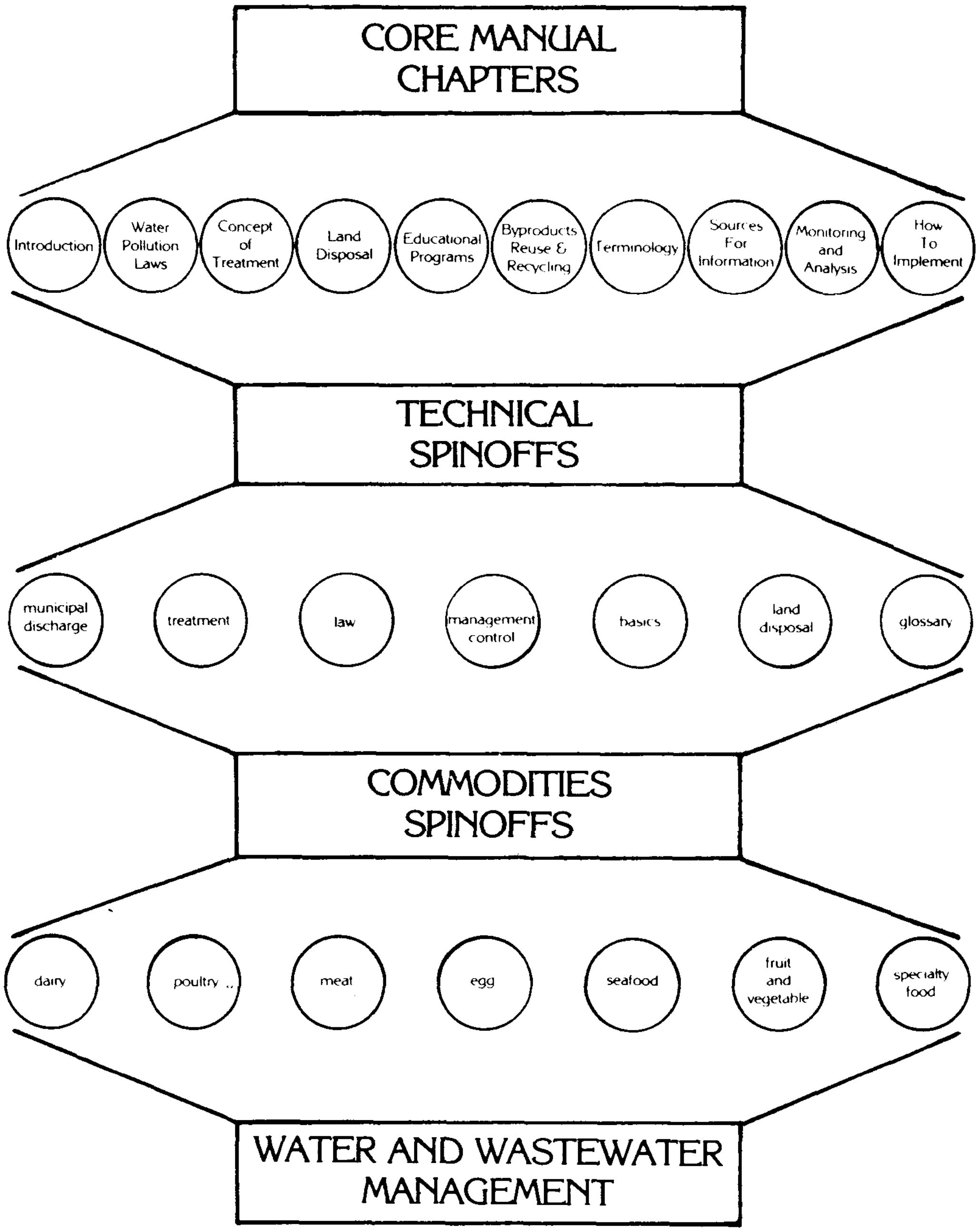
WATER AND WASTE WATER MANAGEMENT IN FOOD PROCESSING

WATER AND WASTEWATER MANAGEMENT

In Food Processing Plants - An Educational Program

The objective of this program is to increase the knowledge of food scientists, food processors, engineers, scientists, waste management specialists and other practitioners in the concepts and principles needed to properly control water use and product waste in food processing facilities. The materials are designed for individuals concerned with management of food plants, with pretreatment of food processing wastewaters, with treatment of food processing wastewaters and with the utilization or disposal of food plant residuals. The modules in this program incorporate knowledge from food science and technology, food processing, sanitary and environmental engineering, agronomy, soil science, agricultural engineering, economics and law.

The program consists of some 15 modules. Introductory material is presented in the Core Manual to introduce the program. Technical specifics are provided in 7 technical spinoffs. The application of water and waste management in specific food plants is related in 7 commodity Spinoff Manuals.



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SPINOFF ON

DAIRY PROCESSING WATER AND WASTEWATER MANAGEMENT

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PREFACE

Purpose:

The main purpose of this DAIRY PROCESSING WATER AND WASTE-WATER MANAGEMENT SPINOFF is to be a primary reference document for the extension specialist to supplement his processing training and experience in dairy processing with knowledge needed to assist food plants in water and waste control. The primary thrust of this document is to provide information to encourage management recognition of current and future problems in the pollution area and management action to control water use and waste. This document is intended as a guide, in that it attempts to provide broad coverage, but cannot be totally comprehensive on all topics. Instead, it gives general information *on* a wide scale, and then directs the reader to additional specific data and bibliographic information.

By presenting the fundamentals of proven management techniques for recognizing and controlling water and wastes such as monitoring, employee training, management action programs and data interpretation, the authors hope the materials presented will assist the extension specialist in helping the dairy plant manager develop an effective water and waste control program. Thus, this guide can be a tool to help extension specialists and food processors alleviate present misunderstandings and avoid future problems. In addition, this guide can aid in bringing together representatives from the food industry and regulatory agencies to coordinate their mutual interest in reducing water pollution.

Audience:

This guide should be valuable not only to extension specialists for which it was prepared but also for food processors and regulatory officials charged with the review and approval of wastewater discharge from food plants not only to surface waters but also to municipal wastewater treatment systems.

Scope: The subject of this guide is the management and control of water use and waste discharge in dairy processing, with emphasis on necessary legal, sanitary, environmental and energy factors. This specific document emphasizes pollution contributors in dairy plants; management control techniques such as waste watching centers, proper accounting and employee training; proven techniques to reduce water use in dairy processing; proven techniques to reduce wastes in dairy processing and detailed questions management must answer before effectively controlling water and waste in food processing.

In preparing this guide, the committee has attempted to maintain a uniformity of recommendations and suggestions, despite the disparity of requirements throughout the country. However, the use of the procedures identified in this document will assist in solving any specific pollution problem.

Limitations: This document emphasizes the techniques for water and waste control in the typical fluid milk, cottage cheese and ice cream plant and specifics for all dairy commodities such as cheese, condensed, evaporated are not specifically identified. The management control program is directed at medium to large sized plants and may have to be modified depending on plant size, product mix, etc.

Disclaimer: The mention of manufacturers, trade names or commercial products is for illustration purposes and does not imply their recommendation or their endorsement for use by the Agricultural Extension Service.

Preface continued ...

Learning Objectives:

1. Recognition of unit operations and, plant practices that can or do contribute to pollution.

2. Comprehension of proper sampling techniques for dairy plant wastewaters.

3. Categorization of parameters of importance in dairy wastewaters.

4. Interpretation of wastewater data for understanding of pollution parameters and product loss acounting.

5. Understanding of key elements in a water and waste control program for a dairy processing plant.

6. Identification of the key federal, state and local pollution laws and regulations that affect dairy processors.

7. Appreciation of the possible role of an extension specialist in assisting processors to meet water pollution control regulations.

SUMMARY

The important considerations for extension specialists to consider in developing programs to assist the dairy industries in meeting water pollution requirements are presented. This document includes the following: (1) role an extension specialist can play in dairy plant pollution problems, (2) components of an effective water and waste control program in dairy processing, (3) methods for monitoring and analyzing dairy wastewaters, (4) terminology and concepts of pretreatment and treatment of dairy wastewaters, and (5) notes on developing an effective extension program for dairy processing plants.

Each dairy plant has numerous operations that use water and discharge milk, cream, whey or rejects which can contribute to pollution and specific examples are reviewed for selected plants. The possible ways these operations can be modified or employee practices changed to reduce water use and waste are identified and discussed. The role of management in processing water and waste control is explained.

Procedures for evaluating the level of management of water and waste in a dairy plant are identified and discussed. The possible role of the dairy extension specialist in assisting a dairy plant in meeting water pollution requirements is explained.

Various practices to reduce pollution after the institution of in-plant water and waste management procedures are presented. These practices include pretreatment, by-product recovery and/or treatment. The most important aspects of each of these are reviewed.

The opportunities for wastewater discharge from a dairy processing plant are recognized as either discharge to a municipal system or discharge directly to a stream, estuary or the ocean. The important factors to consider in municipal discharge of dairy processing wastes are identified as sewer use ordinances, user charges and pretreatment. State, federal and

Summary continued ...

local regulations for pretreatment are reviewed. State and local requirements for discharge limitations to meet NPDES permits or water quality criteria are listed and discussed.

As most dairy plants discharge to municipal systems, municipal discharged is emphasized. The fundamentals of interpreting sewer use and surcharge ordinances are reviewed. Specific requirements for sewer use ordinances are identified. The relationship of federal, state and local authorities in controlling municipal discharge for pollution control is examined.

Parameters of importance for dairy processors for municipal or direct discharge are identified as BOD_5, TSS, FOG, pH and flow. The importance of proper sampling and analytical techniques are explained.

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INTRODUCTION

Relation To Dairy Industry

Intent of Material

The purpose of this dairy spinoff manual is to aquaint you, the food processing extension specialist, with important factors relating to water use and waste problems in the dairy processing industry. As an extension specialist you can help management with environental pollution problems if you can understand the language, adopt a good basic industrial waste control philosophy, understand all the legal aspects of environmental rules and regulations, and thoroughly know the industry so you can relate to the problems facing management. To accomplish these goals you must get the exact specifics of the problems as management describes them, or call attention to problems which management does not recognize. Here is where your role as an educator is most important. Often you may have to help motivate management toward action and will need to present viable alternatives to solve their problems. Hopefully, the Dairy Processing Water and Wastewater Management Manual presented here will provide valuable information in your task of helping assist dairy processing plants meet their federal and state environmental standards.

Nature of Involvement By the Dairy Industry

The 1960's saw a great number of Americans concerned about the protection of their environment. One area of the environment that received particular interest was the protection of the waters of the United States. The interest in the environmental area concerning protection of the waters brought about the passage of the Federal Water Pollution Control Act of 1972, PL 92-500, and the Clean Water Act of 1977, PL 95-217.

Two areas of regulations have been implemented by the United States Environmental Protection Agency (EPA) under the authority of Public Law 92-500 which have and will have a significant impact on the dairy industry. First, the requirements for effluent standards and limitations will place stringent requirements for treatment of dairy plant wastewater. Second, the requirements that municipalities receiving federal monies achieve an equitable recovery of cost from all industrial dischargers will place a new economic burden on the dairy industry.

Many municipalities with the guidance of state and regional EPA offices will continue to pass sewer use ordinances which severly restrict or prohibit what can be discharged into a municipal sewer system. The sewer use ordinance usually contains surcharge and industrial cost recovery provisions which are the proposed solution to equitable recovery of costs. Some municipalities have even required dairies and other industries to pre-treat their wastewaters with the equivalent of secondary treatment before they can be discharged to the municipal system. The sewer use ordinances have and will continue to effect the United States dairy industry since about 90 percent of the dairy plants producing ice cream and fluid milk products discharge their wastewaters to municipalities.

The waste load in the dairy industry is largely a result of milk products which are intentionally or inadvertently lost to the sewer system. Improved operation and management practices may effectively reduce much of the water use and waste load that is generated in dairy processing. However, management has not been able to find the technical and economic linkage between product wasteage, water use, waste load and profit. Until recently, water and wastewater charges have been low. Cost accounting records and material balances have not given management an indication of significant product losses. Subsequently, processors have had no need to monitor loads or volumes. Equipment manufacturers and suppliers therefore have been reluctant to suggest machinery to reduce water and waste when the industry was more interested in increasing productivity than in decreasing costs. Major technological advances in the reduction of water and waste in the past have largely been ignored while the dairy industry tried to achieve efficiency in productivity per man hour, profit per unit process, or profit based on a percentage of total sales.

The reduction of water and waste in a dairy processing plant requires the application of the best technology to achieve reduced product loss, reduced water usage, and reduced ingredient loss. Moreover, there is a fallacy in the assumption that water and sewer costs are too small to be of importance. This was only true when the dairy industry could discharge wastewater with little regard for treatment costs. With the passage of an ordinance enabling a surcharge which requires the plant to pay for the discharge of its waste load in terms of biochemical oxygen demand (BOD_5), suspended solids, pH, and/or hydraulic loads, the plant with a small monthly water and sewer charge finds its bill can quadruple. The surcharge usually is accompanied, within several years, by an increase in water price and a similar increase in sewer rates.

A proven way to reduce water use, wastewater discharge and waste loads discharged is to operate the plant more efficiently. Another is to institute process changes which have been demonstrated to reduce water use and wastes. There are many alternative process schemes known but not generally practiced in the dairy industry. Many of these alternative processes are to reduce product loss and wastes in dairy processing. A number also reduced water use and wastewater discharge.

Classification and Structure

Introduction

In the 1972 Census of Manufacturers, there were 3,698 plants in the dairy products industry. Plants range in size from a few thousand kilograms to over 1 million kilograms of milk received per day.

The basic function of the dairy processing industry is the manufacture of foods based on milk or milk products. There are approximately 20 basic types of milk products manufactured with a limited number of non-milk products, such as fruit juices, produced by the industry. Many plants engage in multiproduct production.

For the purpose of establishing effluent limitation guidelines and standards of performance by the EPA, the dairy industry was subdivided into categories according to the type of product manufactured. Factors such as size and age of plants, minor variations in processes employed, and geographical location generally do not have an effect that would justify additional subcategorization based on the degree of pollutant reduction that is technically feasible. An economic study by Development Planning and Research Associates indicated that the costs of comparable treatment imposed a severe economic impact on smaller plants and a further subdivision according to size of plants is adviseable. This additional division allows smaller plants to implement technology that is economically feasible to maintain operations of the plant.

Standard Industrial Classification (SIC) Codes and Title - Group 202

2021 Creamery Butter
2022 Cheese, Natural and process
2023 Condensed and Evaporated Milk
2024 Ice Cream and Frozen Desserts
2026 Fluid Milk

Subcategories for Effluent Guidelines

Receiving stations
Fluid products
Cultured products
Butter
Cottage cheese and cultured cream cheese
Natural cheese and processed cheese
Ice Cream, novelties and other frozen desserts
Ice cream mix
Condensed milk
Dry milk
Condensed whey
Dry Whey

Industry 2021 - Creamery Butter

Includes establishments primarily engaged in manufacturing creamery butter. Value of shipments in 1972 totaled $808.3 million. Specific products are anhydrous milkfat, butter, creamery, and whey.

Industry 2022 - Cheese, Natural and Processed

Comprises producers that primarily manufacture natural cheese, processed cheese, cheese foods and cheese spreads. Value of shipments in 1972 totaled $3,195.0 million. Specific products include cheese (except cottage cheese) and cheese spreads, pastes, and cheeselike preparations.

Industry 2033 - Condensed and Evaporated Milk

Industry includes establishments primarily engaged in manufacturing condensed and evaporated milk and related products. Value of shipments in

1972 totaled $1,667.8 million. Specific products include baby formula; concentrated, condensed, dried, evaporated, and powdered buttermilk, milk, whey, etc.; casein, dry and wet; cream, dried, powdered, and canned; ice milk mix; lactose, edible; malted milk; and milk, whole; canned and powdered.

Industry 2024 - Ice Cream and Frozen Desserts

This industry comprises establishments primarily engaged in the manufacture of ice cream and other frozen desserts. Value of shipments in 1972 totaled $1,244.7 million. Specific products are custard, ice cream, ice milk, ices and sherberts, and mellorine-type products.

Industry 2026 - Fluid Milk

Includes establishments that are primarily engaged in the processing and distribution of fluid milk, cream and related products (cottage cheese). Value of shipments in 1972 totaled $9,395.8 million. Specific products include: buttermilk, cultured; cheese, cottage; milk and cream products; and yoghurt.

General Facts About the Dairy Industry

Introduction

The gross national-product of the United States is enriched by the dairy industry to the extent of about 12.9 billion dollars per year, which accounts for about 16% of the contribution of the total food industry to the nation's economy. General trends in the country indicate the dairy industry will continue over the next several decades to be a significant contributor to the *economy* of the country. The trend over the last several years for reduced milk production appears to be reversing and the amount of product being processed has actually increased from 103.9 billion pounds in 1960 to 108.4 billion pounds in 1969, whereas the total production of milk on the farm changed from 123.1 billion pounds in 1960 to 116.2 billion pounds in 1969.

Trends in the Dairy Industry

Trends which have significance to the nature of dairy wastes and waste treatment include, (a) the marked decrease in the number of dairy plants and increased production per plant, (b) changes in the relative production of various types of dairy foods with different levels of waste loads, (c) automation of plant processes to an increasing degree with increasing plant size and consolidation, and (d) a shift in the location of new plant facillities.

Over the past 20 years there has been a marked change in the number and size of many types of dairy food plants. For cheese and butter plants, a marked decline in plant numbers occurred prior to 1948. For fluid milk plants, there was a decrease of about 75% in numbers between 1948 and 1958. Ice cream plants showed a similar decline. In the past decade, the decline in plants has been exponential, showing a linear semilog relationship. Assuming that the numbers of plants will continue to decrease at a declining rate, the annual decline in plant numbers for various operations can be projected for the next thirty years as follows:

Type of Plant	Decline in Number of Plants Per Year, %
Cheese	3.9
Ice cream	6.0
Evaporated and condensed milk	4.0
Fluid milk	5.6
Cottage cheese	6.6
Butter	6.2
Dried milk	4.8

In 1969 the total amount of whey produced was approximately 21 billion pounds with about 6 billion pounds being acid whey. These figures are based on calculated whey volumes from the USDA figures for cheese production. USDA figures for whey production were 17 billion pounds and would appear to be based on incomplete reporting. Whey has long been the most visible pollutant of the dairy food industry. The potential significance of whey and the magnitude of the problem facing the industry in eliminating this material as a waste product is illustrated by the fact that about 20%

of the total milk produced in the country is converted into whey at the present time. The very magnitude of the volume of whey contributes materially to the problem. Cottage cheese whey represents a more serious problem than sweet whey because of its acid nature which limits its utility as a food or feed. Also, of special concern is the more than 6 billion pounds of cottage cheese wash water with approximately 70,000,000 pounds of BOD. The solids are too dilute to recover economically, and the wash water may create problems in waste treatment which will be detailed later in the report.

At the present time, the fluid milk plants, which operate under various Federal Milk Market Order systems and handle about 50% of the fluid milk volume, average over 100,000 pounds of milk per day. This could be expected to increase to about 225,000 pounds per day by 1983. Technologically, maximum plant size appears to be unlimited, but specific limitation on plant size in the future includes: (a) procurement problems associated with bringing milk long distances, (b) the problems of distribution over long distance, (c) manageability of large, complex plants, (d) control of waste loads, and (3) local sanitary district regulations and taxation policies.

As plants become larger in the future, there will be greater utilization of mechanization and automation in all phases of dairy food plant operations. Waste profile No. 9 in 1967, adequately outlined the differences in old, typical and advanced technology. The larger plants today and those of the future will rely upon advanced technology, and automation will be the center of this technology. Key advanced technologies applicable to all types of dairy food plants that has significance to dairy plant waste loads include:

(a) Milk receiving tank trucks with automated rinsing and cleaning of the tankers at the dairy plant.

(b) Automated dairy food processing operations processing milk at rates up to 100,000 pounds/hr, including the use of CIP separators and clarifiers that automatically discharge sludge every 15 to 30 minutes.

(c) Automated circulation cleaning, using liquid detergents and chemical sanitizing agents on a controlled basis.

(d) High speed filling and packaging operations.

(e) Automated materials handling, using conveyors, casers and stackers requiring significant quantities of lubricants.

As dairy food plants become larger, they have a greater need to be located in an area that provides for optimum access to major highways. The tendency is to locate these large plants near interstate highways in suburban areas, frequently in small to medium-sized cities.

The trend is for dairy plants to service a larger and larger area, trucking in raw milk from considerable distances and hauling out packaged products in semi-trailers as many as 500 miles from the processing plant. The independence of the plant location from closeness to the market has resulted in the trend to locate new large plants in surburban areas, some distance from any major waste treatment facility.

Frequently, little attention has been given to the problem of waste disposal as key criteria in the location. A number of new plants, discharging up to 8,000 pounds of BOD per day, have been located in suburban areas or in cities of under 50,000 population. Where such plants utilize the municipal waste treatment facility, they can become the major contributor to the BOD load of the municipal system.

The trend towards larger, centralized dairy foods plants generating 2,000-10,000 pounds of BOD per day, will frequently place an additional burden on municipal treatment plants that may already be marginal in their operation. The average milk plant of 1980 (250,000# milk/day) can be predicted to have waste loads with a population equivalent of about 55,000 unless special effort is made to pretreat and/or markedly reduce these wastes.

Closure

This manual is about the dairy products industry and water pollution. It is intended to help you understand how the industry, as are other industries in the United States, is affected by laws such as PL 92-500, passed by Congress to reduce and eliminate water pollution. EPA has estimated that dairy plants produce about 600 million pounds of wastes each year. Those wastes include 400 million pounds of organic material, equivalent to the sewage generated by six and one-half million people.

Some 4,000 dairy plants send their waste discharges to publicly-owned sewage facilities where the pollutants are treated along with wastes from homes and other industries. But about 1,400 dairy plants discharge their wastes directly into water bodies. This manual describes what you can do to assist these dairy plants to help keep their wastes from polluting the Nation's waters. In non-technical language, this manual explains that:

- Wasted milk may contribute 90% of the typical dairy waste load.
- The technology exists to reduce water pollution from dairy plants to safe levels although the most stringent water quality standards may not be economically achieveable.
- Applying that technology costs money - but most dairy plants can afford to make the necessary investments to control pollution. EPA estimated that some 100 plants would not be able to meet the costs and these must close.
- Pollution control investments by most dairy plants will have slight impact on their financial condition and on the price consumers pay for dairy products.
- Management recognition of waste is the single most important aspect of water control.
- As much as 50% of the product now wasted may be saved through increased efficiency.

This manual describes why some dairy plants may not be able to comply with pollution control standards and why, unfortunately, some jobs in the industry may be lost or require relocation. In brief, this spinoff discusses the facts of life about water pollution - how it affects all of us, why it must be controlled, and what the law requires the dairy industry to do as its part of the national program to help clean up our Nation's waterways. Further, this spinoff presents the facts you will need to enable you to assist dairy plants in coping with the increasing array of environmental regulations.

DAIRY PROCESSING PLANT SCHEMES

Introduction

This chapter is intended to provide the reader with an insight and review into the different operations involved in processing dairy commodities. Special note will made of those processes common to much of the industry. The authors assume the readers of this document are already knowledgeable about the dairy industry. If you are not, you should read one of the textbooks on dairy processing or visit a dairy processing plant(s).

Processing Operations

A great variety of operations are encountered in the dairy products industry, but in oversimplification they can be considered as a chain of operations involving receiving and storing of raw materials, processing of raw materials into finished products, packaging and storing finished products, and a group of ancillary operations (e.g., heat transfer and cleaning) only indirectly involved in processing of materials.

Facilities for receiving and storing raw materials are fairly consistent throughout the industry with few, if any, major modifications associated with changes of raw materials. Basically they consist of a receiving area where bulk carriers can be attached to flexible lines or cans dumped into hoppers, fixed lines and pumps for transfer of materials, and large refrigerated tanks for storage. Wastes arise from leaks, spills and removal of adhering materials during cleaning and sanitizing of equipment. Under normal operations, and with good housekeeping, receiving and storing raw materials do not constitute major sources of wastes.

It is in the area of processing raw materials into finished products that the greatest variety is found, since processes and equipment utilized are determined by raw material inputs and the finished products manufactured. However, the initial operations of clarification, separation and pasteurization are comnon to most plants and products.

Clarification (removal of suspended matter) and separation (removal of cream, or for milk standardization to desired butterfat content) generally are accomplished by using large centrifuges of special design. In some older installations clarification and separation are carried out in separate units that must be disassembled for cleaning and sanitizing, and for sludge removal in the case of clarification. In most plants clarification and separation are accomplished by a single unit that automatically discharges the sludge can can be cleaned and sanitized without disassembly (cleaned-in-place, or CIP). Some plants may use inline filters to remove suspended matter.

Following clarification and separation, those materials to be subjected to further processing within the plant are pasteurized. Pasteurization is accomplished in a few older plants by heating the material for a fairly long time period in a vat (vat pasteurization). In most plants pasteurization is accomplished by passing the material through a unit where it is first rapidly heated and then rapidly cooled by contact with heated and cooled plates or tubes (high-temperature short-t.ime, or HTST pasteurization).

After the initial operations mentioned above, the processes and equipment employed become highly dependent on product. Examples of equipment encountered are; tanks and vats for mixing ingredients and culturing products, homogenizers (enclosed high-pressure spray units), evaporators and various driers for removal of water, churns and freezer:;. Selected processes employed for manufacture of various products are indicated in Figures 1 through 5 for fluid milk, cultured products, butter. cheese and cottage cheese production, respectively. The finished products are then packaged, cased and sent to storage for subsequent shipment.

The product fill lines employed in the dairy products industry are typical liquids and solids packing units, much like those employed in many industries, with only minor modifications to adapt them to the products and containers of the industry. Storage is in refrigerated rooms with a range in temperatures from below zero to above freezing.

The product manufacture and packing areas of a plant are the major sources of wastes. These wastes result from spills and leaks, wasting of by-products (e.g., whey from cheese-making), purging of lines during product change in such as freezers and fillers, product washing (e.g., curd washing for cheese) and removal of adhering materials during cleaning and

