The Disposal of Wastes from Milk Products Plants
Michigan State University Agricultural Experiment Station
Special Bulletin
E.F. Eldridge, Engineering
Issued June 1936
17 pages

Special Bulletin No. 272 June, 1936

THE DISPOSAL OF WASTES FROM MILK PRODUCTS PLANTS

By E. F. ELDRIDGE

AGRICULTURAL EXPERIMENT STATION

MICHIGAN STATE COLLEGE
Of Agriculture and Applied Science

SECTION OF ENGINEERING

East Lansing, Michigan

THE DISPOSAL OF WASTES FROM MILK PRODUCTS PLANTS

E. F. ELDRIDGE

Factories and plants that handle milk for manufacture into dairy products or for distribution have certain milk losses that may be accounted for by the milk solids in their factory wastes. For two important reasons these milk losses should be reduced to a minimum in any milk products plant. The first is obvious to an efficient plant manager and may be the means of more profit to his company. The other, while it is just as obvious, usually is not recognized until complaints are brought to the attention of the management by governmental agencies. This second reason has to do with the insanitary conditions and nuisances caused by the discharge of milk solids into streams and ditches.

The problem of milk waste disposal may be solved to a considerable extent within the factory by preventing milk losses through careful operation. Thus, this paper will discuss the waste problem from two standpoints: (a) How to eliminate as completely as possible the loss of milk solids within the factory; and (b) how to treat those solids that cannot be economically saved in such a manner that they may be safely discharged.

Why a Nuisance is Produced

A better conception of this problem and the discussions that follow may be possible if consideration is first given to the effect of those wastes on stream water and aquatic life. It is well known that milk solids as well as other organic materials are excellent food for fish and other forms of aquatic life. Why then is this life destroyed by the presence of those solids in stream water? Briefly, the reason is as follows:

Milk solids decompose rapidly because of the action of bacteria. There are two general types of decomposition, one taking place in the presence of oxygen (aerobic) and the other in the absence of oxygen (anaerobic).

Milk waste when it first enters a stream containing dissolved oxygen will decompose by the aerobic process, using the oxygen available in the stream water. No apparent ill effects on aquatic life result until the oxygen is almost depleted. Anaerobic decomposition then begins, resulting in the formation of septic conditions, unpleasant odors, and a nuisance. At the same time, the water is depleted of its oxygen, and as a result all forms of fish life in the stream are destroyed by suffocation.

The limits within which a stream may be used for the disposal of wastes are clearly defined by a study of the oxygen conditions of the water. The demand for oxygen must never exceed the supply.

Milk solids require a large quantity of oxygen for the aerobic process of decomposition; the average stream water contains but a very small amount. A comparatively large volume of water, therefore, is required to furnish the oxygen for the process. Every pound of milk, containing about 12.5 per cent milk solids, requires about 3,000 gallons of the average stream water for dilution to maintain satisfactory stream conditions. If it is possible to reduce the milk losses from a factory to a point where this amount of dilution is available during periods of lowest stream flow, then the stream may safely be used for the disposal of the waste. Careful operation is necessary in factories where dilution is used as a means of disposal, in order to keep within safe limits at all times.

Suggestions for the Decrease of Milk Losses

The first attack on the waste disposal problem should be made within the plant by providing means by which milk losses may be minimized. In some cases the reductions obtained may be sufficient to meet local requirements, and no waste treatment processes will be necessary.

The following suggestions will serve to point out some of the general sources of milk losses and ways by which the losses may be decreased:

(a) A large share of the milk solids in the wastes of many factories comes from the can washer. Usually about one pound of milk is lost for every nine cans washed. Some plants wash as many as 2,000 cans daily, which means a loss of 200 pounds of milk. These solids are discharged over a 3- to 4-hour period and would require a stream having a minimum flow of about 55 cubic feet per second for satisfactory dilution.

One-half of the milk lost through the can washer may be prevented by collecting the drip. Every washer should be provided with a drip collector.

Eighty per cent of the remainder of the milk may be saved by collecting a short cold water rinse of the cans. The disposal of this rinse may be difficult, and its collection may or may not be practical. In some cases, however, its elimination from the wastes may avoid the cost of building treatment units. In such cases, it could be mixed with the drippings and sold or given to the producer for feeding purposes.

(b) The drainage from storage tanks, coolers, churns, vats, and other equipment should be collected in cans and either returned to the product or used for feeding purposes. A cold water rinse of these units may also be collected and used. For instance, condenseries in many cases might find that it is less expensive to evaporate the small excess of water required for these rinsings than to provide structures for the treatment of the waste.

(c) Skimmilk, buttermilk, and spoiled milk should be considered by-products and should never be discharged into the factory sewers. These by-products are highly concentrated, and treatment processes for wastes including them are costly.

(d) Whey and cheese washings are also concentrated and wherever possible should be used either for the manufacture of other products or for feeding. A limited amount of whey and washings may be treated by the processes outlined later in this bulletin. Considerable effort should be spent in finding an outlet for the whey and as much of the first washings as is possible. These efforts will be amply repaid by the savings in the cost of the treatment required for the factory wastes.

