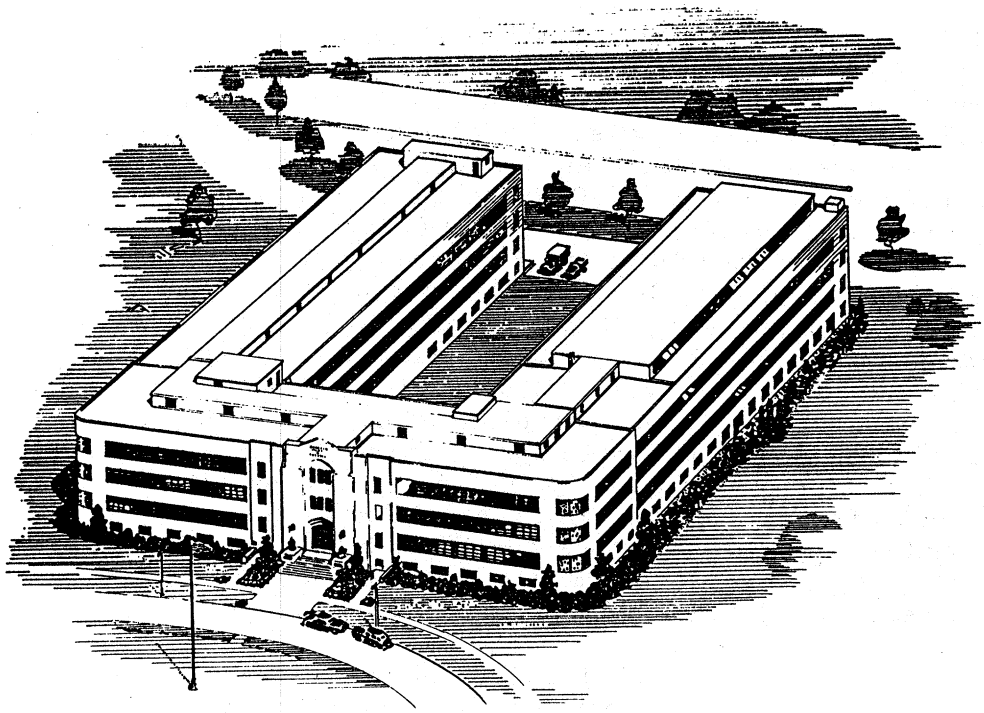
628

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Administration
Bureau of Agricultural and Industrial Chemistry

TREATMENT OF DAIRY WASTE BY AERATION

Sam R. Hoover and Nandor Porges



Eastern Regional Research Laboratory
Philadelphia 18, Pennsylvania.

TREATMENT OF DAIRY WASTE BY AERATION

Sam R. Hoover and Nandor Porges

Historical Background

The waste waters from milk processing plants contain the residual milk washed from cans, coolers, bottling machines, pumps, etc., plus that lost by leaks, spilling and occasional overfilling of tanks and bottles. Losses of about 1% of the milk handled are considered reasonable operating losses in the industry. The smallest plants handle about 10,000 pounds of milk a day; many plants process 100,000 pounds per day, and the number of large installations receiving over half a million pounds daily is increasing. Thus a milk processing plant may discharge from 100 pounds to over two tons of fluid milk daily to the stream. The wastes from fluid milk processing are about the same as those from drying and condensing plants.

This waste milk is greatly diluted by the wash water and cooling water used in the plant. The resulting effluent contains about 0.1 - 0.2% milk solids, which has a biochemical oxygen demand (BOD) of about 800 to 1500 parts per million (p.p.m.). Domestic sewage has a BOD of about 200 p.p.m.; thus milk wastes are 4 - 8 times as strong a pollutant as sewage. For example, the wastes were surveyed (10) from an integrated milk processing plant which processes 435,000 pounds of milk daily in separating cream, condensing the skim milk and manufacturing ice cream mix. With careful operation the waste averaged 133,000 gallons per day with a BOD of 1400 p.p.m., equivalent to the sewage of a community of 8750 people. Similarly, the smallest plant studied, which processed 42,000 pounds of milk daily, had a population equivalent of 135. The amount of waste to be treated parallels the amount of milk handled closely except where poor plant management allows excessive loss of milk solids. Although the larger plants produce more waste, the small fluid milk plants are often in a residential area and must be extremely careful about offensive odors, while receiving plants are located primarily in the mountains on streams whose purity is zealously guarded by sportsmen. Therefore, almost every segment of the industry is vitally interested in the abatement of pollution by milk wastes.