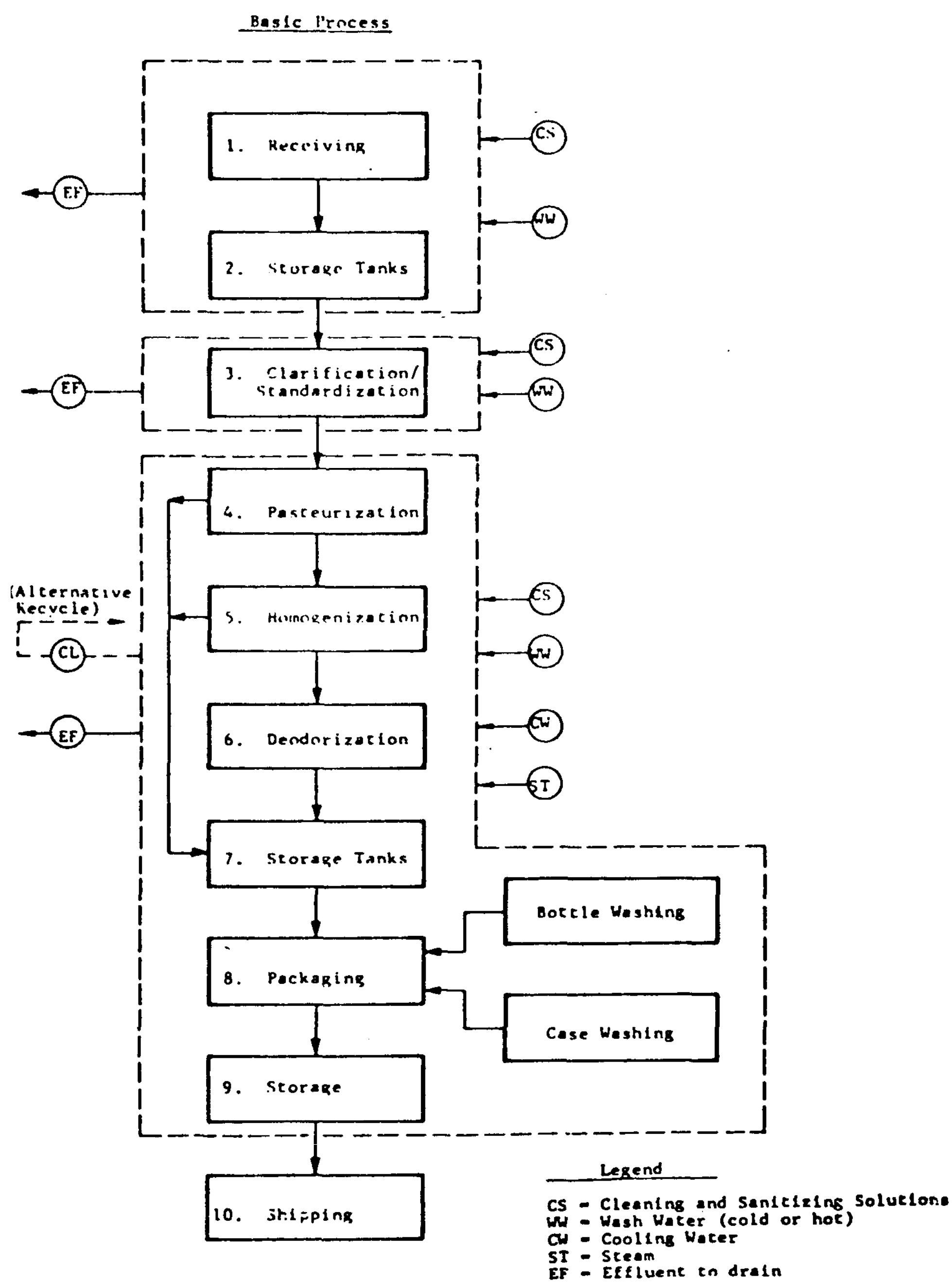

Figure 1. Fluid Milk

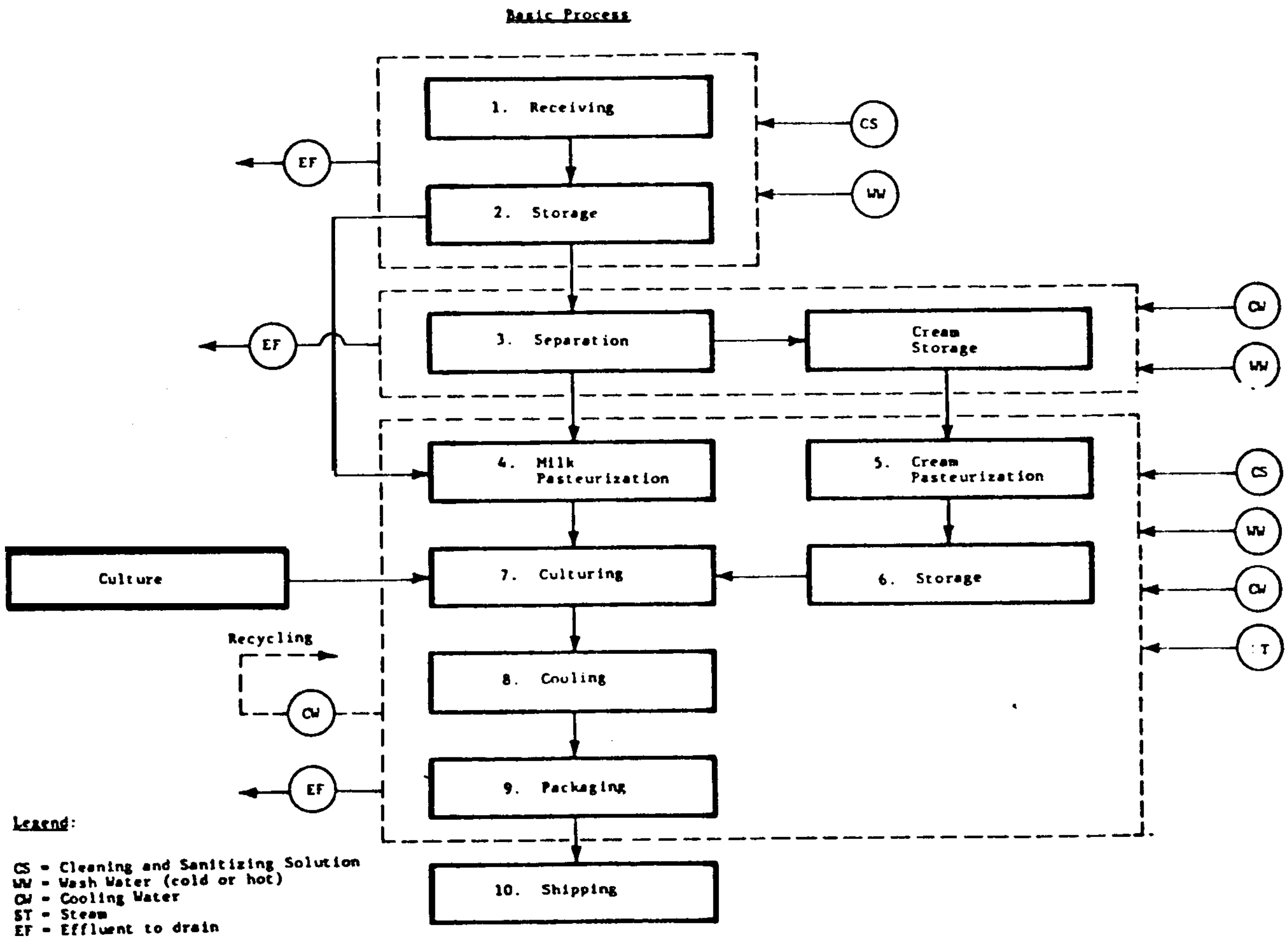

Figure 2. Cultured Products

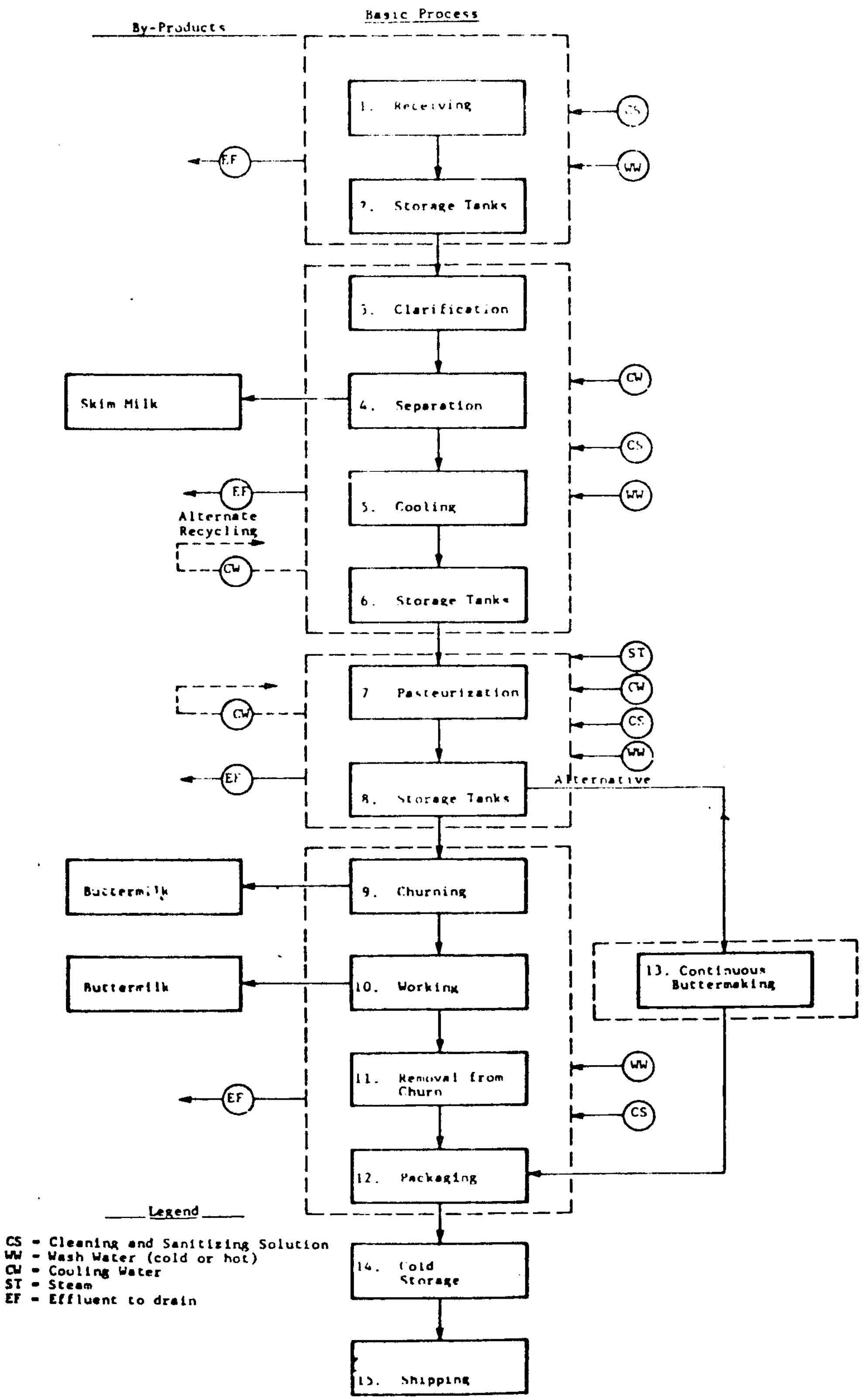

Figure 3. Butter

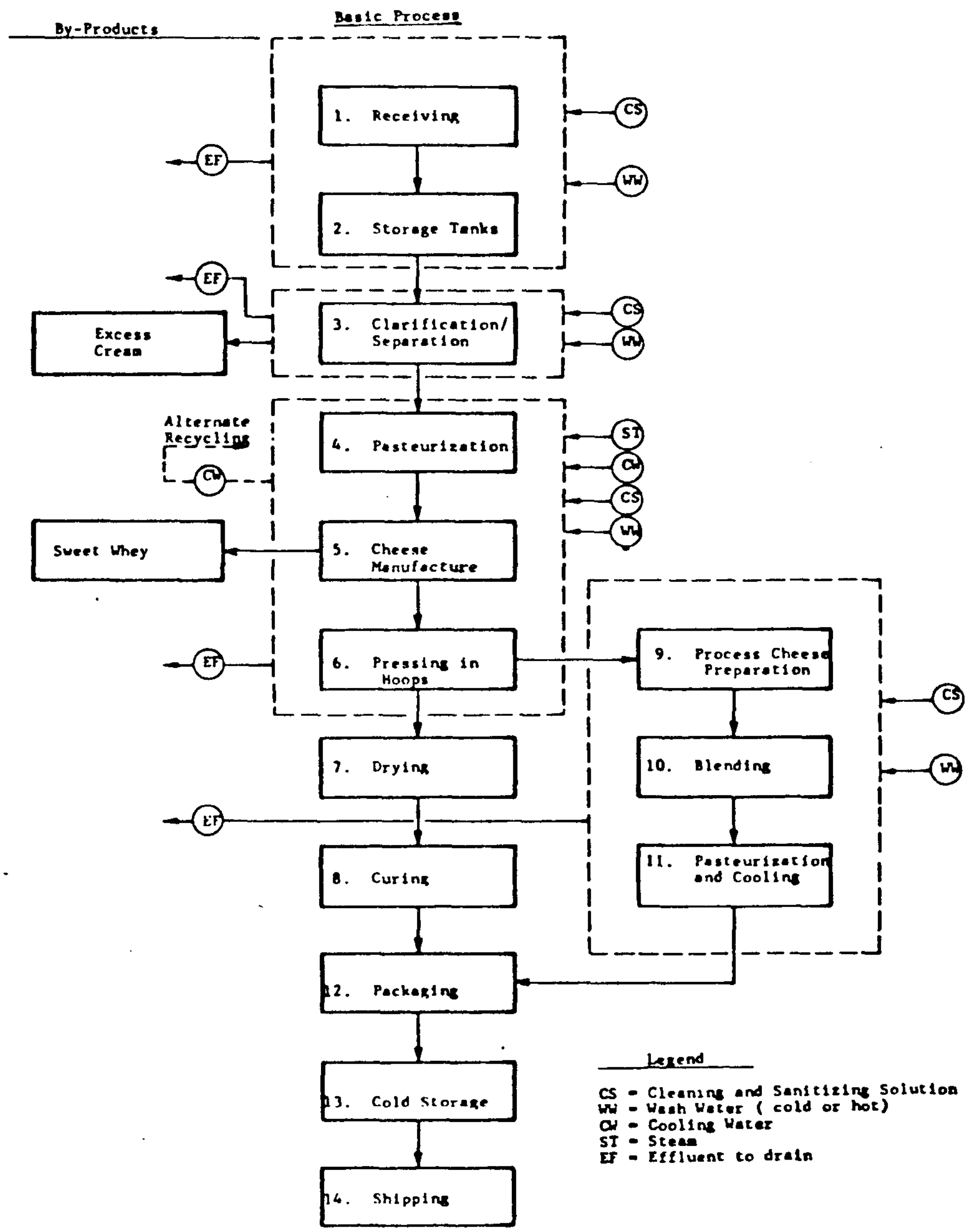

Figure 4. Natural and Processed Cheese

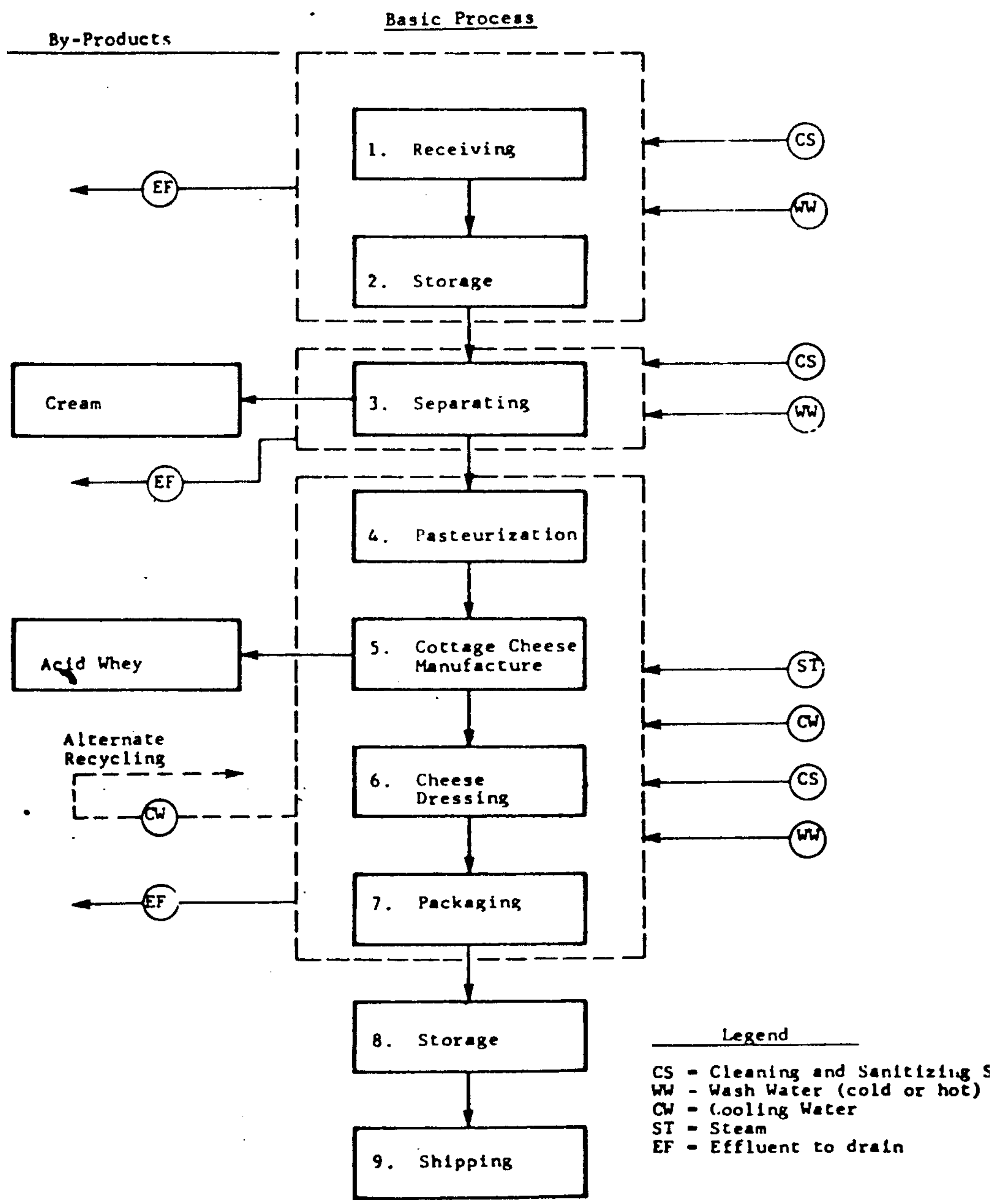

Figure 5; Cottage Cheese

sanitizing of equipment. Wastes from storage and shipping result from rupture of containers due to mishandling and should be minimal.

Realize that most plants are multiproduct facilities, and thus the process chain for a product may differ from the single product chain indicated in Figures 1 through 5. Also, a number of other product chains are possible for producing a multitude of products. Frequently in multi-product plants a single unit, such as a pasteurizer, may be utilized for processing more than one product. This represents considerable savings in capital outlay as process equipment, being specially designed and constructed of stainless steel, is quite expensive.

WASTEWATER CHARACTERIZATION

Introduction

Whenever food, in any form, is handled, processed, packaged and stored, there will always be an inherent generation of wastewater. The quantity of this processing wastewater that is generated and its general quality (i.e., pollutant strength, nature of constituents) has both economic and environmental consequences with respect to its treatability and disposal.

The economics of the wastewater lie in the amount of product loss from the processing operations and the cost of treating this waste material. The cost for product loss in self-evident, however the cost for treating the wastewater lies in its specific characteristics. Two significant characteristics which dictate the cost for treatment are the daily volume of discharge and the relative strength of the wastewater. Other characteristics become important as system operations are affected and specific discharge limits are identified (i.e., phosphorous).

The environmental consequences in not adequately removing the pollutants from the waste stream can have serious ecological ramifications. For example, if inadequately treated wastewater were to be discharged to a stream or river, an eutrophic condition would develop within the aquatic environment due to the discharge of biodegradable, oxygen consuming compounds. If this condition were sustained for a sufficient amount of time, the ecological balance of the receiving stream, river or lake (i.e., aquatic microflora, plants and animals) would be upset. Continued depletion-of the oxygen in these water systems would also result in the development of obnoxious odors and unsightly scum.

Dairy Industry Wastewater

The first step for EPA in applying the 1972 law to the dairy industry was to identify the industry's water pollution problems and to find out what can be done to solve those problems. To do that, EPA assembled available information on the dairy industry. That included two major studies of the industry, one by a private research firm, the other by a university.

Those studies provided basic data about the industry and virtually all available information on the technology of dairy products processing. Then, waste samples were taken and analyzed at dairy plants, some by dairy companies, some by independent laboratories, and some by EPA, with the cooperation of dairy companies. Information was obtained from state and local pollution control agencies that have been monitoring dairy plants. Dairy companies supplied additional data. Another university survey was undertaken. The Dairy Industry Committee sent out a voluntary questionnaire that produced still more data. And there were visits to dairy plants and conferences with dairy industry officials.

Out of this extensive study emerged this picture:

1) The more than 5,000 dairy plants in the United States discharge about 53 billion gallons of wastewater each year - about 31 billion gallons into municipal treatment plants, and 22 billion gallons directly into water bodies.

2) That the typical wastewater stream from a dairy plant has the following characteristics

Typical Waste Stream from a Dairy Plant

a) BOD - 2300 mg/l

b) SS - 1500 mg/l

c) FOG - 700 mg/l

3) The major pollutant in waste discharges from dairy plants is organic material. When dumped untreated into a stream or river, this organic material is decomposed by micro-organisms in the water. But in breaking down the organic pollution, the micro-organisms consume oxygen in the water. That degrades water by depleting its oxygen content. Oxygen depletion, in turn, can have a catastrophic impact on life in the water body, for fish and other aquatic animals and plants must have dissolved oxygen to survive. When all the oxygen in a water body is used up, as frequently happens, the decay of organic matter continues without oxygen. As a result noxious gases such as hydrogen sulfide and methane are produced. A measurement of pollutants that consume oxygen in water is called "biochemical oxygen demand," or BOD. Water with high BOD contains a large amount of decomposing organic matter.

4) Another major pollutant in dairy plant discharges is suspended solid waste, such as coagulated milk, particles of cheese curd, and in ice

cream plants, pieces of fruits and nuts. The measurement of this pollutant is called "total suspended solids," or TSS. These solids discolor and cloud water. They impair photo-synthesis in aquatic plants. They can settle on the bottom. When they contain organic matter - as dairy wastes do - the bottom deposits become sludge beds that can further deplete the water's oxygen content. As the sludge decomposes, it gives off gases that are toxic to aquatic life and cause odor problems.

In addition to the adverse esthetic and ecological effects, suspended solids in water from streams used by industry can interfere with many industrial processes. They can cause foaming in boilers, damage equipment, and impose high purification costs on industries that need clean water to make their products, such as the pharmaceutical industry.

5) Raw wastes from dairy plants contain excessive amounts of organic materials and suspended solids. The wastes thus have to be treated before they can be discharged into a water body. However, the major dairy industry water pollutants - organic material and suspended solids - can be treated successfully.

6) Other identified pollutants in dairy plant wastes are phosphorus, nitrogen, chlorides, and heat. In general, however, treating dairy wastes to reduce the amount of organic material and suspended solids will keep these other pollutants at satisfactory levels. In isolated cases, some of the minor pollutants may be critical and may need special treatment.

7) Another consideration is the acid or alkali content of liquid wastes. The pH of many individual wastes within a dairy plant fall outside the acceptable range for direct steam discharge. In general, however, the wastes are neutralized when they are mixed within a plant or during the treatment process. And where necessary, pH can be easily adjusted.

8) Finally, research also has revealed that wastes from most dairy plants can be successfully treated by municipal treatment plants and pose no dangers to the municipal plants. However, in some situations, a by-product cheese-manufacturing - whey - may create problems in some municipal treatment plants. Typically, whey only causes a problem when it is a large (greater than 10%) portion of the flow to a treatment plant. Where whey causes a problem, pretreatment as previously mentioned, may be required by the municipality.

The Dairy Industry

The dairy processing industry manufactures various food products utilizing milk as a base. In addition, a limited number of non-milk products such as fruit juices are processed in some plants. There are about 20 different types of products manufactured by the industry. A substantial number of plants in the industry engage in multiproduct manufacturing, and product mix varies broadly among such plants as reviewed in Chapter 2. The Dairy Product Processing Industry includes Standard Industrial Classifications (SIC) 2021, 2022, 2023, 2024, 2026 and 2043 and these can be subcategorized as follows:

Subcategory	Designation
Receiving Stations	A
Fluid Products	B
Cultured Products	C
Butter	D
Cottage Cheese and Cultured Cream Cheese	E
Natural Cheese and Processed Cheese	F
Ice Cream Mix	G
Ice Cream, Novelties, and other frozen desserts	H
Condensed Milk	I
Dry Milk	J
Condensed Whey	K
Dry Whey	L

Process Description

Figure 6 is a flow diagram which shows a process representative of the industry. The industry includes the following operations: the receiving and storage of raw materials, processing of raw materials into finished products, packaging and storing of finished product, and a group of ancillary operations (e.g., heat transfer and cleaning) only indirectly involved in processing of materials.

Facilities for receiving and storing raw materials consist of a receiving area, transfer equipment, and large refrigerated tanks for storage. Waste arises from leaks, spills and equipment wash outs. Under

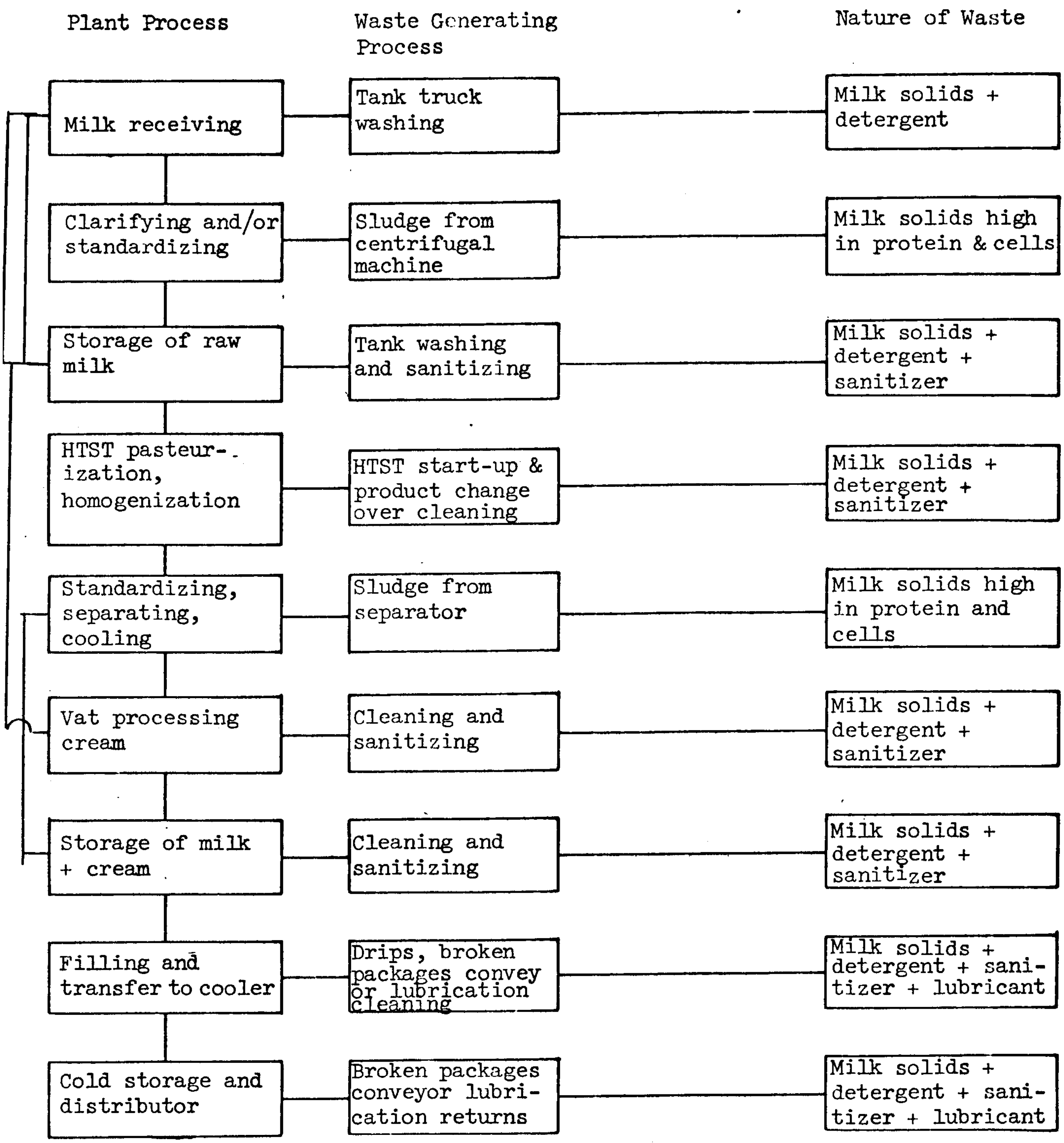

Figure 6. Typical Dairy Process - Market Milk

normal operations and with good housekeeping, receiving and storage of raw materials are not a major source of waste load.

The initial operations of clarification, separation and pasteurization are common to most plants and products. Clarification (removal of suspended matter) and separation (removal of cream) generally are accomplished by using large centrifuges of special design. In some older installations clarification and separation are carried out in separate units that must be disassembled for cleaning, sanitizing, and sludge removal. In most plants clarification and separation are accomplished by a single unit that automatically discharges the sludge and can be cleaned and sanitized without disassembly (cleaned in place, or CIP).

Following clarification and separation, those materials to be subjected to further processing within the plant are pasteurized. Pasteurization is accomplished in a few older plants by heating the material for a fairly long period of time in a vat (vat pasteurization). In most plants pasteurization is accomplished by passing the material through a unit where it is first rapidly heated and then rapidly cooled by contact with heated and cooled plates or tubes (high temperature short time or HTST pasteurization).

After the initial operations, the processes and equipment employed become dependent on the product to be manufactured. The processes employed for the manufacture of various products include churning, homogenizing, culturing, condensing, and drying. The finished products are then packaged, cased and sent to storage for subsequent shipment. The flow diagram shown in Figure 6 is representative of many processes in this industry.

The product manufacture and packaging areas of a plant are the major sources of wastes. These wastes result from spills and leaks, wasting of by-products (e.g., whey from cheese making), purging of lines during product change, product washing, and equipment washups. Wastes from storage and shipping result from the rupture of containers due to mishandling and should be minimal.

Sources of Waste

The main sources of waste in dairy plants are the following:

1) The washing and cleaning out of product remaining in the tank trucks, cans, piping, tanks, and other equipment is performed routinely after *every* processing cycle.

2) Spillage is produced by leaks, overflow, freezing-on, boiling over, equipment malfunction, or careless handling.

3) Processing losses include:
   a) Sludge discharges from CIP clarifiers
   b) Product wasted during HTST pasteurized start-up, shut-down, and product change-over
   c) Evaporator entrainment
   d) Discharges from bottle and case washers
   e) Splashing and container breakage in automatic packaging equipment
   f) Product change-over in filling machines.

4) Spoiled products, returned products, or by-products such as whey are wasted.

5) Detergents and other compounds are used in the washing and sanitizing solutions that are discharged as waste.

6) Entrainment of lubricants from conveyors, stackers and other equipment appear in the wastewater from cleaning operations.

7) Routine operation of toilets, washrooms, and restaurant facilities at the plant contribute waste.

8) Waste constituents may be contained in the raw water which ultimately goes to waste.

The first five sources listed relate to the product handled and contribute the greatest amount of waste.

Nature of Dafry Plant Wastes

Material Wasted

Materials that are discharged to the waste streams in practically all dairy plants include:

1) Milk and milk products received as raw materials.

2) Milk products handled in the process and end products manufactured.

3) Lubricants (primarily soap and silicone based) used in certain handling equipment.

4) Sanitary and domestic sewage from toilets, washrooms and kitchens.

Other products that may end up in the waste flows include:

1) Non-dairy ingredients (such as sugar, fruits, flavors, nuts, and fruit juices) utilized in certain manufactured products (including ice cream, flavored milk, frozen desserts, yoghurt, and others).

2) Milk by-products that are deliberately wasted, significantly whey, and sometimes, buttermilk.

3) Returned products that are wasted.

Uncontaminated water from coolers and refrigeration systems, which does not come in contact with the product, is not considered process wastewater. Such water is recycled in many plants. If wasted, it increases the volume of the effluent and affects the size of the piping and treatment system needed for disposal. Roof drainage will have the *same* effect unless discharged through separate drains.

Sanitary sewage from plant employees and domestic sewage from washrooms and kitchens is usually disposed of separately from the process wastes and represents a very minor part of the load.

The effect on the waste load of the raw water used by the plant has often been overlooked. Raw water can be drawn from wells or a municipal system and may be contributing substantially to the waste load arising from cooling water and barometric condensers unless periodic control of its quality indicates otherwise.

Composition of Wastes

The principal organic constituents in the milk products are the natural milk solids, namely fat, lactose and protein. Sugar is added in significant quantities to ice cream and has an important effect in the waste loads of plants producing that product. The average composition of selected milk, milk products and other selected materials is shown in Table 1.

Cleaning products used in dairy plants include alkalis (caustic soda, soda ash) and acids (muriatic, sulfuric, phosphoric, acetic, and others) in combination with surfactants, phosphates, and calcium sequestering compounds. BOD_5 is contributed by acids and surfactants in the cleaning product. However, the amounts of cleaning products used are relatively small and highly diluted.

Table 1. Composition of Common Dairy Products Processing Materials.

Material	% Protein	% Fat	% Carbohydrate	BOD_5 Kg/100Kg (lb/
Almonds (dried)	18.6	54.2	19.5	80.89
Blackberries (canned, Light syrup)	0.8	0.6	17.3	13.30
Buttermilk				
Fluid(cultured skim milk)	3.6	0.1	5.1	7.22
Dried	34.6	5.3	50.0	74.63
Chocolate (semi-sweet)	4.2	35.7	57.0	65.49
Cheese				
Brick	22.2	30.5	1.9	51.35
Cheddar	25.0	32.2	2.1	55.89
Cottage (uncreamed)	17.0	0.3	2.7	19.66
Cherries (sweet, Light syrup)	0.9	0.2	16.5	12.51
Cocoa (dry powder, Low-med fat)	19.2	12.7	53.8	68.17
Cream (fluid)				
Half and Half	3.2	11.7	4.6	16.89
Light (coffee or table)	3.0	20.6	4.3	24.39
Light whipping	2.5	31.3	3.6	32.93
Heavy whipping	2.2	37.6	3.1	37.87
40%	2.1	40.0	2.9	39.77
Milk (fluid)				
Whole, 3.7% Fat	3.5	3.7	4.9	10.39
Whole, 3.5% Fat	3.5	3.5	4.9	10.23
Skim	3.6	0.1	5.1	7.44
Milk (canned)				
Evaporated (unsweetened)	7.0	7.9	9.7	21.74
Condensed (sweetened)	8.1	8.7	54.3	53.76
Milk (dried)				
Whole	26.4	27.5	38.2	78.85
Skim	35.9	0.8	52.3	75.01
Orange Juice				
All commercial varieties	0.7	0.2	10.4	7.85
Peaches, canned				
Water pack	0.4	0.1	8.1	6.11
Juice pack	0.6	0.1	11.6	8.75
Pecans	9.2	71.2	14.6	83.17
Strawberries				
Canned, water pack	0.4	0.1	5.6	4.40
Frozen, sweetened	0.4	0.2	23.5	17.06
Sugar	0.0	0.0	99.5	68.75
Walnuts, Black	20.5	59.3	14.8	85.15
Whey				
Fluid	0.9	0.3	5.1	4.72
Dried	12.9	1.1	73.5	65.07
40% Solids	5.3	0.5	30.1	26.71

Sanitizers utilized in dairy facilities include chlorine compounds, iodine compounds, quaternary ammonium compounds, and in some cases, acids. Their significance in relation to dairy wastes has not been fully evaluated, but it is believed that their contribution to the BOD_5 load is quite small.

Most lubricants used in the dairy industry are soaps or silicones. They are employed principally in casers, stackers and conveyors. Soap lubricants contribute to BOD_5 and are more widely used than silicone based lubricants.

The organic substances in dairy wastewaters are contributed primarily by the milk and milk products wasted, and to a much lesser degree, by cleaning products, sanitizing compounds, lubricants, and domestic sewage that are discharged to the waste stream. The importance of each source of organic matter in dairy wastewaters is illustrated in Table 2 and Table 3.