After a careful check on milk losses in the plant, further reduction of the milk solids by treatment may or may not be necessary, depending upon local conditions. In any event, the reduction of losses in the plant will prove to be a good investment since less equipment will be required for the treatment of the remaining waste. The remainder of this bulletin is devoted to a discussion of methods of milk waste disposal and the design, construction, and operation of milk waste treatment structures.

METHODS OF MILK WASTE DISPOSAL

Because of the great variation in the size of milk products plants and in the local conditions surrounding these plants, a general method for waste disposal cannot be recommended. A method which can be successfully used in one place, may or may not be applied at another.

In general, biological filtration is the recognized method for the treatment of milk waste and is particularly adaptable to the larger plants. The process will be described later. Since the process is not so readily adaptable to small plants, it is often necessary to resort to other methods of disposal.

The Septic Tank

The septic tank has been used in the past as a "cure-all" for all waste disposal problems. The septic process, however, cannot be successfully applied to milk waste, since products are formed by the septic fermentation of milk solids that are much more detrimental to the stream than are the fresh solids. The septic tank, therefore, is not recommended for milk waste disposal.

Irrigation

In the case of small plants located on farms or in sparsely populated districts, irrigation may be used as a means of waste disposal. This method consists of pumping or otherwise spreading the waste onto several acres of land that are kept under constant cultivation. Provision must be made to apply the waste to various portions of the field on alternate days so as to allow the waste to seep into the soil before a second application is made. Sandy soil is best adapted for this practice. Should odors become obnoxious, chloride of lime, sodium hypochlorite, or liquid chlorine may be applied to the waste before it is pumped to the field. Usually the method is used only during the summer months when stream flows are low.

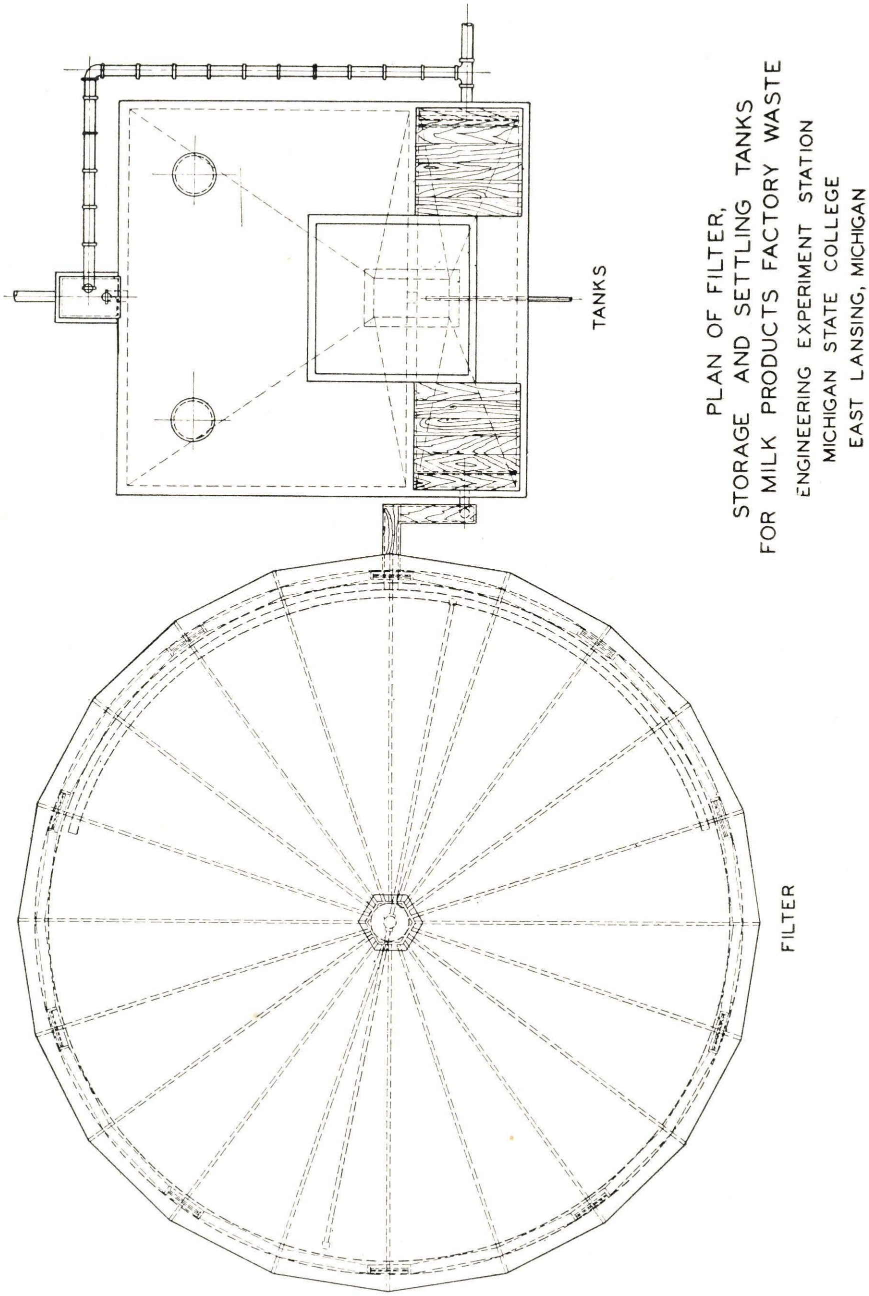

Fig. 1. General plan for milk waste treatment plant.

