A STUDY OF THE DISPOSAL OF CREAMERY WASTES

Thesis for Degree of M. S.

C. E. Slaughter

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THESIS

Sewage disposal

Title Creamery wastes

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creamery wastes

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A STUDY OF THE DISPOSAL OF
CREAMERY WASTES

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A THESIS, SUBMITTED
TO THE FACULTY OF
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* * *

BY

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INTRODUCTION

To anyone who has observed the sewer outlet of the average creamery the importance of this subject will be apparent.

There are few odors quite as offensive as those evolved from stagnating milk wastes. This is the main objection ~~raised by~~ the average person but there are other dangers which creamery wastes ~~cause~~ which are not so generally realized. It has been found that milky wastes not only have a toxic effect on fish and other aquatic life but also cause their death by suffocation by absorbing the dissolved oxygen and producing anaerobic conditions in a stream.*

When anaerobic conditions occur, any self purifying tendency that the stream might have had is reduced and a menace to public health exists.

Pollution of streams by trade wastes and more especially by creamery wastes is therefore a serious public nuisance.

Such pollution also has an economic significance for it endangers the recreational facilities of the State. Our streams and lakes with their scenic effect and the recreation and fishing they afford constitute a great natural resource by drawing to Michigan vast numbers of tourists who every year spend in the neighborhood of twenty-three million dollars**

* Cornell University Exp. Sta. Bulletin, Disposal of Dairy Wastes, p 61

** Mich. State Conservation Dept. Estimate.

LEGISLATION

The growing pollution of streams in Michigan which in the past has presented a problem since the beginning of industry, and has become more serious as the trade wastes have increased in quantity, has resulted in some important legislation which promises to become quite an issue with those industries whose wastes are difficult to dispose of.

In the early history of the State the bad effects of certain wastes were realized. Thus in 1865 we find in, Act 350, 1865,

"An Act to Protect Fish and Preserve the Fisheries of the State."

"The People of the State of Michigan Enact:"

"It shall be unlawful for all persons to put into any of the waters of this State, where fish are taken, any offal, blood, putrid brine, or filth of any description and any person so offending shall be fined in any sum not exceeding $300 or imprisonment not exceeding 30 days or both at the discretion of the court."

"Provided, however, that this act shall not be construed to apply to discharging the waste matter of any paper mill into any of the streams or their tributaries on sections 13, 23, and 24 of Schoolcraft Township, Kalamazoo County."

Although this act prevented gross pollution, in many instances, still its ineffectiveness is seen in the deplorable condition of many of our streams today.

The paper mills around Kalamazoo were exempt

from this act, probably, for the very good reason that absolutely no method was available for the disposal of their waste, and these plants are still discharging their raw wastes into the Kalamazoo River for exactly the same reason.

The act that created the Conservation Department in 1921 also placed the responsibility of pollution prevention in their hands, thus,

Act No. 17, 1921, Sect. 3.

"It is to be made the duty of the Department of conservation to protect and conserve the natural resources of the State of Michigan,----------- to guard against the pollution of lakes and streams within the State and to foster and encourage the protection and propagation of game and fish."

Some beneficial results followed the creation of the Conservation Department. However they felt the limitation of their authority. Many creameries and ~~other~~ factories continued to discharge their wastes into the streams in ~~the face~~ of restraining orders from the Conservation Department. Hence the Act of 1925.

Act No. 201, 1925

"Section 3 of Act No. 17 of the Public Acts of 1921 is hereby amended to read as follows."

"It is hereby made the duty of the Department of Conservation to protect and conserve the natural resources of the State of Michigan and ---------------- to guard against the pollution of lakes and streams within the

State and to enforce all laws provided for that purpose with all athority granted by law and to foster and encourage the protection and propogation of game and fish".

By this act the matter is placed squarely before the Conservation Department which is now vested with full power to enforce their orders.

PRESENT STATUS OF PROBLEM

On March 30, 1926 a hearing was held at the State Office Building by representatives of the Attorney General's office, ~~Board~~ State Dept of Health, and Conservation Department. Representatives of all the important creameries in the State were present.

The future policy of the State was outlined in a general way and it was announced that the creameries would be given thirty days in which to formulate a plan or a program leading to the satisfactory disposal of the wastes at their respective plants.

The State Departments, very properly, steadfastly refused to set any standards for treatment or to recommend any process. The problem of finding a process which will reduce wastes to a stable effluent is left entirely to the creameries.

The creameries are now facing the dilemma of immediately planning some disposal system for wastes when the Board of Health freely admits that no reliable

process is known.

What little research has been done in this field has been mostly in connection with fairly large inflexible tanks, fed by creameries whose wastes vary greatly in volume, quality, and concentration from day to day. In most cases the design of these plants did not lend itself well to experimental purposes and because of inflexibility their advantages were largely lost.

Such large scale experiments are interesting and valuable; in fact necessary because, without doubt, many factors enter into the operation of large plants that never manifest themselves in laboratory operations. But it was felt that any further field experiments should be preceded by a program on a laboratory scale in which some fundamental data and comparisons could be obtained. This thesis is presented with this idea in mind.

For preliminary work, the many advantages of this method of study over field observation are apparent. Many processes can be carried on at the same time and subjected to the same conditions of changing temperature, etc. It is possible to secure a uniformity of influent that would be impossible on a larger scale. The visible manifestations of the processes can be more easily observed in reasonably small glass containers than in large tanks.

CONDITIONS GOVERNING THE TESTS

The operations as carried on in the laboratory were made to simulate actual conditions as closely as possible. All of the laboratory operations were carried on in the Bacteriology Building. As most of the work was done during the winter, spring and fall months, the room temperature was practically constant at 70°F.

The experiments, for the most part were made in glass jars, as large as could be handled and photographed conveniently.

For the sake of uniformity, and in order that accurate comparisons might be made, an artificial milk-waste was arbitrarily chosen. This was a 2% milk solution prepared from College Dairy whole milk thoroughly mixed with tap water. This gave a reasonably uniform product which resembled the average creamery waste.

METHODS OF MAKING CHEMICAL AND BACTERIOLOGICAL TESTS

Milk-wastes are ordinarily much more concentrated than ordinary sewage and invariably contain large quantities of lactose.

The procedure outlined in the American Public Health Association Manual for the testing of sewage was followed as closely as possible but with the following modifications which seemed necessary.

T. Total Solids

1 and 10 cc. was evaporated in a platinum dish over a water bath and dried at 103°C for one hour. The ash was then determined by igniting to a constant ~~temperature~~ weight.

Oxygen Consumed.

This in its modified form proved to be a very valuable test. The biochemical oxygen demand test seemed unreliable in many cases because of the necessity of stirring and mixing incident to some of the experiments. However, the oxygen consumed and the oxygen demand usually have about the same value.* The modification consisted in using 10 cc. of waste, diluting to 100 cc. with distilled water. The solutions of potassium permanganate and oxalic acid were ten times the specified strength. The high dilutions required when using the specified solutions of 0.7880 g. /liter of oxalic acid and an equivalent amount of potassium permanganate. gave erratic results. The effect of the modification was to stabilize results and several comparisons failed to show any great discrepancy between the modified and the standard methods.

Relative Stability.

This valuable test was tried, but inconsistent and abnormally low results were obtained in practically all

* Max Levine, Aeration Studies of Creamery Wastes p 13 - 14

cases except with the effluent from the chemical precipitation process.

These abnormal results have been noticed by Max Levine* and are probably due to the absorption of the dye by colloidal and suspended matter.**

Acidity.

Solutions of NaOH and H_2SO_4 of approximately 0.06 N. were used on wastes of high acidity.

Grease.

Grease was determined by extraction with ether.

Hydrogen Ion Concentration.

This test was made by the colorimetric method using Brom thymol blue as an indicator, as described in Giltner's ~~Manual~~.

Bacteriological Tests.

Bacteriological counts were made by the dilution method using milk powder agar in preference to lactose agar. This is made by the method described in The Journal of Bacteriology, V. [illegible], N. 6, [illegible]. It contains skimmed milk powder, sodium dibasic phosphate, peptone, meat extract, and agar. Many organisms that would otherwise fail to develop will grow on this agar, and acid, neutral, and alkaline colonies as well as casein liquifiers can be differentiated directly.

Gelatine was also used in a few cases.

With the preceding exceptions all tests were performed strictly in accordance with the A. P. H. A. Specifications.

* Aeration Studies p. 13.
** Taylor's Chem. of Colloids. p 256

INSPECTION OF CREAMERY WASTE DISPOSAL METHODS

Serious attempts to properly dispose of creamery wastes are quite rare in this State. However, in order to obtain an idea of the nature of the problem as it existed, as well as to answer a call for advice on the part of a few creameries, an inspection of some typical creameries in Southern Michigan was undertaken by Prof. Wallmann of the Bacteriology Department, Mr. Tobey of the Extention Division and the writer.

The East Saugatuck Creamery Co. was the first visited. It is located about two miles from East Saugatuck and its business covers the territory between Saugatuck and Holland its chief product being butter. Its wastes, although only amounting to three hundred gallons per day are very highly concentrated and are discharged into a small ditch which is practically dry, except for the discharged wastes, most of the year. This ditch is intended to flow into the Rabbit River, but most of the wastes never reach a distance of five hundred feet, for they gradually seep away and stagnate resulting in putrifaction and the most obnoxious odors imaginable. A picture of the ditch near the drain outlet is shown in Fig. 1.

The creamery has received numerous complaints from the community and will undoubtedly be compelled to use a different method of disposal before long.