The inorganic constituents of dairy wastewaters have been given much less attention as sources of pollution than the organic wastes simply because the products manufactured are edible materials which do not contain hazardous quantities of inorganic substances. However, the nonedible materials used in the process, do contain inorganic substances which by themselves, or added to those of milk products and raw water, potentially pose a pollution problem. Such inorganic constituents include phosphates (used as deflocculants and emulsifiers in cleaning compounds), chlorine (used in detergents and sanitizing products) and nitrogen (contained in wetting agents and sanitizers).

For purposes of calculations, it is frequently useful to know the BOD values for various constituents for dairy foods. Average values in pounds of BOD/pound of component were 0.65, 0.87, 1.03 for lactose, milk fat and milk protein, respectively.

Relationship of Product Viscosity to BOD

Different products differ markedly in their viscosity and limited data is available to interrelate the product residuals left OR surfaces. Table 4 gives the relationship between viscosity of the product and the loss for various dairy products, and Table 5 provides BOD conversion factors to interrelate different products. This conversion system is to

Table 2. Estimated Contribution of Wasted Materials to the BOD_5 Load of Dairy Wastewater. (Fluid Milk Plant).

	kg BOD5/kkg (lb/1000 lb) Milk Eqivalent Processed	Percent
Milk, milk products, and other edible materials	3.0	94%
Cleaning products	0.1	3
Sanitizers	Undetermined, but probably very small	--
Lubricants	Undetermined, but probably small	--
Employee wastes (Sanitary and domestic)	0.1	3
	3.2	100%

Table 3. Reported BOD Value for Various Milk Constituents and Related Constituents.

Constituent	Average Pound BOD_5/Pound Component
Lactose	0.65
Glucose	0.66
Lactic Acid	0.63
Milk Fat	0.89
Glycerol	0.75
Butyric Acid	0.75
Sodium Butyrate	0.41
Palmitic Acid	1.07
Sodium Palmitate	0.70
Stearic Acid	0.80
Sodium Stearate	1.20
Milk Proteins	1.03
Casein	1.04
Hydrocolloids	
Sodium Alginate	0.36
Carboxymethyl-cellulose	0.30
Surfactants	
Soap	1.43
Dreft	0.49
br. ch. Alkyl Benzyl Sulfonate	0.02
Tween 80	0.35

Table 4 - Relationship of Product Viscosity, Product Loss and Residual BOD_5 for Dairy Products.[a]

Product	Viscosity	Product Remaining on Surface	Residual E (BOD_5/Proc
	(cp)	(%)	(lb/1000 l
Skim Milk	1.4	0.0	0.072
Low Fat	-	-	-
Whole Milk	2.0	0.26	0.26
Chocolate Milk	21.0	0.47	0.69
Half-n-Half	15.6	0.39	0.61
Cream, 40% BF	91.0	0.95	3.80
Cultured Buttermilk	500.	2.30	1.47
Sour Cream	9000.	3.50	7.00
Ice Cream Mix	121.	0.86	3.4
Condensed Skim	-	0.50[b]	1.04[b]
Whey (no fines)	-	-	-

[a]Harper *et al.*, 1971

[b]Estimated by Carawan, 1977

Table 5 - BOD_5 HFactor and BOD_5 Ratio HFactor.[b]

Product	BOD_5 HFactor[a]	BOD_5 Ratio HFactor
Skim	.76	.30
Low Fat	.86	.60
Homogenized	.95	.80
Half-n-Half	1.53	2.4
Chocolate	1.33	2.6
Buttermilk	.98	5.6
Sour Cream	2.35	27.
Drinks	.53	NA
Orange Juice	.73	NA
Cottage Cheese	1.98	NA
Dressing	1.78	14.
Curd	1.99	NA
Ice Cream	2.64	13.
Whey (No fines)	.38	.30
Returns	.92	.70
High Solids Recovery	.50	.50
Receipts (Whole Milk)	1.00	1.0
Cream	4.03	15.
Liquid Cane	4.43	NA
Corn Syrup	5.13	NA
Condensed Skim	2.12	4.00

[a]BOD5 HFactor = $\frac{BOD_5 \text{ Product}}{BOD_5 \text{ Whole Milk}}$

[b]Carawan, Roy E., 1977.

provide a basis for calculation of unit process coefficients for different types of products when the coefficients are known for some other products.

Water Use

Water is used for a number of purposes in a dairy plant. For example, water is used for washing trucks, cooling products, make-up for products, as a cooling tower medium, for washing and sanitizing and for employee drinking and restrooms. Some selected coefficients for water use are given in Table 6. Relatively clean water from condensers, refrigeration and air compressors and air conditioning systems can be a substantial part of the water use in a dairy plant.

Wastewater Characterization

Tables 7 and 8 show typical waste and flow characteristics for the dairy industry. A significant characteristic of the waste streams of all dairy plants is the marked fluctuations in flow, strength, temperature, etc. due to daily and seasonal variations. For example, see Figure 7.

Based on industry observation and evaluation of literature data, volume and BOD coefficients per thousand pounds of milk processed (or milk equivalent) is presented in Figure 8 for a normally operated market milk plant.

Table 9 summarizes other wastewater useage and BOD coefficients found for various dairy plant operations. The data presented in Table 9 and Figure 8 should be considered as guides only, which would require a relatively good management to achieve, and may be expected to vary from plant to plant. Much more data on specific unit operations of different type plants measured under controlled conditions is needed to provide a truly reliable index of the role of various unit operations in waste loading.

As information is obtained about a given dairy plant operation, some in-plant control activity can be initiated to reduce the wastewater discharges. Such activties as using improved management control including measures to minimize product losses, maintain equipment, develop alterna-

Table 6. Coefficient Water Use for Various Plant Operations.

Operation	Pounds of Water/Pounds o:
Can washing	0.001
Truck washing	0.07
Cooling milk in storage	0.2
Pasteurization	0.35
Bottle washer	0.5
Boilers & Evaporators	0.25
Cleaning	0.25
Spray cleaning tanks	
Pre-rinses	0.005
Cleaning	0.010
Post-rinse	0.005
Sanitizing	0.005
Lines	
Pre-rinse	0.0005
Cleaning	0.001
Post-rinse	0.0005
Sanitizing	0.025
Evaporating (3:1) (triple effect) Calander cond.	9.0
Condensing (triple effect) Plate cond.	12.0
Cottage cheese wash water	1.2
Cooling	
Receiving, bottling, ice cream & cream cheese	1.2
Receiving past. separating, condensing & spray drying	1.1 - 1.5
Receiving cond. canning & sterilizing	0.02- 0.4

Table 7. Raw Wastewater Characteristics.

Parameter	Concentration Range
Flow	Intermittent
BOD (mg/l)	40 - 10,000 1000 - 4000[1]
TSS (mg/l	400 - 2,000
TDS (mg/l)	-
COD (mg/l)	400 - 1500
pH	4 - 11 7.8[2]
Phosphorous (mg/l) (as PO_4)	9 - 210 48[2]
Ammonia Nitrogen (mg/l)	1 - 13 5.5[2]
Total Nitrogen (mg/l)	1 - 115 64[2]
Chloride (mg/l)	45 - 2000 483[2]
Color	High
Coliform	Present

[1]Narrower range encompassing the majority of plants
[2]Mean for plants reporting

Table 8. Raw Wastewater Volume Attainable Through Good In-Plant Control

Subcategory	1/kkg M.E.*	1/kg BOD_5	gal/1000 lb M.E.	gal/1000 lb BOD_5
Receiving Stations	999	9.6	120	115.5
Fluid Products	4663	44.9	560	539.0
Cultured Products	4663	44.9	560	539.0
Cottage Cheese	9243	89.0	1110	1068.3
Natural Cheese	999	9.6	120	115.5
Ice Cream Mix	2498	24.0	300	288.7
Condensed Milk	4746	45.7	570	548.6
Dry Milk	2248	21.6	270	259.9
Condensed Whey	1249	12.0	150	144.4
Dry Whey	1249	12.0	150	144.4

*M.E. - Milk equivalents

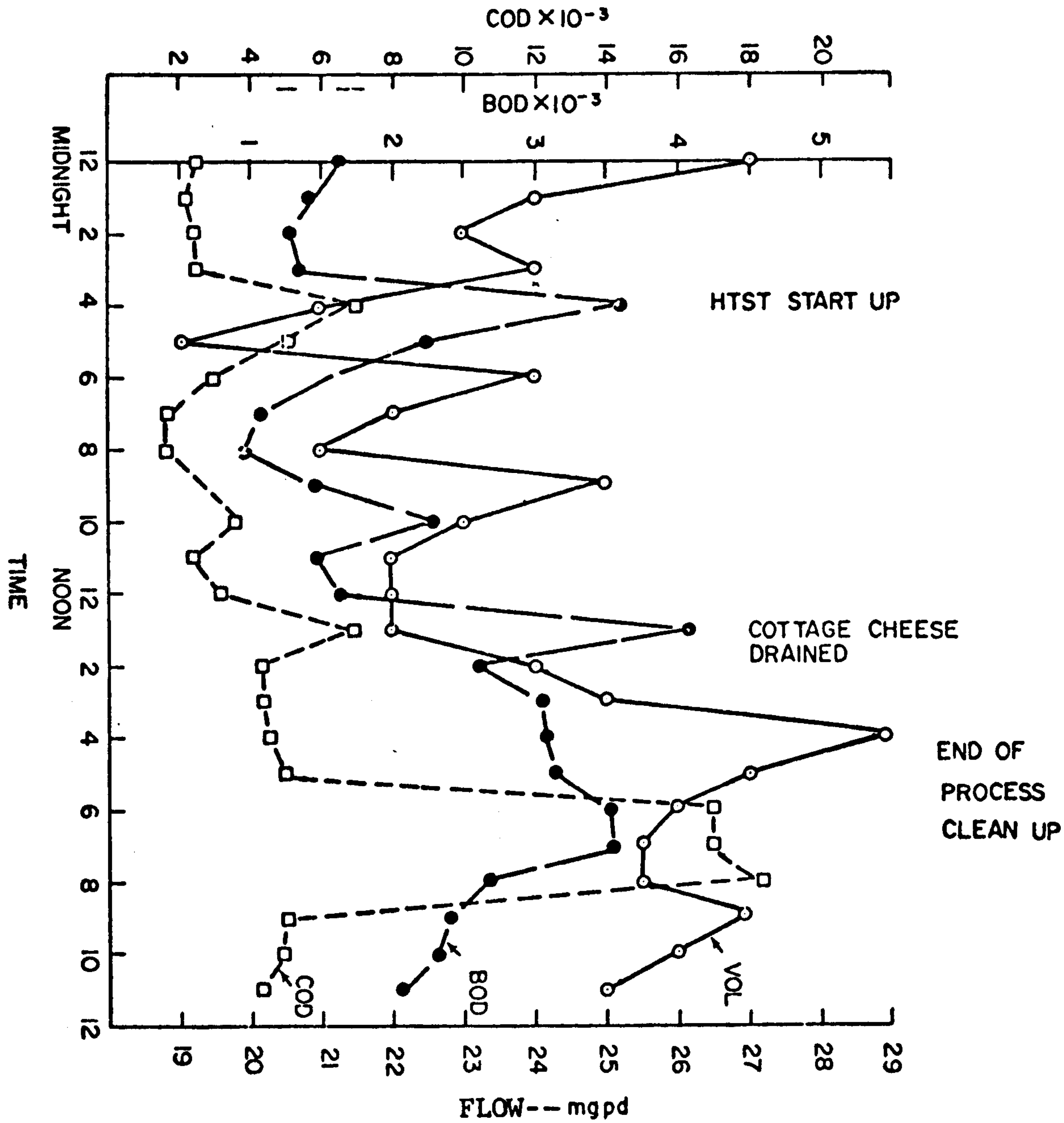

Figure 7. Houly Variations in ppm BOD_5, COD and Wastewater for a Dairy Plant

Plant Process	Vol. Waste Pound Water/ Pound Milk	Pound BOD/1000 Pound Milk Processed
Tank truck	0.125	0.2
Clarifying and/or standardizing	0.015	0.08
Storage of raw milk	0.10	0.2
HTST Pasteurization, homogenization, automatic by-product formulation	0.5	0.8
Storage	0.10	0.2
Filling (paper & plastic)	0.05	0.3
Conveying	0.02	0.1
Cold storage	0.01	0.1
Distribution	0.1	0.5 (Returns)
Total	1.00	2.48

Figure 8. Waste Coefficients for Market Milk Processing

Table 9. Summary Table for Various Dairy Plant Operations Relative to Wastewater Useage and BOD Coefficients Per 1000 lbs of Milk Processed (or Milk Equivalents).

	Type Operation	Pound Wastewater/ Pound Milk	Pound BOD/1000 lb Milk Processed
1.	Market milk with initial rinses saved from processes	0.50	0.46
2.	Market milk-subprocesses: Skimmilk, creams and special milks by continuous process alternatives	1.14	2.2
3.	Market milk-subprocesses: Buttermilk, yogurt and sour cream	1.16	Buttermilk - 1.85 Yogurt - 1.89 Sour Cream - 2.90
4.	Butter-churn process	1.45	2.6
5.	Butter-continuous process	1.06	1.96
6.	Cottage cheese	11.6	2.85
7.	Cheedar cheese mfr.	0.77	Cheddar - 1.25 Washed curd - 1.7
8.	Cheese - Provolone and Mozzarella mfr.	1.09	1.37
9.	Ice cream	1.15	2.09
0.	Ice cream novelties-stick	0.37	1.3
1.	Ice cream novelties - stickless	0.46	0.95
2.	Condensed milk process	11.5	1.88
3.	Spray drying process	0.44	1.25

tive uses for wasted products, and carefully supervise the operation could be implemented as will be examined in the following chapter. Other activities might include engineering improvements to the plant, equipment, processes, and ancillary systems that could improve production efficiency and reduce waste loads. Such activities can greatly reduce the waste coefficients as can be seen by contrasting Figure 9 with Figure 8. The management practices included in Figure 9 appreciably reduced the water and waste load coefficients.

Coefficients for Fluid Milk, Cottage Cheese and Ice Cream Plants

Wastewater and BOD_5 coefficients for fluid milk, cottage cheese and ice cream plants are presented in Tables 10 and 11. Detailed information on other segments of the dairy industry are not summarized but are readily available in the Development Document (1974) and Harper et al. (1971). The average wastewater coefficient is 389 gal per 1000 pounds of milk received (Table 10). However, the reader is cautioned that water use does not necessarily equal wastewater. In fact, Carawan et al. (1979) found that only 64% of the water use in a multiproduct dairy plant was discharged.

The average BOD_5 coefficient for a fluid products dairy plant is probably between 3.21 and 3.60 lb BOD_5 per 1000 lb milk or milk equivalent received (Table 11). Ice cream and cottage cheese plants have significantly higher coefficients.

Plant Process	Pound Waste Water/ Pound Milk	Pound BOD/1000 Pounds Milk
Tank truck milk receiving	0.10	0.05
Clarifying and/or standardizing	0.015	0.01
Storage of raw milk	0.08	0.05
HTST Pasteurization, homogenization, automatic by-procuct formation	0.2	0.15
Storage	0.08	0.05
Filling (paper & plastic)	0.05	0.05
Conveying	0.02	0.10
Cold storage	0.01	0
Distribution	0	0
Total	0.50	0.46

Figure 9. Waste Coefficients-Market Milk (rinses saved) CIP Sludge Saved, HTST Start-Up, Change-Over and Shut-Down Segregated and Saved: Returns Used as Feed.

Table 10. Wastewater Coefficient for Commercial Plant Survey.[a]

Manufactured	Number of Plants	Wastewater Coefficient (Wastewater/Milk)		
		Range[b] (lb/lb)	Average[b] (lb/lb)	Average[b] (gal/1000lbs)[c]
Milk (FM)	6	0.1-5.4	3.25	389
Ice Cream (IC)	6	0.8-5.6	2.80	336
Cottage Cheese(CC)	3	0.8-12.4	6.00	719
FM,IC,CC	9	1.4-3.9	2.52	302

[a]Harper et al. (1971)

[b]Based on milk received

[c]Calculated by Carawan, 1977

Table 11. Summary of Literature Reported and Identified Plant BOD_5 data.[a]

Type Plant	Literature[b]			Identified Sources[c]		
	Number of Plants	BOD_5 Load per ME[d] Received		Number of Plants	BOD_5 Load per ME[d] Received	
		Range	Mean		Range	Mean
		(lb/1000 lb)			(lb/1000 lb)	
Fluid Products	16	0.14-17.06	3.60	6	0.30-7.16	3.21
Cottage Cheese	5	1.30-42.00	14.64	-	-	-
Ice Cream	7	1.90-21.04	5.54	10	0.68-19.60	6.75
Fluid-Cottage-Ice Cream	10	0.90-12.90	6.79	1	-	6.24

[a]Development Document (EPA, 1974)

[b]Literature = Values obtained from literature review

[c]Identified Sources = Data obtained from operating plants which could be identified by name and location

[d]ME = Milk equivalent

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MANAGEMENT CONTROL OF WATER AND WASTEWATER

Introduction

Estimates indicate that about half the water pollutants generated in some dairy plants can be eliminated by improved in-plant procedures and better housekeeping in the plant. Some examples: More attention can be given to controlling spills. Start-up and shut-down operations can be reduced and controlled. Some raw materials can be salvaged and recycled instead of discharged. Some by-products can be salvaged and sold as feed or food products instead of discharged. Product loss and water use can be reduced by education programs for management and plant operators. Cleaning operations can be made more efficient and thus the amount of water and cleaning chemicals used can be reduced. And plant design changes can also produce less waste in some dairy plants.

For fluid milk plants, management must realize that the BOD in their sewer should be correlated to their milk loss in the plant. If we assume that 90% of the BOD comes from milk, then 1 lb BOD_5 in the sewer is equal to 9 lb of milk lost in the plant.

Plant management must look at in-plant reductions as being the simplest method. The simplest method has been expressed by one leading dairy engineer:

> "Plant people should exhaust the in-plant short-of-treatment approach as the soundest and simplest method of controlling a waste problem. In addition to coming to grips with the pollution problem, such action will also result in cost reductions through improved production efficiencies, reductions in losses, and reductions in water usage."
>
> -Kenneth S. Watson, Former Director of Environmental Control, KraftCo Corporation, Glenview, Ill.

Initial Plant Survey

Plant surveys involve five basic steps: (a) Flow measurement, (b) Sampling, (c) Sample storage, (d) Analysis, and (e) Computation and review. Each step is equally important and details are explained in the Basics and Management Control Spinoffs.

A Waste Monitoring System should become an integral portion of the manufacturing process and be used as a measure of efficient operation. Once incorporated into the production system, it will be an invaluable check on on the overall efficiency of plant operations as well as an aid in meeting legal requirements. The monitoring program will also provide basic data that will be valuable in the design of a wastewater treatment system to meet regulatory requirements. Complete details of an initial and comprehensive plant survey are contained in the Management Control Spinoff.

Use of Effluent Data

In a manufacturing plant with no product losses from any area, the quantity of material sold will be equal to the material delivered to the factory. However, in any manufacturing process there are inherent losses. In a market milk dairy, these will include packaging losses due to overweight packs, material used for samples and all losses of liquid and semi-solids associated with operation of the manufacturing equipment, many of which are avoidable.

The traditional method by which dairy plants determine plant productivity and yield information is to compare the quantities of product packed with the quantities credited to the plant as raw materials. Due to the inaccuracies of this determination on a day-to-day basis, it has become necessary for management to know quickly when major losses have occurred to develop another means of arriving at the true yield information. With the increasing attention being paid all over the world to environmental control and the reduction of all forms of pollution, equipment has been developed to enable accurate measurement and sampling of liquid waste streams and it is from these developments that another method of determining yields has developed. This will never supercede the traditional methods which must continue to be used for accounting purposes.

Example - Losses and Yields

An example is used of a multi-product dairy, utilizing where possible, the latest in sophisticated techniques to obtain values for raw materials received and products manufactured. The yield of material for the whole plant is then calculated from the sum of the products, whether by weight, milkfat content, total solids, chemical oxygen demand or nitrogen; divided by the sum of the raw materials entering the plant and measured by any of the above parameters.

$$\text{i.e., Yield \%} = \text{Out/In} \times \frac{100}{1}$$

If the measurements of material entering or leaving the plant (or still in transit through the plant, when a day or period is considered to be over, e.g., cream held in a silo for the next day's manufacture), is subject to any errors, then the yield figure also will be in error.

Yield Calculation

If yield is determined by products/raw materials, then assuming a 2% loss of solids to the liquid effluent and overweight packaging, the yield calculation becomes:

$$\frac{\text{Solids packed}}{\text{Solids in raw material}} = \frac{98}{100} = 98\%$$

However, if the errors in the measurements are included, the equation becomes:

$$\frac{\text{Solids packed}}{\text{Solids in raw material}} = \frac{(98 \pm 0.8)\%}{(100 + 0.6)\%}$$

As a guide to management of any day-to-day losses occurring in the plant, this method of determining yield is limited. Further problems arise when quantities of material are held over in a semi-processed state until the processing day.

Yield Determinations by Loss Measurement Technique

The yield equation can be rewritten

$$\text{Yield \%} = \frac{\text{Product out}}{\text{Raw Materials in}} \times \frac{100}{1}$$

But product out must equal the raw materials in minus the losses or,

$$\text{Yield \%} = \frac{\text{Raw material in - losses}}{\text{Raw material in}} \times \frac{100}{1}$$

Alternatively, this can be written as

$$\text{Yield \%} = \frac{\text{Product out}}{\text{Product out + losses}} \times \frac{100}{1}$$

or from raw materials,

$$\text{Yield \%} \ (1 - \frac{\text{losses}}{\text{raw material}}) \times \frac{100}{1}$$

or from product,

$$\text{Yield \%} = (1 - \frac{\text{losses}}{\text{product out + losses}}) \times \frac{100}{1}$$

Using the equation for the raw materials, and assuming,

(a) losses can only be measured accurately to within 5%;

(b) raw materials measurement errors are as for the calculations used previously; and

(c) a plant whose true yield is 98%.

Yield calculation becomes

$$(1 - \frac{2}{100}) \times \frac{100}{1} = 98\%$$

$$[1 - \frac{2\ (\pm\ 5\%)}{100\ (\pm\ 0.6)}] \times \frac{100}{1}$$

or a possible range from

$$(1 - \frac{1.9}{100.6}) \times \frac{100}{1} \quad \text{to} \quad (1 - \frac{2.1}{99.4}) \times \frac{100}{1}$$

i.e., from 97.89 to 98.11%.

This is almost an order of magnitude better for the prediction of day-to-day yield analysis for management control than the traditional method.

This has been an example for a simple case (total solids) in a complex multi-product plant, but the same reasoning holds true for all instances, with slight modifications required for the determination of the raw material, products, and losses.

Determination of Achievable Goals

This section of the Handbook provides background information upon which to make judgment of the degree of preventable and unavoidable wastes in a particular plant situation. Specifically needed are detailed composition of dairy products (Table 1), the BOD relationship for these products (Table 1), sources of waste, and achievable water and waste coefficients for unit processes and for different types of dairy plant operations as have been discussed in the previous chapter.

For purposes of calculations, it is frequently useful to know the BOD and/or COD values for various constituents for dairy foods. Average values in pounds of BOD/pound of component were 0.65, 0.89, 1.03 for lactose, milk fat and milk protein, respectively. Table 12 gives BOD and COD values for a number of common dairy products. Primarily because of fat, BOD/COD ratios are variable and COD may provide a better index of product losses than BOD for high fat products such as ice cream mix.

Relationship of Product Viscosity to BOD

Different products differ markedly in their viscosity and limited data is available to interrelate product loss with residuals left on surfaces. Table 4 gives the relationship between viscosity of the product and the loss for various dairy products, and Table 5 provides BOD conversion factors to interrelate different products. This conversion system is to provide a basis for calculation of unit process coefficients for different types of products by multiplying the coefficient for milk times the BOD conversion factor. For example, the processing of cream in an HTST results in 15 times the loss and BOD5 load than if milk is processed similarly (Table 5, BOD_5 Ratio HFactor).

Sources of Dairy Food Plants Wastes

Determination of the significant sources of dairy food plant wastes requires an understanding of the processing of dairy foods, the various unit operations and their potential role as sources of wastewater, milk solids and refractory compounds. Flow diagrams of various unit processes for processing milk into its various products, waste generation processes and the general nature of the waste for each type of unit operation were presented in Figures 1-5 for selected products.

The unavoidable waste generating processes of major significance include:

- washing, cleaning and sanitizing of all pipe lines, pumps, processing equipment, tanks, tank trucks, and filling machines;

Table 12. Literature Values for BOD and COD of Various Dairy Products.

Product	Percent Organic Solids	BOD5/ Average	BOD5/ Organic Solids	COD	BOD/COD ratios
	(%)	(mg/l)	(lb/lb)	(mg/l)	
Skimmilk	8.2	67,000	.82	103,000	.65
Whole milk	11.7	104,600	.88	173,000	.60
Half & Half	19.5	175,000	.88	365,000	.48
Cheese dressing	2.0	150,000	.86	312,000	.48
Yoghurt	10.5	98,000	--	270,000	.36
Ice milk	32.5	218,500	--	400,000	.55
2% milk	12.2	90,500	--	146,000	.62
Cream - 18%	29.3	215,000	--	440,000	.49
Cream - 40%	44.9	399,000	.88	2,100,000	.19
Concentrated Skimmilk (2:1)	26.2	208,000	.79	346,000	.60
Ice cream Mix (10% fat)	34.0	292,000	.85	540,000	.54
Churned Buttermilk	6.8	51,600	.75	86,000	.59
Whey (sweet)	6.0	33,900	.56	61,600	.55
Whey (acid)	5.8	32,000	.53	70,000	.54

- start-up, product change-over and shut-down of HTST and UHT pasteurizers;

- loss in filling operations; and

- lubrication of casers, stackers and conveyors.

The piping associated with a unit process must be considered to be an integral part of that operation. Thus, the waste generating process of tank truck washing would include all pumps and piping in the receiving room; cleaning of raw storage tanks would include the associated raw milk pumps, valves and lines.

Spills and leaks from pipe line joints, valves and pumps must be included as waste generating processes for any process. Although these sources are significant to varying degrees in different dairy food plants, they are inherently controllable through the application of good management practices. Generally, the nature of the wastes generated by the various processes are similar; including milk solids in some form, plus detergents and sanitizers in most product processing steps and these same materials plus lubricants are generated in packaging and distribution operations. The significance of various waste generating processes to the total waste load of the dairy food plant wastewater is a characteristic of the individual process.

Coefficients for Plant Operations

The first step in establishing reasonable goals for a dairy plant to achieve is to review the status of the plant in regard to the industry. References such as Harper et al. (1971) provide much of the needed information.

A meaningful survey and goals must include an analysis of the key operations in the plant. For example, the water use, effluent, BOD_5, product loss and fat loss for fluid milk processing are shown in Table 13. Most authors have agreed that almost any dairy plant should be able to achieve a 50% reduction in water use and waste load.

For fluid milk processing, plants are operating with less than 100 gallons of water use and 0.5 pounds of BOD_5 per 1000 pounds of product. Every plant may not be able to achieve these levels but management can make significant reductions if they are dedicated to change.

Table 13. Coefficients for Fluid Milk Processing in Case Study Plant.[a]

Process	Water Use	Effluent[a]	BOD_5[a]	Product Loss	Fat Loss
		Fluid Milk	Processed		
	(gal/1000 lb)	(gal/1000 lb)	(lb/1000 lb)	(lb/1000 lb)	(lb/1000 lb)
Receiving	16	16	0.2	2	.07
Separation	2	2	0.1	1	.03
Clarification	2	2	0.1	1	.03
Raw Storage	20	20	0.2	2	.07
HTST	110	100	1.3	14	.45
Pasteurized Storage	20	20	.2	2	.07
Filling	10	10	.3	3	.10
Conveying	1	1	.1	1	.03
Storage	2	2	.1	1	.03
Returns	12	12	.4	4	.14
Distribution	5	5	-	-	-
Miscellaneous	10	10	-	-	-
Total	210	200	3.0	31	1.02

[a]Carawan, 1977

Case Study

Traditionally dairy food plants, handling fluid milk and ice cream, have relied on their Federal monthly market report to assess their product losses and have assumed that these are equivalent to their organic waste loads. The Federal Market Order permits a 2% product loss without payment penalties and most plants feel that they are doing well if they achieve a reported loss of 1% for milk fat and/or skimmilk.

Analyses of COD and BOD in waste streams can be used to more accurately reflect true loss and the degree of preventable losses can be estimated by using standard raw waste loads (SRWL) for good management practices. To utilize this approach a number of calculations must be made. In these calculations the following assumptions are made, based on industrial experiences:

(a) Product loss is in equivalent pounds of 3.5% fat milk with a BOD_5 of a 100,000 mg per liter.

(b) An average of 90% of the BOD load of a dairy plant is derived from product losses.

On the basis of the pounds of BOD lost per hundred pounds of BOD processed values relating % loss and BOD loss are as follows:

%Product Loss In Market Report	Lbs of BOD Lost/100 lbs of Processed BOD or (1000 lbs at 3.5% Milk Processed)
0.5	.56
1.0	1.11
1.5	1.67
2.0	2.22
2.5	2.75

It is possible to make a predictive estimate of losses based on dairy production figures and judgement of management efficiency and the assessment of waste loads for different levels of management and advanced technology. This procedure involves use of milk equivalents or calculations of the pounds of BOD_5 processed; an assessment of management proficiency; and a calculation of expected waste loads for a given level of management efficiency.

Calculation of BOD Processed: The simplest approach is to use milk equivalent values to convert all products back to 3.5% milk. In this case, the # BOD processed

= (pounds of product x milk equivalent) x 0.1 pound of BOD/ pound of 3.5% milk.

Milk equivalents:

Skimmilk	0.72
2% milk	0.82
3.25% milk	0.87
3.50% milk	1.0
Cottage cheese	6.3
Ice Cream	2.7
Condensed milk	2.4
Dry whole milk	7.4
Dry skimmilk	11.0
Dried whey	18.0
Cheddar cheese	9.9
Butter	21.3

A more accurate approach for a multiple product plant is to calculate BOD from composition.

Example

The following is an example of the calculations needed for a milk, ice cream and cottage cheese plant.

Milk:

a) for 3.5% milk,
pounds of BOD_5 = pounds of milk x 0.10
(where: BOD_5 = 100,000 mg/l)

b) for mixed fluid products,
pounds of BOD_5 = pounds of product x [(% fat x .09) + (% protein x .103 + % carbohydrate x 0.065)]
(where: # of BOD_5/# of product = 0.9, 1.03, and 0.065 for fat, protein and carbohydrate, respectively.)

Ice Cream:

a) for 10% fat ice cream,

pounds of BOD_5 = pounds of ice cream x .320

(where BOD_5 = 320,000 mg/l)

b) for frozen deserts of mixed composition,

pounds of BOD_5 = pounds of product x [(% fat x 0.09 + (% protein x 0.103) + % carbohydrate x 0.07)]

Cottage Cheese:

Cottage cheese is a blend of curd and cream dressing.

$$\text{pounds of } BOD_5 \text{ processed} = \left[\left(\frac{\%\ \text{curd}}{100} \times \#\ \text{of}\ BOD_5\ \text{in skimmilk processed}\right) + \left(\frac{X\ \text{dressing}}{100} \times \#\ \text{of}\ BOD_5\ \text{in dressing}\right]$$

$$\text{pounds of } BOD_5 \text{ processed into curd} = \left[\text{pounds of curd} \times \frac{100}{\left(\frac{\%\ \text{yield of curd}}{100}\right)} \times .072\right]$$

(where skimmilk = 72,000 mg/l BOD_5; generally this would be pounds of curd x 0.4752)

pounds of BOD_5 from dressing = [(pounds of dressing)] x [(X fat x 0.09) + (% protein x 0.103) + (% carbohydrates x 0.065)]

The pounds of BOD processed into milk, ice cream, and cottage cheese are shown for a case study plant in Table 14 for 6 months during 1976. Milk was calculated as a 3.5% fat product, ice cream was calculated on the basis of 10% milk fat and cottage cheese was a blend of 55% curd and 45% dressing with 165,000 mg/l BOD_5.

