of acids which arrested all further bacterial decomposition. It was noted[3] that if the wastes were diluted ten times with sewage the acidity could be controlled and complete anaerobic decomposition of the organic matter brought about. Dilution, however, has the disadvantage

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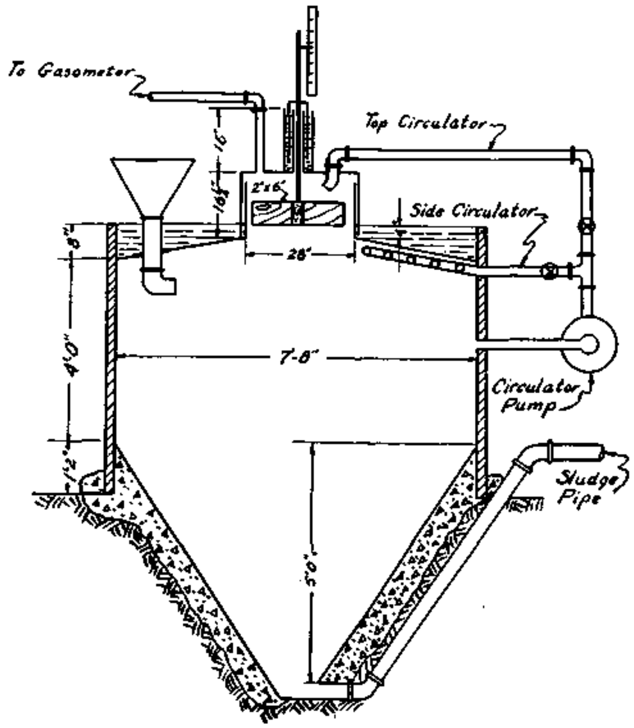


Digester Equipped for Scum Wetting to Equalise Alkalinity and Speed Digestion

that the total volume to be treated is increased, thereby necessitating extra tankage capacity.

In the case of wastes containing more or less fibrous material or grease, a firm scum or mat forms[5,8] at the top of the digesting tank, frequently to considerable depths. This further hinders the process by creating an acid zone and decreasing the effective volume of the tank.

Correcting Interferences with Anaerobic Treatment

Limitations to the anaerobic method of stabilization have been under investigation in the laboratories of the Illinois State Water Survey for about ten years. The solutions proposed are as follows:

Control of Acid Production.—It has been shown by numerous investigations- that practically any kind of organic matter except mineral oils will decompose under the action of anaerobic bacteria to form methane and carbon dioxide. Fats, proteins, carbohydrates, alcohols, and even phenols are decomposable in this manner. The chemical reactions which take place in this decomposition occur in the main in two steps; the complex organic molecules combine with water to form the simpler organic acids (acetic, propionic, etc.) and then these acids decompose to methane and carbon dioxide. If an abundance of food material is available for the bacteria they tend to form acids more rapidly than such acids can be decomposed. It is well known that under these conditions the acid soon reaches a concentration at which all bacterial action is stopped. If on the other hand the amount of food material is properly limited the bacteria will decompose the acids as fast as they are formed, and the fermentation goes on smoothly and continuously. Fresh material may then be added regularly to the fermentation vessel in controlled amounts.

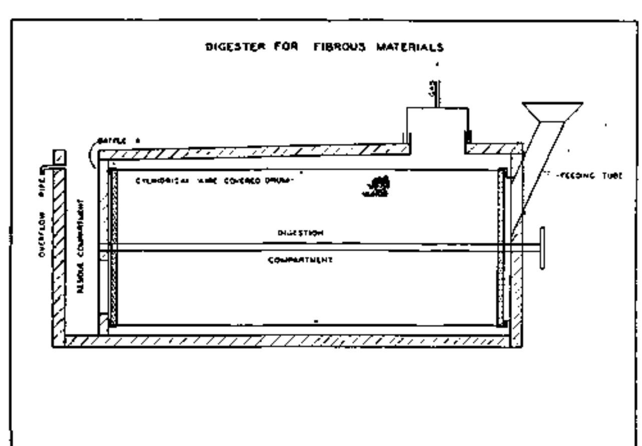
The Duclaux* method for total volatile acid is used to determine the rate of accumulation of acids during digestion. These organic acids are only slightly ionized and it is the acid radical not the hydrog?? must be transformed into CO_2 and CH_4. For these ?? sons it has not been found possible to depend on the ?? determination for control of the process.