Fig. 2

Showing the discharge from the East Saugatuck Creamery. Note the small flow and the heavy growth of weeds that holds back the sewage.

Pearl Creamery.

The second plant at Pearl manufactures various dairy products. It has had considerable trouble during the winter months because of the accumulation of milk and whey in their discharge ditch. When thawed out in the Spring frightful odors resulted. At present as much whey and milk is excluded from the discharge as possible and what is left is diluted with about ten thousand gallons of cooling water per day. Although this gives a very dilute waste it is an expensive process and is causing trouble from an adjoining land owner who claims that the discharge of such large quantities of water keeps his land too wet for profitable farming.

The Hartford Creamery

The third creamery, at Hartford in Van Buren County, is trying, temporarily, to alleviate what would otherwise be be a very disagreeable condition. Since there were no sewers and no neighboring streams a two thousand gallon wooden tank was constructed and buried in the sandy soil. From this four or five short tile drains radiated. This was intended to act as a seeping cesspool and the wastes amounting to four or five hundred gallons per day were discharged into the tank. In a very few months it was found that the capacity of the tank had been reached. The surrounding soil was completely clogged and the tank was filled with a nearly solid, highly offensive mass, which had accumulated.

Fig. 2.

Seeping cesspool used at the Hartford Creamery. Note the tar paper covering used in an attempt to confine the odors, also the excavation at the side of the tank. This was made in an effort to clean out a drain which had clogged.

The tank was cleaned out at an excessive cost and again used but the clogged condition of the soil soon made it necessary to build a new tank in a new location.

The new tank, Fig. 2 was rapidly filling up at the date of inspection and it seems probable that it will be necessary to clean out and relocate the tank once a year or oftener.

International Milk Products Co., Bad Axe, Michigan

This plant was visited later in the fall, October 21 - 24. It is located in the outskirts of Bad Axe and its business extends throughout the thumb district. The plant uses 50,000 to 65,000 gallons of milk per day and manufactures varying quantities of butter, condensed milk, milk powder, etc.

Mr. Gibson, the superintendent of the plant, stated that the quantity of their wastes varied somewhat but amounted to approximately 325 lbs. of solids per day.

Until last year all of the whey and other by-products of the creamery were dumped into the disposal plant which was designed only for municipal use and Bad Axe was widely known for its disposal problem. Unless the wind was blowing in the opposite direction the entire city was pervaded with odors from the overtaxed disposal plant. At present the creamery separates the whey and more concentrated milk-wastes and hauls them to a distant orchard where they are dumped on the surface of the ground, and used for what fertilizing value they have. The wastes now consist of the 325 pounds of solid matter, enormously diluted ~~with~~

DISPOSAL PLANT
BAD AXE, MICHIGAN.

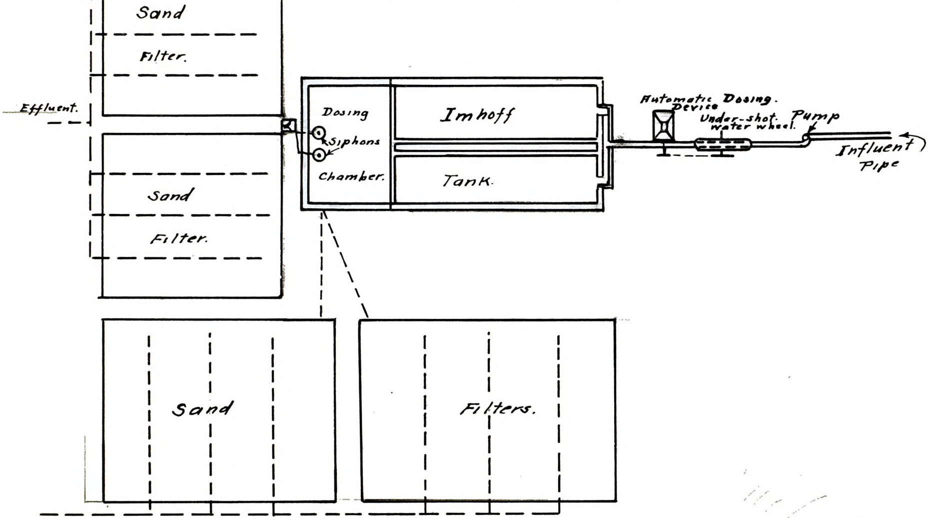

Fig. 3

with cooling and condensery water.

These wastes when combined with the municipal sewage amount to about 120,000 gallons per day and are discharged into the disposal plant for treatment. Fig. 3.

The first step in their treatment is a process developed by Mr. Travis of the Ohio Conservation Dept. This is essentially a chemical precipitation process, carried out by adding 825 pounds of a precipitating mixture to a days run of sewage. The mixture consists of 600 pounds of dried pulverized marl, 200 pounds of hydrated lime and 25 pounds of ferrous sulphate.

This compound is continuously added in quantities proportional to the daily flow, by an ingenious device invented by a member of the Bad Axe Council, Fig. 4.

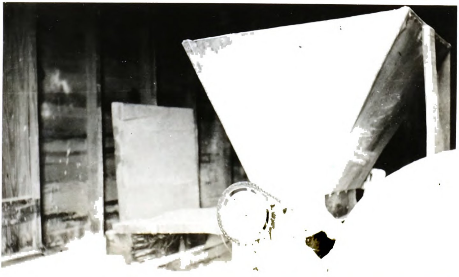

Fig. 4

This device is used for adding the precipitating compound to the influent stream at the Bad Axe Disposal plant

The mixture is placed in the hopper and is slowly added to the influent by a worm feed. driven by a small water turbine.

This chemical treatment was found to be apparently ineffective and the plant seems to work just as well if it is omitted entirely. It is thought that the compound merely settles to the bottom and adds itself to the sludge. It was intended at the time of the inspection to discontinue its use altogether. Mr. Gibson stated that the operating cost of the process amounted to approximately ten dollars per day.

After this chemical treatment the flow is divided and passes through an Imhoff tank. Here the solids are supposed to precipitate into the lower chamber. The inefficiency of the tank, however, is shown in the analysis of the influent and effluent.

From the Imhoff tank the sewage passes over wiers into the dosing chamber, Fig. 5. where it is dosed alternataly onto two of the sand filters having a combined area of 0.8 Acre.

The effluent from these filters is comparatively good having a relative stability of 50 - 70%.

The other two filters which are only about 18 inches deep are often subject to a continuous flow and give a somewhat inferior effluent.

Some trouble is experienced with the sand filters which clog often and require frequent cleaning.

Fig. 5.

This shows the twelve thousand gallon dosing chamber of the Bad Axe Disposal plant. In the background are the sand filters; four in number, totalling 1.30Acres.

Note the flooded condition of the one on the left. This was due to several repeated doses.

The effluent is discharged into a county drainage ditch which flows through the clump of trees in the background and into the Pinnebog River.

Note the recording device in the corner of the dosing chamber, also the wiers and baffle boards, and also the gas vent of the imhoff tank in the foreground.

College Dairy

A few samples were taken from the college Dairy waste in order to compare it with others of its class. The results are shown at the end of the following table.

Report of Tests of Sewage and Milk Wastes at East Saugatuck, Bad Axe, Caro, and M. S. C. Dairy.

Discharge from sewer at East Saugatuck Creamery October 13, 1925.

Oxygen Consumed	901 parts/Million
Aerobic organisms on:	
Plain agar	160,000 per cc.
Milk powder agar	26,035,000
Casein Liquifiers	20,000
Anaerobic organisms	
Plain Agar	120,000
Milk agar	6,600,000
Gelatine liquifiers (Aerobic)	80,000

Influent of Plant at Bad Axe October 22, 1925

Oxygen consumed	130 p,p.m.
Organisms growing on	
Milk Agar:	
Total aerobic	420,000
Casein liquifiers	20,000
Anaerobic	370,000

Influent at Bad Axe. Cont'd

Gelatine liquifiers	20,000

Effluent from Imhoff tank

Oxygen consumed	200 p.p.m.
Aerobic organisms	420,000 / cc
Anaerobic "	600,000
Casein liquifiers	30,000
Gelatine liquifiers	100,000

Sand Filter Effluent

Oxygen consumed	150 p.p.m.
Aerobic organisms	100,000
anaerobic "	70,000
Casein liquifiers	0
Gelatine liquifiers	50,000

Condenser water

Oxygen consumed	70 p.p.m.
Aerobic organisms	0
anaerobic "	0
Casein liquifiers	0
Gelatine liquifiers	20,000

Wash Water

Oxygen Consumed	4390 p.p.m.
Total solids	3000 p.p.m.
ash.	1300

Disposal plant at Caro,Michigan

Septic tank effluent.

Oxygen condumed	290 p. p. m.
Aerobic organisms	990,000 /cc
Anaerobic organisms	610,000
casein liquifiers	100,000
Gelatine liquifiers	50,000
Total solids	1500 p.p.m

M. S. C. Dairy Waste.

Can Washings April 20, 1926

Oxygen Consumed	120 p.p.m.
Total Solids	810
Inorganic solids	160
Organic solids	650

Coolong Water and small

amount of Sewage. April 21, 1926

Oxygen consumed	60
Total Solids	530
Inorganic solids	150
Organic solids3	380
Organic Nitrogen	16

Floor washings, Small quantities of sewage, whey, milk, and large quantities of cleaning powder. April22, 1926

Oxygen consumed	47
Total solids	3640
Inorganic solids	2700
Organic solids	940

M. S. C. Dairy, Cont'd

Large quantities of whey and wash water.