The BOD coefficients for "Average, Good and Excellent" management levels are given in Table 15. These coefficients were based on the industry observations by Dr. W. J. Harper of The Ohio State University.

Using data in Table 14, and coefficients in Table 15, total BOD for different levels of management were calculated and compared to total pounds of BOD based on the sewer bill and on the market report (Table 16). The

Table 14 - Pounds and Percentage of BOD Processed for Milk, Cottage Cheese, and Ice Cream Operations for Six Months.

Month	Milk		Ice Cream		Cottage Cheese	
	# BOD	% of Total	# BOD	X of Total	# BOD	% of Total
1	77.022	53	58,894	40	10,357	7
2	66,794	50	56,886	42	11,149	8
3	84,664	41	68,192	41	11,619	8
4	70,274	48	65,165	44	11,730	8
5	79,078	49	72,478	45	10,718	6
6	80,757	48	76,408	45	12,155	7

Table 15. BOD Coefficients for Three Levels of Management.

Level of Management	Lbs of BOD Lost/100 lbs of BOD Processed			
	Milk	Ice Cream	Cottage Cheese	
			Plus Whey*	Whey Excluded
Excellent	0.3-0.5	1.5	32	1.0
Good **	1.0	3.0	35.5	2.2
Average**	2.5	5.0	39.5	8.0

*1.32 x 76,000 mg/l skimmilk = 100,000 mg/l; 1320 lb skimmilk = 100 # BOD

**The difference between this value and excellent = preventable wastes.

daily BOD loss tabulations show that the values from the market report are generally about l/5 to l/4 of the losses calculated from the city sanitary report. This type of comparison is not unusual and generally market report losses are much less than those determined from actual measurement of losses. In this particular situation, the city sanitary report is based on a single period analysis of BOD and these values would probably be considered to be inaccurate. The city is making its survey, surveyed for one week and the analyses are based on time aliquot and not flow proportional aliquot samples.

The calculations of estimated losses under different management levels and comparison to sewer losses provides a basis for assessment of the waste mangement for the plant and also gives a starting point for the development of a program of waste control

Wastewater flow is given in Table 17. Water usage in an average milk-ice cream-cottage cheese plant is 444 gal/100 lb BOD processed, in good plants it is about 250 gallons/100 lb BOD_5, and in the best plant it is 100 gallons/100 lb/BOD_5. Cottage cheese cooking, cooling and washing requires about 200 gallons/100 lb of BOD processes. Goals for any plant can be set using the current usage and comparing this with the industry average.

This approach can be used to determine where the plant is in respect to waste control following the initial survey.

The steps to follow are:

1. Determine % of each product produced.
2. Calculate BOD (or COD) for each product.
3. Calculate total BOD processed.
4. Calculate an expected BOD (COD) loss/100 pounds of BOD processed from data in Table 15 and % of product processed.
5. Compare these figures to those obtained in the survey.
6. Differences between survey data and those for excellent management provide an index on the preventable waste in the plant.

Detailed Plant Survey and Special Studies

After the initial survey, and the determination of preventable vs unpreventable wastes, a series of detailed studies need to be undertaken.

Table 16. Estimation of Daily BOD_5 Loses by Various Methods.

# BOD Loss/Day-					
Month	Based on Market Report	Production Management Analyses** Excellent	Good	Average	Based on City Sewer Bill*
Jan.	2,708	4,250	6,375	9,044	7,640
Feb.	1,923	4,765	6,202	8.763	6.662
March	1,190	5,115	7,566	10,713	8,129
April	2,458	5,337	7,565	10,690	9,047
May	1,498	4,785	6,489	8,536	7,946
June	1,750	5,080	7,181	10,060	9,560

*Based on single survey of 7 days made in 1975; samples based on time composites (1539 mg/l) (considered to be low by about 25% on basis of testing method).

**Using coefficient in Table 15, including cottage cheese with whey included.

Table 17. Wastewater Coefficient in Gallons/lOO# BOD Processed.

Period	Total BOD Processed/day	Total Waste Water/day (gal)	Gal/lOO# BOD
1	148,273	595,238	401.4
2	134,830	519,048	385
3	164,476	633,333	385
4	147,169	704,762	479
5	162,274	619,048	381
6	169,323	650,715	384

Continuous Wastewater Survey

A continuous survey of wastewater and waste strength being discharged from plant. This will involve measurement of flow and sampling -- preferably on a flow composite basis. Analysis will be made to provide continuous data on waste loads.

Water Use Survey

Determination of water coming into the plant and specific determination of water utilization within the plant.

Materials Balance

Determination of products in and products out to determine product losses. This will include determination of the BOD lost related to product lost.

Departmental and Unit Process Survey

The study of the contribution of individual unit operations and for different departments in a multi-product plant, to the water and waste loads.

Energy Survey

Determination of energy losses by unit processes and by department.

The analyses to be made will depend to a large part on permit and/or municipal ordinance requirements. In most cases, these will include volume, BOD and suspended solids. In many cases, analyses will also be required for nitrogen, phosphorus, chloride, and fats, oils and grease.

For rapid results, that can be useful in assessing losses, and also to approximate BOD, the COD test provides some very real advantages. The test can be accomplished in 2-3 hours as compared to 5 days and does provide a means for assessment of product loss. To estimate BOD it is necessary, over a period of time, to establish a BOD/COD ratio and this ratio can be utilized to predict an approximate or estimated BOD. In most plants, over a continued period of time, the ratio will be relatively constant, although the ratio from individual unit operations may vary widely. An industry average of .45 $\pm$ .03 is common for most dairy plant operations.

A recommendation is made that COD and flow measurements be made on a regular basis on a 24-hour composite. The time of initiating and stopping samples should be related to the beginning of the work day and will vary widely from plant to plant. It is extremely useful to take a series of samples and to correlate these samples with operations within the plant. This study may be of a relatively short-term basis on detailed analysis, such as over a 2 or 3 week period. However, continuing to take multiple samples and cornpositing them on a daily basis has the value of being able to very rapidly assess what has happened in the previous 24 hours.

Water meters should be installed at all high use areas, as well as determination of water-used in product make-up. An accurate measurement of water in versus water out provides a basis for establishing a more realistic charge basis for muinicipalities. Most municipalities, in the absence of records, will charge for waste treatment at a volume equal to that of the water coming into the plant. Records provide a basis for obtaining charges on waste volume discharge only.

In-Plant Control of Dairy Wastes

Introduction

Most food plants fail to measure wastes as a separate identifiable byproduct. Management generally recognizes only product recovery in terms of finished food yields, either as percentages or as pounds per ton of raw ingredients. Management generally ignores those wastes which are not recovered and sold. Most food plants fail to accurately account for the water used in processing food and materials into finished food products. Record keeping is expensive and has increased enormously in all industries. Plant managers often try to avoid duplicating accounting records by substituting required records for inhouse needs without a very thorough review of the situation. Records should be tailored to fit the individual needs of the user. They should not be generated just for use for outside agencies. Though rather adequate information should be collected continously for use by management to determine efficiency, profits, and the need for changes. Each food plant has inherent product loss factors due to the building, equipment, chillers and the like. Product accounting is meant to explain where and why there are differences between receipts and usage and to pinpoint any locations where these losses might be reduced. For example, when an employee decides to fill 1 pound cartons of food products with 1 lb 2 oz to avoid any short weights, then the plant experiences unexplained losses if accounting records and bookkeeping notation credits each unit produced with being only 1 pound.

Probably no food firm exists that is not troubled daily with operational problems created by its own staff of men and women. Each day's food plants require workers with technical expertise in areas of sanitation to electronics as we seek improved operation and sophistication through automation. Workers must be unafraid of horns, buttons and lights and have professional pride in their speciality.

New workers are generally fast to learn, well informed, worldly and generally mechanically inclined. They do not want to work an 80 hour work week. The new applicant to a food plant wants instruction on the job as to what he is suppose to do and what takes place biologically and chemically in the product as he works with it. Training workers to develop pride in their occupation in the food field is a real task and concern for management. The manager of any food plant must realize that he cannot do everything alone. Food processing plants today work around the clock seven days a week.

Waste control in a food plant can be improved through proper scheduling. Shut downs, regardless of the cause, represent lost time which can never be recaptured and generally result in loss product. Documentation of operations is needed in the form of a written log or a recording chart which highlights variances from norms. Workers will forget what happened two days ago and management needs to make changes if a particular piece of equipment is frequently shut down. An evaluation of need changes to increase efficiency can only be made from properly kept records. Good records, not guess work, are necessary for keeping a business prosperous and waste free.

In-Plant Control Measures

The control of dairy wastes requires many in-plant measures which combine to effectively reduce wastes in dairy processing. A number of the following steps are necessary to solve a dairy plant waste problem:

(1) See that the entire program has the active support of management.

(2) Install modern equipment and piping in order to reduce loss of products.

(3) Impress the people working in the plant with the importance of reducing wastes.

(4) Secure the proper separation of wastes into process wastes, sanitary sewage and clean water.

(5) Provide for recovery of by-products.

(6) Select and install the waste disposal system best suited to your plant.

(7) Follow through with good operation and maintenance in both the dairy plant and the waste treatment plant.

In-plant control measures for the control of dairy wastes, include plant management improvement, employee education and motivation, proper scheduling, segregation of concentrated wastes, proper design and utilization of engineering processes, by-product and waste product recovery and water use reduction practices.

Plant Management Improvement. Management is one key to the control of water resources and waste within any given dairy plant. Management must be dedicated to the task, develop positive action programs, and follow through in all cases to control water and waste. For best results, a clear understanding of the relative role of engineering and management supervision in plant losses is needed by management.

The best and most modern engineering design and equipment cannot alone provide for the control of water and waste within a dairy plant. In fact, Table 18 presents some. aspects of modern plants contributing to wastes. A new (six-month old), high-capacity, highly automated multiproduct dairy plant, incorporating many advanced waste reduction systems, was found to have a BOD_5 level in its wastewater of more than 10 g/kg (10 lb/1000 lb) of milk equivalent processed (EPA, 1974). This unexpected and excessive waste could be related directly to lack of management control of the situation and poor operating practices. Management must do their part to have an effective water and waste control program in dairy processing. Management's role includes:

(1) Understanding water and waste control in dairy processing including the need for such a program, the economic benefits that can be accrued and being cognizant of all interrelated factors,

(2) Developing job descriptions for all plant personnel,

Table 18. Characteristics of Mechanization and Automation Which May Increase Waste Loads.[a]

Characteristic	Description
1.	Utilization of chain and belt conveyors requires relatively high quantities of lubricants which are high BOD_5 containing materials.
2.	Incorporation of casers, case stackers and conveyors increase spillage and loss of product to drain in relatively large volumes because of the dumping of entire cases or case stacks if the equipment is not continuously maintained in good operating conditions.
3.	Utilization of high capacity equipment up to 100,000 pounds per hour. In the case of pasteurizers, the start-up, shut-down or product changeover of a pasteurizing unit operating 100,000 pounds an hour will cause product loss of about 1700 pounds (170 pounds BOD_5/minute) diverted to drain.
4.	CIP separators which shoot sludge to the sewer every thirty minutes have increased the waste load. With hand-cleaned separators it was possible to scrape out the sludge and handle it as a solid waste.
5.	The product lines in large capacity plants that are CIP cleaned hold from 0.8 to 1.2% of the total milk received. Careful design of piping systems, maximum utilization of gravity draining, adequate time for draining product before initiating the washing cycle, and proper designed air blow-down are essential to avoid excessive losses.

[a]Harper _et al_., 1971

(3) Providing an environment that permits supervisors to supervise waste management and

(4) Utilizing a continuing education program such as that outlined by Carawan and Jones (1977).

Recommendations for management control of wastes are listed in Table 19.

Harper, et al. (1971) made visitations to evaluate management practices at 20 dairy plants for which waste data was available. After their visits they developed a number of criteria for evaluating a dairy plant's water and wastewater management practices as shown in Table 20. Although their criteria were described as subjective in nature and not lending themselves to quantification, they concluded that the listing lends itself to describing the over-all quality of management practices with respect to waste control. They recognized and demonstrated the influence of management practices affecting waste coefficients, both volume and BOD_5 coefficients, and this data is summarized in Table 21. Evaluation of the information indicates a direct 'relationship between the quality of management practices with respect to wastewater and waste coefficients.

Under good control, both wastewater volume and BOD_5 coefficients were low. Based on observations obtained during the investigation of Harper et al., wastewater volume or BOD_5 levels below one pound/pound and one pound/1000 pounds, respectively, were expected if management was conscientiously carrying out good practices (Table 20). Under poor management, both BOD_5 and volume coefficients were described as high. They concluded that values greater than 3.0 lb wastewater/lb milk received or 3.0 lb BOD/lOOO lb milk received would reflect poor management practices.

The Development Document presents the conclusion that the minimum level of wastewater and BOD_5 load would be found in a fluid milk plant. The minimum level thought attainable with current technology would be 100 gal wastewater/1000 lb milk received. Also, the minimum waste load level would be 0.5 lb BOD_5/1000 lb milk received. These values would correspond to a wastewater concentration of approximately 600 mg/l BOD_5.

Employee Education Program. Carawan et al. (1972) observed the need for a program of employee education in water and waste related areas

Table 19. Recommendations for Management Control of Dairy Wastes.[a]

Number	Recommendation
1)	Installation and use of a waste monitoring system to evaluate progress.
2)	Utilization of an equipment maintenance program to minimize product losses.
3)	Utilization of a product and process scheduling system to optimize equipment utilization, minimize distractions of personnel, and assist in making supervision of the operation possible.
4)	Utilization of a planned quality control program to minimize waste.
5)	Development of alternative uses for a wasted product.
6)	Improvement of processes, equipment and systems as rapidly as economically feasible.

[a]EPA, 1974

Table 20. Criteria for Evaluating Dairy Plant Management Practices.[a]

Number	Criteria
1)	Housekeeping practices.
21	Water control practices; frequency with which hoses and other sources of water were left running when not in actual use.
3)	Degree of supervision of operations contributing to either volume or BOD coefficients.
4)	Extent of spillage, pipe-line valve leaks, and pump-seal leaks.
5)	Extent of carton breakage and product damage in casing, stacking and cooler operations.
6)	Practices utilized in handling whey.
7)	Practices utilized in handling spilled curd particles during cottage cheese transfer and/or filling operations.
8)	Utilization of practices to reduce the amount of wash water from cottage cheese or butter operation.
9)	Extent-to which the plant is utilizing procedures to segregate and recover milk solids in the form of rinses and/or product from pasteurization start-up and product change-over.
10)	The procedures utilized in handling returned products.
11)	Evaluation of the management attitude toward waste control.

[a]Harper et al., 1971.

Table 21. The Effect of Management Practices on Wastewater and BOD_5 Coefficients for Multiproduct Dairy Plants[a]

Products	Milk Received	BOD_5/Milk[b]	Wastewater/ Milk[b]	Level of Management Practices
	(1000 lb/day)	(lb/1000 lb)	(lb/lb)	
Milk, Cottage Cheese	1,000	8.6	2.0	Poor
Milk, Cottage Cheese	900	3.3	1.1	Fair
Milk, Cottage Cheese	1,000	4.12	1.2	Good
Milk, Cottage Cheese	465	1.8	1.1	Good
Milk Ice Cream Cottage Cheese	400	3.9	1.4	Fair
Milk Ice Cream Cottage Cheese	800	7.7	3.5	Poor to Fair
Milk Ice Cream Cottage Cheese	600	12.9	3.3	Poor
Milk Ice Cream Cottage Cheese	900	9.1	2.8	Poor

[a]Harper et al., 1971

[b]Milk Received

for dairy processing employees. A program was presented and has been modified after actual plant use (Carawan and Jones, 1977).

The key to a successful water and waste management program was postulated as a water-waste supervisor with responsibility for plant water use and waste (Carawan and Jones, 1977). Their program places emphasis on management knowledge and action. All plant employees are scheduled for four hours of instruction in water and waste management terminology and techniques.

Zall (1968) expressed his belief that employees reduce water use and wastes. He cautioned that records are necessary to keep them aware of their progress. However, he concluded that first employees must understand about water and waste management in dairy processing.

Segregation of Dairy Wastes. Zall pointed out that stringent regulatory control forced operators to prevent water from being mixed with dairy products. Cleaning and rinsing waters accumulated milk or milk product residuals from storage tanks, vats, pipe-lines, and other pieces of equipment. He noted that piping and equipment in a dairy plant will sometimes dictate inherent product losses. Zall noted that dairy plant management can successfully recover product losses and salvage these materials for useful purposes.

Harper et al. (1971) cautioned that when planning new dairy plants or remodeling existing facilities consideration should be given to the segregation of those sewers expected to receive high BOD_5 wastewaters. Wastewaters from high BOD_5 drains could be returned to a tank to be metered out for load equilization or subjected to pretreatment. They indicated that lubricants, milk from filling areas, solid particles from cottage cheese operations, HTST discharge and CIP discharges would all be areas to consider segregating and combining into a high strength waste.

Besides strong process wastes, wash waters, cooling waters and sanitary wastes are other waters that may be segregated (MIF, 1967). Wastes should be segregated to reduce the volume and to reduce the strength of wastewaters. Either of these can reduce the installation and operating costs of waste treatment facilities. Surcharges can also be reduced.

Scheduling. Zall and Jordan (1973) pointed out that scheduling is one of the best waste controls in the dairy processing plant. An example is given of running chocolate milk between two white products thereby requiring two water rinses between the products with the flushing of product to the sewer. Unnecessary shutdowns or other interruptions were said to almost always produce product losses to the sewer. These unnecessary shutdowns might be prevented if written records as to the cause of stoppages were made enabling corrective action.

By-Product and Waste Product Utilization. Harper et al. (1971) pointed out that because of the national attention and visibility of whey as a waste product, the dairy industry was aware of the significance of using whey as a food or feed product to minimize pollution and to gain a profit from such operations. However, they indicated that the dairy industry was less aware of the potential in respect to the utilization of product rinses, dilute milk solutions resulting from start-up, change over and shut-down of pasteurizers on water, which is a major source of BOD_5 in most milk plants and the recycling or utilization of returned product. Carawan (1977) presented details of product recovery systems such as shown in Figure 10.

The complete removal of whey from wastewaters is a continuing problem in the United States. Harper et al. (1971) estimated that about 20% of all the milk processed ends up as whey of one type or another. Also, there is a limited market for whey solids, and technological problems in developing products from whey. Acid whey, because of the presence from 0.5 to 0.7% lactic acid, provides problems in respect to drying the material and also in respect to its utilization in food. Many industry leaders still feel that whey is a disposal problem or hog feed rather than a food. Wisconsin whey (other than cottage cheese) use had gone from less than 30% to 91% in ten years. Estimates indicate that 70 to 74% of the sweet whey is utilized while only 20% of the acid whey is utilized.

Foam Spray-drying, foam mat drying, reverse osmosis, gel filtration, mysost cheese making, electrodialysis, hydrocolloid protein precipitation, ultrafiltration for protein recovery, utilization or the growth of yeast protein, fermentation and animal feed use are all methods which have potential for the conversion of whey into more usable forms. Whey can be fed to animals and ruminants can consume up to 30% of their dry-matter intake as liquid whey while swine often experience diarrhea if more than 20% of their dry matter is liquid whey. Further, calves have been fed up to 89% dried whey with favorable growth rates.

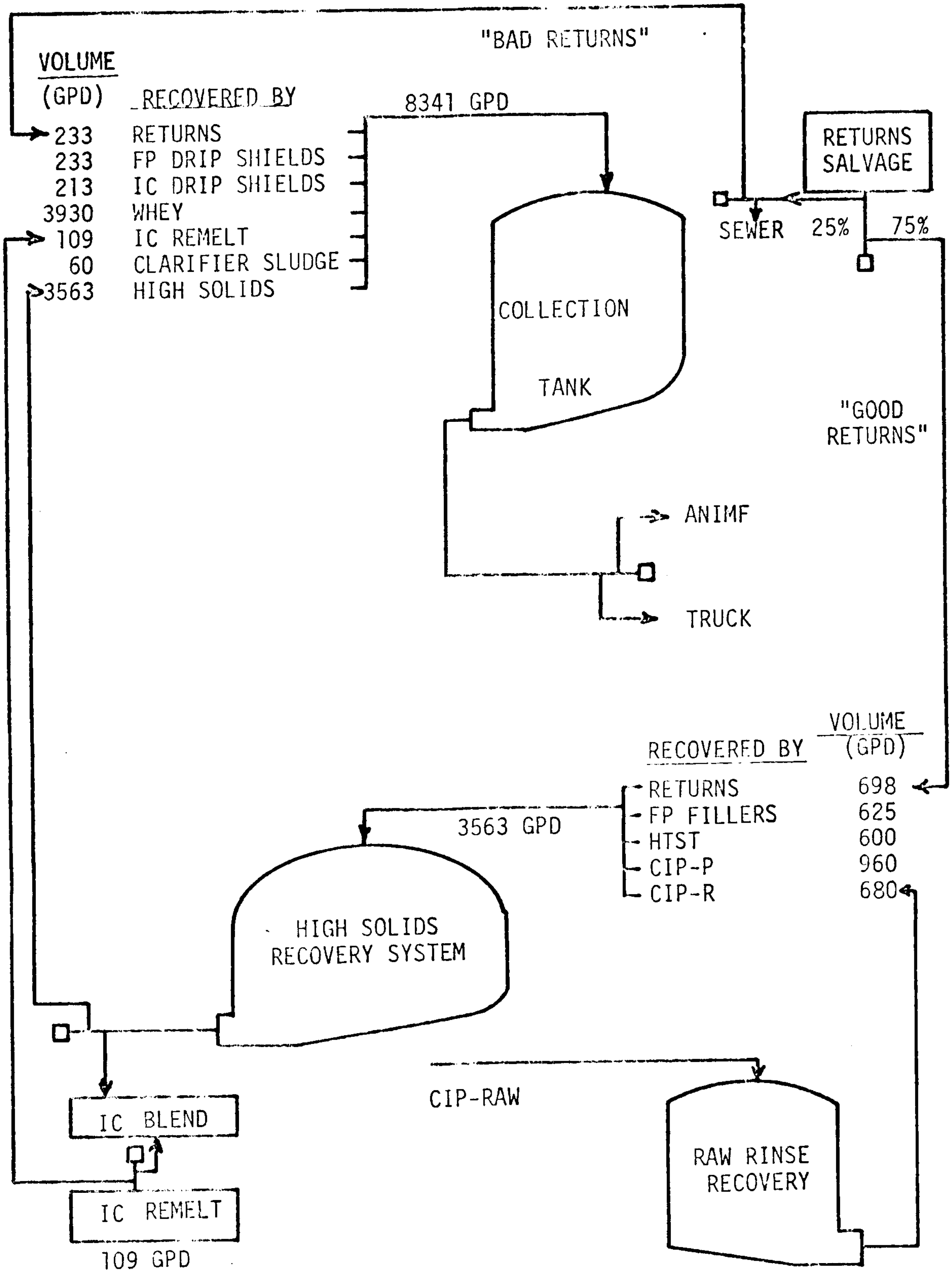

Figure 10. Schematic. of Dairy Product and Diluted Product Recovery for a Dairy. (IC = Ice Cream, FP = Fluid Products, ANIMF = Animal Feed, P = Pasteurized, R = Raw, TRUCK = Truck Disposal on Land)

Watson et al. (1977) reported on recent investigations with spreading whey on agricultural lands. Proper practices for land spreading whey on agricultural lands. Proper practices for land spreading were detailed and explained. They reported that up to 102 mm whey yearly produced improved corn yields and that the beneficial effect could be observed a year after application.

Harper et al. (1971) expressed the opinion that one of the most promising developments in respect to whey utilization lies in recovering the protein fraction. The nutritional value of the whey protein exceeds that of casein and the protein has unique whipping and emulsifying properties. Removal of the protein from the whey reduces the whey solids approximately 13% and the BOD approximatley 20%.

Nickerson (1976) reviewed the use of the milk derivative, lactose, in other foods. Lactose use in foods was based on its specific properties which were given as relative sweetness, browning reaction, protein stabilizing properties, alteration of crystallization patterns, flavor accentuation, selective fermentation and nutritional attributes. Specific food uses listed included toppings and icings, fresh-pack pickles, baked goods, candy, milk based beverages, beer, wine and infant foods.

Harper et al. (1971) indicated the potential exists for elimination of all the milk solids present in rinse waters from tank truck, storage tanks, lines and equipment, for saving the milk solids diverted to drain in the start-up, changeover, and shut-down of HTST pasteurizers and for removal of milk solids put into the wastewater by virtue of returned products. They estimated that up to one pound of BOD_5 per thousand pounds of milk processed could be eliminated through the collection and utilization of these solids. Also, in the case of highly viscous products, such as cream, churned buttermilk, sour cream, yogurt, ice cream mix and similar products, they estimated the amount of BOD_5 that could be recovered from wastewaters might be as high as three pounds per thousand pounds of product in some plant operations. These diluted milk solids are considered to be adulterated products by many health officials and changes in laws and regulations will have to permit their utilization of foods. They observed that methods for segregation and utilization of these dilute materials are needed. Two possibilities were mentioned with present laws and technology. First, a possibility exists at the present time of using them in ice cream mix or any other products where solids must be added to the material. Second, the possibility also exists of utilizing reverse osmosis to concentrate the materials. This will require additional membrane technology since protein and lipids tend to foul the reverse osmosis membranes currently in use.

Harper et al. (1971) related that dairy automation systems could be used to help recover rinses from tankers, tanks and lines. They reported that a 6000 gal raw milk tanker normally was rinsed with 250 gal of water and this rinse contained 9.10 lb BOD_5. An initial 30 gal burst-rinse could recover 7.5 lb BOD_5. The rinse contained 1.5% butterfat and reduced the receiving process BOD_5 coefficient by 0.05 lb BOD_5/1000 lb milk received. The fat content was observed to be 3.4% butterfat for high solids products or rinses from tank trucks which has over 1 hour before unloading (see Figure 10).

Water Use Reduction. The reduction of water use will simultaneously reduce wastewater discharge. Farrall (1976) has presented information on the water used in food processing. He emphasizes a number of techniques to reduce water use. First, he recommends controlling water use at hose stations and recognize the value of shut-off nozzles. Solenoid valves were recommended for equipment which is operated intermittently such as can washers, condensers and other equipment. He noted that water regulating valves are commonly used for refrigeration systems where the volume of water needed is influenced by the system head pressure. Last, he urged the use of evaporative condensers for refrigeration systems. Water use can be reduced by as much as 95% when an evaporative condenser replaces a shell-and-tube condenser.

The water quality needs for dairy plants have been reviewed (MIF, 1967). They concluded that water conservation is a part of and intimately related to waste saving. A number of water conservation measures were suggested and they are presented in Table 22.

Potable water is normally used in a cleaning in-place (CIP) system to flush the product from the lines, act as a carrying and flushing agent to clean the lines, to flush the cleaning solution from the lines and finally as a carrier or sanitizing agent. The CIP operation is probably the largest water consumer in a normal dairy plant operation. The water use

Table 22. Water Conservation Measures.[a]

Number	Description of Conservation Measures
1.	Adopt a definite water conservation program and make all personnel familiar with the program. The program should be discussed frequently in plant meetings and employees encouraged to make suggestions for further savings.
2.	From time to time a thorough study should be made to determine where additional water savings can be effected without sacrificing product quality or good housekeeping.
3.	Wherever economical, water used for cooling purposes should be re-used for other purposes or recirculated over a cooling tower, in a spray pond, or through an evaporative condenser.
4.	Only where cheap and abundant water is available should it be used for cooling and then discharged to a storm sewer or water course.
5.	Hot water should be supplied from a hot water tank rather than from mixing tees.
6.	Water running through hoses should be shut off when not in use.
7.	All hoses should be equipped with shut-off valves.
8.	Cleaning should be done by recirculation with re-use of cleaning solutions as long as they are effective.
9.	Wherever economical, condensate from heaters and overflows from hot water circulating systems should be returned to the boilers.
10.	Fix leaky water lines or valves as soon as leaks are detected.
11.	Eliminate product wastes due to leaks and spills to help reduce the amount of water needed for cleaning.

[a]MIF, 1967d.

depends greatly on the type of CIP system installed and also on the decisions that have been made by the operator in terms of time of rinse. For instance, the rinses for a CIP system might consist of pre-rinses with volumes of 250, 95, and 110 gallons. Post-rinses after CIP cleaning could be 20, 75 and 100 gallons. Thus, for each CIP cycle, a total of 650 gallons of water would be used for the rinses for each CIP cycle. Most modern dairy plants have at least two and possibly three or more CIP systems. The total number of cycles may exceed 30 cycles per day.

One dairy has installed a water reclaim tank. This larger dairy installed an 8,000 gallon tank which receives and stores uncontaminated water from two air compressors and a vacuum pump. The water is cooling water and is delivered to the tank heated above the inlet temperature. When a CIP system demands, the reclaim tank supplies the need when there is sufficient quantity in storage. This particular dairy has found that the reclaim tank supplies an adequate amount of water during the day. However, during the final period of cleanup which includes the pasteurized milk lines and associated tanks, the large CIP system is activated and the supply is inadequate and city water supplements the demand.

When the demand for reclaim water is less than the in-flow the reclaim tank in the tank recovers to the capacity, the tank then over-flows to the wastewater system. In as much as the demand on the system is relatively light during day, and the supply from the compressors and vacuum pump is relatively constant throughout the day, there is a substantial over-flow.

A study has shown that the tank over-flows a substantial part of the time, usually between 10 and 15 hours a day. The non over-flow occurs about midnight to about 5 or 6 AM because the compressors and vacuum pump are shut down during this time. The over-flow rate was measured at 22 gallons a minute and on the basis of discharging for 10 to 15 hours a day, this correlates to a discharge volume of between 13,000 and 20,000 gallons per day.

Proper Design and Utilization. Harper et al. (1971) observed that as plants incorporated cleaning-in-place (CIP) and process automation capabilities, proper design of plants and processes can afford material reductions in waste loads. The theoretical effect of advanced technology on reduction of waste loads was illustrated in Waste Profile No. 9 (FWPCA, 1967). Such reduction as that predicted for fluid milk plants from 2.6 to

0.5 pounds of BOD_5 per 1000 pounds of milk has not occurred in real practice within the industry at the present time.

Current design of HTST systems require that they be started and stopped utilizing water and Harper et al. (1971) found that the HTST start-up, changing from water to product and back to water, and the shut-down were the major sources of product losses to drain in the pasteurization process. They indicated that 60 gallons of product usually becomes diluted during each start-up, switch-over, or shut-down and is often dumped to the sewer. Also, as most plants start and stop pasteurizing units 2-3 times per day, then make about 6 changes a day, over 150 pounds of BOD_5 would be generated. An HTST recycle system, could save 44% of the BOD_5 normally generated in the pasteurization process. The BOD_5 coefficient would be reduced from 0.80 to 0.45 pounds of BOD_5 per 1000 pounds of milk processed. The recycle system would collect the diluted product-water mixtures during start-up, shut-down and product change-overs. Elliot (1977) has reported on such an installation in a new California dairy plant.