The limit of acidity for smooth continuous fermentation has been found for most materials to be about 2,000 p.p.m. calculated as acetic. When the acidity of the liquor in a fermentation tank exceeds this value it may be reduced either by decreasing the rate of feed of raw material or by dilution. Decreasing the rate of feed would involve storing or by-passing untreated waste which would be objectionable. Dilution with water may be used but we have found it advantageous to carry out the fermentation in two or more tanks operating in series and use of the spent liquor for dilution. The rate of feed is adjusted so that the acidity in the first tank is kept near the upper limit in order to obtain maximum efficiency. The secondary tanks receive the overflow liquor from the first tank at a rate to keep the acidity at a low value. To reduce the acidity the liquor from the secondary tanks may be pumped to the first tank allowing a like amount of liquor from the first tank to flow into the second tank. In other words the liquor in the two tanks is intermixed and the acidity reduced. Suppose in an installation with two tanks of equal size the acidity in the first tank has increased to 2,500 p.p.m. while that in the second is 500 p.p.m. After back circulation of liquor from the second tank for a few minutes allowing that displaced from the first tank to flow- to the second the acidity will be 1,500 p.p.m. in both tanks. This is below the tolerance limit and the feed of raw material to the first tank may proceed without interruption.

Scum and Foam Control.—Wastes of a greasy or gummy character frequently produce a scum over the top of the fermentation tank. If allowed to accumulate this scum becomes sour and impairs the general operation of the tank. In our experience it can be easily controlled by pumping liquor from well above the sludge line and allowing it to flow back onto the scum. A few minutes a day of this sort of circulation is sufficient to prevent any appreciable accumulation of floating solids. Some operators have suggested circulating sludge from the bottom of the tank over the scum. This is no doubt effective but it impairs the quality of the digested sludge.

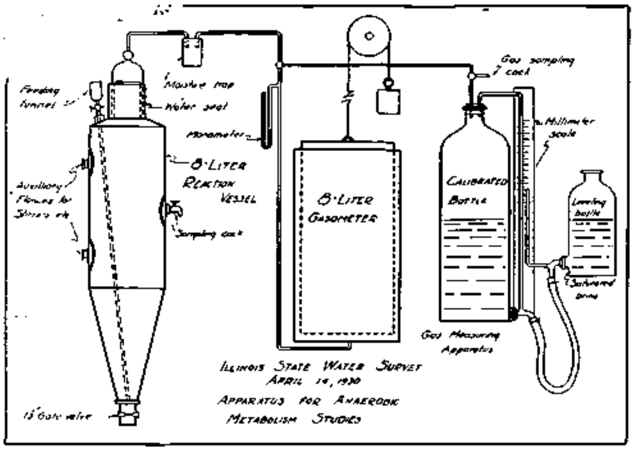
Foam may be controlled in a similar manner but in this case the discharge at the top of the tank should be at a low velocity to avoid any jetting action. A high speed jet of water frequently produces foam.

Handling Fibrous Wastes.—Packinghouse wastes[8], citrus fruit pulp, and sewage screenings[5] tend to form



The Drum-Screen Digester for Tibrous and Scum Forming Materials

*State Water Survey Bull. 30, p. 77 or standard texts on Organic Analysis.



Laboratory Equipment Used in Anaerobic Digestion and Stabilisation Studies

a fibrous mat over the top of the fermentation tank which cannot be controlled by circulation as described above. A special mechanical digester[8] has been designed to solve this difficulty.

This digester consists of a perforated horizontal drum submerged in a covered tank. A feeding tube pierces the outer wall of the tank at a point within the circumference of the drum. The fibrous wastes are fed automatically or manually through the feeding tube into the perforated drum inclosed in the rectangular tank. Both ends of the drum are equipped with seal rings. These allow the drum to be turned in its bearings without the escape of fibrous material from the drum into the rest of the tank. The digester is filled with water or sewage until it runs out the overflow pipe. A gas-tight cover and water-sealed hood serve to keep out air and collect the gases formed during the digestion. Slow or intermittent revolution of the drum liberates the entrapped gas bubbles and breaks up the thick mat which collects at the top. Frequent charging of the tank with fresh waste, together with revolution or inversion of the drum causes the digested material to work itself out through the opening in the lower end of a baffle into the residue compartment. This digested material is still fermenting sufficiently to cause the entrapping of gas bubbles within its mass, which, in turn, causes it to float to the top of the residue compartment from which it can be removed periodically with forks or other suitable means.