Oxygen Consumed	824 p.p.m.
Total solids	2730
Inorganic matter	320
Organic	2410
Organic Nitrogen	12

	-------Dilution------------------		
Bacteria	1/100	1/1000	1/10,000
Total	---Too thick----		5,240,000 / cc.
Neutral colonies			4,500,000
Acid			600,000
Alkali			140,000

QUESTIONNAIRES

In addition to the personal inspections, ~~four~~ hundred questionnaires similar to the one on the following page were distributed through the State Bureau of Dairying with the understanding that they would be filled out and returned by the inspectors. However very few of them returned and the results are not sufficiently significant for presentation here.

QUESTIONNAIRE

Kindly indicate below the products and average amounts of each produced at your plant, weekly.

Butter________________________

Cheese

Kinds

____

____

____

____

Market Milk____________________

Average amount of milk received weekly________________

About how much water is used per week?________________

Estimate the amount of waste material per week.________

Buttermilk_________________

Whey ___________________

Skimmilk ____________________

____

____

Method of disposing of this waste

Septic tank

Seeping cesspool

Discharge, directly into river or stream

Discharge into municipal sewage system

____

Is the waste of the dairy combined with any other sewage?

Please state any trouble experienced in the disposal of waste

____

____

____

Have any objections been raised to your method of disposal?

____

____

Do you anticipate any trouble in the future? ______________

____

Have you any plans or suggestions for improving your system?

____

____

____

Have you experienced any trouble in disposing of grease in the sewage?

____

Do you use a grease trap for its removal?_________________

QUANTITY OF WASTES

Col. E. D. Rich, State Sanitary Engineer, contributed the following results from a recent questionnaire issued jointly by the Conservation and Health Departments.

Concern	Production	Quantity of Waste
Creamery Co.	500,000 #Butter/ Yr.	4500 gal/ Wk.
	850,000 #Butter/ Yr.	?
Co.-Op. Creamery	60,000 # Whole Milk/day	350 gal./ day
Condensery	65,000 "	120,000 Gal/day
Butter +Powder milk.	80,000 "	5000 gal/day
	1,240,000 # Butter/ Yr.	?
	660,000 Butter/Yr.	700-900 Gal./day
Condensery	20,000 # Milk/day	200 Gal/day
	100,000 "	3% Solids
Butter, Cheese, Ice cream	30,000 "	100-500 Gal/day
Ice Cream Co.	10,000 Gal Ice cream/Yr.	500 Bbl/day

It is apparent from the foregoing data, that creamery wastes from various plants differ widely, both in quantity and in quality. It was estimated that an average creamery waste from a plant making a variety of products might be expected to contain, 0.05 - 0.12 % fat; 0.05 - 0.10% Casein; 0.01 - 0.02% Albumin; 0.10 - 0.20 Lactose; and 0.01 - 0.05 % Inorganic matter.

Often the waste contains quantities of sawdust, bits of glass and usually cleaning powder. These latter constituents present no serious problem. Heavy solids

can be removed in a grit chamber, and experiments conducted at Cornell University show that moderate quantities of cleaning powder are not objectionable.*

The disposal of the other constituents, however, presents one of the most difficult and complex problems that is ever met in the Sanitary Engineering field.

Butter fat, if present, is very difficult to dispose of. It is very slowly attacked by bacteria, it forms unsightly and offensive scums wherever the waste is stored; it rapidly clogs filters and stops up drainage systems; it interferes with the settling of sludge, and finally, upon decomposing it gives rise to disagreeable odors.

Casein is a protein with an acid reaction. As it exists in milk it is soluable but it combines with a fixed proportion of alkali and is then soluable. It is present in milk in a suspended or colloidal condition. and may be removed by filtration.** If milk wastes are allowed to acidify a point is reached between pH 4 and pH5 at which the casein is precipitated. It rises to the surface and is slowly acted upon by protein liquifying bacteria. with more disagreeable odors.

* Cornell Exp. Station Bulletin No. 62. p 62.

** Taylor, Chemistry of Colloids,

Barthel, Milk and Dairy Products.

Albumin is present in smaller quantities in a form known as lacto-albumin. This is similar to other albumins and upon decomposition it also contributes to the odors characteristic of creamery waste.

Lactose, known also as milk sugar, is the common and most troublesome constituent of all creamery wastes. It is a disaccharide and is immediately attacked by all members of the Colon group of bacteria which convert it, for the most part, into lactic acid.

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow 4\,C_3H_6O_3$$

The characteristic rapid rise in acidity is shown clearly in later experiments.

A hydrogen Ion Concentration of pH 5.5 has been found by Max Levine to markedly inhibit bacterial action and it can be readily seen that the rapid rise in acidity will soon destroy the bacterial flora, after which it may require weeks for a bacterial flora to develop which will continue the reduction under the highly acidified condition.

DISPOSAL

Disposal by dilution which is recognized as a standard method for most sewage is dangerous in the case of milk wastes. If they could be discharged into a rapidly flowing stream which was never completely covered with ice and which had plenty of dissolved oxygen this method might be safely employed.

A dilution of less than fifty times the volume or with a previously polluted stream has always been found objectionable. The already grossly polluted streams of this State which are invariably covered with ice during the winter preclude any feasibility of this plan in Michigan.

Typical examples of this condition exist in Bay City and Saginaw. The Saginaw River is grossly polluted by various concentrated trade wastes which rapidly absorb the dissolved oxygen in the stream. During the winter months the river is completely covered with ice which prevents the readsorption of oxygen from the air. Most aquatic life dies from suffocation if not from the toxic effect of the waste. It is reported that during the late winter months the banks have been literally lined with dead fish. The danger of such a condition is obvious.

Disposal of creamery wastes by such means is very seldom satisfactory, and in the future will not be permitted in this State.

DISPOSAL BY STORAGE

In order to observe the effect of storage on the acidity and character of milk wastes a five liter glass cylinder, Fig. 7 was filled with 2% milk solution and stored for several months in the laboratory.

During this time several tests were made, the averaged results of which are given in the following table.

Fig. 7

One of the two septic cylinders used for studying the effect of storage on 2% milk solution.

Table.

January	12, 192	1100 p.p.m.	Oxy. Cons.
	13	998	
	14	900	
	15	950	Odor first noticable
	17	831	Strong odor, slight sludge forming.
March	5	433	
	23	380	Odor disappeared
June	15	220	
Nov.	23	100	

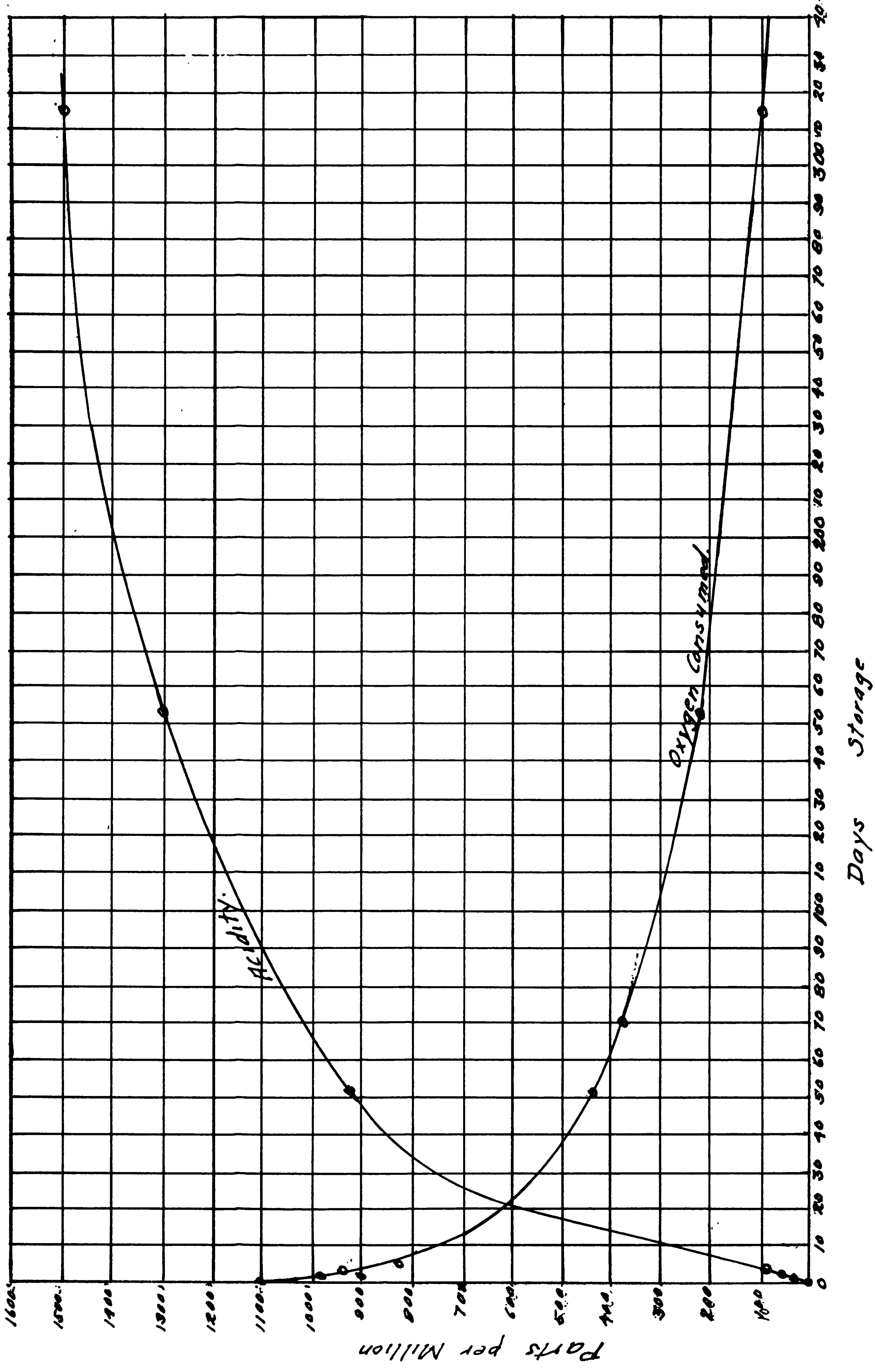

Fig.