Harper et al. (1971) presented modern methods that eliminate intermediate process vats from processes or of fluid milk products. The system utilizes the centrifugal machine in the form of the clarifier-separator in combination with the HTST system. Seiberling (1976) discusses this system in detail. Harper et al., pointed out that product change-overs are made product-to-product with no discharge to the drain and the elimination of the intermediate vats saves product losses with a BOD_5 of 0.2 pounds per 1000 pounds of milk processed. They note the losses associated with the intermediate tanks for higher viscosity products such as cream may be 3.0 pounds of BOD_5 per 1000 pounds of milk processed.

Zall (1968) explained how water valves on hoses and modifications of plumbing to convey water to places of use can reduce water use. The use of the hose valves was mentioned as being not possible with cold water-steam mixing tees. He recommended that a central water heating system be installed to supply hot water to the hose stations. The pressure of delivery to hose stations should be 15-20 psi (MIF, 1967). A general recommendation was made by MIF (1967) that hose stations supply water at 115F. They noted that the needed wastewater temperature is controlled by the melting point of milk fat which is 84 to 97°F. They concluded that water hoses should not be used for "chasing" waste or debris such as caps, containers, or product toward the open floor or drain they emphasized. Long handled brushes or rubber-bladed devices were recommended.

Zall (1968) emphasized that one cannot fault workers for not turning off water when valves are difficult or impossible to operate because of faulty maintenance consequently allowing water to run needlessly. Also, changing needs for different temperature water were often not met because of the long walk to the hose control station. Zall recommended piping to be installed to each point in the plant where water is often required instead of using hoses for a supply source.

Elliot (1973) examined a number of new practices in dairy processing that relate to wastewater. He explained how CIP cleaning and welded pipeline systems have helped to reduce water use waste load and helped to automate dairy processing. He postulated that CIP cleaning was more efficient than hand cleaning and welded pipeline systems were not subject to leaks at joints. CIP systems were explained. The distinction between the "throw-a-way" or single use system and the "reuse" system was explained. However, his conclusion that less water is used in a "reuse" type system was not found in the study of Richter et al. (1975). They found for washing dairy transports that "reuse" type sytems required more than 500 gallons per tanker while a single-use system only used 217 gallons per tanker with identical cleaning and sanitation.

Elliot (1973) described the collection of milk-water mixtures for use in dairy products or for animal feeding. He observed that through the use of air operated valves, level controls and a timed flow element a dairy plant could collect product-water mixtures and intermixed products. He explained that both of these mixtures were not legal milk products. Also, he explained how the first rinses from CIP circuits could be similarly collected. Elliot (1977) has described a plant utilizing both of these concepts. Carawan (1977) included many of these concepts in his study of a case study plant.

The filling area is another area reviewed by Elliot (1973) for measures to conserve water and prevent product wastes from going into the plant wastewater system. He concluded that a plant recovery system was desirable to collect product from defective or damaged cartons. Conveyor lubricant usage in the filling area should be controlled as the lubricant contains about 25% hexane solubles.

Many plants were reported to have installed separators and clarifiers that automatically desludge (Elliot, 1973). The automatic desludging feature requires water and flushes solid residues to the sewer. Elliot concluded that the sludge should be collected.

Elliot (1977) noted the use of a water feed recovery system on a separator-clarifier. He reported that it saved 250 gallons per hour or 2500 gallons per day in a new, large dairy plant utilizing two separator-clarifiers.

Specific In-Plant Control Recommendations

Maintenance Program

The level of control of water and wastes in a dairy food plant can be correlated directly to the maintenance program in operation in the plant. A good waste management control program cannot be achieved without a good maintenance program. It should be stressed that a maintenance program involves more than the engineering department. Operators of equipment are also essential to the maintenance program. Communication between operators and plant engineers is essential. Too often a situation develops where the operator states that the problem is because the engineer hasn't fixed the equipment, and the engineer says that the operators are using the equipment incorrectly. In such instances, nothing gets done and waste can increase markedly. Also in such cases, there is often a bit of truth in the viewpoints of both parties. This interface between engineer and operator is a critical one and must be recognized by management and the waste control manager as a key in the success of the waste control program.

The larger the plant, or the more shifts in operation, the more difficult is the achievement of good waste control and a continuing good preventative maintenance program. Recognition must be given to the need for adequate supervision of second and third shifts, in order to obtain the greatest efficiency from the engineering crew.

A maintenance program should be separated into four parts: (1) emergency repair, (2) "chronic" repair or minor repair, (3) operator-associated maintenance, and (4) preventative maintenance. Of these, the operator-associated maintenance and the preventative maintenance programs are most important to waste control and generally the ones given the least attention.

In respect to water and waste control, the preventative maintenance program includes more than the routine oiling of parts and equipment -- such a program requires a regular survey of plant equipment with attention to those aspects that create waste problems.

Operator-Engineering Interfacing: To facilitate communication between the plant engineer(s) and the operators, a system needs to be developed to provide a means for operators to initiate maintenance requests. At the same time, a method needs to be established to permit the engineering staff to initiate action to correct operator-induced problems associated with improper *use* of equipment.

In the small plant, oral communication generally will be adequate, because in most instances this works well and directly. In large, multi-product and multi-shift plants, a more formal system is frequently required. For this purpose a "Maintenance Request Form" provides a means of allowing operators to initiate maintenance requests. These requests should be routed through the Production Superintendent to the Engineering Department. The Chief Engineer will fill out a "Work Order Form" with an expected date of completion. The Waste Control Manager can *serve* as coordinator and expediter, to make sure that dates are realistic and also that dates are met. Follow through on repair requests is essential to the success of the program and to keeping communications open between the Production and Engineering Departments.

In respect to training of operators on the care and operation of equipment, the Chief Engineer or his delegate should take an active part in the training program.

Operator Responsibilities: Management is responsible to see that operators are fully trained in the use and operation of assigned equipment. The Chief Engineer, or the Waste Control Manager, as training officer, should instruct each new operator on the engineering aspects of the particular equipment. In the latter instance, the Chief Engineer should provide information and follow-up to insure that the operator is familiar with all essential engineering-related information. This should include:

1. Information on how to disassemble equipment, including tools to use and precautions in handling each subpart to prevent any damage -- especially to metal-to-metal contact surfaces that could cause leakage.

2. Detailed instructions on machine settings. This is particularly important in respect to packaging equipment, where there may be a number of settings that must be made on a regular basis. The operator should understand the interdependence of the settings on complex equipment.

3. Instruction on how to assemble lines and equipment and how to check on proper alignment and set-up.

4. Instruction on the interrelationship between the operator's job and other operations in the plant that may result in wastes. Compliance to pre-planned production scheduling can be a factor in a maintenance program and also to plant losses.

5. Instruction on proper shut-down procedures for the equipment in an emergency situation.

6. Information on how to initiate maintenance requests.

Above all, the operator must exercise care in the handling and operation of the equipment and to minimize engineering repair requirements and also minimize direct loss through leaks, spills, etc.

<ins>Preventative Maintenance</ins>: A regular program of preventative maintenance should be in continual operation. In many multi-shift plants, this preventative maintenance may best be fitted into the third shift -- since this is generally the period of lowest processing operation in most plants. A sufficient engineering staff should be available to take care of emergency repair and also provide for a continuing preventative maintenance program. A preventative maintenance program includes:

1. A regular planned replacement of worn parts, gaskets, and fittings.

2. A regular routine inspection of the plant on a planned basis, giving attention to leaking connections, valves and pump seals. In complex, multi-product plants, a rotational basis for regular inspection of components may be desirable. A few units per day or per week to provide complete review every three months may be adequate. Where leaks are noted, a work order should be placed for routine repair on a priority basis -- with the most serious situations being given highest priority (once a week).

3. Routine and regular check of pipelines, to make sure that lines have retained their pitch and that they are free from vibrations (every 4 months).

4. Routine inspection and planned replacement of rubber gaskets and "O" rings on automated valves, filler parts, etc. (every 3 months).

5. Check of air-blow systems on a planned basis (every 2 months).

6. Check on operation of high level and low level controls (once a month).

7. Check on accuracy of indicating thermometers (once a month).

8. Inspection of settings on packaging machine (once a week).

9. Check filling valves and regrind as required.

10. Check homogenizer packings (once every 2 weeks).

11. Check on seals and automatic desludging systems on separators.

12. Check on equipment leaks (homo, pumps, etc.) that may cause overflows

13. Regularly check on flow and pressure drops in CIP systems to insure proper operation (every month).

Operation

The successful waste management control program requires continuous daily attention to detail. This involves the operators checking the equipment during start-up, ensuring that all fittings are tight and that no seals are leaking on the pumps. It also requires continued attention to the operational performance of the equipment, proper setting of machines and when small parts are being cleaned up, we need to *give* attention to care of the equipment to avoid damage. At the same time, there is a necessity to have open communication channels between the production and maintenance operations. Problems that require maintenance attention should be communicated promptly and follow-up, if possible, should be through the continuing maintenance program

Operational Maintenance. Every dairy plant preventative maintenance program to maintain all equipment in good operational form so as to avoid excessive water usage and waste discharges. Such a program requires daily attention from plant operators.

A maintenance program should include consideration of the following:

1. Regularly inspect water hose stations to insure no leakage of shut-off valves or supply lines. Valves and fittings having defective automatic shuf-off valves should be replaced.

2. All manual and CIP fittings should be inspected and replaced on a regular basis as needed.

3. Pump seals should be checked regularly to insure that they are not leaking and request repair and/or replacement whenever leaks are noticed.

4. All pipe connections should be checked regularly to insure that they are not leaking product or permitting the incorporation of air into the product which would cause foam.

5. All cases, conveyors, and stackers should be maintained in proper adjustment to avoid jamming and subsequent loss of product from spillage or broken packages.

6. Filler valves should be checked to see that they are not leaking product and are filling product to the correct capacity. Check machine adjustments to insure proper filling, capping and sealing.

7. Plastic and glass bottle fillers and cappers should be maintained in excellent condition to avoid breakage and product losses. A regular maintenance program should be adopted to maintain these machines in top operating condition to avoid jam and product spillage.

8. Centrifugal machines should be checked to insure that seals are maintained in good condition to prevent leakage of product. Automatic desludging separators should be checked during desludging to make sure the system is operating properly and not sticking open.

9. High level controls should be checked to make sure that they are in continuous operating condition.

The waste control supervisor should be making daily inspection tours through the plant, communicating with plant operators to determine any new problems and to check on follow-up and find out why corrections have not been made and then taking steps to facilitate the corrections. Unless maintenance problems are promptly attended to, the attitude of the operators will become negative, they will fail to report problems, and lose interest and motivation.

Tank Truck Receiving:

1. Make sure that each tank is properly connected to the transfer pump on initial unloading of the first tank day, check should be made to insure that all couplings and pump seals are not leaking. Immediate attention should be given to attempting to correct any leaks that are observed. If leaks cannot be corrected, then a request should be make to maintenance to make repairs.

2. Tank trucks should not be permitted to stand more than one hour prior to unloading. Long standing of tank trucks in the quiescent state permits creaming and once creaming occurs, even extensive agitation will not prevent adherence of the cream material to the sides of the tank.

3. Allow adequate time for the tank truck to drain prior to disconnecting the transfer hose. Care should be taken to show that all product in the transfer hose has been properly emptied prior to disconnecting the tank.

4. Where legally acceptable, a 20-40 gal burst rinse flush of the tanker with portable water should be made and this transferred to the silo. This is only feasible in large plant operations, where dealing with receipts into 20,000 gallon or larger silo tanks. The dilution factor for a standard tanker will be less than .01%.

Can Receiving: -Utilize a product-saving pre-rinse at the end of the can washer over the drip pan saver with adequate time for complete drainage.

Raw Receiving: Raw milk lines are generally filled with milk between receiving different lots of the product; at the end of the total receiving operation all milk should be removed from the lines between the receiving room and the storage tanks. In most modern operations this is accomplished by air blow down. In all cases the lines must be emptied prior to cleaning to avoid extensive product losses.

Processing

1. All sanitary fittings, valves, rotary seals, pump parts, and filler parts must be handled with extreme care during every phase

of operation to prevent damage to the surface which may cause leaks. Small parts should be properly washed in small parts washers and placed on rubber mats for draining to minimize any damage.

2. Do not use a constant running water hose in any area.

3. Employees should either eliminate the cause of spillage or report it to the waste control supervisor rather than washing away spilled product. Valves, pipelines, and pumps should be properly installed, and gaskets installed and carefully seated to prevent leakage.

4. Thoroughly drain all lines, tanks, and processing vats before rinsing. The process equipment surfaces should be rinsed as soon as possible after use so that the product does not dry on and increase cleaning requirements.

5. Make sure that all lines on the suction side of pumps are properly sealed to avoid air leaks and resultant foaming which can cause excessive waste.

6. Make sure that correct connections are made on plate type heat exchangers so that there is no possibility of milk being pumped to the water side of the exchanger or water being pumped to the milk side.

7. Make sure that all worn and obsolete equipment is observed during plant operations and reported to maintenance for repair.

8. Drips and leaks occurring during processing runs should be corrected if possible and if it is not possible, then the drips should be collected in containers and not allowed to go down the drains.

9. Where drip shields are supplied, they should be in place and provided with adequate containers for each day's operation.

10. For processing vats that are not supplied with high level shut-off controls, the employee responsible for filling the processing vat should pay careful attention to the filling operations so that overflows do not occur.

Packaging and Handling of Products:

1. All bottles should be inspected carefully at the beginning of the bottle washing operations so that defective bottles do not get to the filler and thus avoid product losses.

potentially toxic materials or wastes at excessively high or low pH levels.

Distribution: Care should be exercised in the handling of packaged products to minimize the leakage of damaged packages in the delivery truck.

Special Recommendations for Cheese Plants:

1. Employees should be paying particular attention to cheese vats during filling so that they will not be overflowed, with subsequent loss of product to the drain. Liquid level in the cheese vats should be at least three inches below the top edge of the vat to prevent spillage during agitation. All valves, pumps, and line fittings should be checked on a daily basis to make sure that they are leak free.

2. In cheese operations, especially in acid set cheese, particular care needs to be taken in determining the time of cut, and in handling the curd during initial cooking and subsequent mechanical handling and any other operation. This is essential to minimize fines, which can contribute up to 30% of the organic waste load going out with the whey.

3. All spills of curd particles from cheese operations should be swept up and handled as solid waste and not washed down the sewer drains. After the curd has been removed from the vat, the remaining curd in the vat and outlet valve, which can be up to 10-20 pounds per vat, should be washed out of the vat, collected in a strainer and handled as solid waste. If this material is handled properly, it can be utilized for pet food or animal feed.

4. Any mechanical handling equipment for curd should be inspected daily to insure that the equipment is operating properly and that the settings on the machinery are proper to minimize loss.

Special Recommendations for Ice Cream Plants:

1. Avoid overfilling ice cream mix vats to eliminate the spillage of high BOD-containing materials during agitation. During filling, attention should be maintained on the filling operation to avoid overflow.

2. Food stuffs and other dry ingredients from ice cream operations should be swept up and treated as solid waste.

2. For plastic and glass bottle fillers, cappers should be maintained in first-class condition to avoid breakage and/or product loss.

3. Paper filling machines must be maintained in proper operating condition during operation. Settings on paper forming equipment should be checked frequently to insure proper package formation and sealing to minimize leaking.

4. Filler valves should be checked to see that all containers are filled to correct capacity. In glass bottles, filling up to the cap seat may create spillage when milk is forced up past the cap seat with temperature changes.

5. Operators should check the filler supply bowl for foam and eliminate any foam to minimize spillage and help insure proper operating of packaging machine.

6. Bottles, plastic and paper containers should be handled carefully during casing, stacking, loading and delivering to avoid product losses.

7. Spilled dry ingredients should be handled as solid waste and not washed down the drain.

8. Return products or products that have to be repacked should be handled in a sanitary manner and collected to use as animal feed and not discarded to the drain.

9. Products that are damaged and dumped at the fillers should be recovered in a sanitary recovery system. The transfer should be made promptly without allowing the product to warm to any degree to minimize microbial contamination. This product can be reused in ice cream or some special products providing that it meets microbiological standards.

10. Product remaining in the filler bowls of milk operation should be drained and collected at the end of the processing day and not be merely rinsed to drain.

<u>Cleaning and Sanitizing Wastewater Handling:</u>

1. Care should be taken to avoid incorporation of cleaning compounds and/or sanitizing solutions into milk products, thus eliminating the need for disposal of large quantities of milk solids.

2. Concentration of cleaning and sanitizing compounds needs to be carefully controlled. Where cleaning compounds are added by hand, only sufficient cleaning compounds necessary to insure adequate cleaning and sanitizing should be used to minimize discharge of

3. Ice cream mix has a very high BOD level and frozen products that are dumped on the floor during filler breakdowns should not be washed down the drain but placed in a container for handling either as a high solids waste or for animal feed. The collecting container for ice cream that cannot be used as rerun (has come into contact with contamination in jamming of a packaging machine) has to be made convenient enough for operators to utilize it. Collection of this material on a mobile 55 gallon drum wheeled cart, followed by freezing and utilization as animal feed is to be preferred to dumping it down the drain.

4. Products that are not normally used for rerun, such as sherbet, require special handling as solid waste.

5. Because of propensity for jamming, the operator must give continual attention to the settings on the packaging equipment to avoid jams. Wherever feasible, automatic recycle needs to be put into operation to divert ice cream if the system jams.

6. During wash-up, the lines and freezers should be rinsed with a minimal volume of water on a time-controlled basis. This material should be used for rerun since it could be handled in a completely sanitary manner. Rinsing should be done with fully potable and microbiologically satisfactory water. In plants where water is contaminated with psychotrophic organisms, this could require a pre-chlorination.

7. Novelty operations are especially prone to high losses. The minimalization of losses from novelty operations requires a careful and continual attention by both operators and maintenance people to avoid problems. The following are common things that need to be given attention:

a) Proper setting of water flow controls to insure proper extraction and complete cleaning of molds.

b) Proper setting of freezing temperature so that the stick is properly placed in the novelty.

c) Checking to be sure that the springs are present on the extractor bars for the novelty operation and that the spring tension is correct.

d) Proper setting of defrost temperature to insure extraction without excessive melting.

e) Continued attention to the stick feed to be sure that the sticks are available and feeding properly without jams.

f) Continued attention to the settings on the bagging and boxing machines to avoid jams. Good operation of the freezing operation minimizes problems with bagging and packaging.

Special Recommendations for Plant Manufacturing of Condensed and Dry Milk Products:

1. Where hot wells are utilized, care must be taken to avoid overfilling and to prevent boiling over.

2. Evaporators should be operated at sufficiently low liquid level as to prevent product boiling over.

3. Where dry ingredients are utilized, or where milk powder is spilled on the floor, contents should be swept up and not washed into the sewer.

4. Care must be taken in materials handling to avoid breakage of containers and product spillage.

5. During start-up, shut-down of condensers (evaporators) the product water mixture should be saved for rerun. Most operations can be started up and stopped by careful operator attention to minimize losses at this point.

6. Careful attention needs to be given to lactose crystallization and storage of condensed product to minimize precipitation of lactose crystals and loss of product that cannot be pumped.

Value of In-Plant Control

Management of dairy plants will institute water and waste control programs if they realize fully the costs of their losses. For example, the surcharge costs for a plant may look large but the sharp operator or manager realizes that lost product, wasted water, wasted product, wasted energy and wasted chemicals are much more costly.

Case Study

Carawan (1977) made an extensive attempt at putting accurate costs on a water and waste control program for a case study dairy plant. The case study plant included production of approximately 1,000,000,000 lb/yr - a medium to large size dairy plant.

Water Use: Changes to reduce water consumption included such activities as installing solenoids on compressors, high pressure hose stations, case washer recycle and reuse of truck wash water. Water use was reduced by 36 million gallons a year with investment costs of $67,979. Annual costs were $14,981 and annual savings were $26,503. The net savings per year divided by the increased annual cost for the changes ranged from $0.32 to $16.96. All nine changes evaluated, resulted in savings when all expected costs were included.

Waste: Thirteen changes for waste reduction were evaluated for the case study plant. Changes made included changes such as clarifier sludge recovery, collection tank installation for product-water residue collection, drip shields on ice cream and fluid product fillers, CIP rinse recovery systems and returns recovery. A schematic of the recovery systems is included in Figure 10. Over 1,000,000 pounds of BOD_5 could be eliminated with the institution of all the changes. Total investment was predicted to be $174,686. Net savings per year were found to be $349,389 with increased costs of only $78,064. Net savings per year divided by annual costs for the changes ranged from $1.15 to $30.30.

Net Effect: As a result of the changes study added to an effective management action program, water use was reduced by 416,947,886 gallons per year and BOD_5 by 1,572,250 pounds per year. Net savings per year for this 500,000 lb/day plant were $921,581 per year for the total water and waste control program. Most dairy plant managers would love to consider an increase of $1 million per year in profits which was shown to be the value of in-plant control for the case study dairy.

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RECYCLING AND REUSE

Introduction

This section explores several aspects of recycling and reusing food processing wastewaters. It is meant to give you an overview of the factors affecting wastewater reuse and recycling in dairy processing.

Keep the following basic concept in mind with regard to reusing wastewater. Reusing wastewater basically involves collecting the effluent from one or more unit processes, and then using that effluent as the influent for other unit processes. The key to wastewater reuse lies in matching the effluent from one unit process with the influent requirements of another unit process. The "matchmaker" must be careful to take into account the effluent's quantity and quality when examining the source requirements of prospective processes.

Legal Aspects of Water Reuse

Water rights and related laws are under nationwide review. Scientists, economists and lawyers are evaluating current and future use of our water resources; constitutional rights as well as individual state laws may be involved before the present systems of water regulations can be applied to multiple-use water.

Reusing water is not a new concept. Published data estimate that 60 percent of the population presently reuses water. The intake water supply pipe of one city is often downstream from the discharge sewage pipe of another metropolis, and coastal municipalities have no choice but to commingle supply and wastewaters when tidal conditions return the sewage effluents into the water supply storage reservoir. The use of interstate streams is not only subjected to the laws of each user state but is also under regulations and control by federal authorities.

Two basic systems of water law in the United States include riparian and appropriation. Generally, those areas with abundant water supplies use the common-law doctrine of riparian rights. Areas sparse in water resources found the first users and statutory prior appropriation doctrine more suitable. Unfortunately, there are also some states that use combinations of both systems with regional special interpretations. These systems are detailed in the Legal Spinoff.

Pollution abatement programs have generally classified state waters according to use and thus have established standards of quality in accordance with these objectives. It seems only prudent that the processor should consult the stream classifications and standards that govern water purity in the state within which wastewater is to be reused.

Public Health Aspects of Wastewater Reclamation

Decision to reuse renovated wastewater for human consumption or in processes that normally require potable water (i.e., food processing), must be equated with potential health risk and hazards. The U.S. Public Health Service in a policy statement believes that renovated wastewater is not suitable for drinking water when other sources are available. Any consideration to using wastewaters or reusing process waters should be cleared with the local inspection officials.

Reclamation Methods

Water is absolutely necessary in food processing, and by practicing conservation, reuse and recycling, the amount of liquid waste and consequently the pollution load from food processing operations can be reduced. Reduction of water use through reuse of the same water can pay significant dividends in improving a waste disposal situation. Water reuse is beneficial because water is no longer a free commodity; it costs money to procure water; it costs money to pump water; and it costs money to dispose of water.

Food processing waters cannot be reused indiscriminately. Their recirculation in contact with food products must allow satisfactory product and plant sanitation. To offer more specific guidance in the use of reclaimed waters, National Canners Association (NCA) offered the following recommendations:

- The water should be free of microorganisms of public health significance.
- The water should contain no chemicals in concentrations toxic or otherwise harmful to man, and no chemical content of the water should impose the possibility of chemical adulteration of the final product.

- ° The water should be free of any materials or compounds which could impart discoloration, off-flavor, or off-odor to the product, or otherwise adversely affect its quality.

- ° The appearance and content of the water should be acceptable from an aesthetic viewpoint.

Water is best saved by reducing its rate of consumption. Industries that routinely monitor their water usage and their waste effluent flows have been able to reduce the in-house uses of water by as much as 50%. Unfortunately, some water managers consider renovated wastewater to be acceptable only as a last resort alternative. Such attitudes obscure the real importance of wastewater as being potentially the most economical choice available as a source of water.

Wastewater treatment and renovation can exist in varied forms. Direct reuse occurs in canneries when counterflow untreated streams are used stepwise. Clean water is piped into the cooking areas where, following use, it flows to blanching operations. Having fulfilled its service here, it discharges to water-conveying canals and finally to incoming washing troughs where it removes filed detritus from fruits and vegetables.

Spent water handling can be simplified by segregating wastes into appropriate categories. The commingling of fluids into common sewers complicates reuse and reclamation programs. The first task in reusing wastewater is to establish the objectives. A water demand inventory should be taken to determine usage amounts with quality levels of purity. Subtotals of departmental. (industrial plant sections) use should add to the total documented need required for the site.

The dairy industry (Fig. 11) collects salvaged condensed milk vapors from vacuum pan evaporators and uses them for boiler water feed and for plant cleaning wash water. Inline turbidity meters monitor the salvaged condensate and divert contaminated milk and water vapors to the sewer in case of a malfunction.

Salvageable Fractions

Dairy wastes found in water can consist of particulate matter, dissolved solids and fats - either as an emulsion or in a free-floating state. Both the food and the water quality have an influence on deciding whether or not the salvaged fractions gathered from wastewater are suitable

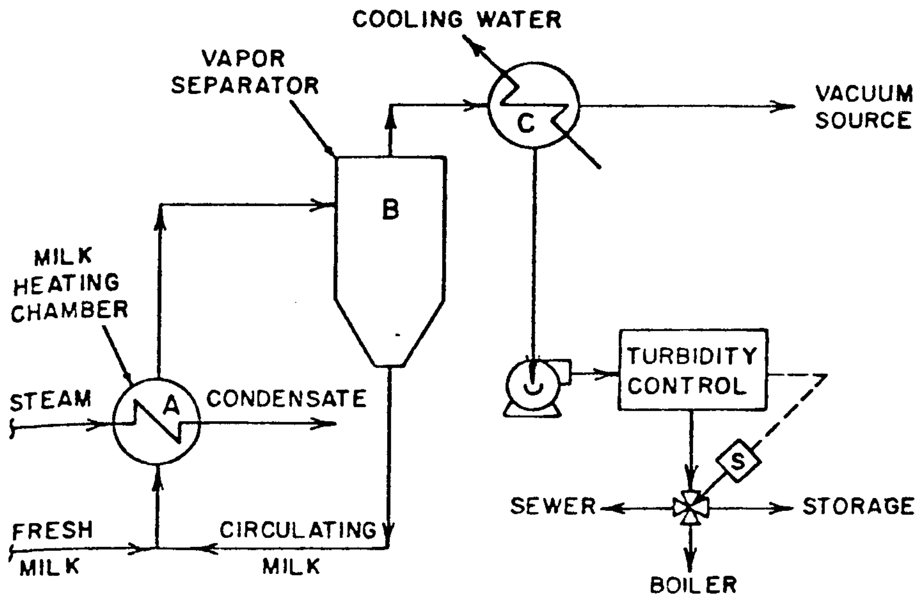

Fig. 11. Recovery of milk vapors in powdered milk production. The milk evaporator functions much like steam generated in a boiler. Because the vacuum pan is subjected to a high vacuum through the air ejector system, milk boils at low temperature that rarely climb higher than 1500F. Milk vapors change back to water, which collects against the cold condenser tubes. Vacuum increases linearly to maximum with lowest temperature thus vapors flow from A to B to C. Malfunctioning milk evaporators tend to foam, carrying over milk solids; 'hence, an inline turbidity meter safeguards the condensate purity for the salvaged water reuse.

for human or animal consumption. If wastes are channeled into sewer lines, these materials become a treatment burden, at some cost to a waste treatment system. Obviously, processes that reclaim human food-grade materials must meet sanitary standards. By-products for animal foods are continuously being upgraded; thus, it may be prudent to furnish reasonable duplication in nonhuman food production of those techniques used in human food processing.

Food as particulate matter is often separated from liquids by settling, screening, skimming, or centrifuging. Automated continuous processes suitable for cleaning in place are most attractive (as contrasted with batch methods) for both short-term and long-term goals. Careful planning with well-defined objectives is required to create resources from wastes.

Recovery of Chemicals

While cleaning chemicals in waste matter often cause toxicity and poor performance of the biological treating processes, they also represent a BOD demand. For example, surfactants or common acid detergents produce 0.65 lb BOD_5/lb of substance. Table 23 shows the BOD demand of selected substances, cleaners and sanitizers.

Liquid detergents, sanitizers and other analogous products can be handled in bulk in a series of vessels. These materials may then be piped to reservoirs that can store and feed the cleaning solutions. Clean-in-place (C.I.P.) circuits can be designed to reuse fluids that are circulated by pumping through pipelines, bulk tanks, storage reservoirs and other media. Final uses of captured liquids include floor cleaning or use as the fluidizing liquid in sludge pumping.

Heat Recovery

Flow measurements are also necessary because the temperature alone is not adequate to reflect the magnitude of potential heat recovery. Wastewaters should be grouped according to purity and temperature, and the hot-test water should be without dilution to avoid heat dissipation. Steam condensate is returned to the boiler by deaerators because the water is soft as well as hot.

Table 23. BOD_5 of selected chemicals in detergents, sanitizers and lubricants used in food plants.

Material	*Pound of BOD per Pound of Product Material*
Acetic acid	0.65
Duponol D, alkyl alcohol, sulfonated	0.45
70% hydroxyacetic acid	0.07
Alkyl phenyl condensate of ethylene oxide	0.04
Phenoxypolyoxyethylene	0.005
Nacconol NR-Na alkylarylsulfonate	0.004
Neutrony x 600, aromatic polyglycol ether	0.0
Nopco 1111-sulfonated coconut oil	0.96
Nopco 1665-soluble fatty acid ester	0.12
Pine oil	1.08
Tallow	1.52
Triethanolamine	0.01
Ultra-Wet DS-sodium alkylarylsulfonate	0.0
Linear alkylarylsulfonate	0.65
Ethylene glycol	0.70
Zalon-fatty amide	0.20

Sometimes a water demand may be satisfied by preferential water make-up, where the idea is to use all the salvage water first with fresh water supplied only when the other sources are exhausted.

Water Reuse

Water reuse may be adopted with economical advantage when:

- there is insufficient water available locally to maintain an open circuit system all year 'round.
- valuable by-product materials can be economically recovered from the treatment processes.
- treatment cost of recycling water is less than the initial cost of water, plus the cost incurred in discharging the effluent into the sewer.
- cost of treating the effluent to a required standard is such that, for a little extra investment, the water quality can be made suitable for recycling.

The practice of water reuse can be divided into sequential reuse, recirculation without treatment and recirculation with treatment. Sequential reuse is the practice of using a given water stream for two or more processes or operations before final treatment and disposal, i.e., to use the effluent of one process as the input to another. Recirculation is the practice of recycling the water within a unit process or group of processes. A combination of these practices will probably be required for an optimum reuse scheme.

In an effort to optimize industrial water use and wastewater management, emphasis is now being given to decreasing the quantities of water used and the contaminants introduced during use. Alternatives available for volume and pollutant reduction include water conservation, good housekeeping, waste stream segregation, process modification and water reuse.