Milk contains about 5% lactose, 4% protein and 3% fat. The whey remaining after cheese is made contains almost all the lactose and about 1/4 of the protein originally present, or 1/2 the total solids of the milk processed. Industrial utilization of this whey is increasing, but a recent survey of the industry gave the following data for 1951:

Total production	14.2 billion pounds
Available for manufacturing	8.4 " "
Utilized	5.4 " "

The 5.8 billion pounds considered unavailable for use is produced in plants where the cost of transportation to a central processing plant would be greater than the value of its contents. Thus there are many cheese plants in which 1/2 of the milk solids received are an industrial waste which must be treated as a waste disposal problem. Development of new uses for whey will decrease this amount but cannot be expected to eliminate it.

An increasing interest in clean streams for recreation and as a source of pure water for cities and industries led to new laws and stricter enforcement of existing anti-pollution laws soon after the close of World War II. The states of Pennsylvania, Wisconsin and New York, especially, have broad programs aimed at the virtual elimination of polluted streams. Over 100 dairy plants in Pennsylvania were under legal action to treat their wastes during the past year.

The research problem presented to the Department of Agriculture by the Research Advisory Committee was the development of an efficient, economical process for the treatment of the dilute processing wastes of the dairy industry. There were waste treatment plants in various places which successfully treated milk wastes, but the costs of installation and operation were both quite high. The development of a rapid, simple, chemical test for pollution by milk wastes was also requested by the committee.

Previous results on direct aeration processes had been unsatisfactory. The BOD of the waste was reduced 50% in 12 - 24 hours but the failure to obtain a greater reduction was puzzling. Also, aeration systems often became so acid that oxidation virtually stopped and no reduction in BOD was obtained.

Experimental Study

Late in 1947 a study of aerobic oxidation by a mixed culture of soil organisms was initiated at the Eastern Regional Research Laboratory. An experimental system containing a 5 gallon aerator with control of temperature, air supply, and rate of addition of waste was put in operation. A synthetic waste containing 0.1% dry skim milk was used, for it was believed that most of the fat lost in whole milk could be removed in small skimming tanks before the waste entered the aerator. Skimming tanks of this type have been used in many installations.

This study required rapid methods of analysis for oxygen demand, lactose and protein. A test for oxygen demand of milk wastes had been one of the research aims proposed by the Advisory Committee. While studying various tests we heard of an unpublished adaptation of one which had been made by Professor E. F. Eldridge, then at Michigan State College. Comparison of various procedures showed the Eldridge method to be an excellent one for the purpose (8, 9). Professor Eldridge did not wish to publish the method but gave us permission to do so. Later a detailed study of the method, its accuracy and utility on a variety of fat, protein and carbohydrate materials, was made (7). It has been widely adopted as a rapid field and control method for measuring the strength of not only dairy wastes but of cannery, slaughterhouse, soap factory and other wastes of industries processing agricultural products.

The chemical oxygen demand (COD) is the amount of oxygen required to oxidize organic substances completely. It is about equal to the standard biological oxygen demand (BOD) test when it is run to completion, about 20 days. The 5-day BOD, which is commonly used by sanitary engineers to determine the pollution characteristics of a waste, is usually considered to be 67% of the 20-day BOD, but varies depending on the constituents of the waste.

By detailed examination of the effluent we found, as earlier workers had, that a reduction of 50% of the oxygen demand was readily achieved. The nature of the material was completely changed; the soluble protein and sugar of milk had been used by the bacteria to produce cell tissue with no appreciable amounts of soluble byproducts. The latter result was new, and led to an altered concept of the biochemistry of the treatment process. Measurement of the rate and extent of synthesis of bacterial cells showed that 1000 p.p.m. of milk solids (0.1% solution) was completely assimilated in 5 to 6 hours. The yield of cell substance was slightly over 50% (1).

The further oxidation of these cells by their own metabolism is a slow process, requiring 30 to 40 hours. The rate of removal of oxygen from the solution was also determined (6). During the rapid reaction as much as 0.4 p.p.m. oxygen per minute is used. If oxygen is not supplied fast enough to satisfy this high rate, the system becomes anaerobic and organic acids are produced. The resulting fall in pH depresses the activity of the culture and may even kill it. The latter result explains many of the previous failures of aeration systems; the supply of air was insufficient to maintain aerobic conditions.