Acidity

January	12,	5 p.p.m.
	14	33
	15	47
	17	93
March	5	910
June	15	1300
Nov.	23	1500

November 23, 1926

Total solids	360 p.p.m.
Inorganic "	140
Organic "	220
Suspended "	7

These results are shown graphically in Fig. 2, p. 28

The decreasing rate of fall of the oxygen consumed curve as the acidity mounts higher can be readily seen. This is because of the decreased activity of the bacteria under the highly acidified aonditions.

SEPTIC TANKS

If the preceeding experiment represented the most effective storage conditions a retention of several months would be required in order to produce even a fairly satisfactory effluent.

It would be expected that in a septic tank the gradual introduction of fresh effluent would not only

keep down the acidity but would also result in a continuous seeding action which would result in a quicker reduction.

This proved to be true.

A small model plant consisting of a septic tank and a contact bed was constructed as shown in Fig. 8.

Fig. 8

Model septic tank and contact bed. The ten gallon jar at the left served as a septic tank and discharged through a siphon into the metal drum which was filled with crushed rock, passing a 1-1/2" and retained on a 1/2" screen.

The capacity of this tank was 8.50 gallons= 32.2 liters. The capacity of the contact bed used in connection with this process was 4.5 gallons = 17.0 liters. In order to fill the contact bed this amount was withdrawn

at every dosing period and an equivalent amount was replaced in the tank.

During the operation of the tank no decrease in the capacity of the contact bed was observed thus proving that the voids in the crushed rock were not being filled up.

Operation of the tank was started October 19, 1925. Tests of the effluent were made at intervals with the following results.

One Day Retention

Date	Oxy. Cons	Acidity.
Oct. 29	410 p.p.m.	410 p.p.m.
30	410	400
Nov. 2	360	400
3	380	410

Total Solids	1900 p.p.m.
inorganic "	220
Organic matter	1680

A bacterial analysis was made October 29, with the following results.

	------ Dilution ------------	
	1/100	1/10,000
Total Aerobic	Too ~~thick~~ numerous	9,000,000
Casein liquifiers		110,000
Total Anaerobic		2,300,000
Anaerobic casein liquifiers		0
Gelatine liquifiers		11,220,000

Because the results of tests made on sucessive days failed to show any material change in the effluent, it was apparent that the tank had reached its maximum efficiency. A few doses were then made using a retention period of three days, with the following results.

Threee Day Retention Period

Date	Oxy Cons.	Acidity
Nov. 10	260	650
13	270	
16	250	600

Total solids		1400
Inorganic	"	180
Organic	"	1220

Notwithstanding the fact that the tank was operated under a closed hood the odors were so offensive that it was necessary to draw off the effluent and dose the tank at night when the laboratory was vacant.

Conclusions from Storage Experiments.

(1)High acidity inhibits the reduction of wastes.

(2) Under ordinary storage conditions a reduction in oxygen consumed is accompanied by an increase in acidity.

(3) The acidity in a septic tank using a one day retention period will range around 400 parts per million and with a three day retention period will be in the neighborhood of 600 parts per million. The oxygen consumed will be about 400 and 250 parts per million respectively.

(4) Sludge does not form readily but a heavy offensive scum forms on the surface of the waste.

(5) Large quantities of many types of bacteria are present including gelatine and casein liquifiers Casein liquifiers are in the minority, however, which may account for the persistence of the scum in the highly acidified wastes.

(6) The effluent from this process is extremely offensive and even with a three day retention period contains large quantities of organic matter.

(7) The septic tank is not well adapted to the disposal of creamery wastes.

Contact Bed.

A model contact bed was used in conjunction with the septic tank just described. It was constructed as shown in Fig. 3 from an 8.5 gallon tank. This was filled with crushed trap rock ranging from 1/2" to 1-1/2"

The capacity of the voids was found to be 4.5 Gallons The time required for filling the tank through the siphon

was twenty minutes, it was allowed to stand full for thirty minutes and was then emptied in about ten minutes. It was dosed once a day for about a month As no improvement in its performance could be observed during this time its use was discontinued. Its lack of efficiency is shown in the following data

Oxygen Consumed (Parts per million)

		Influent	Effluent	Reduction, E/I
October	29,	410	380	7.2%
	30	410	350	14.6
Nov.	2	360	330	8.3
	3	380	350	7.9
	~~10~~	~~260~~	~~280~~	~~-7.7~~
	13	270	250	7.4
	16	250	250	0.0
Average	Reduction =			7.~~4~~6%

Acidity (Parts per million)

Date		Influent	Effluent	Increase.
October	29	410	480	17.1%
	30	400	430	7.5
Nov.	2	400	420	5.0
	3	410	490	19.5
	~~10~~	~~650~~	~~600~~	~~-7.7~~
	16	600	680	13.3

Average increase in acidity = ~~7.4~~ 13.5

Change in Bacterial Flora.

October 29, Milk powder agar and gelatine 1/10,000 Dilution

	Influent	Effluent	Increase	
Total	9,000,000	13,200,000	46.7%	= I
Casein liquifiers	110,000	180,000	63.5	= I
Total anaerobic	2,300,000	2,280,000	-0.9	= R
Casein Liquifiers	0	0	0	
Gelatine liquifiers	11,220,000	9,000,000	19.8	= R

I = Increase; R = Reduction

Relative stability of effluent

Oct. 29 20%

Oct 30 4%

Nov.10 8%

The relative stability seemed to bear more relation to the turbidity of the sample than to the amount of organic matter or the period of storage.

The inconsistent and abnormally low results were probably due to the absorption of the methylene blue dye by the colloidal and suspended matter.*

Conclusions from Operation of Contact bed.

(1) Using a retention period of thirty minutes a reduction in the oxygen consumed of 7% ~~may be~~ was

* Taylor's Chemistry of Colloids.

expected. This will be accompanied by a rise of about 7 % in acidity.

(2) The relative stability test is not applicable to effluents of this kind.

(3) The operation of a contact bed for this purpose results in very offensive odors.

(4) It would seem, therefore, that contact beds are not satisfactory for creamery waste disposal.

FIXED HYDROGEN ION CONCENTRATION

Since septic action had failed because of the rapidly rising acidity and treatment in a contact bed had failed to produce any further material reduction, it was thought that by preventing the rapid rise in acidity the bacterial action might be continued.

Accordingly a series of five four-liter glass jars were filled with 2% milk solution and by the addition of calcium hydroxide were brought to hydrogen ion concentrations of pH 7.6, 7.2, 6.8, 6,4, and 6.0 Once a day enough calcium hydroxide was added to bring the pH value back to the previously determined amount.

Some interesting observations on the rate of acid formation were made, Fig. 4, p 37. The ordinates are the pH value to which the waste had climbed each day before being neutralized with the calcium hydroxide.

It will be seen that most of the acid production took place during the first two or three days. The great

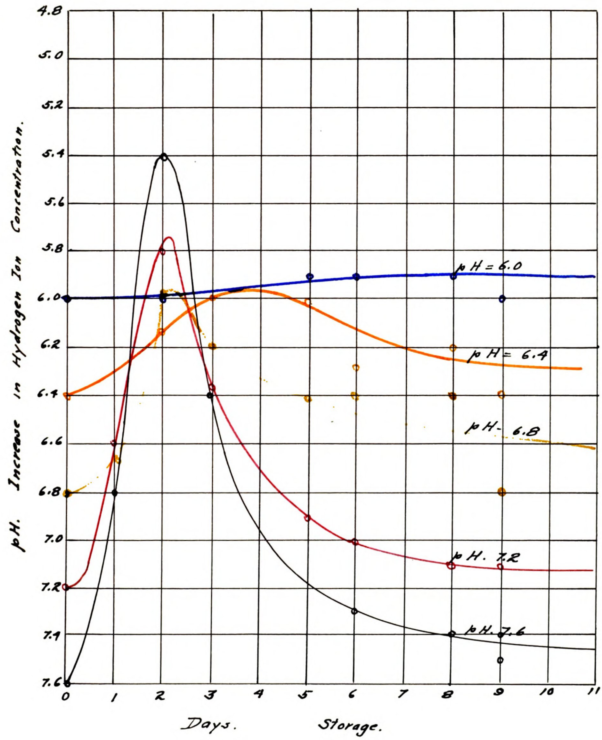
4.8
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6
6.8
7.0
7.2
7.4
7.6
pH. Increase in Hydrogen Ion Concentration.
pH = 6.0
pH = 6.4
pH- 6.8
pH. 7.2
pH. 7.6
0
1
2
3
4
5
6
7
8
9
10
11
Days. Storage.