For the treatment of beer-slop from distilleries and steep water from breweries the acid control is the most important operating factor. By taking advantage of this method of control it has been possible not only to treat these sour wastes but to handle them at loadings of 0.3 to 0.9 lbs. of organic matter per cubic foot of tank volume per day. These figures are to be compared with loadings of 0.05 to 0.08 lbs. per cubic foot for domestic sewage sludge. Table I (appended) summarizes data on a wide variety of wastes.

The gas production per unit of tank volume is of course increased proportionately by these heavy loadings. Three cubic feet of gas per cubic foot of tank volume are easily obtained and twice that rate is attainable. Since the principle cost of anaerobic fermentation is the installation charge it then decreases proportionately with increased loading rates. Gas production under these conditions is taken out of the waste disposal class and becomes a profitable manufacturing process. Calculations based on the data in Table I indicate that a gas of 540 B.T.U. can be produced for a cost as low as three cents per thousand cubic feet, although ten cents would be the cost in many cases. As the waste to be

TABLE I—FEEDING AND GAS PRODUCTION RATES OBTAINED DURING THERMOPHILIC DIGESTION OF VARIOUS INDUSTRIAL WASTES

A. Commercial Solvents' Beer-Slop (Acetonic)
- 1. While fermenting rye
  - 3.3% Total solids, 91% volatile
    - Rate of feed:
      - Volume basis—½ vol./day/tank volume
      - Solids basis—0.93 lbs. T.S./day/cu. ft. tank
    - Gas recovery:
      - Volume basis—7 vol. of gas/day/unit tank vol.
      - Solids basis—7.5 cu. ft. gas/lb. T.S.*
    - Rate of feed:
      - Volume basis—¼ vol./day/tank volume
      - Solids basis—0.62 lb. T.S./day/cu. ft. tank
    - Gas recovery:
      - Volume basis—4.2 vols. of gas/day/unit vol.
      - Solids basis—8.6 cu. ft. gas/lb. T.S.
    - Rate of feed:
      - Volume basis—1/6 vol./day/tank volume
      - Solids basis—0.31 lb. T.S./day/cu. ft. tank
    - Gas recovery:
      - Volume basis—3.0 vol. of gas/day/unit tank vol.
      - Solids basis—9.7 cu. ft. gas/lb. T.S.
- 2. While fermenting corn
  - 2.0% Total solids, 92% volatile
    - Rate of feed:
      - Volume basis—¼ vol./day/tank volume
      - Solids basis—0.33 lb. T.S./day/cu. ft. tank
    - Gas recovery:
      - Volume basis—3.7 vol. of gas/day/unit tank vol.
      - Solids basis—11.0 cu. ft./lb. T.S.

B. Heinz Distillery Waste
- 1. 7.1 Total solids, 96% volatile pH 4.1
  - Feeding rate:
    - Volume basis—1/28 vol./day/unit tank vol.
    - Solids basis—0.16 lb. T.S./day/cu. ft. tank
  - Gas recovery:
    - Volume basis—2.0 vols. of gas/day/unit tank vol.
    - Solids basis—12.5 cu. ft. gas/lb. T.S.

C. Buttermilk and Whey Waste
- 1. 7.0% Total solids, 91% volatile pH 5.0 High in sugars
  - Feeding rate:
    - Volume basis—1/29 vol./day/tank vol.
    - Solids basis—0.15 lb. T.S./day/cu. ft. tank
  - Gas recovery:
    - Volume basis—1.6 vols. of gas/day/unit lank vol.
    - Solids basis—10.7 cu. ft. gas/lb. T.S.

D. Artichoke Waste
- Rate of feed:
  - 0.095 lbs./cu. ft./day
- Gas recovery:
  - Volume basis—0.81 vol. gas/day/unit tank vol.
  - Solids basis—8.35 cu. ft. gas/lb. T.S.

E. Extracted Chicory
- Rate of feed:
  - 0.156 lbs./cu. ft./day
- Gas recovery:
  - Volume basis—1.64 vol. gas/day/unit tank vol.
  - Solids basis—10.5 cu. ft. gas/lb. T.S.

F. Sugar Beet Waste
- Rate of feed:
  - 0.078 lbs./cu. ft./day
- Gas recovery:
  - Volume basis—0.96 vol. gas/day/unit tank vol.
  - Solids basis—12.3 cu. ft. gas/lb. T.S.