The laboratory aerator was run for several months both with continuous flow and as a fill-and-draw operation. Two processes were proposed to the industry, each of which should meet a definite need depending on the degree of treatment required by circumstances at various plants. They are discussed below in a logical order which reverses the chronological order in which they were worked out.

Partial treatment process: The wastes from a receiving station or fluid milk bottling plant are normally produced in 4 to 6 hours in the morning. These wastes would be pumped directly into one or more aeration tanks and aerated continuously. The tanks would contain as an inoculum about 1/5 their volume held over from the previous day. The rapid growth reaction would be ended almost as soon as the inflow of waste was completed, as our data show. Endogenous respiration, the auto-oxidation of the cells for their own maintenance, would proceed for the remaining 16 hours. The tank would be drained down to the desired level of inoculum late in the night, ready for the next days operation, a so called fill-and-draw process. The effluent would be a well aerated dilute suspension of bacterial cells. The reduction in total solids would be about 50%. The BOD of the waste would be reduced about 75% by this partial treatment, for the bacterial cells are relatively stable toward further oxidation. Typical results upon three different simulated wastes are presented in Table I. The system requires only tank capacity, air, and a timing mechanism to control the discharge from the tank.

There are two possible applications of such a system. First it would suffice where the receiving stream is not of the highest quality or has a large flow to dilute the waste. Second, the effluent would be amenable to further treatment in a municipal sewage treatment plant. Many dairy plants are enjoined from use of municipal sanitary sewer systems because the high oxygen demand of milk wastes upsets the operation of municipal plants. Also, the effluent from the fill-and-draw process would enter the plant at night when sanitary sewage flow is low and greater oxidation capacity is available.

TABLE I

Analysis of Whole Effluent from Fill-and Draw Operation

(Samples taken 16-18 hours after addition of waste)

	Simulated Waste		
	0.1% Skim milk	0.5% Whey	1.0% Skim milk
Initial COD, ppm	1,050	5,000	10,500
Final COD, ppm	448	2,220	4,700
COD, % reduction	60	55	55
Initial 5-day BOD, ppm	640	4,300	6,400
Final 5-day BOD, ppm	118	1,120	1,560
5-day BOD, % reduction	80	75	75
Initial 20-day BOD, ppm	1,060	5,000	10,600
Final 20-day BOD, ppm	286	2,110	3,100
20-day BOD, % reduction	73	58	71

Complete treatment process: An effluent of excellent quality would result if the bacterial cells produced in the rapid growth reaction were removed. Tests upon the effluents of the experiments discussed above showed a 90-95% reduction in 5 day BOD after removal of the cells (table II).

Table II

Analysis of Centrifuged Effluent from Fill-and-Draw Operation

(Samples taken 16-18 hours after addition of waste)

	Simulated Waste		
	0.1% Skim milk	0.5% Whey	1.0% Skim milk
Final COD, ppm	120	312	730
COD, % reduction	89	94	93
Final 5-day BOD, ppm	52	190	400
5-day BOD, % reduction	92	95	94
Final 20-day BOD, ppm	--	340	850
20-day BOD, % reduction	--	93	92

In the laboratory the cells were removed satisfactorily by a centrifuge, and it was proposed that the centrifugal separation be tried on a plant scale. Such a plant could be operated either as a continuous flow constant level system or by fill-and-draw operation (4,5). This process therefore is identical with the partial treatment process except for the removal of the cells.

The cells removed, or "sludge" would have to be disposed of in some manner. For small plants, handling say 20,000 pounds of milk a day, the amount would be about 10 pounds on a dry basis or 75 pounds of wet solids. This amount would probably not justify installation of drying equipment; the sludge could be diluted to a slurry and put on pasture fields. Larger plants would produce comparably larger amounts of sludge, so the possibility of utilization of the sludge was considered (see below).

Alternative methods of removal of the sludge such as filtration or simple settling have not been investigated. The success of physical methods of separation depends on particle size to a great extent; therefore, the type of floc or aggregate of cells would depend on the degree of mechanical agitation and other features of large scale operation which cannot be reproduced in the laboratory.

These proposals were received with great interest by sanitary engineers in many companies. Certain of the difficulties encountered in operation of existing facilities are explained by our data.

Several existing plants have been altered successfully to provide greater aeration capacity or to remove the sludge produced. However, new waste disposal plants are built because state authorities require the dairy plants to provide treatment facilities, and both company and state officers are loath to construct treatment plants of an admittedly experimental design. Therefore, no plants have been built on the recommended processes.