Fig. 9.

improvement of this method over ordinary storage can be seen by comparing this diagram with Fig. 2 where acid formation continued for several months. Since the rate of acid formation indicates the rate at which lactose is fermented the great advantage of keeping the waste alkaline is obvious.

The data that was obtained from this experiment is contained in the following table.

Fresh 2% milk solution

#	pH	Oxy.Cons.	pH after 24 Hrs.	---Solids--------- Total	Grease	Ash	Org.
1	7.6	1065	6.8	3480	750	350	3130
2	7.2	1065	6.6				
3	6.8	1065	6.8				
4	6.4	1065	6.4				
5	6.0	1065	6.0				

First Day

#	pH	pH after 24 Hrs.	--------Solids------------ Total	Grease	Ash	Organic
1	7.6	5.4	2710	430	350	2360
2	7.2	5.8	2640		270	2370
3	6.8	6.0+				
4	6.4	6.1				
5	6.0	6.0				

Second day

#	pH	pH after 24 Hrs.	Oxy. Cons.
1	7.6	6.4	660, 659
2	7.2	6.4	605
3	6.8	6.2	650
4	6.4	6.0	650
5	6.0	6.0	710

Fourth Day

#	pH	pH after 24 Hrs.	Oxy. Cons.
1	7.6	7.2	510
2	7.2	6.9	
3	6.8	6.4	
4	6.4	6.0	
5	6.0	5.9	

Fifth Day

#	pH	pH after 24 Hrs	Oxy. Cons.
1	7.6	7.3	430
2	7.2	7.0	455
3	6.8	6.4	468
4	6.4	6.3	429, 434
5	6.0	5.9	494

Seventh Day

#	pH	pH after 24 Hrs.	Solids Total	grease	ash	organic
1	7.6	7.4	3820	140	2430	1390
2	7.2	7.1	4200		1030	2170
3	6.8	6.4				
4	6.4	6.2				
5	6.0	6.1				

#	Suspended Solids	Suspended inorganic	Oxy. Cons. Filtrate
1	1872	296	21
2	948	136	12
3	828	116	79
4			
5	800	38	105

Eighth day

#	pH	pH after 24 Hrs.
1	7.6	7.5, 7.4
2	7.2	7.1
3	6.8	6.8
4	6.4	
5	6.0	6.0

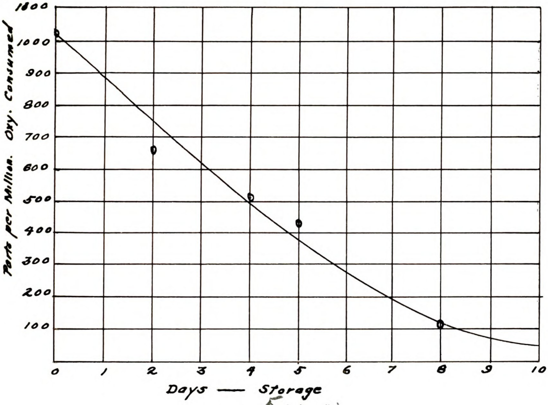

Fig. 5

Fig. 5 shows the decrease in oxygen consumed that occurs when 2% milk solution is stored at a constant hydrogen ion concentration of pH 7.6. If compared with Fig. 2 it will be seen that the process of reduction is shortened up to about one-tenth the time required with ordinary storage.

It was found, as shown in the preceeding tables 38, 39, 40. that at the end of seven days most of the solid matter is in suspension and that after this suspended matter is removed by filtration the oxygen consumed is very low, 21 p.p.m. when stored at 7.6 pH and 12 when stored at pH 7.2

If it had not been necessary to mix the waste daily in order to neutralize the acid and if the

operation had been caried on in a larger tank a much better effluent would probably have been secured because of the better opportunity for sedimentation.

One important feature of this process is that offensive odors are greatly reduced.

Septic Tank Action with Constant Hydrogen Ion Concentration

Although the bacterial action was rather slow in ~~getting started~~ in the preceeding experiment it was expected that when the fixed hydrogen ion concentration principle was applied to a septic tank and a portion of the ~~old~~ fermented contents was retained to seed the incomming influent, quicker action would be secured. This proved to be true.

Referring to the table an d Fig. 9 it will be seen that pH 7.6 was the most favorable hydrogen ion concentration for rapid reduction of the waste. and it was,therefore, selected as the one to be used in further experiments .

A four liter jar was filled with 2% milk solution and inoculated with bacteria from the preceeding experiment. Once a day, two-thirds of the liquid was siphoned off and replaced with fresh 2% milk solution. The resulting mixture was then brought t to a pH value of 7.6

This process was continued for about a week

in order to stabilize the action, then the following analysis was made.

Total solids	2510
Inorganic solids	370
Organic solids	2140
suspended matter	92
Acidity	17
Organic nitrogen	67
Oxygen consumed	362
Oxy. Cons. after suspended solids were removed	226

Bacteria	Dilution			
T	1/100	1/1000	1/100,000	1/1,000,000
Total	---Too ~~thick~~ Spreaders-		46,000,000	47,000,000
Acid				7,000,000
Neutral				20,000,000
Alkaline				20,000,000
Casein liquifiers				3,000,000

In order to determine what would happen if the process was neglected for a day as might occur in an actual plant over a week end or a holliday, the change of waste and restoration to pH 7.6 was omitted one day and on the next an analysis was made with the following result.

Total solids	1930
Grease	0
Inorganic matter	650

Organic matter	1280
Suspended solids	460
Organic Nitrogen	72
Oxygen consumed	211
Oxy. Cons. after removal of Suspended matter	155

Bacteria	Dilution			
	1/100	1/10000	1/100,000	1/1000,000
Total	Too ~~thick~~ numerous	---	49,600,000	52,000,000
Acid			8,000,000	11,000,000
Neutral			23,000,000	31,000,000
Alkaline			18,600,000	10,000,000
Casein Liquifiers			200,000	1,000,000

The advantages of maintaining a fixed hydrogen ion concentration are evident. It was possible to accomplish far more with a retention period of one day than with three days in the ordinary septic tank. It is probable that with a large tank aonsiderably better results could be secured because of the more perfect sedimentation .

The effluent from this process, moreover, is less cloudy, and has a much better appearance than that from an ordinary septic tank. The odors while somewhat offensive are not nearly as bad, the scum and sludge accumulation is not nearly as great and the scum is less offensive.

Here again the relative stability test failed because of the cloudy condition of the effluent but the fairly low percentage of suspended solids indicated that the effluent might be safely discharged on a sand filter without danger of rapid clogging and the low acidity would facilitate rapid oxidation. It is also certain that with a longer retention period better results would be obtained.

Conclusions from Fixed Hydrogen Ion Concentration Process.

(1) The decomposition of milk wastes is greatly facilitated by the addition of proper amounts of lime or other basic material.

(2) Best results are obtained when enough lime is added every day, to bring the hydrogen ion concentration to pH 7.6

(3) The effluent, being low in acidity and suspended solids is suitable for treatment on a sand filter.

(4) The sludge and scum accumulation resulting from this process is less in quantity and less offensive than that from a septic tank.

(5) This method of treatment can be applied to any septic tank, thus increasing its efficiency many fold.

CHEMICAL PRECIPITATION

Many serious objections were common to the results of practically all of the laboratory experiments~~, and at all of the plants visited~~.

These seemingly inherent features of creamery waste disposal include, the heavy offensive accumulation of scum. the objectionable odors of the effluent due to the decomposition of the large quantity of protein, the large amounts of grease, and the cloudy nature of the effluent.

These problems were all met in a series of experiments using chemical precipitation.

Chemical p recipitation as applied to creamery wastes consists of adding the salt of some heavy metal such as ferrous sulphate and precipitating it with a base such as hydrated lime.

$$FeSO_4 + Ca(OH)_2 \longrightarrow CaSO_4 + Fe(OH)_2$$

The ferrous hydroxide forms as a heavy gelatinous precipitate which on settling drags down all of the suspended matter.

This method has been tried with ~~little~~ some success in the disposal of creamery wastes. The opinion is popularly held that this process does not materially reduce the oxygen consumed, that an enormous quantity of sludge is produced, that the process is difficult to carry on, requiring considerable technical knowledge, that its

use inhibits bacterial development, and that a poor quality of effluent is produced.

That most of these ideas are fallacious when the process is properly carried on is demonstrated in the following experiments.

The Travis Process.

~~As has been mentioned before~~ The disposal plant at Bad Axe is one of the few plants in the country where chemical precipitation is attempted.

The wastes which are rather highly diluted and in combination with municipal sewage amount to about 120,000 gallons per day. The precipitating compound used daily consists of 600 pounds of dried marl, 200 pounds of hydrated lime, and 25 pounds of ferrous sulphate. This is equivalent to 0.025 g. of ferrous sulphate per liter. The process, as carried out at Bad Axe ~~is~~ obviously ineffective but since the plant was somewhat over loaded it was thought advisable to try a few experiments using small quantities of ferrous sulphate at various degrees of alkalinity. The results are shown in the following table. p 48. The 1% skimmilk solution was arbitrarily chosen because the wastes at Bad Axe ~~are~~ somewhat more dilute than the average.

1 % Skimmilk solution treated with small quantities of Ferrous Sulphate and Lime.