Historically, little consideration was given to water reuse because of its abundance in nature and because it was considered to be hazardous due to bacterial contamination. Contamination potential shows that, in washing fruit, unless 40% of the water is exchanged each hour, the growth rate of bacteriological organisms becomes extremely high. In order to overcome this, other means of control, such as chlorination, must be used. When chlorination is discontinued, the bacterial count more than doubles. As soon as chlorination is resumed, the bacterial counts are again brought under control.

Water conservation can be achieved through counterflow reuse systems. Figure 12 outlines a counterflow system for reuse of water in a pea cannery. At the upper right, fresh water is used for the final product wash before the peas are canned, and from this point the water is reused and carried back in successive stages for each preceding washing and fluming operation. As the water flows countercurrent to the product, the washing and fluming water can become more contaminated; therefore, it is extremely important (Fig. 12) to add chlorine in order to maintain satisfactory sanitation. At each stage, sufficient chlorine should be added to satisfy completely the chlorine demand of the organic matter in the water. With this arrangement, satisfactory bacteriological conditions should exist in each phase of the washing and fluming program. Dairy processing does not easily lend itself to such schemes. However, the use of air compressor cooling water for CIP rinse water is one example of reuse.

Water Conservation

There may be several operations in a dairy processing plant where water is wasted continuously, thus causing an overload to subsequent collection and treatment systems. Consideration should be given to steps that can be taken within a plant to conserve water, thus enabling the liquid waste disposal system to operate more efficiently and thereby reduce water pollution. As an example of water conservation methods the steps possible in a food processing plant include 1) using automatic shutoff valves on all water hoses to prevent waste when hoses are not in use (a running hose can discharge up to 300 to 400 gallons of water/hour), 2) using low-volume, high-pressure nozzles rather than low-pressure sprays for cleanup, 3) avoiding unnecessary water overflow from equipment, especially when not in use, and providing automatic fresh water makeup valves, 4) avoiding using water to transport the product or solid waste when the material can be moved effectively by dry conveyors, and 5) reusing cooling water to accomplish product cooling.

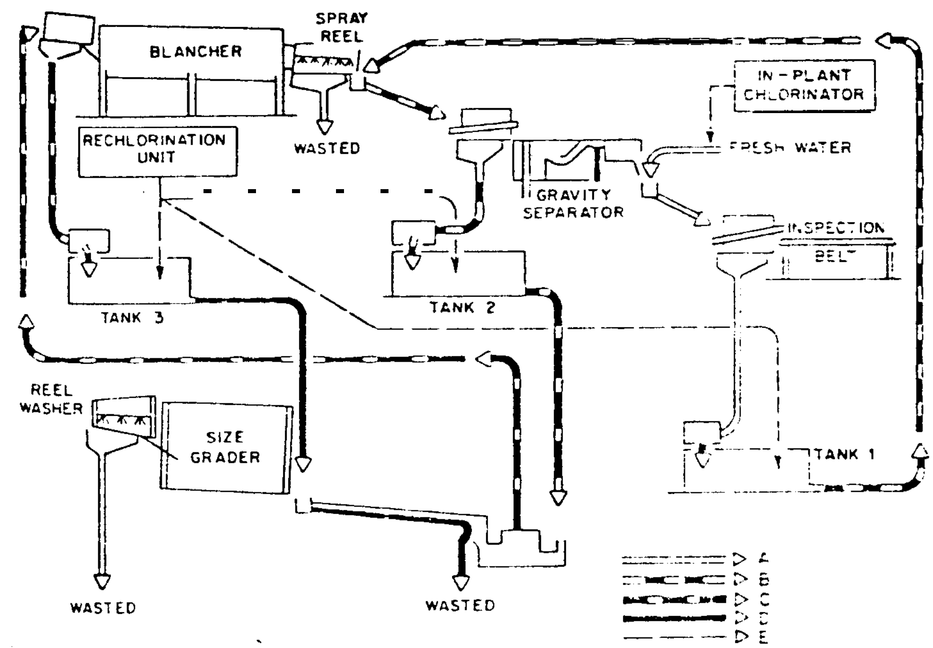

Fig. 12. Four-stage counterflow system for reuse of water in a pea cannery. Key: A. First use of water; B. Second use of water; C. Third use of water; D. Fourth use of water; E. Concentrated chlorine water.

Another water conservation method is using the closed loop systems on certain processing units, such as a hydrostatic cooker-cooler for canned product. The water is reused continuously, fresh makeup water being added only to offset the minor losses from evaporation. Closed loop systems not only conserve water but also reclaim much heat and can result in significant economic savings.

A delicate balance exists between water conservation and sanitation. there is no straightforward or simple formula to obtain the least water use. Each case and each food process has to be evaluated with the equipment used in order to arrive at a satisfactory procedure involving water use, chlorination and other factors, such as detergents.

Elimination of Water Use

Eliminating water in certain unit operations in turn eliminates attendant problems of treating the wastewaters, which were generated by those operations. For example, in dairy processing the use of an air cooled homogenizer eliminates a source of wastewater.

Waste Stream Segregation

Waste segregation involves the separation of waste streams according to their wastewater load. Noncontaminated streams offer the possibility of being discharged directly to receiving bodies of water, whereas contaninated waste streams have to be treated.

As a general rule, all plants should be provided with three water discharge systems, namely 1) storm and cooling water, 2) sanitary waste, and 3) industrial waste.

The stormwater system should receive all surface and storm runoff. This system can also be used for discharging uncontaminated waters, such as cooling waters, that require no treatment prior to discharge. Although it is desirable to keep uncontaminated wastewater out of the treatment plant, the cost of installing separate collection systems for small, isolated streams may be so high that by-passing the treatment plant becomes uneconomical.

The sanitary system should collect the wastewaters from all washrooms and shower rooms. For most industrial plants it is desirable to send these wastes to a municipal plant for treatment, rather than to treat them individually.

Process Modification

One alternative available for eliminating or reducing the wastes created during processing involves the modification or elimination of the step or steps which are producing the wastes. For example, washing and cooling of cottage cheese often results in significant use of water and waste load. Modified washing procedures have been developed to reduce the water use and waste.

A Summary

Reuse of wastewater is the utilization of a process waste stream one or more times before it leaves plant boundaries. This can be accomplished by piping the wastewater from one unit to another, by treating or diluting effluents before reuse in other units, or by combining a few or all effluents, treating them and reusing the water.

Incentives for water reuse involves the possibilities of reduction of wastewater treatment costs and raw water costs. Although lower waste treatment costs currently provide the major savings from reuse, in some areas the supply of acceptable raw water is decreasing, the price is rising, and reduced raw water usage may provide a significant incentive in the future. The typical plant considering reuse seldom plans to completely eliminate wastewater discharges since this would usually require very extensive modifications. The important standard for economic reuse is that an unused makeup process water can be replaced by a lower-quality water without harming the process. So, reuse schemes should always be considered in planning for pollution abatement.

Ultimate requirements for water pollution control may be completely closed systems from which no discharges are permitted, and use of fresh water is only required as makeup for evaporation losses. Closed water systems as the final goal of pollution research has long been an ideal. Even though total reuse may not be legally required, it may be a viable alternative to meeting stringent discharge regulations.

Possible steps for proceeding toward an intermediate or total reuse system are:

- Determine the effluent qualities and quantities and makeup requirements for plant units. A waste stream survey is a must for such an analysis.

- Study the lowest-cost treatments needed for various effluents to reach the required qualities of secondary users. Trends have been toward treatment of combined waste streams. Segregation of waste streams may offer better reuse possibilities.

- Reduce wastewater volumes by increased maintenance and equipment modifications can reduce flows significantly.

- Study the effects of reuse on existing treatment equipment because water reuse generally results in a lower volume, more concentrated waste stream.

Commitment to total reuse requires an economic justification covering the expected future costs of fresh water and ultimate waste disposal. In some areas of the world, the cost of fresh water is rising and the cost for ultimate disposal may gradually decrease as technology improves. The key to inexpensive reuse is volume reduction. The total-reuse will be able to economically treat only a small waste stream for total removal of contaminants.

The decision of whether to implement total reuse will be set by a comparison of costs of raw water and water treatments with and without discharges. These include: water supply; treatment required before use of fresh water; waste treatment required before discharge; treatment required for use of reused water; plant modification to accept lower quality or higher temperature reused water; extra piping and control valving; loss of flexibility due to integrated water system.

A total reuse plan should begin at the individual process units, since it will affect their operation. In certain cases it may even be more economical to modify a process so that it requires little or no water. The economics of total reuse will vary from plant to plant.

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BY-PRODUCT RECOVERY AND USE

Introduction

Food processing plants inherently tend to generate significant quantities of waste material. Frequently, the waste is believed to have potential nutritional or industrial value, thereby representing a possible basis for a new business opportunity. But turning these beliefs into new business is often a complex technical and economic problem. Extracting the critical business and engineering parameters for decision-making requires an analysis of the economic, technological, and marketing factors involved, as well as an ability to resolve problems arising from these factors.

This section presents some recovery attempts by dairy product processors to transform hitherto waste products into useful byproducts. This idea of recovering byproducts from waste has been "catching on" throughout the food processing industry, but many of these recovery schemes have not been published. The examples that follow are not meant to represent a full-scale review of the state-of-the-art.

When one thinks of dairy processing wastes that offer by-product recovery possibilities, the "waste" the comes immediately to mind is whey. The U.S. produces about 13 billion pounds of cheese whey each year which remain unused. Because whey represents such a burdensome disposal problem, many research efforts have been aimed at capturing the useable whey components not only because they exert a strong pollution impact, but also because they constitute valuable nutrients. Let's look at a few of the schemes and products that have evolved from attempts to recover and use whey.

Whey Into Wine

To find an outlet for whey material, Oregon State University, under a research grant from the Environmental Protection Agency (EPA), demonstrated the feasibility of fermenting whey into wine. As an extension of this work, Foremost Foods Co., received an EPA grant entitled "Demonstration Project on the Utilization of Cheese Whey for Wine Production." The study sought to demonstrate the technical and economic feasibility of producing a consumer-acceptable fermented whey beverage (FWB) by wine yeast fermentation of supplemented whey. Under controlled fermentation conditions whole is used without removing the water portion. This, in turn, minimizes energy consumption, eliminates disposal of large volumes of liquid, and permits whey utilization.

Processing Requirements

FWB production, utilizing standard dairy/cheese plant equipment, may offer dairy processors an economical method for whey utilization; for both raw material and production equipment are *in* close proximity. Foremost's preferred method, therefore, employs standard dairy tanks, pumps, separators, etc., where feasible.

Converting natural whey to a clear fermented beverage base is a 5-step operation: clarification; deproteinization; fermentation, de-ashing; and polishing filtration (see process flow chart, Figure 13).

Clarification

During Clarification, gross materials are removed from whey to produce a base for deproteinization. Specifically, standard clarification/separation equipment removes curd fines and/or fat from whey as it is pumped from the cheese vat. Material can, in some cases, be recycled to the cheese, used in associated cheese plant product operations, or employed in animal feeding.

Deproteinization

Whey deproteinization is posible via several protein precipitation and separation techniques involving heat or chemicals. Semipermeable membrane separation technology, such as ultrafiltration (UF), also may be used. The UF approach was selected for this study since its rapid, continuous flow separation yields both clear, deproteinized whey permeate for fermentation, and a high-quality whey protein concentrate (WPC) for food or feed use.

Fermentation

Following addition of dextrose and wine yeast culture, deproteinized whey is fermented in standard sweep-blade, dairy-type tanks. Lactose present in the whey, however, is not fermented for two reasons: lactose fermentation is a slow process, thus increasing processing cost; and final

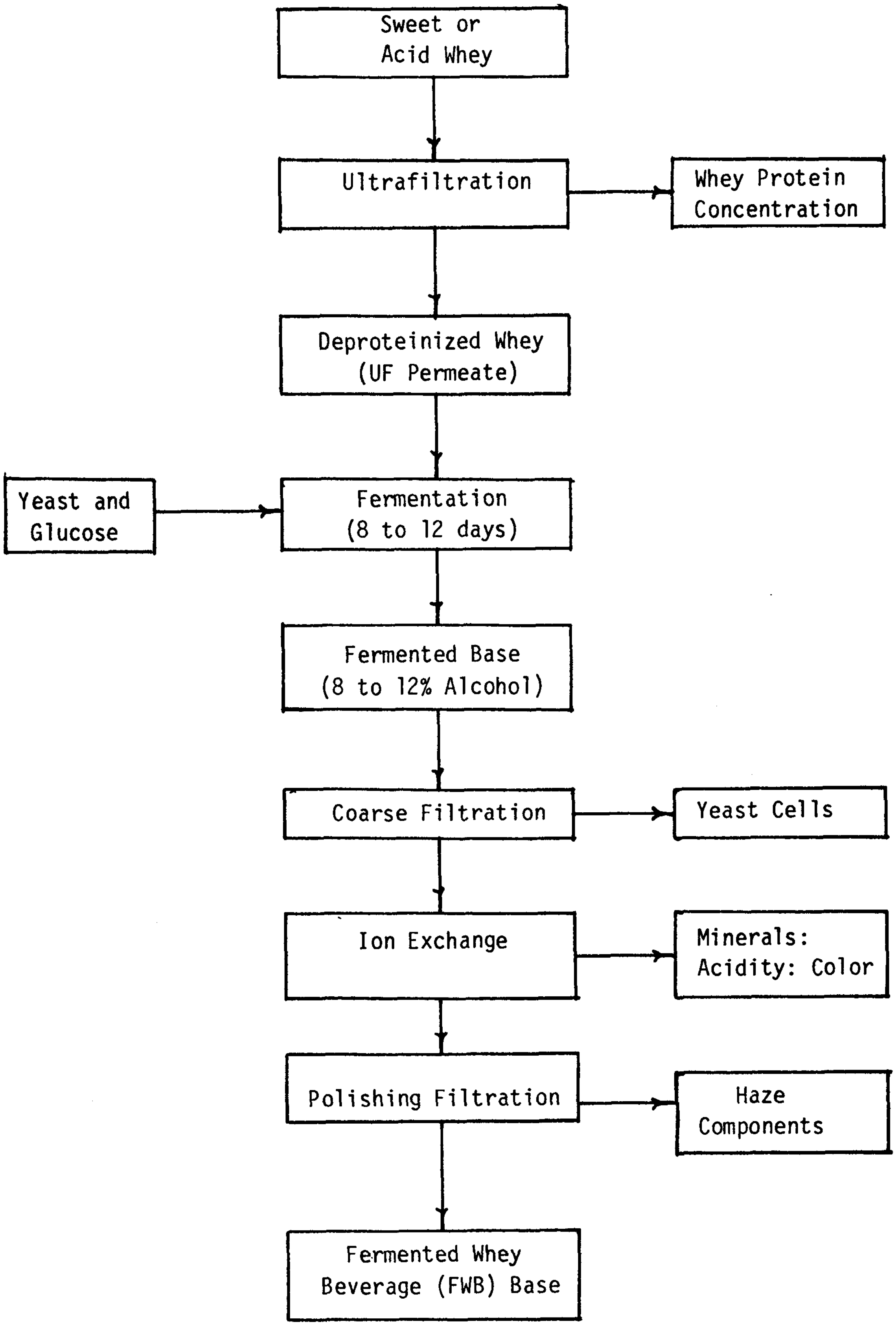

Figure 13. Process for fermented wine base.

formulation expenses can be reduced by taking advantage of the milk sugar's sweetening power.

During early stages, the deproteinized mass is stabilized against wild fermentations by using SO_2 (as in grape wine fermentation), while a selected wine yeast culture converts dextrose to alcohol. Fermentation progresses to completion, and is finalized by removing the yeast via clarification, filtration, or a combination of the two. This organic waste product is suitable for animal feed.

De-Ashing

Following fermentation, the FWB base possesses an overriding salty flavor due to the whey of ash components. Using ion exchange, ash is stripped out of solution, along with objectionable organic flavor and color constituents. De-ashing yields a waste stream composed of dilute salt solution with minimal BOD and little practical application.

Polishing Filtration

FWB base is filtered prior to formulation using a microporous membrane filter. Final "haze" components in the base, including yeast cells which may cause post-formation fermentation, are therefore eliminated.

Resulting waste stream materials are markedly reduced compared to those in the original whey. These accomplishments hold the promise of providing the cheese manufacturer with a profitable product from whey fermentation, while reducing water pollution and disposal costs.

Cocoa Plus Whey Solids

By teaming high-priced, low availability cocoa with inexpensive, overabundant whey, technologists at Fritzsche, Dodge & Olcott Laboratories have developed two new cocoa substitutes. This symbiotic, whey-cocoa relationship satisfies both the needs of cheesemakers faced with waste disposal problems and those of companies manufacturing chocolate-flavored products.

Kokoa™ and Kokoa-Select™ are blends of specialy processed whey solids and natural or artificial flavor components. They replace cocoa (pound for pound) at very high levels and provide all its aromatic qualities and nonvolatile dark chocolate bitter notes. In addition, they replicate the functional properties necessary for successful application in food products.

Whey-Based Beverages

Another intriguing method for whey use has been developed at PFW/ Hercules' Food Technology Center in Middletown, N.Y. This method involves collecting liquid whey, stabilizing it, pasteurizing it, inoculating it with yogurt culture, flavoring it and bottling it.

The result is a tasty, fruit-flavored whey drink consisting of about 80% whole liquid whey. The whey is not dried nor demineralized; so it retains the proteins and minerals of the whey in a stable refreshing beverage with a refrigerated shelf-life of 3 to 6 months.

Similar products already have achieved success in Europe as evidenced by the popularity of "'Rivella", a deproteinized, fermented whey beverage from Switzerland; whey champagne and "Kwas" from Poland, and "Bodrost" from the USSR.

Simultaneous Spray Drying of Acid Whey and Skim Milk

Single-stage drying can be used when acid whey is dried at the same time as skim milk. But due to the acidity of the whey, it is not possible to mix the whey and the skim milk, as the acid will precipitate the casein. To overcome this, the two products can be fed independently to an atomizer so that the actual mixing takes place in the atomizer disc immediately before drying. In this way, a non-caking, free-flowing powder is obtained.

The skimmilk is concentrated to 45-48% solids and the whey is concentrated to 45-50% solids. If two evaporators are available, the evaporation can take place simultaneously. If only one evaporator is available, either the whey or the skim milk must be concentrated first before drying can commence, and the concentrate must be cooled and stored. The dryer will then be fed from the concentrate tanks and from the evaporator.

The atomizer must have twin feed pipes. Two feed pumps and two feed lines must be used for separate feeding of the whey concentrate and the skim milk concentrate to the atomizer.

The quantities of whey concentrate and skim milk concentrate can be varied, as both feed pumps would have variable speed drives. Normally, the composition of the powder is 50% whey solids and 50% skim milk solids, but the ratio can be varied according to the acidity of the whey. The whey/skim milk powder must be an edible grade suitable for use in ice cream and in the bakery industry for bread, cakes, etc., for biscuit manufacture, and as an ingredient of other food products. It is free from chemicals as the whey is not neutralized, and it is favorable in price compared with skim milk powder. The simultaneous drying of whey and skim milk provides an economical process for converting acid whey to a useful product suitable for human consumption. Sweet buttermilk or whole milk can also be used instead of skim milk.

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WASTEWATER TREATMENT

Pretreatment

The pretreatment of food processing wastewaters is commonly associated with discharges to a municipal waste treatment system. The degree of pretreatment required of the food processor is determined by the specified discharge limitations defined in the municipal's sewer use ordinance. These limitations focus on wastewater characteristics which have, historically, caused either a hazardous condition for the waste treatment plant operators or have been responsible for detrimental influences on the waste treatment system's operation and waste removal efficiencies.

Another factor which has identified pretreatment as a necessity when discharging to a municipal waste treatment facility is the advent of the Federal Water Pollution Control Act of 1972 which requires that before any grant is approved to a municipality for facility expansion or improvement, EPA must be assured that provisions are made to prevent the municipal system from receiving pollutants that would inhibit the operation of the municipal treatment works, or that would pass throught the system untreated. Therefore, if the municipality receives a federal grant, the food processor may be required to provide some form of pretreatment if the waste being discharged, “as is", to the municipality is judged detrimental to the system and modifications are indicated. However, EPA has concluded that dairy wastes do not need pretreatment unless they are a large part of the waste plant load.

Alternatives

Of the dairy plants operating in the United States, approximately 90% are discharging to a municipal waste treatment facility and 10% are treating their dairy process wastewaters for direct discharge. A number of the dairy plants with municipal discharge are pretreating their wastewaters prior to municipal discharge. Major considerations for pretreatment of this type of wastewater prior to discharge to a municipal's system are hydraulic shock loads, high BOD strength, high suspended solids content and pH conditions above 9. For cities with populations above 25,000, enough water is discharged to the sewer system to neutralize the above concerns. However, as the percentage of wastewater (10% and above) of the total contributed by the dairy plant operation increases, less dilution of the dairy wastewater occurs. Under this operating circumstance, some form of pretreatment may be required by the municipality as defined in the Sewer Use Ordinance. Some sewer use ordinances require a reduction of the wastewater to strength characteristics similar to domestic sewage. Others may place a fat, oil and grease limitation on wastewaters discharged to the municipal sewer. Whatever the restrictions, the dairy processor must modify his waste stream discharged to the municipal's waste treatment facility.

In addition to the restrictions imposed by the sewer use ordinance, the dairy processor is also faced with fluctuating production volumes and production facility expansion programs. As these activities take place, increasing waste loads can occur which could, and frequently do, reduce the ability of the municipal's waste treatment system to adequately treat the added waste. Should this happend with regularity, then the dairy processor may be faced with a problem of pretreatment or supporting a municipal waste treatment plant modification or expansion program. In either case, careful economic considerations will need to be reviewed. Since the dairy processor knows what his sewer costs are, he can calculate the cost of the added sewage treatment load and determine whether the projected cost could better be handled by pretreatment or financially supporting a municipal expansion program. Of course, inplant reductions are cheaper than either pretreatment or treatment.

Cost Considerations

Inherent in modification or expansion of a municipal waste treatment facility is the federal requirement (if federal grant money is used) that should these activities include treatment capacity for industrial waste-waters, then some form of cost recovery system must be established. Much of the cost recovery program is accomplished through the use of a surcharge system keyed to specific wastewater parameters. Common parameters used are wastewater volumes, BOD strengths, suspended solids and the fats, oils and grease category.

Surcharge systems vary, and no one can predict whether pretreatment can be justified economically until costs are evaluated. A surcharge system should be based upon an evaluation, by the city's consulting engineer, of the cost of the elements of the municipal treatment plant necessary to accomodate the flow, remove the suspended matter, and treat the other ingredients of the industrial wastewater to the required levels all on a unit basis (cost per pound of constituent).

Many surcharge systems start with a flow base rate and apply multipliers for concentrations of any or all such ingredients as BOD, suspended solids, and grease. As an example, the flow base rate charged to all sewer users may be 50 percent of the water bill, including flow from private water supplies. Then, taking BOD as an example, assume that 250 mg/l has been established as a bottom base for surcharges. Then a multiplier might be applied for BOD between 250 and 500 mg/l, and a higher multiplier between 500 and 1,000 mg/l. Another set of multipliers might be applied for suspended solids, another for grease, and others for other factors. These multipliers are then added together to establish a single multiplier to be applied to the flow base charge to arrive at the total bill.

In other revenue collecting systems, charges for the pounds per month above a base quantity of BOD, suspended solids, and other ingredients are added to the flow charges based on gallons.

Costs of pretreatment depend on many factors, such as size of the dairy plant, type of processing, space available for pretreatment, quality of in-house waste conservation, pumping requirements, municipal requirements regarding quality of effluent, local labor costs, construction costs, and Federal and State tax incentives for industrial waste treatment.

The following outline suggests procedures for developing a decision matrix for pretreatment:

1. Select a project manager, he may be a company engineer or a consulting engineer, depending upon the extent of the study and the capability of company personnel to produce the necessary information.

2. Measure flow and collect and analyze composite samples over a period of day sufficient to develop maximum as well as average data.

3. Make an in-plant waste conservation survey. The annual cost for each possible change should include:
   a) Amortized cost of improvements, installed
   b) Power costs (heating, cooling, pumping)
   c) Labor cost (maintenance and operation)

4. Make a study of possible pretreatment systems, with annual costs developed from the inplant waste conservation survey.

5. Determine the annual cost of municipal surcharges and compare with costs already determined.

6. Select the elements of the conservation survey and possible pretreatment systems that are economically justified.

7. Design necessary improvements considering:
   a) Portability of system
   b) Flexibility for alteration and expansion
   c) Operating skills required
   d) Cost of disposal of residual solids

Pretreatment Processes

Three basic strategies are used in the pretreatment of dairy wastewaters. These strategies are oriented to modifying the dairy process waste stream to make it amenable to the municipal's waste treatment processes. A major strategy employs the use of a system to adjust the flow rate and pH of the waste stream. Two other strategies focus on reducing the BOD srength of the wastewater.

The strategy used for modifying the flow rate and pH of the dairy processing waste stream is flow equalization-neutralization. Essentially, the flow equalization-neutralization system evens out the wide variations encountered in a dairy plant's discharge, but also provides a means of isolating accidental caustic of acid spills which would shift the pH of the wastewater above pH of 9..0 or below 6.0. Also, caustic wash waters can be neutralized prior to discharge. This type of pretreatment may be dictated by the sewer use ordinance. This system does require an outlay of capital expenditures and a constant monitoring by plant personnel. An important design feature often overlooked is a provision for adequate aeration of the wastewater and proper mixing.

To reduce the BOD strength of the dairy processing wastewater, the process has an option to: 1) segregate and collect the initial equipment and pipeline rinses as well as high strength caustic wastewater for separate disposal; or 2) the use of a waste treatment system which discharges directly to the municipal's sewer. Segregation and collecton of the initial rinses and high strength caustic wash water is a transportation/energy dependent alternative. This option offers little flexibility to the processor with respect to production expansion and is a cost factor which could continue to increase. On the other hand, a waste treatment system requires a higher initial outlay of capital, is energy dependent, and adds to the manpower requirements for monitoring and operating the plant. In both of these cases, the economics of pretreating the waste stream must be examined and the best alternative selected for meeting the restrictions of the sewer use ordinance.

Treatment Alternatives

A step away from pretreatment of dairy process wastewaters is its total treatment and discharge to a tributary stream. Usually economic and political considerations move the processor toward treating his own wastewater.

As a waste treatment system is considered for treating dairy wastewater, one must keep in mind the unique wastewater characteristics as reviewed in, Chapter 3 of this spinoff. Three critical characteristics are, 1) the daily wastewater volumes and its widely varied flow rate, 2) high BOD strength (range 1500 to 3000 mg/l) and 3) potentially high pH (often above 10). Additionally, dairy wastewater is generally a nitrogen deficient medium and requires nitrogen fortification to maintain the correct BOD:N ratio of 16.7 to 1. Another important factor one should be cognizant of is that treated dairy wastewaters can be high in phosphorous due to the use of phosphoric acid clean-up operations and if the biological growth medium (waste treatment basin) becomes anaerobic, phosphate containing constituents could release phosphorous to the final effluent.

As treatment alternatives are considered, there are two systems which have received wide acceptance. These systems use either land application techniques or the aeration lagoon - stabilization pond system. Both systems depend on land availability and are applicable to rurally-operated plants. These systems offer a simplistic approach to minimizing manpower requirements and operational logistics.

Land Application

Land application techniques for waste disposal is an excellent alternative for treating whey. However, one must provide a system of holding ponds for storage during winter operations and from which the wastewater can be pumped at a constant rate to the land. Land application does have one inherent limitation, weather. This system is extremely limited during winter seasons in the northern portion of the United States. Additionally, unusually wet springs can also limit the disposal activity. If this system is being considered be sure to check out the soil characteristics of land on which the wastewater is to be applied. Of major concern is the protection of the underground water source against pollution from the wastewater.

Lagoon-Stabilization Pond

The aerobic lagoon-stabilization pond system offers another excellent waste treatment alternative. This system can handle "slug" surges for both BOD and hydraulic loading situations while requiring a minimum of manpower and maintenance to operate the system. The keys to operating this type of system *are* detention time temperature and air availability to the wastewater which is essential for biological activity and stabilization of the organic pollutants. The aerobic lagoon-stabilization pond system is also limited by the weather conditions. As with the land application techniques, this system has its poorest waste removal capability during winter months of operation. Water surfaces freeze over and exclusion of air from the system affects is performance.

Aerated Lagoon

Another system similar to the areobic lagoon system is the aerated lagoon. This process utilizes mechanical aerators to mix the wastewater while incorporating air into the water. The design of the aerated lagoon differs from the aerobic lagoon in the depth construction of the basin. The aerobic lagoon is no more than 5 feet in depth and no less than 3 feet for weed control. The aerated lagoon is approximately 8 to 12 feet in depth and requires much shorter detention times for the wastewaters. However, the aerated lagoon does require a stilling area or polishing pond to collect the suspended solids and provide a means of clarification prior to dischage. Both the aerobic and aerated lagoon systems require a periodic sludge cleanout whereby the accumulated sludge solids begin to effect the quality of the effluent and need to be removed from the lagoon systems.

The aerated lagoon does require more energy input, and maintenance than the aerobic lagoon due to the mechanical features.

Extended Aeration

A third alternative for the treatment of-dairy process wastewaters is the extended aeration system which includes the oxidation ditch operating mode. This type system is an activated sludge system which can treat the wastewater within a 24 to 30 hour time frame. The extended aeration system maintains the wastewater under aerobic conditions for the entire detention time of treatment. The operation of this system requires a high level of operator skill and knowledge. This activated sludge system is quite susceptible to "bulking" and requires close attention on a daily basis. Considerable monitoring of the system is required to maintain the system at its peak performance. Day to day adjustments of the system may be necessary to maintain an optimum operation. Key operating parameters are food to microorganism ratios, sludge age, mixed liquor suspended solids concentrations, strength (BOD) of incoming wastewater, daily BOD applied and settling velocity of the sludge. The activated sludge process is a more sophisticated system to operate but is probably the more efficient and effective form of treating dairy wastewaters. Again, cost considerations must be determined when selecting an activated sludge system of this type.

Tertiary Treatment

Even at BOD_5 reduction efficiency above 90%, biological treatment systems will generally discharge BOD_5 and suspended solids at concentrations above 20 mg/l. For further reduction of BOD, suspended solids, and other parameters, tertiary treatment systems may have to be added after the biological systems. This is particularly true for compliance with the 1983 guidelines limitations. To achieve zero discharge, systems such as reverse osmosis and ion exchange would have to be used to reduce inorganic and organic solids that are not affected by the biological process. The following is a brief description of various tertiary treatment systems that could have application in aiming at total recycling of dairy wastewater.

Sand filtration involves the passage of water through a packed bed of sand on gravel where the suspended solids are removed from the water by filling the bed interstices. When the pressure drop across the bed reaches a partial limiting value, the bed is taken out of service and backwashed to release entrapped suspended particles. In lieu of backwashing, the bed may be taken out of service and the first few inches of sand removed and replaced with fresh sand. To increase solids and colloidal removal, chemicals may be added ahead of the sand filter.

Activated carbon adsorption is a process wherein trace organics present in wastewater are adsorbed physically into the pores of the carbon. After the surface is saturated, the granular carbon is regenerated for reuse by thermal combustion. The organics are oxidized and released as gases off the surface pores. Activated carbon adsorption is ideal for removal of refractory organics and color from biological effluent.