Hauling

Some very small plants, located in urban communities, may solve their waste disposal problem by hauling the concentrated waste water to land in more isolated districts. Small creameries, for instance, may dispose of excess buttermilk and butter washings in this manner. The method may also be used by small cheese factories for the disposal of whey and cheese washings.

The equipment necessary consists of a small tank mounted on a trailer. The tank should be of sufficient size to hold the entire volume of waste produced during any one day. Provision should be made for completely draining the tank of its contents. Chloride of lime or sodium hypochlorite may be used to control odors if necessary.

Biological Filtration

This method of disposal consists of the intermittent application of the waste to a filter composed of gravel or crushed stone. After a period of use, a growth of oxidizing bacteria develops on the filter stones. These bacteria oxidize the milk solids, form stable compounds, and reduce the oxygen demand. A properly operated filter of this type should reduce the oxygen demand of the waste 90 to 95 per cent.

The treatment plant necessary for the biological filtration of milk waste consists of three units (Fig. 1). These units are: (a) a holding tank to equalize the waste and to give a longer operating period for the filter; (b) the filter, and (c) a settling tank to remove the suspended material from the waste discharged by the filter. The remainder of the bulletin contains a discussion of the design, construction and operation of a biological filter.

DESIGN AND CONSTRUCTION OF FILTER

Composition of Milk Waste—Table 1 gives the average analysis of a number of samples of whole milk, skimmilk, buttermilk, and whey. Since milk factory wastes are made up of dilutions of these materials, a knowledge of their composition is valuable in a study of milk waste treatment.

Before designing a filter for the treatment of the waste from a milk products factory, consideration must be given to the volume and strength of the waste to be treated. If average care is exercised in the

Table 1. Average analysis of milk and by-products.

	Whole milk p. p. m.	Skim-milk p. p. m.	Butter-milk p. p. m.	Whey p. p. m.
Total solids	125,000	82,300	77,500	72,000
Organic solids	117,000	74,500	68,800	64,000
Fat	36,000	1,000	5,000	4,000
Ash	8,000	7,800	8,700	8,000
Milk sugar	45,000	46,000	43,000	44,000
Protein (casein)	38,000	39,000	36,000	8,000
B. O. D. (5-day)	102,500	73,000	64,000	32,000
Oxygen consumed	36,750	32,200	28,600	25,900

To convert p. p. m. to per cent by weight multiply by 0.0001.

Table 2. Volume and composition of milk wastes.

	Volume per 1,000 lbs. milk gallons	Total milk solids p. p. m.	5-day B. O. D. p. p. m.
*Condensery	150	1,200	800
**Creamery	100	1,500	1,000
Receiving station	160	700	600
Dry milk plant	150	1,200	800
Bottling plant	225	600	500
Cheese factory	170	—	—

*Exclusive of vacuum pan water.
**Including butter washings, but not buttermilk.

use of water and in preventing the excessive loss of milk solids, the various types of plants will have wastes approximating those given in Table 2.

The values given in Table 2 should not be relied upon in the design of a plant. They are given here in order that the management may judge to what extent the individual waste deviates from the average.

Determination of Volume—The volume of the waste may be determined by building a weir box, similar to that shown in Fig. 2, at some point in the sewer line. If the plant makes use of a vacuum pan, the condenser water must be segregated from the other wastes before the measurements are made and the samples collected. Readings of the depth of the water over the weir should be taken at least once every 30 minutes over the period of factory operation. The measurements should be made for at least two days, selecting those days that are representative of the normal operation of the factory.

At the same time, samples should be taken for analysis. These samples should be composited according to flow; that is, at the time the readings of the weir are made, samples of the waste should be taken that will represent the quantity of waste discharged. The quantity of the sample to be collected corresponding to the gage reading at any one period is given on Table 3. These samples, collected at 30-minute intervals, should be poured into a large container. At the end of the day, the composite sample should be well-mixed and a smaller sample (about 1 quart) removed for the 5-day biochemical oxygen demand (B.O.D.) determination. The method for making the 5-day B.O.D. test is given later in this bulletin.

Table 3. Weir readings and sample volumes for 90-degree triangular weir.

Height over weir (inches)	Flow (gallons per minute)	Volume of sample (ml.)
2.0	10.9	109
2.5	19.0	190
3.0	29.	298
3.5	43.6	436
4.0	60.8	608
4.5	81.3	813
5.0	105.6	1,056
5.5	133.7	1,337
6.0	166.0	1,660