Alkalinity Normal	$FeSO_4 - 7H_2O$ Grams/liter	Oxy. cons. p.p.m.	Total Solids p.p.m.	Inorg. Solids p.p.m.	Organic Solids p.p.m.	Suspended Solids p.p.m.	Inorg. Susp. Solids P.p.m.
000	0.00	670	1540	120	1420	239	------
0.005	0.17	670	1140	560	580	239	0
0.010	0.17	720	1320	640	680	192	100
0.015	0.17	670	1520	960	560	163	90

The above table contains the results of some experiments using relative small amounts of ferrous sulphate and lime. The ineffectiveness of this method of treatment is seen in the poor results obtained.

The original Travis process, as used at Bad Axe. failed to give results and, using concentrations as high as 0.17 g. per liter of ferrous sulphate. no appreciable results were obtained. Unfortunately Mr. Travis failed to answer the correspondence of the writer and nothing could be learned of the principles of the process or how it came to be developed.

General Experiments.

In order to determine roughly what might be expected by using widely varying amounts of ferrous sulphate and degrees of alkalinity several general experiments were tried. The results in the following table are typical.

2% skimmilk solution

Mil. Eq./ L $Ca(OH)_2$	Ferrous sulphate g/L	Acidity p.p.m.	Oxy. Cons. p.p.m.	Turbidity	odor after 3 days.
5	0.1	+190	570	Cloudy	++++
5	0.4	+580	640	Cloudy	++
5	1.0	------------- Broken	----------------		
15	0.1	+260	680	Cloudy	+++
15	0.4	+310	570	Sl. Cl.	-
15	1.0	+490	650	Brown	-
30	0.1	+40	850	cloudy	+
30	0.4	+50	840	Sl. Cloudy	-
30	1.0	+70	810	Clear.	-
0 Fresh 2% Skimmilk	0		670	Cloudy	+++++++

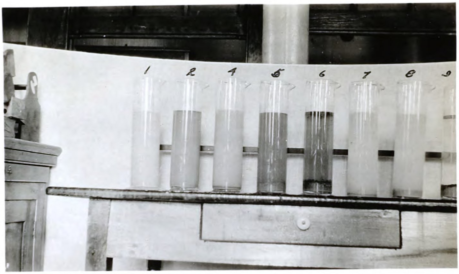

Fig. 11

Chemical precipitation experiment

This shows the appearance of the effluent and the sludge that formed when one liter portions were treated as indicated in the preceeding table. No. 3 is missing, having been broken earlier in the experiment.

It will be seen in the preceeding experiment that best results were obtained when the acidity of the supernatant liquid was lowest and about 0.4 g/l of ferrous sulphate were used. This was further verified in the following data on page 51.

Here again it was apparent that the clearest effluent with the lowest oxygen consumed capacity was obtained when the effluent was about neutral. In this experiment it was between samples 5 and 6.

No.	Mil. Eq./ L Ca $(OH)_2$	Ferrous sulphate grams/liter	Acidity p.p.m.	Oxy. Cons. p.p.m.	Oxy. Cons After 3 days	Turbity 10 Min.	Turbity 18 Hrs	Solids T.	Solids Ash
1	20	0.2	-90	1050	840	Couldy	Cloudy	2300	150
2	20	0.4	-70	1120	950	Cloudy	Cloudy	2000	150
3	20	0.6	-40	940	810	Cloudy	Sl."	1270	180
4	20	0.8	-30	1130	880	Sl."	Clear	1270	260
5	20	1.0	-20	1040	890	Clear	Clearest	2000	180
6	20	1.2	+90	700	700	Clear	Sl. Brown	1900	320
7	20	1.4	+180	800	760	Clear	Brown	2050	200
8	20	1.6	+210	750	510	Clear	Brown	3200	280

The above tests were made using one liter portions of a 2% whole milk solution.

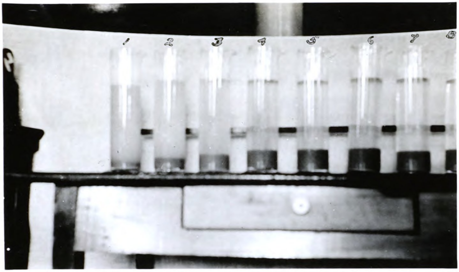

Fig. 7.

This picture shows the one liter samples of 2% milk solution treated as indicated in the previous table. This was taken ten minutes after treatment. Note that the sludge has settled very quickly, also that Nos. 5, 6, 7, and 8,which are not excessively alkaline,are clearest.

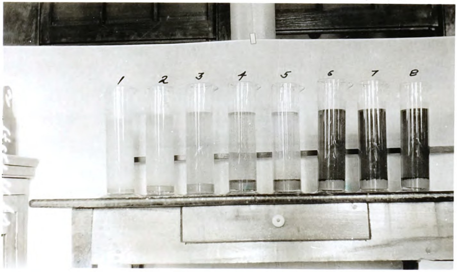

Fig. 8.

Same as Fig. 7 after standing 14 hours. The excess $Ca(OH)_2$ in No. 4 has been neutralized by the formation of lactic acid and it has cleared up. Note the dark color of Nos. 6, 7 and 8 due to oxidization of excess ferrous compounds.

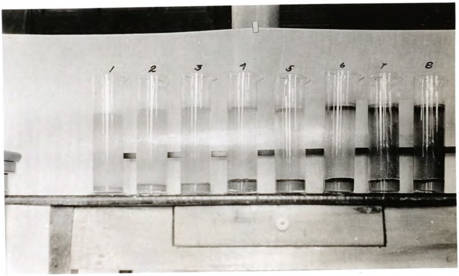

Fig. 9.

Same as Fig. 7 after standing 32 hours. The acidity of numbers 5, 6, 7, and 8 have risen to such a point that the casein has precipitated It can be seen as a thin white layer on top of the sludge. If the basic material had not been added first the casein would have probably been removed by the precipitation.

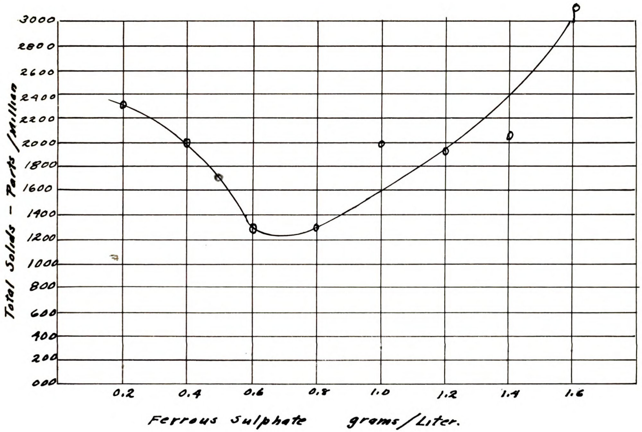

Fig. 15.

Fig. 15 is a chart showing the effectiveness of the various quantities of ferrous sulphate in reducing the amount of total solids in 2% milk solution in the preceeding experiment. It will be seen that 0.6 g. /liter of ferrous sulphate is the least quantity which gives good results.

Proper Order of Adding Basic material and Ferrous Sulphate

Casein is present in milk in the form of a suspension but it behaves like a fairly strong acid and dissolves on the addition of small amounts of alkali.

It is obvious that if the basic material is added first the casein will dissolve and escape precipitation as it did in the preceeding experiment. If the ferrous sulphate is added first this will be avoided and two other advantages will also be gained.

Ferrous sulphate is the more expensive compound and if added first can be used in the most economical quantities, and the basic material if added last produces a color change which will aid in securing the proper degree of alkalinity.

For best results the ferrous sulphate should first be dissolved in water, a 10% solution being convenient. The proper amount of this solution should be added to the waste, first. Absolutely uniform distribution is not necessary but some mixing is desirable.

The lime or other basic material should also be made into a solution. It should be added slowly with constant mixing in order to avoid a local excess of alkali which is shown in a later experiment to be detrimental.

The color chart, Fig. 16 will aid in determining the proper amount of basic material.

As far as could be determined equivalent amounts of calcium hydroxide and sodium hydroxide gave identical results and the latter was used in subsequent experiments because of the greater convenience in handling and storage.

RELATION BETWEEN ACIDITY, HYDROGEN ION CONCENTRATION, RATE OF SETTLING, AND COLOR.

An excess of basic material should not be added. It is not only wasteful but it inhibits bacterial growth and prevents the precipitate from settling readily.

If precipitation is complete the amount of ferrous hydroxide dissolved in the supernatant liquid is more than enough to give sufficient alkalinity to insure good bacterial action. The solubility of ferrous hydroxide in cold water is .0067 g/l *

$$N = \frac{0.0067 \times 2}{278} = .0000482$$

$$\text{Conc. } (H)^{+} \times \text{Conc. } (OH)^{-} = 1 \times 10^{-14}$$

Assuming complete dissociation at these high dilutions pH= 9.7

In order to study, further, the effect of different degrees of alkalinity on precipitation sucessive ~~amounts~~ amounts of NaOH were added to portions of 2% milk waste and the resulting acidity, hydrogen ion concentration, and behavior of precipitate were noted.

*

TABLE SHOWING THE RELATION BETWEEN ALKALINITY, HYDROGEN ION CONCENTRATION, AND BEHAVIOR AND APPEARANCE OF PRECIPITATE.

