Dairy Waste Treatment Pilot Plant*

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In April, 1952, a contract was negotiated between the U. S. Department of Agriculture and The Pennsylvania State College (School of Engineering) for the development of engineering details, based on pilot plant operation, of the treatment of dairy wastes. The initial laboratory research on the principles of the biological oxidation of dairy wastes was performed by Hoover and his co-workers, and presented at previous Purdue Industrial Waste Conferences. This work has been summarized in a pamphlet prepared by the Eastern Regional Research Laboratory (AIC-332).

Contract Requirements

The major features of the contract stated that a pilot plant must be constructed that would treat 10,000 gals. a day of waste from an operating dairy. Chemical analyses of influent and effluent, as well as determinations of oxygen transfer, pH, and redox potentials must be made while the pilot plant was in operation.

The pilot plant was to be operated over a sufficient period of time as a fill-and-draw system so that steady operating conditions are established for temperatures of 50-75-90° F. and at various rates of air flow. After the fill and draw test period, a similar operation schedule on a continuous flow basis must be undertaken. An investigation of alternate methods of aeration must be undertaken. An investigation of the removal of cells (sludge) by various methods and the preparation of at least four 10-pound samples of dried sludge for laboratory study must be carried out. An investigation of the effect of added nutrients, specially in the treatment of whey must be studied. Preparation of recommendations for full scale plants based on the results of this study must be carried out.

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Pilot Plant

Location for the pilot plant was selected adjacent to the creamery building on the campus, with one of the two control laboratories in the building beside the plant. The plant was constructed to first operate as a fill-and-draw unit with a maximum holdover equal to 50 percent of the daily influent volume for "seed" purposes, or a waste capacity of 15,000 gallons with a daily influent of 10,000 gallons. This plant can be converted to a continuous flow unit with a theoretical maximum displacement time of 36 hours, when desired.

The plant design includes temperature control by means of direct steam injection, thermostatically controlled. The operation of the plant is almost fully automatic by means of a six-channel time clock, float switches, limit switches and electro-hydraulic valves. All of the normal variables in such an operation are recorded, including redox potential. The latter is obtained by means of a Micromax unit supplied through the courtesy of the Leeds and Northrup Co., Philadelphia, Pa.

Because of numerous and confusing reports of the clogging of air diffusers in dairy waste oxidation, eight Penberthy injectors (Size 87A) were installed initially to disperse the air from the blowers through eight to nine feet (depth) of liquid. The maximum air supply available is 250 c.f.m. which is dispersed by recirculating 250 g.p.m. of the waste through the eight injectors. Assuming an oxygen transfer efficiency as low as one percent this arrangement can supply oxygen at the rate of 0.5 p.p.m. per minute. Early observations indicate that as much as 10 percent of the oxygen in the air is utilized during the influent loading period. Approximately 20 c.f.m. of air can be aspirated from the atmosphere by use of the recirculating pump only. After the characteristics of the injectors are determined, other types of commercially available aerating devices will be installed and compared. Mechanical aeration will also be investigated, subsequently.

The College Creamery receives approximately 20,000 pounds of milk per day which is made into the following products: whole milk, skim milk, buttermilk, condensed and dried milk, ice cream, cottage and cheddar cheeses, and small quantities of butter. On Saturdays the main activity is pasteurizing and bottling, which reduces the volume and strength of the waste on that day, and on Sundays, the milk is received and refrigerated only.

At present, the waste treatment plant operates on the following program: 0900, waste influent starts; 1430-1500, waste influent ceases; 0500, (after 14 hours of oxidation) effluent valve opens; 0630, effluent valve closes. Modifications were made recently so as to raise the effluent

orifice 30 inches above the bottom of the tank. By stopping the aeration 60 minutes before the effluent valve is opened, the sludge will settle to the bottom of the tank. This also permits the aeration tank to be used as a sedimentation tank, providing the one-hour settleable solids do not exceed 33 percent, and in this way the quantity of sludge can be built up to any reasonable value, or two-thirds of it wasted daily if desired by agitating during the effluent period. If the effluent is withdrawn while the tank is being agitated, the quantity of sludge cannot exceed a fixed value which is dependent upon the weight of milk solids introduced in the untreated waste. As the degree and rate of treatment are dependent on the quantity of sludge present, it is desirable to be able to vary this factor.

During the relatively short time of operating, the B.O.D. reductions averaged 90 percent with sludge removed, and the reductions in lactose were practically 100 percent. The B.O.D. of the normal influent (without whey) was 950 p.p.m. The B.O.D. of the influent containing whey was between 10,000 and 15,000 p.p.m. and when added to the tank in controlled amounts, could be treated to give an effluent with a B.O.D. ranging from 0 to 50 p.p.m. Although experimentation on the treatment of cheese whey is incomplete at this time, it was found that a longer treatment time is required to achieve a high degree of treatment. The pH varied between 7.0 and 7.6. During the peak of the oxidation (or loading) period, D.O. values of four to five p.p.m. could be obtained.