Lime precipitation clarification process is primarily used for removal of soluble phosphates by precipitating the phosphate with the calcium of lime to produce insoluble calcium phosphate. It may be postulated that orthophosphates are precipitated as calcium phosphate, and polyphosphates are removed primarily by adsorption on calcium floc. Lime is added usually as a slurry (10%-15% solution), rapidly mixed by flocculating paddles to enhance the size of the floc, then allowed to settle as sludge. Besides precipitation of soluble phosphates, suspended solids and colloidal materials are also removed, resulting in a reduction of BOD, COD and other associated matter. With treated sewage waste having a phosphorus content of 2 to 8 mg/l, lime dosages of approximately 200 to 500 mg/l, as CaO, reduced phosphorus content to about 0.5 mg/l.

Ion-exchange operates on the principle of exchanging specific anions and cations in the wastewater with nonpollutant ions on the resin bed. After exhaustion, the resin is regenerated for reuse by passing through it a solution having the ion removed by wastewater. Ion-exchange is used primarily for recovery of valuable constituents and to reduce specific inorganic salt concentrations.

Reverse osmosis process is based on the principle of applying a pressure greater than the osmotic pressure level to force water solvents through a suitable membrane. Under these conditions, water with a small amount of dissolved solids passes through the membrane. Since *reverse* osmosis removes organic matter, viruses, and bacteria, and lowers dissolved inorganic solids levels, application of this process for total water recycles has very attractive prospects.

Ammonia air stripping involves spraying wastewater down a column with enforced air blowing upwards. The air strips the relatively volatile ammonia from the water. Ammonia air stripping works more efficiently at high pH levels and during hot weather conditions.

A recycling system utilizing tertiary treatment systems that could be used for treatment of secondary wastewater for complete recycle would include a combination of the preceeding in the following order: secondary treatment, lime precipitate-clarification, ammonia stripping, recarbonation, sand filtration, reverse osmosis, and activated carbon filtration.

For recycling of treated wastewater, ammonia has no effect on steel but is extremely corrosive to copper in the presence of a few parts per billion oxygen. Ammonia air-stripping and ion-exchange are presently viewed as the most promising processes for removing ammonia nitrogen from water.

Besides the secondary biological sludge, excess sludge from the tertiary systems--specifically the lime precipitation clarification process--would have to be disposed of. Sludge from sand filtering backwash is recycled back to biological system. Organic particles, entrapped in the activated carbon pores, are combusted in the carbon regenerating hearths. Thus, recycle of water in dairy processing may be theoretically possible but the management and operational costs would be prohibitive not even considering the high capital outlay needed for such an elaborate system.

Land Disposal of Dairy Processing Wastes

All of the information in this section is taken from a publication by Harper, et al. These authors made quite an extensive survey of the reports describing research conducted on land disposal of dairy processing wastes. They cite the names of many researchers whose work they reviewed, so some of those names will appear in this text. If you are interested in knowing more about a particular study, please turn directly to the "irrigation" section of the Harper, et al. publication, and from there to the desired references as listed in the "References" section. Referring you directly to the Harper, et al. source will hopefully make for easier reading of this section by lessening the burden of wading through so many reference notations.

During the last fifteen years, wastes from small dairy plants in rural areas have often been spread on fields using the same application as those techniques used in irrigation. The relatively low cost and apparent ease of management are particularly attractive for these operations.

Several case studies have documented many successful and some grossly unsuccessful operations. Run-off, ponding, odors or marked loss infiltration, and loss of cover crop were signs of failure. Success is more difficult to measure since there is not yet an integrated biological oriented design approach; measurement of ground, surface and soil waters is difficult and often the economic base of operation has been small.

The Hydraulic Approach

The Harper, et al. study cites McDowall and Thomas who prepared a manual on disposal of dairy wastes by spray irrigation on pasture land for the Dairy Waste Comnittee of the Pollution Advisory Council, Wellington, New Zealand, in 1971. The publication included material on waste conservation and how to make infiltration tests setting up the irrigation system. The material provided is generally sufficient for application of wastes by spray irrigation systems.

The maximum rate which may be applied is that which will satisfy the needs of the cover crop, other evaportaion, and the infiltration capacity without exceeding field capacity. Run-off without surface detention times sufficient to give "aerobic" treatment is undesirable.

The authors cited Table 24 showing the U.S. Soil Conservation Service maximum application rates for water for various soil types and slope. After making allowances for rainfall, they then suggested recommended applications of dilute waste for soil types for both fine weather and rainy weather as shown in Table 25. Table 25 was said to represent an estimation of suitable rates for average conditions based on the assumption that irrigation will be continued for eight hours daily. The assumptions were that, 1) the absorptive capacities after gravity draining vary from 5 in/foot of depth for coarse sandy soil, to 3 in depth for heavy clay, and 2) on the average the absorptive capacity available for the disposal of

Table 24. Maximum Application Rates for Water as Recommended by United States Soil' Conservation Service.

Soil Type	Application Rate (inches per hour*) for Slope of:							
	0-5%		5-8%		8-12%		12% and Over	
	With Cover	Bare	With Cover	Bare	With Cover	Bare	With Cover	Bare
Coarse sandy soils uniform to 6 ft. depth	2.0	2.0	2.0	1.5	1.5	1.0	1.0	0.5
Coarse sandy surface soils over more compact sub-soils	1.75	1.5	1.25	1.0	1.0	0.75	0.75	0.4
Light sandy loams, uniform	1.75	1.0	1.25	0.8	1.0	0.6	0.75	0.4
Light sandy loams over more compact subsoils	1.25	0.75	1.0	0.5	0.75	0.4	0.5	0.3
Silt loams over more com-pact subsoils	0.6	0.3	0.5	0.25	0.4	0.15	0.3	0.1
Heavy-textured clays or clay loams	0.2	0.15	0.15	0.1	0.12	0.08	0.1	0.06

*1 in. per hour = 22,600 gallons per acre per hour (g.p.a.b.)
10,000 g.p.a.b. = 0.44 in. per hour

Table 25. Recommended Applications of Dilute Waste per Irrigation. (1 in. = 22,600 gallons per acre)

Soil Type	For Use in Fine Weather	For Use in Rainy Weather*
Coarse sandy soil --	in.	in.
6 in. deep, poorly drained	1.25	0.25
12 in. deep, poorly drained	2.5	1.5
18 in. deep, poorly drained	3.75	2.75
Well drained	12.0	11.0
Light sandy loam --		
6 in. deep, poorly drained	0.9	
12 in. deep, poorly drained	1.8	0.8
18 in. deep, poorly drained	2.7	1.7
Well drained	8.0	7.0
Silt loam --		
6 in. deep, poorly drained	0.6	--
12 in. deep, poorly drained	1.2	0.2
18 in. deep, poorly drained	1.8	0.8
Well drained	3.5	2.5
Clay loam --		
6 in. deep, poorly drained	0.35	--
12 in. deep, poorly drained	0.7	--
18 in. deep, poorly drained	1.0	--
Well drained	2.0	1.0
Heavy clay --		
6 in. deep, poorly drained	0.15	--
12 in. deep, poorly drained	0.3	--
18 in. deep, poorly drained	0.45	--
Well drained	1.0	

*In unusually extended periods of heavy rain these figures may have to be reduced.

water is from 1/2 for coarse sandy soil, to 1/10 for heavy clay, of the total absorptive capacity immediately after draining.

The USDA Soil Conservation Service, in cooperation with the state universities and the U.S. Weather Bureau, provide regional irrigation guides. These guides provide moisture extraction depth of the cover crops, maximum application rates for various soil management groups and recommended maximum crop irrigation intervals. Similar guides are available for drainage, which are useful for water table control. These agencies also provide soil maps and reports of monthly and annual precipitation probabilities.

Other useful source materials for U.S. applications are the American Society of Agronomy monographs on irrigation of agricultural lands, and drainage of agricultural lands.

Resting between dosing was suggested, 1) to avoid scorching of the pasture, 2) to provide time for recovery of growth and for utilization of the growth by livestock or by harvesting, 3) to allow the resting period to permit destruction of a biological film produced by the nutrients, and 4) to allow time for the dissipation of possible contamination by tuberculosis or other pathogenic organisms. A dosing cycle of 4 to 10 days was recommended for general dairy plant effluents but not for whey or casein washings. A resting period of 2 to 4 weeks was found to be sufficient in New Zealand to obtain sufficient forage production. A resting period of at least 10 days was suggested for avoidance of tuberculosis in line with the New Jersey State Board of Health recommendations.

Eckenfelder applied the following formula to predicting the quality of wastewater which can be applied to an acre of land after equilibrium conditions have been attained:

$$Q = (328 \times 10^{-3})KS$$

where

Q = steady rate for downward flow, gpm/acre

K = overall coefficient of permeability for the soil for the distance between ground surface and ground water table, ft/min.

S = degree of saturation, this could be 1.0 under steady state conditions.

He suggested that the site should be level; covered with vegetation; light soil texture; high sand and gravel content avoiding high clay content; spray tested and soil analyzed prior to full scale irrigation; and cultivated to prevent compaction. Ground water levels at least 10 feet below the surface were said to be necessary to allow the proper decomposition of waste as well as more rapid percolation.

Lawton et al. have reported that hot wastes may damage a cover crop but often may be successfully irrigated by elevating the spray nozzle to permit evaporative cooling before contact. The temperature of the dairy food plant wastes are expected to vary widely but average 30°C. In an aerated holding tank with about 3/4 of a day detention time ahead of irrigation, the temperature of the applied waste should be about 25-30°C.

Proper irrigation is suggested as a means to permit oxidation of organic materials and restoration of permeability. However, the large amounts of easily oxidizable material which occur in milk wastes are said to constitute no serious problem when the irrigation system is well managed.

Earlier researchers noted the problems of ponding which could occur on relatively level land with poor drainage. In a particular instance the soil was sandy loam overlying a very slowly permeable clay at a depth of two feet. Under these conditions the loading rates will be almost entirely dependent upon transpiration and evaporation, which would be about two tenths of an inch per day during the growing season in the Wisconsin area. At another site, permeability had nearly ceased following irrigation for for several years with water of relatively high organic content. The soil, which was clay loam, had increased in organic content from 1.8% for the unirrigated areas to 2.9% for the irrigated areas of the field. The clogging was attributed to filling of soil pores by bacteria, slime molds and other growths as a result of lack of aeration.

These researchers recommended no specific design criteria except caution to observe the health of a crop as a means of judging excessive application. Another researcher also maintained that hydraulic load was much more significant than BOD load.

Deep rooted grasses such as Reed's Canary grass are suggested to be most satisfactory. Panding with odor development has been noticed in areas where sprinklers were not moved frequently. Every day movement is suggested unless the soils are sandy. Precaution is especially necessary when the soil has low permeability or there is a high water table.

Odors were also noticed when holding tanks were sized for once a day irrigation in the winter or the contents became septic in the summer when aeration was not provided.

A screening unit was said to be desirable. The screen size suggested was one-fourth inch. This size is probably much too large to collect fines from cheese manufacture or small nut and fruit pieces.

One firm uses whey sedimentation prior to reverse osmosis to avoid clogging of the small pores with larger size casein particles. This is probably a good idea to reduce clogging of soils as well.

The Saline-Alkali Water Approach

Excess salinity or alkalinity content of waters for irrigation may adversely influence crop response or soil permeability. Sodium ions are a particular problem because an excess in relation to other cations, especially Ca and Mg, may lead to disintegration of clays in soil with subsequent ponding. It has been suggested that the sodium content of water for irrigation should not be more than 80% of the soluble mineral ions present, (that is, sodium x 100/calcium + magnesium + sodium) and that the total concentration of cations in equivalence per million should not be greater than 25.

Subsequently, the U.S. Salinity Laboratory staff have recommended that sodium-adsorption ratio, SAR, be used with the conductivity, C, uho/cm to classify irrigation waters.

$$SAR = \frac{NA^{+}}{\sqrt{\dfrac{CA^{++} + Mg^{++}}{2}}}$$

where the bounds for low, medium, high, and very high salinity hazards are:

$$SAR = 18.87 - 4.44 \log c$$
$$SAR = 31.31 - 6.66 \log c$$
$$SAR = 43.75 - 8.87 \log c.$$

The bounds for low, medium and high salinity hazards are 250, 750, and 2,250 umho/cm.

McDowall and Thomas have reported that the sodium/total cation ratio for milk with ash composition as shown in Table 26 is 17%. That for cheese whey is 23%. The compositions given by Schraufnagel are 19 and 21%, respectively.

Irrigation of pastures with milk, whey or dilute solutions of them, appears unlikely to cause physical deterioration due to high sodium content. Such negative results have been reported by other researchers.

Lawton et al. made an analysis of the cation and the ion content of the wastes from 5 plants. Only the sodium concentration was of concern to the investigators. The high sodium content was not expected from the consideration of the sodium content in the milk itself. The major source of the phosphorous and potassium was presumed to be the cleaning compounds. The highly variable percentage of sodium in the plant wastes varied from 63% at one plant to 44% at another plant. This is below the threshold of 80% proposed earlier but is sufficiently high to be of concern. They also found that sodium ions tended to accumulate in the first 6 inches, and sometimes in the first 12 inches of soil horizons. Values for cheese factories are generally higher than those for other milk plants.

McDowall and Thomas report that the concentration of all cations in equivalents per million is 120 for milk and lactic casein whey, and 89 for cheese and rennin casein whey. These figures are considerably higher than the 25 equivalents per million criteria suggested earlier. Thus, some soil damage is likely. McDowall and Thomas report they were aware of no reports of soil damage. Damage to growth of the grass cover crop has also been noted when the applied waste was rich in sodium.

Reduction of sodium concentrations in the effluent by diversion of caustic waters from boil-out and from water softening were suggested. The addition of lime, calcium chloride, gypsum, iron and sulfur or aluminum sulfate were suggested depending upon the individual soil problem. Dilution of wastes by including cooling waters has also been suggested. These fragmentary data suggest that initial cation analysis of dairy waste may vary sufficiently that perhaps analysis should be part of irrigation design and be monitored several times a year.

Table 26. Content of Mineral Matter and Nitrogen in Milk and Its Products and By-products

Dairy Product	Unit of Measurement	Calcium as CaO	Sodium as Na_2O	Potassium as K_2O	Phosphorus as P_3O_5	Magnesium as MgO	Chlorine as Cl	Nitrogen as N
Whole milk	As percentage in the ash	20.1	8.3	26.8	26.8	2.80	14.1	--
Cream (40% fat)		12.1	5.0	16.1	16.1	1.70	8.5	--
Butter (1.6% salt)		--	0.9	--	--	--	1.0	--
Butter, unsalted		--	--	--	--	--	--	--
Skim milk		20.1	8.3	26.8	26.8	2.80	14.1	--
Buttermilk		20.0	8.3	26.8	26.8	2.80	14.1	--
Cheese whey		10.0	9.9	30.0	--	--	21.0	--
Rennet casein whey		9.2	9.0	30.0	--	--	21.0	--
Lactic casein whey		20.0	8.0	27.0	27.0	--	14.0	--
Whole milk	As percentage in the dairy product	0.151	0.062	0.201	0.201	0.02	0.105	0.55
Cream		0.09	0.037	0.121	0.121	0.012	0.063	0.33
Butter, salted		--	0.66	--	--	--	0.94	--
Butter, unsalted		--	--			--	--	--
Skim milk		0.159	0.065	0.211	0.211	0.02	0.110	0.57
Buttermilk		0.157	0.064	0.209	0.209	0.02	0.109	0.56
Cheese whey		0.05	0.066	0.202	0.101	0.01	0.114	0.136
Rennet casein whey		0.046	0.06	0.20	0.09	0.01	0.114	0.136
Lactic casein whey		0.15	0.6	0.20	0.2	0.02	0.1	0.130

Experiences With Whey

Sharrett et al. have reported an increase in soil aggregation resulting from dosing with whey. This aggregation increase was noted at application levels of up to 40,000 gallons per acre per week. At applications above this level, physical deterioration of the soil was reported. Similar findings have been supported by plant growth trials. It has been discovered that whey application has a greater stimulating effect on pasture growth on sandy soil than on pasture growth on loamy soil.

The addition of dairy waste to soil would be expected to influence the soil. Soils with low buffer capacity would be expected to have pH levels close to those for the effluent and, subsequently, all soils would be expected to have a slight decrease in acidity or a raise in pH.

When dairy wastes are added to soils, the microorganisms convert the lactose to lactic acid. This and other acids will subsequently be utilized with an accompanying decrease in acidity or increase in pH. These effects may be considerably larger for soil with low buffer capacity. This sequence of pH value changes have been observed by two groups of researchers.

Other researchers reported on using casein waters for pasture irrigation. An estimated one million gallons of whey and two and one-half million gallons of whey wash water were applied to a 14-acre test plot. The wastes were applied on each acre on a 7 to 21-day cycle at the rate of 2500-3000 Australian gallons per hour for three to eight hours. The soil was a Krasnozem developed on basalt.

The whey had a pH ranging from 4.2 to 4.6; an acidity in the range of 0.4 to 0.45%; the chloride approximated 3000 ppm; and suspended particles at a rate estimated to be content average 0.54% by weight, i.e., 3.5 to 10.4 pounds per 100 gallons.

Soil analysis showed a drop in pH from 5.4 to 5 and an increase in available phosphate. There was a buildup in chloride during the winter and spring months with a return to substantially lower and safer levels, due to leaching, in April. The high chloride contents were in the vicinity of 420 to 650 ppm in the top five inches of soil and had increased from about 80 to 500 ppm in the lower 5 to 10 inches in the period of July to October. Leaching decreased the values to 32 ppm in the upper five inches, and 20 ppm in the following five inches. There was a general decrease in exchange calcium and magnesium. This effect was overcome by the application of dolomite in a quantity of two tons per acre. No visual symptoms of magnesium deficiency developed.

Two grasses common to Australia were utilized. The distribution of grasses was changed by the application of waste. Some scalding was evident when the proportion of whey was high, relative to wash water, and three inches per acre of effluent was applied in eight days. The soil was also observed to become soggy.

Scott reported on the practical aspects of disposal of high organic content wastes on land. A number of application examples are given in his paper:

1) Three thousand pounds per day of whey were applied on a 40-acre field without problems.

2) Fifty tons of whey per year were applied without difficulty.

3) Whey was applied on 61-acre test plots at rates ranging from 5,800 to 70,000 pounds per day per acre on a nine-day application cycle. At the end of the 30-day test period, the cumulative loading ranged from 220,000 to 1,600,000 pounds per acre or from 0.76 to 5.1 inches per acre. Observations indicated the ready assumption of whey in the sandy soil at all levels. The oat-alfalfa crop withstood the lightest application but was killed at the higher levels. Overall harvest yield return was 32 bushels per acre including the areas with complete vegetation loss.

4) An application of 1450 pounds per day on 10 acres for 45 successive days, amounting to 326 tons of whey (BOD 30-50,000 ppm) per acre, without odor problems runoff or fly breeding problems were reported.

5) The maximum loading rate encountered was 300,000 pounds of whey for 80 consecutive days on six acres for a cumulative 2,000 pounds per acre. Whey accumulated in low areas, with production of magots. New furrows were turned every 20-25 days when the infiltration rates were significantly reduced.

McDowall and Thomas reported the application of whey to grassland under their conditions could be as much as 5,000 gallons of undiluted whey or its equivalent, or up to 10,000 gallons of lactic casein whey provided there was a resting period of about 14 days between dosings.

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Schropp and Vogt investigted the effect of whey waste on plant growth. In some experiments, various proportions of whey and wastewater were utilized as a nutrient supplement for broad beans, maize, and spring barley on sand, clay and loam soils. In additional experiments liquid manure was utilized in conjunction with fresh whey, whey after storage, and mixtures of whey in dairy wastes containing various proportions of cheese dust.

The data shows that the addition of whey to clay soil did not significantly change the pH, but increased the pH one-half unit in loam soil and increased the pH from 6.5 to 8.3 in sand. Proportional pH changes were observed for water and whey mixtures.

The addition of whey to clay soil had an insignificant effect on the harvest weight of corn seedlings but reduced yields 30% when applied to loam soils. However, intermediate amounts of milk and whey produced a slight increase in seedling harvest weights. The addition of whey to sand decreased the plant weight to 17% of that when water alone was added, and mixtures of milk and whey decreased the yield but not as dramatically as did the whey.

Other Experiences With Dairy Wastes

McKee has reported several instances of spray irrigation as well as suggestions for a successful operation.

In the first installation in Camden, New Jersey, 75,000 gallons per day of waste was spread on the 45 acres. Unacceptable odor nuisance was attributed to holding the waste five to six days prior to irrigation.

In a second milk processing plant, also making cheese, a waste of 30,000 to 75,000 gallons per day was applied on three ten-acre fields in rotation. The applications were made daily within three hours. No problems with winter operation have been reported although heavy sheet ice formed on the ground and fences.

McKee suggested spray irrigation on slopes of less than 6%. March was found to be the most difficult month for operation because of alternate periods of thawing and freezing. The ground is normally saturated with water due to the melting snow, the grass has not started to grow, and there is little opportunity for evaportion-transpiration. Consequently, runoff might be expected during this period.

McKee reports that experience indicates that spray irrigation systems will operate successfully with considerably higher proportions of whey than can be tolerated by other treatment methods, such as trickling filtration or activated sludge. However, large amounts of whey in the effluent were expected to adversely affect grass growth, and to promote weed growth. Application rates of 2500-10,000 gallons of waste per acre per day were recommended, depending on soil types and vegetation.

Sanborn has reported on the disposal of food processing wastes by spray irrigation. Two plants pastured dairy cows on the fields after observing the 10-day intervals. No difficulty had been experienced with winter spraying at one plant. Application rates with good cover crops are suggested at 0.4 to 0.6 inch per hour.

Researchers at the University of Wisconsin and the USDA Eastern Regional Laboratory had made an in-depth study of spray irrigation of dairy waste at five plants in Wisconsin. The early phases of this investigation were reported by Breska et al., a later report is presented by Lawton et al., and the overall work is discussed in greater depth in a joint agricultural-engineering experiment station report of the University of Wisconsin.

Some operational problems were encountered. At one plant, good drainage permitted retention of the same irrigation plot for the two months during the summer of 1956. However, the grasses were killed during the winter irrigation and did not return until the plot was reseeded.

At another plant where the wastes were applied all winter, the crop was almost completely killed but did recover. By July, there was no difference in cover crop between the area covered by ice and that not previously covered by ice. At this site the slope was sufficient to permit some runoff.

At a third site, where the silt loam was underlain with a fairly tight clay, runoff occurred almost every day shortly after irrigation had begun.

A number of the plants in the Wisconsin study had alternate means of winter disposal other than irrigation. These methods included use of septic tanks or dry wells, direct discharge to streams, discharge to roadside ditches, and lagooning. Generally, cooling water was discharged directly to water courses. This Wisconsin study was conducted in 1960 when direct discharge to streams and ditches may have been acceptable. It is unlikely that today's pollution-related statutes would find favor with these practices.

The spray irrigation during winter was not entirely satisfactory because of the death of the cover crop. This problem would require approximately double the irrigation acreage otherwise necessary in order to permit disposal on one section during reseeding of the other. Further precautions are necessary to assure line drainage and sprinkler head operation and satisfactory operation immediately after startup during the winter.

Ridge and Furrow Irrigation

Ridge and furrow irrigation uses methods of supplying water similar to the furrow or correlation irrigation used in the West. and Southwestern states. The waste is diverted into furrows higher than the main ditch by the use of dams or other structures. The furrows are loaded within a few inches of their tops and then flow is diverted to another area. The furrows or trenches are generally 6 to 15 feet apart, 1 to 2 inches deep and 1 to 3 inches wide. It has been reported that the wastes are generally absorbed in less than 24 hours. The negative slope of the furrows should be slight because ponding is reported at lower ends during winter periods. Ridge and furrow irrigation is generally preferred for strong wastes of low volume, whereas spray irrigation is indicated for larger volumes of lesser strength.

Contour furrows also have been used with success. Two-thirds of the 35 installations in Wisconsin using ridge and furrow irrigation were reported to be doing a good job. Insufficient land area, low infiltrtion rates, high water table, odor, and poor operation are said to be responsible for the defects found in the upper third of the installations.

Sands and gravels were reported to tolerate much higher loadings than clay and other poorly drained soils. A maximum consumptive rate of water for purposes of evaporation and transpiration was suggested to be about three-tenths (or 0.3) inch per day or slightly over 8000 gallons per acre per day during hot months. This loss was believed little affected by the type of forage crop. Normal evapotranspiration was said to amount to 3500 to 7000 gallons per acre per day.

It has been suggested that the spring is the critical season with respect to ridge and furrow application because the milk receipts by processing plants are generally high and the infiltration rates were low due to low temperatures and high water tables. In this period, as in the winter months, vegetation cover is minimal so runoff losses are higher and evapotranspiration is low.

One study reported that ridge and furrow seepage trench systems initially may handle as much as three to five gallons of wastewater per day per square foot of wetted area but often, due to microbial growth, can handle only 1 to 1.5 gallons per day per square foot after one to three years use.

Drainage permits higher loadings and removal of the concentrated salt solution. Such drainage is more necessary when poorly drained soils are used. Placing drainage tiles at depths greater than 2-1/2 feet below the furrows was said to be usually satisfactory unless the waste had a BOD of more than 1000 ppm. Experience in Wisconsin is said to have indicated BOD's of 10 ppm less during the summer unless short circuiting occurs. During winter months and early spring, the BOD's are said to be in the range of 20-50 ppm.

Reed Canary grass was suggested as a cover crop because it is permanent, reproduces itself, has substantial root structure and endures water and ice coverage well. Rome or Kentucky grasses were not as well suited because of poor water and ice cover endurance.

The nutrients provided from an installation with a processed 0.1 MGPD product and a 1% loss would have a fertilizer equivalent of 15 pounds per day of 10-12-15, (i.e., nitrogen-phosphorous pentaoxide-potash).

Schraufnagel has reported on the ridge and furrow treatment approaches at several Wisconsin installations.

The first plant studied was the Moliant Creamery which produced market milk products and butter. The disposal area contained approximately 2.75 acres and was relatively flat. It was divided into three sections by means of check dams and was underlain with one line of drain tile. The infiltration rate in the clay loam was one inch in 33 minutes, with an effluent of

0.05 MGPD and an estimated BOD of 210 ppm. Approximately 90% BOD reduction was reported. A small grease trap was used; odors have not been sufficient to cause complaints.

The Mindoro Cooperative Creamery made butter and occasionally operated as a receiving station. The irrigation area approximates three acres and is divided into three nearly equal parts which are underlain with two lines of drain tile perpendicular to the furrows and 2-1/2 to 3 feet underneath them. Approximately three-fourths of the disposal area was in grass. The remainder being trenches and headers. A detention period of three days was estimated. The soil was believed to be a Toddville silt loam. Infiltration in the unused areas indicated a seepage rate of about one inch in 18 minutes with a waste concentration estimated to be 300 ppm BOD. The loading is estimated to be 312 tons/year or 58.3 pounds BOD per acre per day. A small flow, estimated at less than five gallons per minute, has been found from the drain lines from about November to May, varying in strength from 25-50 ppm. No significant odors have been reported.

The Barnevelt Swiss Cheese factory used three ditches, each 3 feet wide, 3.5 feet deep and 75 feet long, in rotation for disposal. Odors were sometimes noted but were attributed to accidental whey discharge.

The Hillside Dairy, which processed 30-71 TP of milk for cheese used a 1.75 acre plot divided into three sections with a distribution ditch in the center. The soil was essentially gravel, and about 40,000 pounds per day of whey was successfully discharged. The field was about eight to ten feet above the stream level..

The Dairy Maid Cooperative, a butter and dried by-product plant, irrigated three sections in which the soil consisted of clay loam over white sand. The hydraulic load on the 4.6 acres was about 17,000 gallons per day.

Clifton Farmer's Cooperative Creamery used three plots, the largest of which was underlain with two lines of drain tile. Flooding has been observed in the winter. Ground water was near the surface at the time of the installation of the system.

The Lafayette Cooperative Creamery disposal system, which consists of two fields, was laid out on sandy loam. The furrow size averaged 2 feet by 18 inches, approximately 6 feet center-to-center. Drainage tiles were not used.

The Farmer's Cooperative Creamery Association system was not used only during the period from freezing time to April 15 or May 1. Spray irrigation was used during the warmer months. The soil was a heavy clay with some gravel streaks. Tile lines had been put in for drainage.

The Sherry Dairy treatment system consisted of a main ditch, and eight perpendicular lateral ditches-two to three feet deep. This disposal field was about four feet above the normal level of an adjacent creek. Poor infiltration was noted during the periods of high water level; one summer, scum was noted in all of the ditches.

The Garden Valley Condensery used ditches every 10-15 feet. The disposal area had a 0.57 inch slope, sandy soil and good drainage above it, so drain tiling was not used. Pooling at the low end of the furrows had been reported.

The Modena Cooperative Creamery used a herring bone distribution pattern. The soil was Waukegan silt loam, with sand and gravel occurring 3 feet below the surface. Drain tile was not used. Schraufnagel has reported that at the Moland Creamery where the tile drain discharge is about equivalent to the waste volume applied, the treatment efficiencies were usually on the order of 98-99%. At another installation, one winter flooding decreased the BOD efficiency as measured from drain tile effluent to about 50%.

Odors are a potential problem with ridge and furrow irrigation. Schraufnagel suggested that control can be maintained by reduction in waste concentration and by diverting cooling water to the treatment system. Treatment fields at least 500 feet from the nearest residence were suggested. Use of grease traps was suggested to avoid soil blockage, and the consequent ponding which leads to malodors.

Schraufnagel also compared spray and ridge and furrow approaches. The spray irrigation systems were said to: 1) be of lower cost, 2) have less danger of nuisance, 3) require no land preparation, 4) be easy to expand, 5) be easier to crop, and 6) be more suitable for woodland and hill slopes than ridge and furrow irrigation systems. The ridge and furrow systems are said to have the advantages in that they: 1) require less land, 2) are cheaper to operate and maintain, 3) have less difficulty with winter operation, 4) have less problems with removal of gross solids, and 5) may or may not require pumping.

Performance Data

Available performance data for spray irrigation, ridge-and-furrow irrigation and the Lawton spray irrigation study are summarized in Table 27. Rationalization of these reports is difficult due to the fragmentary reporting of the rates of moisture loss and not distinguishing between maximum application rate, infiltration rate, and cumulative utilization.

Comnents On State Of The Art Of Irrigation

The influence of BOD loading for various soils, and influence of air availability appear to be voids in our basic understanding of waste disposal by the irrigation process. BOD loading, however, is not completely uncoupled from hydraulic loading for increased hydraulic loadings decrease the aeration of soils with poor drainage characteristics.

Relatively little quantitative work has been cited in the waste disposal literature on the loss in soil permeability due to the buildup of lactose-based polysaccharides and other microbial flora alone, or of the residence time distribution required for the interpretation or irrigation in terms of our understanding of trickling filters.

Comparatively few studies have been concerned with evaluating the actual performance in some quantitative manner. Fields have infrequently been underlain with tile and, if so, rarely have the tile effluents been monitored. Except in areas of deep percolation, tiling, system monitoring and lagoon capture may be desirable. Only infrequently have tile contributions to streams been approximated by measuring upstream and downstream concentrations and volumes.

It should be possible to make a materials balance on soil systems by monitoring what goes in, what goes out, and the accumulation of materials at various levels. Operators should log rainfall, estimated crop use and material applied as big irrigation schemes do on a regular basis. Both short-term and long-term aerated storage capacity are required to permit operation in periods of high rainfall, or low permeability and usage (as in the winter). Lagoons may be used as a possible storage mechanism.

There is little indication that lands with slight slopes have collection ditches to divert runoff or tile effluent to some kind of lagoon

Table 27. Operational Characteristics of Five Spray Irrigation Systems.