3 liter portions of 2% milk. 0.5 g/liter of ferrous sulphate.

cc. 50% NaOH	Alkalinity Normal	pH	Precipitate	Supernatent liquid after precipitation	Color immediately after treatment, before settling
0.00	-0.0170	6.4	None		Light yellow
0.50	-.0084	6.9	Very light green settled out slightly in 10 Min.	Very little change	light bluish green.
0.75	-.0078	7.3	Light blue ppt. forms readily settles slowly	Cloudy	Very light greenish blue.
1.00	-.0070	7.6	Large light blue flakes of Ppt. form almost immediately and settle fairly well in 10 Min.	Clear with a few flakes of Ppt. suspended	Medium Blue.
1.25	-.0030	7.8	Med. Blue ppt. Settles out very quickly, leaving a clear Supernatent liquid at end of 10 Min.	Clear	Medium Blue
1.50		8.0	Medium Blue ppt. Settles out quickly.	Clear	Medium Blue
2.00	+.0015	8.0+	Med. Blue ppt. Settles out quickly.	Clear	Rather dark blue
2.50	+.0049		Darker ppt. Settles out quickly	Clear	Rather dark blue.
3.00	+.0052		PPt. rather dark blue. Does not settle out so readily.	Slightly cloudy	Quite dark blue

Table Continued.

cc. 50% NaOH	Alkalinity Normal	pH	Precipitate	Supernatent liquid after precipitation	Color immediately after treatment before settling
4.00 6.00	+.0091 +.0225		Rather dark blue ppt. Does not settle out readily	Cloudy	Quite dark blue
6.00	+.-225		Settles out Slowly	Cloudy	Quite dark
10.00	+.0385		Settles very slowly	Very cloudy	Dark bluish slate color
14.00	+.0584		No ppt.	No settlement	Dark

It will be noticed from the preceeding table that good precipitation took place at a H ion concentration range of PH 7.6 to well above. PH. 8.0. This PH range is also the most satisfactory for bacterial action as is shown in Fig. 5. In fact it closely approximates the alkalinity of domestic sewage which ranges around PH. 7.6

The change in color and appearance at this point is quite striking. A medium blue color and the formation of a heavy feathery precipitate. indicates that the proper amount of alkali has been added. If the mixture is too acid it will have a light buff color and if too alkaline the color will be dark blue and the precipitate will not form.

The color changes that accompany varying degrees of alkalinity are shown in Fig 16.

A few experiments were tried to see if the process could be reversed after too much alkali had been added.

The sample in the preceeding experiment which had been brought to an alkalinity of .0584N, at which point no precipitate formed, was treated with successive amounts of sulphuric acid. The mixture...

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COLOR CHART

SHOWING CHANGES IN COLOR AND APPEARANCE OF PRECIPITATE CORRESPONDING TO VARIOUS HYDROGEN ION CONCENTRATIONS.

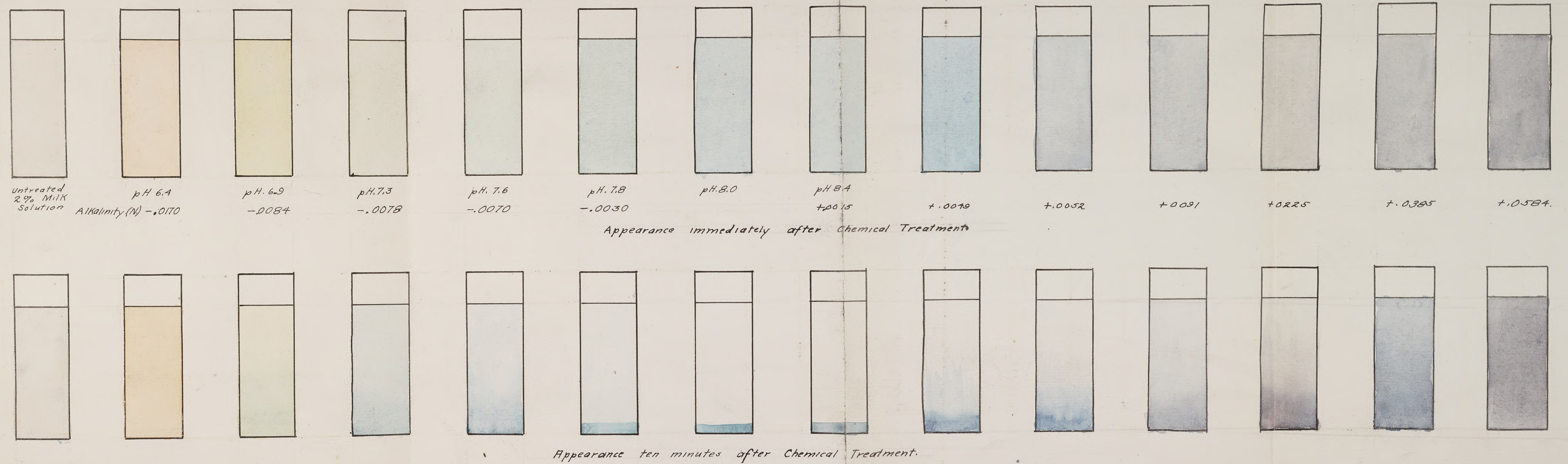

Fig. 16

went through approximately the same color changes but a precipitate did not commence to form until an alkalinty of .0018 or ppt. 8.0 was reached.

Beyond this point a precipitate formed but did not settle readily. Some of it rose to the surface and the remaining liquid was cloudy. (sample #1 Fig. 18)

Another portion was made 0.010 N acid with H_2SO_4 then made slightly alkaline, PH. 8.0 with NaOH. The settlement in this case was also bad as shown in sample 2 Fig 17.

Fig. 17.

Showing the effect of variations in the precipitation procedure on the sludge formation.

(1) Waste made strongly acid and then brought back to PH 7.8. Note that part of the sludge rose to the surface leaving a cloudy effluent.

(2) [illegible]

(2) Waste made strongly acid and then brought to pH 8.0. Note the poor sedimentation.

(3) Waste properly treated. Note that all ~~waste~~ Precipitate. settles directly to the bottom.

(4) Untreated milk waste.

The character of the effluent resulting from these variations from the regular proceedure can be judged from the following partial analyses.

(1)	Total solids =	6100 p.p.m.
	Organic nitrogen	27 p.p.m.
(2)		
(3)	Total solids	1730
	Inorganic "	580
	Organic "	1150
	Organic Nitrogen	36
(4)	Total solids	2460
	Inorganic "	260
	Organic "	2200
	Organic Nitrogen	159

Fig. ~~18~~ 12

Same as Fig. ~~17~~ 11 after standing three days Note the increased thickness of the scum in No. 1 and 2 also the scum that is starting to form on No. 4 . Note, however that the appearance of No. 3 has not changed. The lowering of the level in some of the jars is due to the use of some of the effluent for analysis.

Fig ~~19~~ 13.

(1) Fresh 2% milk solution.

(2) Milk solution after standing 12 hours.

(3) 2% milk waste after chemical treatment.

Effect of Chemical Precipitation on Bacterial Flora.

It was expected that the precipitate in dragging down the suspended matter would also remove many of the bacteria that were in the waste. The following experiment proved this to be true.

A 2% milk solution was prepared in a three liter jar and seeded with bacteria from various septic tanks, sewage, other milk wastes, etc. and allowed to stand two days, after which a bacterial count was made. The waste was then treated in the usual way by chemical precipitation and another analysis made. The decrease in bacteria is shown below.

Dilution	1/100,000	1/100	
	Before	after	% remaining
Totals	22,200,000	11,400	0.05%
Acid	600,000	400	0.07
Alkaline	100,000	100	0.10
Neutral	21,500,000	10,900	0.05
Casein liquifiers	600,000	400	0.07

This decrease in the bacterial flora indicates that if the waste is to be further reduced after precipitation that it should be stored in a separate tank where bacteria will be free to develop, as otherwise the subsequent precipitations would continually reduce the bacterial flora.

Septic Tank Principle and Chemical Precipitation

While it is obvious from the preceeding experiment that precipitation should not be conducted in a tank used for subsequent storage of the effluent, a slightly different condition was tried in the following experiment.

Three liters of a 2% milk solution were placed in a four liter glass jar shown in Fig. 14. Once a day two liters were siphoned off leaving one liter in the jar. Two liters of fresh 2% milk solution were prepared in a separate vessel and treated with ferrous sulphate and sodium hydroxide, in the usual way. This mixture was added, carefully through the funnel to the one liter remaining in Jar (A).

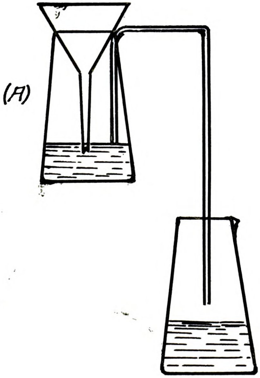

Fig. 14

When this process was first started, 100 cc. of the waste from the fixed pH. septic tank process was added after the precipitation in order to seed the supernatent liquid with bacteria.

It will be seen, that in this experiment the precipitate had formed in the fresh 2% milk solution before it was added to the one liter of waste remaining in jar (A) (A) An analysis after several days of operation indicated that a good bacterial flora was being maintained. However the highly acidified nature of the one remaining liter of old waste was sufficient to prevent good sedimentation.

The effluent was somewhat cloudy, scum formed on the surface and the effluent and scum had offensive odors.

A typical analysis of the effluent is given below.

Total Solids	2580 p.p.m.
Grease	0
Inorganic solids	475
Organic solids	2105
Suspended matter	356
Oxygen consumed.	150
Organic nitrogen	72.4

Bacteria/cc :

Dilution	1/100	1/1000	1/10,000	1/100,000
Total	---Too ~~thick~~ numerous--		1,310,000	1,900,000
Acid			0	0
Alkaline			210,000	600,000
Neutral			1,100,000	1,300,000
Casein liquifiers			110,000	300,000

Results obtained when Chemical Precipitation is Properly Conducted.