RMA Contract

The need for large pilot plant study of our proposals was evident. We therefore contacted a number of research organizations and after discussions and negotiations have arranged a research contract for pilot plant study with the Pennsylvania State College. The major features of it are:

1. Construction of a pilot plant to treat 10,000 gallons a day of waste from an operating dairy. The system will be flexible and all operating variables will be under control. Chemical analyses of influent and effluent, as well as determination of oxygen transfer, pH and redox potential will be made throughout.

2. Operation of the plant over sufficient time as a fill-and-draw system so that steady-state operating conditions can be established for temperatures of 50-75-90° F. and at least 4 rates of air flow.

3. A similar operation schedule on a continuous flow basis.

4. Investigation of alternative methods of aeration.

5. Investigation of the effect of added nutrients, especially in the treatment of whey.

6. Investigation of the removal of cells (sludge) by various methods and the preparation of at least 4 ten-pound samples of dried sludge for laboratory study.

7. Preparation of recommendations for full scale plants based on the results of this study.

The plant is expected to be in operation by June. One year's operation on fill-and-draw and continuous flow each is planned, followed by a 6-month period for completing the report and plans, a total of about 3 years from January 1, 1952. The total cost of the contract is to be $33,480.

Composition of Sludge

The amount of sludge produced by treating the waste from large plants would be appreciable, amounting to 200 to 500 pounds a day. The sludge was therefore analyzed for various constituents. It contains 65% protein (5), a very high value, and relatively large amounts of vitamin B_{12} (2, 3). The analogy between this sludge and that produced in the "activated sludge" process for municipal sewage treatment was apparent, so vitamin B_{12} analyses were made on the dried sludge which is sold as a fertilizer. It was found that the commercial fertilizer contains about 4 mg/kg of B_{12}, which is to be compared with the required level of 2.2 mg/kg for a commercial feed supplement. The possibilities of this tremendous potential supply of vitamin B_{12} are being studied by municipal authorities and feed supplement manufacturers. Further consideration of vitamin B_{12} in dairy waste sludge is being held in abeyance until the question of industrial use of activated sludge as a source of this vitamin is settled.

Bibliography

1. Hoover, Sam R., Jasewicz, Lenore, Pepinsky, Janet B., and Porges, Nandor. Assimilation of Dairy Waste by Activated Sludge, Sewage and Ind. Wastes 23, 167 (1951).

2. Hoover, Sam R., Jasewicz, Lenore, and Porges, Nandor. Vitamin B_{12} in Activated Sewage Sludge, Science 114, 213 (1951).

3. Hoover, Sam R., Jasewicz, Lenore, Pepinsky, Janet B., and Porges, Nandor. Activated Sludge as a Source of Vitamin B_{12} for Animal Feeds, Sewage and Ind. Wastes, 24, 38 (1952).

4. Hoover, Sam R., Pepinsky, Janet B., Jasewicz, Lenore, and Porges, Nandor. Aeration as a Partial Treatment for Dairy Wastes, Proc. 6th Ind. Waste Conf., p. 313, Purdue Univ. (Feb. 1951).

5. Hoover, Sam R., and Porges, Nandor. Treatment of Dairy Waste by Aeration. II. Continuous Aeration Studies, Proc. 5th Ind. Waste Conf., p. 137, Purdue Univ., (July 1950).

6. Hoover, Sam. R., and Porges, Nandor. Assimilation of Dairy Waste by Activated Sludge. II. The Equation of Synthesis and Rate of Oxygen Utilization, Sewage and Ind. Wastes (in press).

7. Pepinsky, Janet B., Porges, Nandor, and Hoover, Sam R. Application of a Rapid Chemical Oxygen Demand Test for Determining Organic Pollutions, Proc. 6th Ind. Waste Conf., p. 367, Purdue Univ., (Feb. 1951).

8. Porges, Nandor, and Hoover, Sam R. Treatment of Dairy Waste by Aeration. I. Methods of Study, Proc. 5th Ind. Waste Conf., p. 130, Purdue Univ. (July 1950).

9. Porges, Nandor, Pepinsky, Janet B., Hendler, Nancy C., and Hoover, Sam R. Biochemical Oxidation of Dairy Wastes. I. Methods of Study, Sewage and Ind. Wastes 22, 318 (1950).

10. Trebler, H. A., and Harding, H. G. Dairy Waste Disposal, Chem. Eng. Progress, 43, 255 (1947).