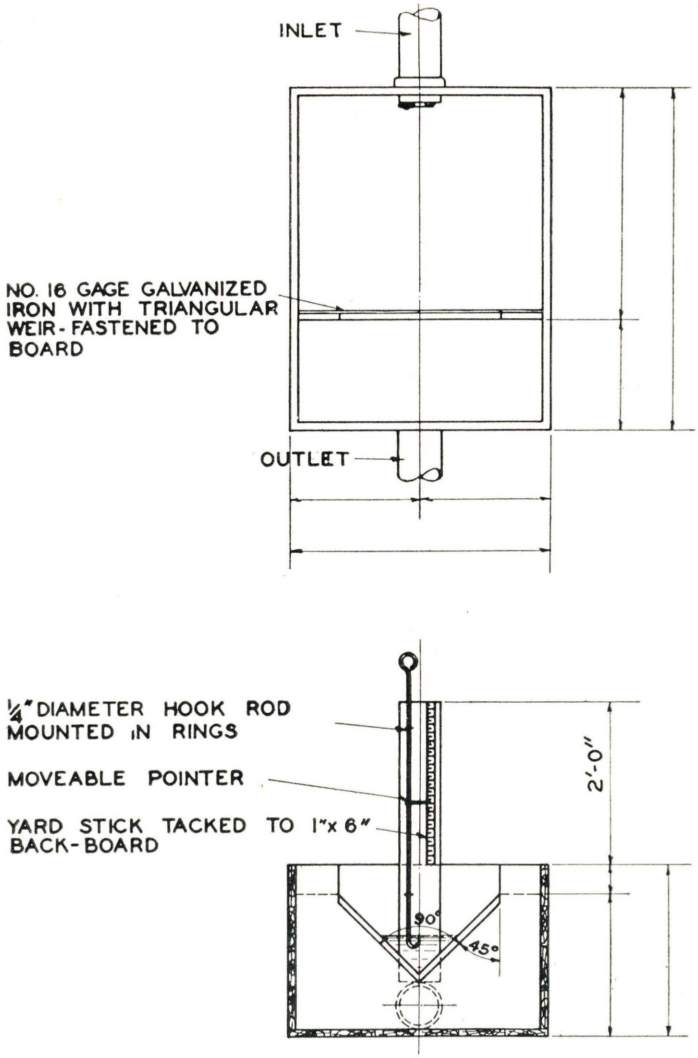

Fig. 2. Triangular weir and hook gage.

Table 3 gives the volume of flow over a 90-degree triangular weir for the various readings of water depth above the vertex of the weir.

Segregation of Clean Water—A major portion of the water used in a milk products factory does not contain milk solids. Water from cooling coils and ice machine, together with any other clean water may be segregated from the other wastes. Care must be taken, however, not to segregate too much water since the waste may become too concentrated for efficient filter operation. The 5-day B.O.D. of the applied waste should not exceed 1,000 p.p.m., and an average of 700 to 800 is desirable. After the waste is adjusted to about this concentra-