Normally the limits of the redox potential were +50 to —300 millivolts during a 24-hour period. Originally it had been planned to use the decrease in redox potential, which would occur with the influent of the waste to increase the quantity of air being supplied and thus insure a continuous aerobiosis. While this feature can be used it has not been incorporated due to the false potential values obtained by the fouling of the platinum electrode with a sludge film and the production of negative values. Modification of the platinum electrode are being studied to eliminate this difficulty.

The most outstanding early problem encountered was the production of foam in quantities of 10,000 to 12,000 gallons daily. This occurred approximately three to five hours after the cessation of the waste influent. It was brown, gelatinous, and sticky, and could not be broken readily with a water stream or spray. It possessed the property of removing paint where it dried on piping. The regular production of this unwanted product in such quantities finally caused a shutdown of the plant. It is interesting to note that this condition coincided with an abnormally high production of cheese. During the foaming condition, the redox potential dropped to a negative value of 400 mv., although dissolved oxygen was present. Bacteriophage tests were negative; and the total plate counts (68° F.) decreased as did the motile organisms observed microscopically. The presence of yeast cells was noted but the extent of these cells is unknown. Surface tension values which were normally in the neighborhood of 68 dynes increased slightly. Complete stoppage of air for 24 hours did not appreciably affect the quantity of foam, and laboratory samples were kept for several days without any noticeable change in volume. In the initial stages of this condition, the addition of waste did appear to destroy a good portion of the foam.

Analysis of the foam by Hoover and Porges showed a total solids of 30,000 p.p.m., of which 2700 p.p.m. was ash and 9300 p.p.m. protein; 37 percent of the total solids were water soluble. It also contained 1350 p.p.m. reducing sugars and gave a strong qualitative test for "dextrins."

Using a sewage plant activated sludge as a seed, four identical cultures were established in 16-liter quantities using skim milk as a food. They were then operated on single separate foods, namely: Skim milk, whole milk, cheddar cheese whey, and cottage cheese whey. This experiment, up to this date, has not produced the type of foaming which occurred at the pilot plant. It should be noted that in the initial laboratory work done by Hoover, et al., silicone anti-foams were used.

The foaming problem was solved by reducing the air used. The initial rate during the break-in period was approximately two cfm. per pound of B.O.D. When the air rate was reduced to less than one cfm. per pound of B.O.D., no trouble was encountered. Later tests at the pilot plant indicated that the addition of controlled amounts of cheese whey did not cause foaming while aeration continued at the reduced rate.

A polarograph, loaned by the Eastern Regional Research Laboratory, is being used to observe the D.O. content during oxidation and to supplement the more precise usual chemical test. To also study aeration criteria, and more specifically, the efficiency, of various types of aerating devices, a Beckman magnetic oxygen analyzer is employed to measure the oxygen partial pressure in the "air" escaping from the surface of the waste. This escaping "air" is caught at the surface by means of a floating inverted-funnel device and the gases piped to the analyzer. Preliminary observations indicate that during the waste influent period, the D.O. decreases, the O.R.P. becomes more negative and the percentage oxygen in the escaping "air" decreases, but all of these decreases can be reduced in magnitude by increasing the rate of air supplied.

Studies are also being made on the rate of sludge burn-up (endogenous respiration) during the period between influent loadings. This will profoundly affect the operation schedule and the problems of sludge disposal. After one year of operation, there has been no need to dispose of any sludge. Thus far, 10 gallons of sludge containing 98 percent moisture have been removed for experimental purposes.

Borax as a Preservative of Dairy Waste for the B.O.D. Test

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In pilot-plant investigations and industrial waste surveys, it is often almost impossible to run B.O.D. tests immediately after sampling. The validity of analyses of samples that must be held for several days or shipped to a laboratory is open to question, especially when a soluble material that is readily attacked by microorganisms makes up a major portion of the oxygen-demanding substances. Previous studies at this laboratory demonstrated that a dairy waste heavily inoculated with aerobic microflora is rapidly oxidized if sufficient oxygen is available. Thus a solution containing 1000 p.p.m. milk solids was about 40 percent oxidized in six hours, with an accompanying loss in B.O.D. of more than 50 percent (2, 3).

Several possible methods of preserving B.O.D. have been studied by other workers. Freezing the sample and holding it in the frozen state is effective but often inconvenient. Use of a completely filled sample container has been investigated by Horton (4), who found that filled bottles of milk waste kept under water showed a negligible loss in B.O.D. over several days. In studies requiring storage of casein solutions at this laboratory, borax had been found effective at a concentration of two percent but completely ineffective at concentrations below one percent. The work reported in this paper, which is of a preliminary nature, was undertaken for the purpose of determining the use of borax as a preservative for dairy wastes.

Borax, sodium tetraborate ($Na_2B_4O_7.10\ H_2O$), consists of colorless, odorless, transparent crystals that have a solubility of one gram in 16 ml. water at room temperature and one gram in 0.6 ml. boiling water. The resulting solution at room temperature is buffered at pH 9.2. Borax is not oxidized under the conditions of the C.O.D. test.

Buchanan and Fulmer (1) in their discussion of effects of chemical environment on the physiology and biochemistry of bacteria report findings of other authors. *Aspergillus* was inhibited by one percent boric