G. Packinghouse Paunch Manure
- Rate of feed:
  - 0.37 lb./cu. ft./day
- Gas recovery:
  - Volume basis—3.1 vol. gas/day/unit tank vol.
  - Solids basis—8.95 cu. ft./lb. T.S.

*T.S.—Total Solids.

TABLE II—PARTIAL ANALYSIS OF CITRUS PULP

	Per cent*
Ash	0.46
Ether extract	0.38
Crude fiber	0.84
Protein	1.28
Carbohydrates	9.38
Organic nitrogen	0.197
Kjeldahl nitrogen	0.198
Total nitrogen (salicyclic)	0.208
pH	4.0
Moisture	85.5

*A11 of above data are on a wet basis.

TABLE III—ANAEROBIC DIGESTION OF CITRUS PULP

Bottle Number	1	2	3
Time, days	180	180	180
Weight of pulp added			
(a) Wet (gms.)	69	138	273
(b) Dry (gms.)	10	20	40
Volume of gas evolved			
(cc.) N.T.P.	7,045	12,955	7,105
Volatile acids as acetic at			
end (p.p.m.)	90	90	4,880
pH at end	6.0	6.0	5.0
Per cent digested	84.0.	78.0	...

treated becomes more dilute the costs naturally increase. The character of the wastes is also a factor, the fibrous wastes decomposing more slowly than the soluble by-products.

Table III summarizes three batch experiments with citrus pulp. In our experience batch fermentation requires about ten to twenty times as long a period for a given degree of gasification as is needed when the material is fed continuously in controlled amounts. It should be possible to treat citrus pulp on a large scale at about the rate that proved satisfactory with paunch manure.

Effluent Quality

The degree of purification accomplished varies from 75 to 90 per cent. Since these raw materials frequently have B.O.D. values ranging from 15,000 to 35,000 p.p.m. the effluent B.O.D, may run from 1,000 to 3,000 p.p.m. Aerobic methods may be applied to the effluent where necessary. Naylor, more than thirty years ago, showed that even a short septic action treatment of such wastes previous to trickling filters was highly advantageous. The volume of these wastes is so small in proportion to the clean water discharge that the dilution available from this source may be sufficient in some cases. Distilleries, for example, discharge about six times as much cooling water as "beer-slop."

In some cases with which we are familiar the domestic sewage flow is ten to twenty times the volume of heavy industrial wastes. With preliminary anaerobic treatment the effluent could be discharged into the sewers without producing an abnormal industrial load.

Comparison of Costs

In so far as the anaerobic method is applicable it is decidedly the simplest and cheapest method of converting organic matter into inoffensive materials. Even in the conventional type of sewage treatment plant it is in the sludge digestion tank that 60 to 70 per cent of the organic matter is finally stabilized, the end products being insoluble combustible gas and humus.

A comparison of costs per pound of matter stabilized was worked out by the writer and Dr. C. S. Boruff for creamery wastes[6]. The figures are worthy of serious consideration.

On the basis of an average feeding of one twenty-fifth of a volume of milk waste (undiluted basis) per day per tank volume, would require 5.72 cubic feet of tank capacity for the anaerobic fermentation of one pound (dry weight) of milk waste solids. ?? cubic foot, this amounts to only $2.86 ?? pound of milk solids treated per day. This ?? would remove at least 95 per cent of the pollution load. The remaining 5 per cent contained in the overflow liquor could be stabilized readily on filters. Assuming that this final treatment could be made at a cost similar to that given for filter treatment by various investigators, the total investment for complete treatment would be $8.70 per pound of solids if trickling filters were used following the anaerobic digestion, or $17.46 per pound if sand filters were used, as compared with $116.80 per pound if trickling filters were used alone, or $292 per pound if sand filters only were used. The above figures are not given to show actual costs but rather relative costs of the two processes.

Recovery of Stock Food

It is not within the scope of this paper to discuss the evaporation of wastes for stock food recovery. It is doubtful whether this can be done with profit unless the solids run higher than 7 per cent. We are certain that with 1 to 3 per cent solids the net profit is in favor of anaerobic fermentation.

As a waste disposal process evaporation is not a complete solution to the problem since the "carry-over" from the evaporators amount to 400 to 1,000 p.p.m.

The data on which this paper is based were taken from publications prepared with the writer's former collaborator, Dr. C. S. Boruff.

Acknowledgment—The above paper was presented before a joint meeting of the California Sewage Works Assn. and the Public Health Eng. Section of the American Public Health Assn. at Pasadena, Calif.

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