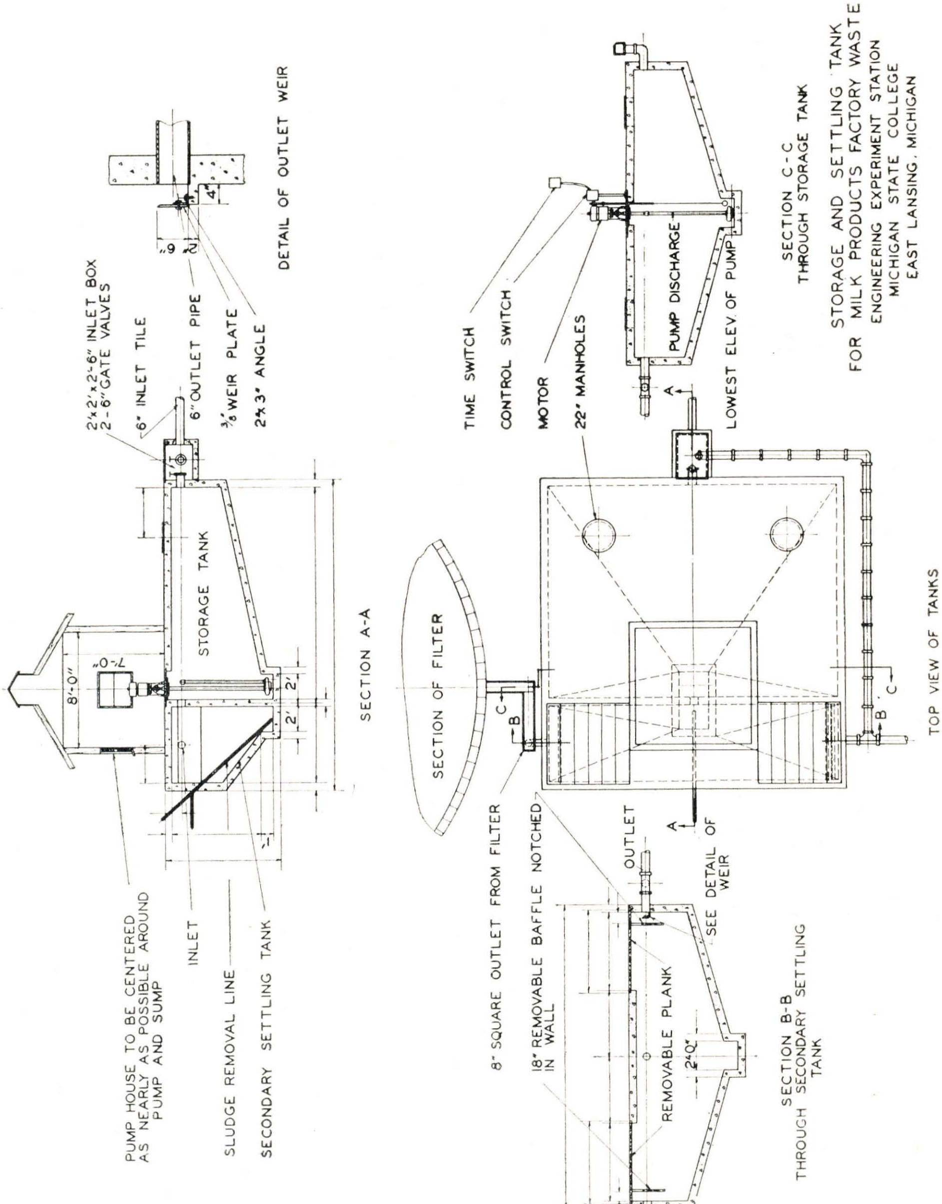

Fig. 3. Plan of holding and settling tanks for milk waste treatment plants.

tion, a final reading of volume must be made before the capacity of the required structures may be determined.

GENERAL SPECIFICATIONS

Holding Tank—Figure 3 is a line drawing showing the suggested design of the holding tank, which is built in combination with the settling tank. The vertical section on this plan shows an inlet or diversion box by means of which the waste may be by-passed around the tank when necessary. The floor of the holding tank should slope to a sump in which the suction of a centrifugal pump should be placed.

The tank should have sufficient capacity to allow operation of the filter for about 18 to 20 hours daily, but should be of such a size that it will be completely emptied at least once each day. A capacity of about 40 per cent of the total daily volume of waste is generally sufficient. Table 4 gives the recommended capacity of tanks for various volumes of waste.

The depth of the tank is governed to some extent, by the vertical shaft centrifugal pump used to pump the waste to the filter. About 6 to 8 feet from the water line to the sump should meet most conditions. The other dimensions are governed by the capacity required. Table 4 also gives the recommended dimensions for holding tanks based on the volume of waste to be treated.

The tank should be of reinforced concrete construction. The walls and floor should not be less than 8 inches in thickness. The concrete should be composed of 1 part cement to not more than 6 parts of other aggregate. The top slab of the tank should be from 4 to 6 inches in thickness and well-reinforced. Manholes should be provided at convenient points.

Pump—The pump should be of the vertical centrifugal type and provided with a float control switch. It should have a capacity to deliver a minimum volume of 2 gallons of waste per hour for each square foot of filter area available and will be much better if considerably oversize. A valve should be installed on the discharge line for the regulation of the quantity of waste delivered.

The float should be set to empty the sump before the pump is stopped. For small filters (30 feet and under), where the rotary distributor turns at a rapid rate, a time switch should be inserted inside of the float control switch. The purpose of this time switch is to give an intermittent application of the waste to the filter and allow a rest period between doses. With the larger filters and slower moving arms, this rest period is obtained on sections of the filter between the revolutions of the arms. The time cycle of the time switch should be about 3 minutes on and 3 minutes off.

Rotary Distributor—The suggested design for the cone of the rotary distributor for small filters is shown in Fig. 4. This distributor may be made to fit the needs of filters up to 30 or 35 feet in diameter. Commercially made distributors are available for the larger filters.

The cone should be supported by means of a pipe imbedded in a concrete pillar at the center of the filter bottom. The pump discharge should be connected to this pipe at a reducing tee located from 2 to 3 feet below the surface of the filter.