When 2% milk solution is treated with 0.5 grams per liter of ferrous sulphate and brought to a Hydrogen ion concentration of pH. 7.8 a heavy gelatinous precipitate of ferrous hydroxide forms which settles out in about ten minutes leaving a perfectly clear supernatant liquid.

All suspended matter including all the butter fat and most of the protein and bacteria are carried down with the precipitate leaving a slightly alkaline liquid containing about 900 p.p.m. of lactose, about 200 p.p.m. of dissolved protein, and about 600 p.p.m. of inorganic matter consisting of dissolved ferrous hydroxide, excess calcium or sodium hydroxide and various salts. The effluent has a relative stability of about 60%, ~~which is as good as the sand filter effluent at Bad Axe.~~

A characteristic analysis of this effluent is shown below.

Total solids 1730 p.p.m.

Inorganic Sol. 580 "

Organic Sol = ~~11.50~~ 1150 p.p.m.

Grease = 0 p.p.m.

Suspended sol = 0 p.p.m.

Oxy cons = ? p.p.m.

Organic N = 36 p.p.m.

Relative Stability = 60%

Upon standing two days considerable bacterial action takes place. The hydrogen ion concentration rises to 5.8 and a reduction in the organic solids occurs.

Total Solids	=	1020
Inorganic "	=	460
Organic "	=	560

No odors develop during this period of storage nor at any later period.

It will be seen that this process produces directly a clear, fairly stable, nonoffensive effluent which in many cases would be considered entirely satisfactory. However if further reduction is desired the effluent is ideal for secondary treatment in a sand filter. Because of the easily oxidizable nature of lactose a high rate of application might be used.

The Cornell University Experiment Station found that septic tank effluent could be treated at the rate of 100,000 gallons per acre per day. The effluent from the chemical precipitation process being more satisfactory for sand filter treatment could probably exceed this amount.

One troublesome feature of the secondary treatment of creamery waste with sand filters which is universally experienced is the constant clogging and the necessity of frequent removal of the scum ~~that is necessary.~~

The absence of suspended matter in creamery waste treated by chemical precipitation would obviate this condition entirely, and a sand filter could succesfully treat large

quantities of such effluent with prastically no maintenance.

Sludge.

The dried sludge from one thousand gallons of creamery waste would contain about 2.7 pounds of ferrous hydroxide and varying amounts of butter fat, casein, suspended solids, and other organic matter. ~~It~~ The sludge settles very quickly and may be removed soon after formation It soon dries, forming a dark brown, granular, odorless, inoffensive, substance. It is probable that it would have considerable fertilizing value.

Conclusions from Chemical Precipitation Experiments.

(1) Milk wastes of high concentration may be very sucessfully treated with ferrous sulphate and lime.

(2) For milk wastes of ordinary concentration the treatment should consist of adding 0.5 grams per liter or 4.2 pounds per thousand gallons, of ferrous sulphate, and then adding the basic material ~~as described on pages 55 - 60~~.

(3) The process removes the butter fat, suspended solids, and most of the protein and bacteria.

(4) The sludge will settle in a very short time after treatment and may then be withdrawn.

(5) The effluent will be clear and nonoffensive and it may be discharged directly or lakes without fear of odors or offensive conditions arising.

(6) The effluent from this process has a relative stability of 60% but if further reduction is desired it may be secured by storage in secondary tanks or by oxidization in a sand filter.

RECOMENDATIONS FOR DESIGN OF DISPOSAL PLANT USING CHEMICAL PRECIPITATION AND SECONDARY TREATMENT.

The wastes from the average isolated creamery are small in quantity and highly concentrated. as is shown by the data on page 23.

This condition presents a very difficult problem when ordinary disposal methods are used but is ideal for the economical use of chemical precipitation. From the data on page 23 it will be noticed that many plants have less than one thousand gallons per day of waste.

For economy the waste should be isolated from cooling and condensery water and kept as concentrated as possible, consistent with convenience.

Fig. 15 suggests a plant arrangement for an average creamery having five hundred to five thousand gallons of concentrated waste per day.

SUGGESTED ARRANGEMENT FOR A DISPOSAL PLANT USING CHEMICAL PRECIPITATION AND SECONDARY TREATMENT

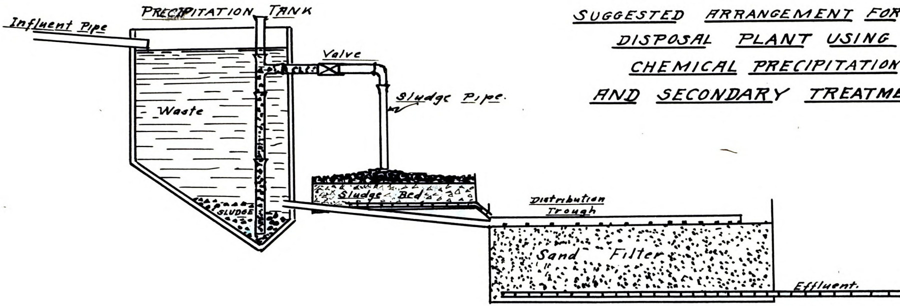

Fig. 21

Throughout the day the wastes should be discharged into the precipitation tank which should be large enough to hold a day's run of waste. The bottom should have a slope of at least 1 : 1 as it was observed that the precipitate would not settle well on a smaller slope.

Some means of mixing the compound with the waste will be necessary. This might be easily done by means of compressed air or steam if available or some mechanical mixer or modification of the "rouser", used for sampling milk might be devised. For smaller tanks of less than a thousand gallons a large paddle would probably be sufficient.

A scale may be placed along the side of the tank to gauge the amount of waste and the ferrous sulphate and lime necessary for treatment.

A sludge pipe or an outlet from the bottom of the tank should be provided for removing the sludge. It should be drawn off to a sand drying bed the size of which depends upon the time it is desired to store the sludge. For a thousand gallon tank a 10' X 10' bed should provide sufficient storage capacity for several months.

The effluent from the precipitating tank is in much better condition for sand filter treatment than the average tank effluent of domestic sewage. It would be on the side of safety to design the filter in the same manner as for a domestic sewage tank effluent of the same size.

COST OF OPERATION

Basing the cost calculations on a discharge of one thousand gallons per day. which is about the amount to be expected from the average creamery, and using current prices the material cost would consist of.

4.2 pounds of ferrous sulphate @ $13.50/ton =	2.82 Cents
1.5 pounds of lime @ $8.50 /ton =	.65 "
Total material cost	3.47 "

This material cost of three or four cents per thousand gallons combined with the labor cost would represent almost the entire cost of operation.

It is difficult to estimate the amount of labor that would be involved in operating such a plant but since the precipitating compound could be added at the close of the days work, and the precipitate allowed to settle over night and the tank emptied the next morning, it is not likely that more than a half hour of a mans time would be required. It is certain that very little maintenance would be required in a plant of this kind and fifty cents per day for the entire operating cost should certainly be adequate. At any rate this compares favorably with the ten dollars per day spent by the International Milk Products Co. for this purpose.

ADVANTAGES WHICH ACCRUE FROM THE USE OF THIS SYSTEM.

(1) Small size of equipment.

A tank sufficient for one days discharge is sufficient. Septic tanks which give inferior results must be designed for three to seventeen days retention.

(2) Low maintenance cost.

The occasional removal of sludge from the sludge bed is about all that should be required. The expensive disagreeable job of frequently cleaning tanks and filters is almost entirely eliminated.

(3) Moderate Operating cost.

Three or four cents worth of material and a few minute's work, daily should cover the operating cost.

(4) Absence of offensive odors.

This solves one of the most exasperating problems encountered in Creamery waste disposal.

(5) High grade of effluent.

A relative stability of 60% can be secured directly from the tank and by the use of a sand filter an effluent of almost any desired quality might be obtained.

SUGGESTIONS FOR FUTURE RESEARCH IN THIS SUBJECT.

Unfortunately it was impossible to carry this investigation to the final proof of its feasibility which should include operation on a fairly large scale.

Chemical precipitation gives every promise of being the ideal treatment for creamery wastes ~~and~~ many other concentrated trade wastes, as well.

The primary treatment of whole milk wastes in ~~in~~ any concentrations that are likely to occur, has constituted the scope of this thesis. It would be important, however, to know the adaptability of these processes to buttermilk, whey, and in fact other trade wastes

The secondary treatment of the effluent should also receive more attention. It would, quite likely, be erring on the side of safety to apply the same methods of design for the secondary treatment of this effluent as are used for domestic sewage. However the high grade effluent from the chemical precipitation process might permit an even higher capacity. The quality of effluent which could be obtained from sand filters of various depths and with various rates of application should be studied.

It is felt that the laboratory investigations presented in this thesis have been carried far enough to warrent their trial on a fairly large scale. and in order that the work pursued in the laboratory may become practicaly valuable it is hoped that this will be done.

SUMMARY OF CONCLUSIONS

(1) Creamery wastes differ widely in concentration but have some similar characteriatics, chief of which are the large quantities of organic matter and the large quantity of acid forming lactose.

(2) Disposal by ordinary storage is not satisfactory for creamery wastes.

(3) Contact beds are not suited for creamery waste disposal.

(4) The usefulness of an existing septic tank can be increased many fold by lime treatment.

(5) Treatment with ferrous sulphate and lime and subsequent precipitation constitutes an ideal treatment for concentrated creamery wastes.

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