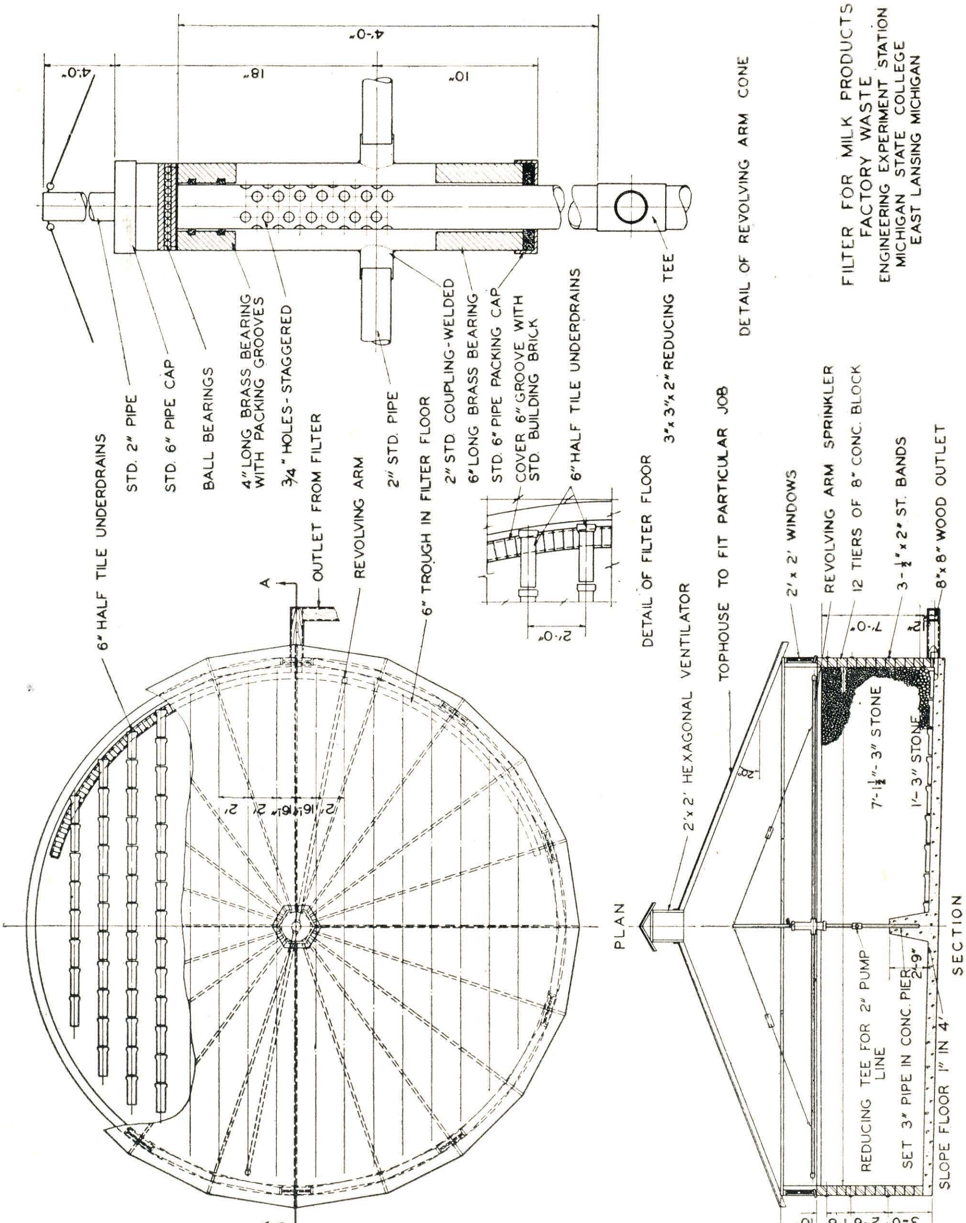

Fig. 4. Plan of filter and rotary distributor cone.

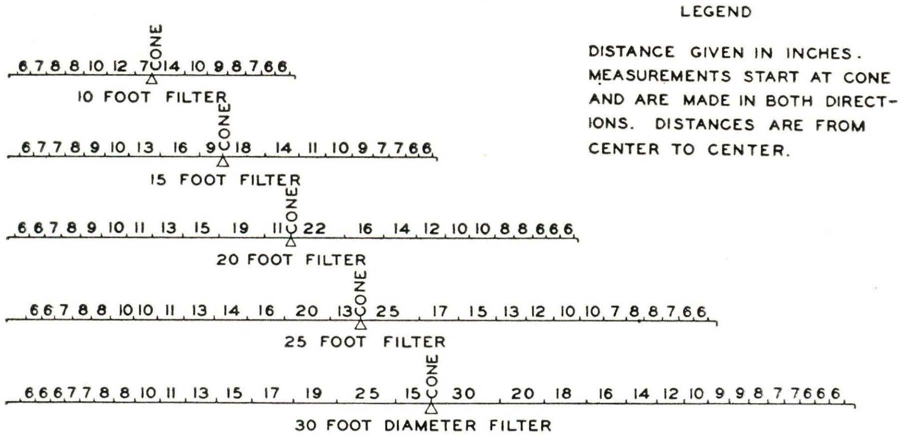

Fig. 5. Spacing of holes in rotary distributor arms.

The cone is so designed that the pressure of the water leaving the holes in the arms rotates them and the outer shell of the cone. This outer shell is supported on the inner cone by a roller bearing race. The waste discharges through holes in the inner cone to the outer shell from which it enters the arms. Only a small amount of packing is necessary to prevent leakage at the bearings.

The holes in the distributor arms should be spaced to give equal distribution of the waste over the filter. These holes should be from ¼ to ⅜ inch in diameter, and on opposite sides of the two arms. Figure 5 shows the suggested spacings (center to center) of the holes for rotary distributor arms of various lengths.

In order to spread the waste evenly over the filter surface, metal plates may be bolted to the arms over the holes in such a manner as

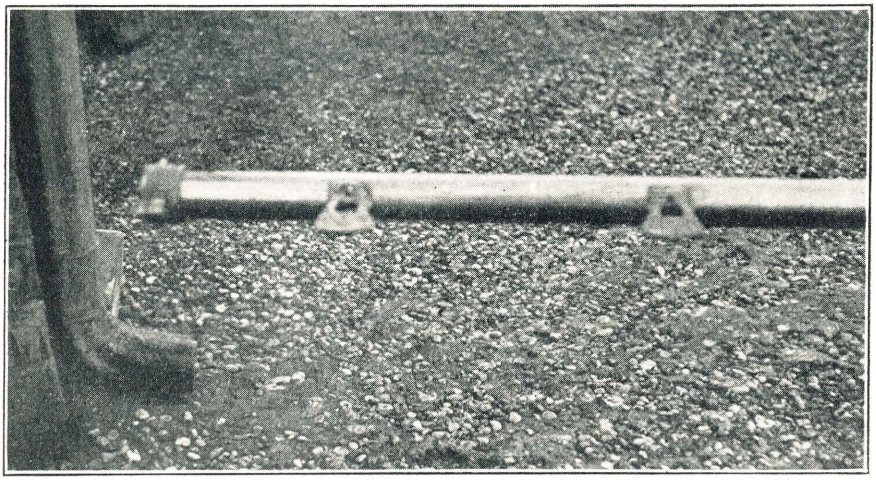

Fig. 6. Metal disks to spread the waste over filter.

to give a fan-shaped spray. Figure 6 shows a commercially made plate in place.

Filter—Figure 4 shows the recommended design of the filter for milk waste treatment. This filter should be 8 feet deep and of sufficient area to allow a maximum rate of application of 1 gallon per square foot per hour. The rate should be based on an 18- to 20-hour operation per day and on the volume of waste produced during peak periods. Table 4 gives the size of filters required for various quantities of waste.

Table 4. Capacity and dimensions of units.

Capacity

Volume of flow (gallons per day)	Holding tank (cu. ft.)	Filter area (sq. ft.)	Settling tank (cu. ft.)
2,000	130	110	—
4,000	260	220	—
6,000	390	330	108
8,000	520	440	120
10,000	650	550	150
15,000	1,000	830	220
20,000	1,300	1,000	300
25,000	1,670	1,400	370

Dimensions

Volume of flow (gallons per day)	Holding tank (feet) Width x Depth x Length	Filter diameter (feet)	Settling tank (feet) Width x Depth x Length
2,000	6 x 5 x 5	12	— — —
4,000	6 x 6 x 8	17	— — —
6,000	6 x 6.5 x 10	20	6 x 3 x 6.5
8,000	7 x 7.5 x 10	24	7 x 3 x 7.5
10,000	7 x 9.5 x 10	26	7 x 3 x 9.5
15,000	8 x 10.5 x 12	33	8 x 3 x 10.5
20,000	8 x 12 x 14	38	8 x 4 x 12
25,000	8 x 12 x 17.5	42	8 x 4 x 12

The filter floor should be constructed of reinforced concrete not less than 9 inches thick. The floor should have a slight slope to a trough that should be located in the floor just inside the filter wall. This trough should extend over about 1/3 of the perimeter of the floor and should slope to an outlet tile, as shown in the drawings. Some designers carry the underdrain tiles through the filter wall, and locate the trough outside of the filter. Such a practice while it has the advantage of admitting more air to the underdrains, causes trouble during winter operation.

A reinforced concrete pillar should be built in the center of the floor to support the rotary distributor.

The walls of the filter may be either of reinforced concrete or concrete blocks. If they are to be of reinforced concrete, they should be at least 8 inches thick and fastened to the floor with reinforcing bars. If concrete blocks are used, a curb 8 inches wide should be built on the circumference of the floor. This curb should be level to support the concrete wall. Concrete block walls should be supported at 2-foot vertical intervals with bands of 1/4 by 2-inch rolled steel, since these walls will not be of sufficient strength to withstand the pressure of the stones if not given some support. The walls should be 8 feet high.

The underdrainage system for the filter may consist of either rows of half-tile laid on the floor, or grooves in the floor loosely covered with brick. The drainage system should lead to the trough on one side of the filter floor. The tile lines or grooves should be spaced at 2-foot centers. A detail of the underdrains at the trough is shown in Fig. 4.

Fig. 7. Covered filter for milk waste, Berne, Indiana.

The filter medium should consist of clean hard gravel or crushed rock. The lower 1 foot of stone should be of from 2- to 3-inch material and the upper 7 feet of 1½- to 2½-inch material. This stone should be well-selected and should be almost free from soft sandstone.

It is usually advisable to cover the filter with a frame housing for winter operation. Such a covering is shown in Fig. 7, which is a picture of the milk waste filter at the United Milk Products factory at Berne, Ind. A house will also be required for the pump motor and control switches. The suggested design of both coverings is shown on the drawings.

Settling Tanks—Figure 3 shows the recommended design of the settling tank that is in combination with the holding tank. This tank should be of such a capacity as to give a 2-hour settling period for the peak volume of waste applied to the filter. Table 4 shows the capacity of tanks required for the various volumes of waste to be treated.

The tank should be of similar construction as recommended for the holding tank. The floor should have considerable slope toward a sump in which a sludge line may be located. In some cases this line may be designed to draw the sludge by gravity. In other cases, it may be necessary to attach a hand pump to the line at such times as it may be necessary to withdraw the sludge.

Wood baffles should be placed at the inlet and outlet ends of the settling tank as shown in the drawings. These baffles are to retain the scum that may accumulate on the surface. The tank may be covered with planks, since these can be readily lifted when it becomes necessary to remove the scum.

COST ESTIMATES

Approximate cost estimates (Table 5) are given in order that those desiring to construct a treatment filter for milk waste may have some idea of the cost. All estimates include every item as shown on the line drawings, that is, for excavation, concrete, pumps, piping, stone, concrete block, underdrains, housing, and other items.

Table 5. Approximate cost estimates.

Volume of flow (gallons per day)	Estimated cost	Volume of flow (gallons per day)	Estimated cost
2,000	$500.00	10,000	$1,500.00
4,000	700.00	15,000	2,000.00
6,000	1,000.00	20,000	2,500.00
8,000	1,350.00	25,000	3,000.00

OPERATION OF THE MILK WASTE FILTER

The biological filter for milk waste treatment must be properly operated if best results are to be obtained. These operating details do not require much time, but must be carefully attended. The following major items are necessary to the successful operation of the filter:

(a) Considerable time is required for the development of the filter organisms. As much as 3 to 4 weeks may be necessary when the filter is first placed in operation. Seeding the waste in the holding tank with a water extract of manure is sometimes used as an aid in building up the filter. Manure is placed in a barrel, soaked with a quantity of water, and the water siphoned into the holding tank. This must be repeated for several days.

(b) The rate of application should be regulated by means of the valve on the pump discharge. The rate of pumping when intermittent application is employed should be about 2 gallons per square foot of filter area per hour. If the waste is applied continuously the rate should be 1 gallon per square foot per hour. These pumping rates, of course, give the same rate of application.

(c) The holding tank must be completely emptied at least once each day. If waste is allowed to stand in this tank, septic conditions, and odors will result. Washing the walls and floor of the tank with a stream of water at regular intervals (once each week) will aid in preventing septic action.

(d) The waste must not have an average 5-day B.O.D. greater than 700 to 800 p.p.m. nor a maximum of more than 1,000 p.p.m when applied to the filter. Composite samples should be collected and analyzed occasionally to determine the strength of the waste applied. If it becomes too strong, some provision must be made for admitting clean water to bring the strength of the waste to a point below the values given.

(e) The holes of the filter arms must be kept clean. If trouble is experienced from clogging of these holes a screen may be placed in the diversion box at the inlet end of the holding tank. This screen must be cleaned regularly.

FIVE-DAY B.O.D. DETERMINATION

Some factories have sufficient laboratory accommodation to make tests of their wastes, and may find it convenient to set up equipment for the 5-day B.O.D. This is the only essential test required to determine the strength of the wastes and the efficiency of the filter. The following method is recommended for making this determination:

Reagents—(a) Cleaning solution: Dissolve 100 grams of commercial potassium dichromate in 375 ml. of water and make up to 1 liter with concentrated sulphuric acid.

(b) Diluting water: Add 6 grams of sodium bicarbonate to 5 gallons of distilled water. Aerate by bubbling air through the water for at least 12 hours. Store for one week before using.

(c) Manganous sulphate: Dissolve 480 grams of manganous sulphate in sufficient distilled water to make one liter.

(d) Alkaline potassium iodide: Dissolve 500 grams of sodium hydroxide and 150 grams of potassium iodide in sufficient distilled water to make 1 liter.

(e) Sodium thiosulphate (0.025 N): Dissolve exactly 6.205 grams sodium thiosulphate in 1 liter of distilled water. Add a few ml. of chloroform. Make up fresh every 2 weeks.

(f) Starch indicator: Make up a thin paste of about 2 grams of starch in cold water. Pour into about 200 ml. of boiling water and stir. When cold add a few ml. of chloroform.

Method—(a) Clean five 8-ounce, glass stoppered bottles, using the cleaning solution. Rinse the bottles thoroughly after cleaning. Fit each bottle with a water seal made of radiator hose or other heavy tubing.

(b) Fill one bottle completely with diluting water [see (b) above], insert the stopper tightly and fill the seal.

(c) Siphon about 500 ml. of diluting water into a clean liter graduate. Add 10 ml. of the raw waste and fill to the liter mark with diluting water. Mix well with a plunger type stirring rod to avoid aeration of the water as much as possible. Fill completely by means of a siphon, one of the 8-ounce bottles with the well-mixed waste. This is a 1 per cent dilution.

(d) Discard all but 500 cc. of the diluted waste remaining in the graduate. Again fill to the mark with diluting water and mix as before. Siphon this mixture into a third bottle. Insert the stoppers and fill the seal. This last mixture is a 0.5 per cent dilution.

(e) Repeat steps (c) and (d) using 20 ml. of the treated waste in place of 10 ml. as used before. This results in a 2 per cent and 1 per cent dilution of the treated waste.

(f) Place all five bottles in a 20° C. incubator or in a place where the temperature is fairly constant and near 70° F. Allow them to remain for 5 days, keeping the seals filled with water.

(g) At the end of five days remove the stoppers and seals and add 1 ml. of manganous sulphate [see (c), page 17] and 1 ml. of alkaline potassium iodide [see (d), page 17]. Insert the stopper and mix by inverting the bottle several times. Allow the precipitate to settle about half-way and mix again. Add 1 ml. of concentrated sulphuric acid, insert the stopper and mix again.

(h) Rapidly withdraw exactly 100 ml. of each solution in turn into a flask and add 0.025 N sodium thiosulphate [see (e), page 17] from a burette until the yellow color almost disappears. Add 1 ml. of starch indicator [see (f), page 17] and again add sodium thiosulphate drop by drop until the blue color just disappears. Record the number of ml. of thiosulphate used in each case.

(i) Calculations:

Ml. of 0.025 N Thiosulphate used in each case $\times$ 2 = p.p.m. dissolved oxygen (D.O.).

$$\frac{\text{p.p.m. D.O. diluting water—p.p.m. D.O. dilution} \times 100}{\text{percent of sample in dilution}}$$

p.p.m. 5-day B.O.D.