	Plant A	Plant B	Plant C	Plant D	Plant E
Milk Intake (lb/day)	20,500	20,000	33,500	10,600	13,500
Waste Volume (gal/day)	4,300	1,770	5,900	1,135	380
Acres Irrigated 1. Total 2. Each Setting	 0.97 0.194	 0.65 0.216	 1.15 0.33	 0.213 0.213	 0.018 (run off) 0.006
Application Rate (in./hr)	0.13	0.20	0.23	0.16	2.3
BOD Loading (lb/A/day)	322	295	139	212	675
BOD*	1752 860-4740	4310 1980-9100	936 400-1620	4790 1849-9440	1280 435-2220
COD*	-	7800 3740-15320	1241 366-1880	4520 1467-11500	1703 552-2830
pH	- -	4.8 4.2-5.7	6.4 4.1-8.7	5.6 4.0-7.2	6.8 4.6-9.5
Suspended Solids* Total	-	1040 600-1940	619 220-1980	1025 510-1800	361 273-502
Suspended Solids* Volatile	-	910 500-1840	561 220-1720	998 488-1540	303 200-390
Na ppm	166 103-216	374 202-642	433 98-675	255 168-320	470 183-796

*Values are given in parts per million
Upper values = average
Lower values = range

for preventing direct entry into streams or other areas. Diversion dikes are needed to reduce rain loadings on irrigated land.

Occurrence of odors has generally been attributed to the development of anaerobic conditions in the holding tank prior to irrigation, ponding in areas of poor drainage and to frozen soil in the spring thaw.

Most of the reports reviewed in this section were made a decade or more before the public became sensitized to environmental problems and odor nuisances. In this decade a substantial portion of the smaller plants which were unable to use irrigation economically have gone out of business; others have consolidated. Generally, the larger plants and, in particular, the fluid milk and ice cream plants, have been located in the highly concentrated areas of the deteriorating inner city or the industrial-blue-collar suburban fringe. In these areas, land costs are prohibitive. Those plants located primarily on the outskirts of cities are being rapidly encroached upon by housing units and so irrigation systems in these areas are a potential nuisance to the public.

Some Costs Associated With Land Disposal of Dairy Plant Effluents

Investment and costs were developed for three levels of wastewater discharge: 10, 40 and 80 thousand gallons per operating day. It was assumed that the maximum daily discharge per acre is 20,000 gallons (0.062 ft or 0.74 in/day) or 150 pounds BOD_5. Although these levels may be considered high, no problems should be encountered if the soil is a gravel, sand, or sandy loam. In tighter soils both hydraulic and organic loadings must be reduced, typically to 4000-6000 gallons and 30-50 lb BOD_5/acre. Such reductions in loadings would result in higher capital and operational costs (e.g., the costs for 10,000 gallons per day would approximate those for 40,000 in the account that follows). During the winter months, it may be necessary to reduce the wastewater-BOD application per acre, particularly in the Lake States region where many dairy processing plants are located.

Other assumptions were, 1) minimum in-plant changes to reduce waste-water or BOD discharge, 2) wastewater and BOD discharge coefficients per 1,000 pounds of milk equivalent (M.E.) are the same as those used in the

DPRA study (phase II, Table V-l) and 3) all plants operate 250 days a year.

Spray irrigation is more expensive to operate than a ridge and furrow system that does not require pumping. Spray irrigation investment for processing plants discharging 10,000 GPD is $2,500-2,750, 40,000 GPD is $4,200-5,200 and 80,000 GPD is $7,999-8,000 (Development Document, 1974). If whey is discharged with the cheese plant wastewater, the investments are $3,250, $7,200 and $13,000, respectively because of the need for additional land. Annual total operating costs are $1,550 for the 10,000 GPD, $2,850 for the 40,000 GPD, and $4,600 for the 80,000 GPD of waste discharge. For the cheese plants discharging whey with the wastewater, the annual total costs are $1,600, $3,100, and $5,200, respectively. About 70% of these costs are variable and the remainder fixed. The dollar values should not be considered firm but only in terms of comparison of expenses per system.

On a per 1,000 pounds M.E. basis, the costs differ depending on the product manufactured. For evaporated milk, ice cream, and fluid plants, the cost decreases from 304 per 1,000 pounds of M.E. throughout to 144 for the 40,000 GPD discharge and 11 cents for the 80,000 GPD discharge. Butter-powder plant costs per 1,000 pounds M.E. decrease with increasing plant size and are 20, **10** and 8 cents, respectively. The cost of cheese plants without whey in the effluent are 14, 6 and 5 **cents** per 1,000 pounds of M.E., but the cost for the cheese plants discharging 10,000 gallons of wastewater including whey is 70 and 35 **cents** for the 40,000 GPD and 29 cents for the 80,000 GPD.

The ridge and furrow costs are lower and the economies of size encountered for spray irrigation are not evident. Investment for ditching and tiling land, the land itself and ditching to the disposal site for 10,000 GPD is $1,600 (one-half acre) for fluid, ice cream, evaporated milk and cheese without whey discharge plants, $3,200 for butter plants, and $6,400 for cheese plants discharging whey. The investments for the 40,000 and 80,000 GPD discharge are respectively four and eight times the investment figures for the 10,000 GPD plants. Annual operating costs (total) are assumed to be 20% of the total investment. This may be considered high, but these systems do require more attention than they generally receive to keep them operating properly at all times.

On a per 1,000 pounds of M.E. basis, the cost is 74 for fluid, evaporated milk and ice cream plants regardless of the size. The cost is 84 per 1,000 pounds M.E. for butter-powder, 34 per 1,000 pounds M.E. for cheese plants without whey discharge, and 554 per 1,000 pounds M.E. for cheese plants with all whey in the effluent. In any case, the cost per pound of finished product is very small. However, the costs must be adjusted to reflect current dollars as inflation has surely increased the capital and operating costs.

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MUNICIPAL DISCHARGE

Municipal Systems

Following a study of the dairy industry, a federal agency estimated in 1967 that 98 percent of the ice cream and fluid milk plants would discharge their wastewaters to municipalities by 1977. Another group of researchers surveyed the dairy industry in 1969 and found 87 percent of the dairy plants discharged their wastewaters to municipal systems (Harper et. al., 1971). They found that over 90 percent of the plants producing milk, ice cream and combinations of milk and ice cream discharged to municipal systems. In fact, 96 percent of the combination ice cream and cottage cheese plants were discharging to municipal systems in their comprehensive 1969 survey. Following a more recent survey, researchers estimated that 96 percent of the fluid milk plants discharge to municipal systems while almost 100 percent of ice cream plants discharge to municipal systems (DPRA, 1975).

The discharge of fluid milk wastes to municipal systems has been found feasible by researchers and EPA. The high BOD_5 load of a new plant, as for any industrial facility would necessitate review of a pal plant's ability to take the load. Pretreatment has generally been found not necessary unless the municipal plant is of inadequate size. However, whey should be segregated if the dairy wastewaters are a significant part of the municipal hydraulic load. The average dairy plant in 1980 should process 250,000 pounds per day of milk. The waste generated from this average plant will have daily BOD_5 loads of 2,000 - 10,000 pounds.

PL 92-500 and PL 95-217 has some subtilities that will cost the food industry dollars and have a great impact on their future. Requirements for industrial cost recovery, user charges and sewer use ordinances can cost and affect dairy plants. Ten-fold cost increases for municipal water and sewer bills may not be uncommon in the next several years.

The sewer use ordinance as used is to refer to the "sewer ordinance" defined as an instrument setting forth rules and regulations governing the use of the public sewer system (Anon., 1975a). In most cases the industrial cost recovery and surcharges (user charges) may be a part of this instrument. Little can be reported about industrial cost recovery as few municipalities have imposed the same and an 18 month moratorium has recently been imposed.

Dairy plant managers must ask themselves what is happening now and what will happen in the near future. Although charges for industrial wastes began as early as 1907 (Cleary, 1971), as late as 1969 only about 10% of United States municipalities collected these charges. Most municipalities did not have a stringent sewer use ordinance until after 1960. Most municipalities do not have one in 1978 although state and federal pressure and encouragement will surely force most municipalities to draft such an ordinance. Key questions industrial dischargers must ask is how can they get a reasonable ordinance that gives both them and the city system protection -- the plants in having sewage treatment, at a reasonable cost and the city in preventing illegal or toxic discharges.

PL92-500 and EPA require that municipalities institute industrial cost recovery, a system of user charges and have a sewer use ordinance if they obtain federal funds for water or wastewater facilities. However, one must look carefully at exactly what else is required.

Industrial input is needed before any municipal sewer use ordinance is instituted. Plant managers must assist in the development of a "practical and sound regulatory ordinance fitted to local conditions" (Anon., 1975a). Industry should want the minimum number of restrictions that will protect the municipal system. These restrictions should be technically sound and rigidly enforced.

Harper et al. (1971) concluded that as municipalities increase the use of surcharges or impose legal limits on wastewater that industry will take a more active role in waste management. However, where management was already initiating action programs to control waste, they felt they lacked essential knowledge to deal effectively with the problem. This information is presented to help you assist in filling this void.

A trend of municipalities setting limits on industrial wastewater discharges at levels commonly found in domestic waste was uncovered during the national dairy wastewater survey (Harper et al., 1971). The survey team concluded that dairy plants <u>cannot</u> possibly meet these standards. Thus, the construction of separate treatment facilities was concluded to be inevitable if the trend continues. Most other food plants also can not meet these standards unless water is wasted in processing. For the dairy industry, separate treatment facilities may cost approximately 25% of the capital cost of new facilities.

A comnon method for municipalities to institute surcharges is to first pass an industrial user ordinance. Model ordinances are presented by WPCF (Anon., 1975a) and Cleary (1971). A method usually presented in such an ordinance for meeting Federal requirements for "equitable" charges is a system of industrial waste surcharges. Surcharges are based on the pounds of waste discharged and/or on the volume of effluent discharged. A surcharge is levied in addition to the normal sewer charges based on water used. Sewer charges are normally a constant proportion of an industrial firm's water bill and examples noted include 10 to 200 percent of the water bill with a normal range of 50-100 percent of the water bill. The general theory of surcharges is to allow a town to recover some revenue while providing industrial firms an economic incentive to reduce the amount of water carried waste.

Municipal Sewer Ordinances

Introduction

Most municipalities have sewer use ordinances. Those that don't will probably institute sewer use ordinances in the near future. Public Law 92-500, subsequent laws and EPA require that municipalities institute industrial cost recovery, implement user charges and have a sewer use ordinance if they obtain federal funds for water and wastewater facilities. Almost all municipalities use federal funds when they build or expand their current sewer system. Industry must assist the municipality in the development of a "practical and sound regulatory ordinance fit to local conditions" (Anon., 1975a). Industry should want the minimum number of restrictions that will protect municipal systems. Everyone should encourage an ordinance that is technically sound and rigidly enforced.

The sewer use ordinance is used to refer to the "sewer ordinance" defined as an instrument setting forth rules and regulations governing the use of the "public sewer system" (Anon., 1975a). In most cases, the industrial cost recovery and surcharge or user charge system will be a part of this instrument. Although charges for industrial waste began as early as 1907 (Cleary, 1971), as late as 1969 only about 10% of the United States' municipalities collected these charges (Anon., 1970). Most municipalities did not have a stringent sewer use ordinance until after 1960. Many municipalities did not have one in 1975 although state and federal pressures and encouragement will surely force these municipalities to draft such an ordinance. Many municipalities ignore most sections of their sewer use ordinance. Industry should not be complacent because there are no problems, for enforcement of existing ordinances can happen at any time. Industry has found a tremendous difference in the way that the sewer use ordinances are interpreted and enforced. A key question that any industrial discharger must ask is how to have a reasonable ordinance that gives both the industry and the city system protection - the industry in having sewage treatment, at a reasonable cost and the municipality in preventing unreasonable or toxic or illegal discharges. Public Law 92-500 puts some specific requirements on municipalities using federal funds to help build sewer systems. However, experiences indicate that there are a number of differences between the way the EPA regional administrators read the law and enforce the sewer use ordinance requirements in the law. One would question how municipalities that pass maximum BOD discharge limitations of 300 mg/l in light of the EPA construction grants guidelines 4.4.5.2 on industrial service which states that industrial use of municipal facilities should be encouraged when environmental and monetary costs would be minimized.

The regional administrator is given the authority to see that a sewer use ordinance or other legally binding requirement will be enacted and forced to prohibit new connections from inflow sources into the sanitary sewer and to insure that new sewers and connections are properly designed and constructed. Also, that a user charge and ICR system are required to be incorporated into the ordinance. Basically, other requirements are at the discretion of the municipal leaders.

Sewer Ordinances - Details

Sewer use ordinances are commonly drafted by city engineers and city legal people. They frequently use model ordinances. Model ordinances include the following:

1) WPCF MOP No. 3 - Regulation of Sewer Use - 1975

2) APWA - Special Report No. 23 Guidelines for Drafting a Municipal Ordinance on Industrial Wastes Regulations and Surcharges - 1971

3) WRRI - UNC - Surcharges for Industrial Waste: Suggestions and Guidelines - 1972

4) League of municipalities has model ordinances that are often used.

5) The Uniform Ordinance Subcommittee of the Industrial Waste Committee of the California Water Pollution Control Association compiled a model wastewater discharge ordinance in April of 1974.

The development of model ordinances is not always contrary to industrial users. In fact the uniform ordinances sub-committee of the industrial waste committee of the California Water Pollution Control Association prepared a model wastewater discharge ordinance in April of 1974, which is very thorough. However, such ordinances are often used without reading the forward which can be found in the model wastewater discharge ordinance. The developers of the ordinance emphasized that the ordinance they prepared is a model and was not intended to be universally applicable. They recommend that agencies wishing to use the model ordinance either in part or wholly should do so with caution after ascertaining its capability with local agency regulations, statutes, administrative policy, and local industry.

The writers of the model wastewater discharge ordinance indicated that the purposes of the model wastewater ordinance were several. These included: 1) establishment of uniform practices for enforcement and to facilitate disposable waste pollutants; 2) promotion of greater efficiency among regulatory and municiple agencies carrying out industrial source control programs; 3) provision of a basis of equity and fairness to industry and private industry dischargers who must comply with regulations which can vary from community to community; and 4) elimination of undesirable relocations of industries from one waste treatment jurisdiction to another.

A sewer use ordinance contains a number of standard items. The sections that are commonly found are as follows: (1) Preamble - This is the whereases that establish the reason for the ordinance. (2) Definitions - definitions that relate to this specific ordinance. Use of public sewers is required. (3) Use of sewers is noted with any further additions and/or regulations. (4) The power and authority of the inspectors is granted. (5) Surcharge or user charge is established with sampling, analysis, and formula provided. (6) Enforcement in penalties are noted. (7) Conflict cause. (8) A review process clause; and (9) an effective date.

Plant management should be especially wary of a number of key parts to a sewer use ordinance which are explained in the Municipal Discharge Spinoff Manual. All key words should be included in the definitions. For instance: Does representative sample mean **a** grab sample, an average of 4 grab samples at 15 minute intervals or a 24 hour, proportional composit sample? Does sample manhole refer to any manhole or does it mean a manhole with a weir and sampling device installed at industry's expense? Some questions that should be asked about a sewer use ordinance include:

- Does the ordinance contain the specifics of resampling if industry objects to a particular sample? What are the costs of the resampling?
- What method(s) is specified for sampling? Is (wastewater the sample proportional to flow? What is the characteristics) frequency of the samples? Does each sample period give a set of characteristics or are sample periods averaged to determine wastewater characteristics?
- Does the ordinance have a special clause allowing a contract or agreement between industry and the municipality to allow otherwise prohibited flows or concentrations? Who okays such a pact? Will you be able to get one approved?
- When, who and how is pretreatment or flow equalization required?
- What is the ordinance going to cost the plant as its proposed after enactment?
- Are there defacto or real limitations prohibiting the discharge from your plant?
- Are there unrealistic limitations on parameters such as pH, FOG, BOD_5?

A common problem area is that either Federal or State Environmental Protection Agency persons represent themselves as "insisting and requiring" that the city have a sewer use ordinance. This may be true, but what one needs to ask is what do they require. In the Municipal Discharge Spinoff, the specific requirements of the Environmental Protection Agency are covered. There are only four or five requirements that must be included in sewer use ordinance and nothing at the federal level except personal whims require the 28 to 30 page documents that are commonly seen.

A real problem is that governing bodies such as the Town Council which usually passes sewer use ordinances had no knowledge about BOD or your particular wastewater situation. It is the responsibility of industry to see that they gain this knowledge.

A problem presented in many sewer use ordinances is that monitoring and analysis costs are prohibitive. These costs are usually passed on in the surcharges and user charges. Experiences indicate that monitoring and analysis costs may be more than 20 to 25% of a surcharge bill. Once wastewater parameters are established, there may be little need for more sampling on a continuing basis if this was done accurately.

Specific problems have been noted in sewer use ordinances for food plants. The following problems have been noted specifically for dairy plants as listed in Table 28.

Specific steps can be taken in obtaining changes in either a new sewer use ordinance or amendments to a sewer use ordinance. The specific steps that can be taken include:

- Make sure that your local lawyer obtains outside legal and technical advice familiar with food plant wastes.
- Find persons on your local authority who will listen intently.
- Do not say that you do not like part 5, section 2, item A; put a proposed change in ordinance language for consideration.
- Get help from other industries and business groups who will be confronted with similar problems from the ordinance.

A number of sewer use ordinances have been modified with a concerted industry effort. Legal and technical advice has been essential in these cases. Most authorities respond to valid attacks on specifics.

The lack of details available about obtaining changes in sewer use ordinances is partially explained by the procedure the development of a sewer use ordinance follows. As a normal rule, the person in charge of the waste treatment works and planning presents an ordinance drafted by an engineering firm for approval of the board or council. As the council members feel incompetent to review and discuss the same, rapid passage is the rule. Mr. Rankine, a noted attorney, stated that it is the most important matter that a sewer regulating authority can pass.

Table 28. Problems Noted For Food Plants In Sewer Use Ordinances

1) Holding tanks being required for flow equilization.
2) The requirements for the construction of a controlled manhole or sampling facility might cost the plant as much as $25,000 or more.
3) Limitations or prohibitions on wastewater discharge that would prohibit the plant from operating.
4) The requirement that production records be released on all products, which becomes a matter of public record.
5) Wording in the sewer use ordinances for samples so that nonrepresentative samples are obtained of your wastewater which can be very costly.
6) The requirement that surcharges be based on water metered into the plant. Dairy plants discharge as little as 45% of the metered water in as wastewater. These plants, if paying on the basis of metered water, then pay twice the surcharge they should be paying.
7) Complete authority given to the engineer manager. As long as your politics are good with the engineer manager, you're in good shape, but experiences indicated that often problems will need the expertise of the Town Council.
8) Surcharge charged for industrial users only. EPA requires that user charges be charged for all users. Municipalities commonly eliminate a number of large contributors of waste load such as laundromats, motels, restaurants, private facilities, who should be paying user charges or surcharges. Then the total bill for industrial users are divided among only the larger users an contributors of wastewater. Therefore, the surcharge bill is more than it should be.

The food industry is almost always affected because it has industries in almost every municipality. For health and sanitation, much cleaning and washing results in large amounts of organic wastes which equate to BOD_5. Also, most food materials contain fat which is forbidden above certain levels in most ordinances.

The most obvious legal fault generally observed in the sewer use ordinance development is the authority giving any or adequate legal notice and a chance for a hearing. A sewer use ordinance requires vast amounts of technological expertise. And if the city is trying to reduce loads and not generate revenue, time is required by industry to institute changes. Another problem presented in many ordinances is that industry is singled out to pay for waste which is not a valid classification, according to EPA, for all users must pay equally.

The technical aspects are examined in detail in the Municipal Discharge Spinoff Manual. An ordinance with technically impossible limitations will receive little industrial support. Cities and industry must work together if wastewater treatment efficiency is to be realized.

The legal field of ordinance making is complex and ill reported. Challenges are usually settled out of court and legal records and precedents have not been established. The best defense to a badly drafted sewer use ordinance is a good lawyer and a friend(s) on the body responsible for voting on the same. Industries faced with bad ordinances must rally their forces and present a united front. City managers should consult industry when they draft or revise sewer ordinances

A pact or contract with the city fathers allowing specific exemption for a plant's wastes is a realistic alternative if an ordinance is in existence with a clause for such a pact. But, an industry must get the best technical and legal advise before doing this. Details for developing such pacts are presented in the Municipal Discharge Spinoff.

A trend of municipalities setting limits on industrial wastewater discharges at levels commonly found in domestic waste was uncovered during the national dairy wastewater survey (Harper et al., 1971). The survey team concluded that dairy plants cannot possibly meet these standards with present technology. Thus, the construction of separate treatment facilities was predicted inevitable if the trend continues.

For example, the Metropolitan Sanitary District of Chicago in 1973 put a restriction on municipal discharge of 100 mg/l of hexane extractable fats, oils and greases (Lassus and Selitzer, 1977). Bagans et al. (1974) reported that a dairy plant was faced with a fine of $1000 per day and a $500 per month surcharge unless their hexane soluble levels were reduced below 100 mg/l.

Municipal Charges

Municipal charges for industrial plants include water, sewer, surcharge (user charge) and industrial cost recovery. Most municipalities compute water and sewage charges as follows:

Water . . .	Based on water consumption metered into the plant. Often on a declining block scale so that the cost/unit decreases as you use more water. Note that the bill is usually in hundreds of cubic feet (1 cu. ft. = 7.48 gal.). Cost usually ranges from $0.10 to $1.00 per 1000 gallons.
Sewer Charge . . .	Based on computed water charge and usually represents 10 to 200 % of the water bill. Normally 100% is the most common figure seen in the Southeast.
Surcharge . . .	Based most often on metered water consumption and a parameter(s) measured in the wastewater. The most common factor is BOD_5 and usually charged at a rate of $0.10 to $2.00 per pound for those pounds in excess of normal sewage. Similarly, the suspended solids (TSS) load is also used. A hydraulic load charge is sometimes included and is often used as a "demand charge" especially for seasonal operations.
Industrial Cost Recovery . . .	Recovery by the grantee from the industrial users of a treatment works of the grant amount allocable to the treatment of wastes from such users pursuant to section 204 (b) of PL- 92-500.

Sewer Charge. In the 1969 industry wide survey, 80% of the dairies discharging to municipalities paid a sewer charge. A sewer charge is a charge based on volume of water purchased and is usually 10-200% of the water bill.

Surcharges

Surcharges are often included in a sewer use ordinance. However, they may be included in a separate ordinance. Surcharges are usually passed because of local government's problems such as: 1) Waste treatment costs are rising, 2) More treatment is being required, 3) Loads are often increasing, 4) Property tax is already overburdened, or 5) because the municipality has received federal funds and is required to institute user charges. User charges were dictated by PL 92-500 (35.925-11) as follows:

... system of user charges to assure that each recipient of waste treatment services within the applicants service area will pay its proportionate share of the costs of operation and maintenance...

Industrial surcharges are expected to (Anon, 1972):

(1) Provide a more equitable recovery of the costs of waste treatment than ordinary charges based on volume alone.

(2) Reduce wastes discharged to the city sewers because industrial firms are required to expend capital to combat excessive surcharges.

(3) Reduce water used by industry because water reductions usually precede waste reductions.

(4) Allow a treatment system to operate at this lower waste loading with the same effect as expansion of facilities, requiring new capital investment.

Surcharge. A charge based on the pounds of waste material in industrial wastewater in excess of normal levels of concentration is called a "surcharge". It is levied in addition to the normal sewer service charge which is the regular charge for treating normal strength wastes and is based on volume alone. A surcharge is normally only for pounds of waste above the waste load from normal (domestic wastewaters) and an economic incentive is provided to reduce the strength of the wastes.

Some 7% of the dairy plants discharging to municipalities in the 1969 survey were found to be also paying a surcharge. A surcharge for dairy plants often is a charge based on strength of the wastewater constituents such as BOD_5 or SS. A surcharge is levied in addition to sewer charges. Watson (1961) reported New York City passed an ordinance requiring a surcharge for wastewaters with a BOD_5 greater than 300 mg/l, chorine demand greater than 25 mg/l, suspended solids greater than 350 mg/l and ether solubles greater than 50 mg/l

Normal Wastes. Normal waste refers to that waste normally found in wastewaters from households. These waters usually have the following composition:

BOD	250-300 mg/l
COD	250-370 mg/l
SS	50-200 mg/l
Hexane Solubles	100 mg/l

Harper et al. (1971) found the waste composition for 10 selected dairy plants processing at least 250,000 pounds per day of milk to be:

	Range (mg/l)	Average (mg/l)
BOD	750-4200	3100
SS	200-3700	2450

Most food plant wastewaters are more concentrated than normal wastes, and surcharges are often being included in billings where authorized by the municipal authority.

Measurement of Flow and Strength. The main weakness in many surcharge ordinances is in the method of sampling. Someone must determine the waste concentration of a plant's effluent and also determine the flow. Flow is often determined from water meter readings which is disadvantageous to the normal dairy plant. The effluent in a multiproduct dairy was determined to be 64 percent of the water received from the city. At least one municipal ordinance in North Carolina and many others throughout the century will allow a plant credit for their consumptive uses in product, cooling tower evaporation and steam losses. The well managed milk, cottage cheese, and frozen products plants will have a consumptive use of at least 20-40 percent of their water received on a yearly average.

A representative sample of dairy plant wastewater is almost impossible to obtain. The wide ranges presented in numerous studies show that day-to-day variations are too large to allow a sample from one day to be representative. Seasonal production of certain items surely eliminates one set of samples being representative of a dairy processing plant. Also, the only true measure of the waste from a plant is a 24 hour proportional, composite sample. This is a sample that mixes volumes of waste in proportion to effluent flow over a representative time period. Night flows from dairy plants are largely cooling waters and leaks and are not heavily polluted. A sample taken from 8:30 a.m. - 4:30 p.m. is not representative of the whole processing day. Sampling by a proportional, composite sampler requires a flow regulating device such as a wier or flume and a sampler such as the arm scoop type. Such techniques are accurate but are expensive. Most municipalities and industries are not willing to go to such extremes to get a representative sample.

Chemical analyses must be run on the sample of wastewater to determine the waste characteristics. These tests should be performed on fresh wastewater samples which have been refrigerated during collection. Failure to follow standard analysis procedures can result in erroneous tests results. Well trained, competent technicians are especially important.

Effect of Surcharge. Most food plants will be forced to reduce their wastes to avoid surcharge costs. Segregation of concentrated wastewater such as whey and subsequent disposal as animal food or surface application may be required. Pretreatment is an expensive option for dairy processing plants. The removal of fats, oils and grease for dairy plants is much more difficult than for meat and poultry wastewaters.

Cost of Surcharge. The potential water and waste charges for a dairy plant were examined by Carawan et al. (1975). The surcharge costs a dairy plant will incur from processing cottage cheese were shown to be approximately $4000/month for a production using 20,000 gallons of milk each day. Water and sewer costs are another $537.72/month with a total cost per pound of cottage cheese produced of 0.9 cents/lb. These figures are for a plant processing 20 days each month.

This cost is a major item in the cost of production of the cottage cheese. However, if the surcharge rate goes up from the $0.0354/1b. BOD and TSS to 0.0739/1b. BOD and TSS, the cost per pound of cottage cheese produced goes up to 1.7 cents/lb. Dairy processors who produce cottage cheese must realize the implication of surcharge costs on the profitability of their finished product.

A plant processing an average of 500,000 pounds of product each day for 22 days of the month was shown to have a monthly municipal bill of approximately $10,000. This represents a cost to the plant of 0.094 cents/lb. of product or approximately 0.8 cents/gal. of product.

Municipal Costs. Carawan (1975) predicted the municipal costs for a multiproduct dairy. Total municipal costs for water use, sewer charge and surcharge totaled approximately $10,000 per month for a plant producing an average of 500,000 pounds of product for each of 22 working days. Water and sewer charge were approximately $1,500 and the remaining $8,600 was surcharge.

A serious effort needs to be made to check the validity of the surcharge calculations. A number of questions about the surcharge calculation procedure include the following: 1) What characteristics determine the charge, flow, BOD_5; 2) SS, peak flow, demand; 3) How are average characteristics used; 4) What is the charge for each characteristic, 5) What flow is used; and 6) How often are samples taken.

The computation of the average characteristics in itself can lead to a number of problems for the average dairy plant. For instance, if the city samples for 3 days, does it average the samples based on concentration or does it compute a weighted mean based on flow which would be more indicative of the wastewater flow? The question of how often the samples are taken is another problem. If the city takes the samples too often, a plant will pay for the cost of the sampling and analysis in its bill, and will get no benefits. If, however, the city takes the samples on a less rigid schedule, then the plant may not get the benefit of its variation in waste. Perhaps the most fair method is for the last three samples to be averaged together to compute what the average characteristics are. Then, you will get the benefit of low and high readings and compute a true average.

A multiproduct dairy might have wastewater parameters such as the following:

Multiproduct Dairy Plant

Production - 50,000 gallons of milk per day

Water Use - 150,000 gallons per day

Wastewater - 100,000 gallons per day
BOD_5 - 3156 pounds per day (3784 mg/l)
SS - 1544 pounds per day (1851 mg/l)
Fat - 1006 pounds per day (1206 mg/l)

The wastewater characteristics for dairy plants are very variable. For example, numerous authors who have studied dairy wastewaters have indicated that the wastewater parameters may have a range such as shown:

Dairy Wastewaters
BOD_5 - 500 to 5,000 mg/l
SS - 400 to 3500 mg/l
Fat - 200 to 3,000 mg/l
Flow - 0.5 to 20 pounds per pound of product

We might consider that a 50,000 gallon of milk per day plant is a typical plant. However, many plants now produce two or three times this amount of milk per day, while some plants produce less. A water, sewer and surcharge bill would look something like the following:

Dairy Monthly Costs
(Production: 50,000 gallons of milk/day)

Water ($.25/1000 gallons)	$825.
Sewer (100% of water)	825.
Surcharge ($.075/lb. BOD_5)	4691.
Total	$6341.

The figures shown above-of $6341 per month for a 50,000 gallon of milk per day dairy plant would represent a cost per gallon of milk of about $.0058. If we note that the profits per dollar sales of average plants in some states have been determined to be 2.8% then we can see that the cost per gallon of milk of over 1/24 is very significant in determining the profit per dollar of sales.

Specific problems can be presented by discharging the whey from cottage cheese manufacturing facilities. For example, if a BOD_5 surcharge is charged at 7.39 cents per pound BOD_5 then the cost per pound of finished cottage cheese will be about 1.7 cents for the surcharge for the acid whey,

Thus, the manager of a dairy plant can see in these costs that if he does not have a surcharge, that the passing of a surcharge ordinance by his local municipality will make a tremendous impact on his plant. This impact is particularly felt in the financial aspects because charges of $5,000 or $10,000 per month are not at all uncommon. The disposal of cottage cheese whey to a municipal system for a large cottage cheese producing facility is prohibited by cost if the city accurately determines the plant's waste discharge. For those smug plant managers who feel they are getting a good deal now, we should caution them that a number of plants have had things going very smoothly and then as personnel changed in the city system, new problems developed for them.

A number of municipalities do not accurately sample the wastewaters. This can be in the plant's favor or the city's favor. A number of municipalities use metered water-in to compute the surcharge bills and this works against a dairy processing facility. The BOD is discussed elsewhere in this handbook but is generally regarded as a measure of the strength of the waste discharged to the city sewer system. A surcharge is computed by sampling the waste drain from a dairy plant, finding the flow from that dairy plant, and then computing the waste load from that dairy plant. Often, plants are allowed to discharge BOD levels up to normal strength with no surcharge.

In addition to the above, Public Law 92-500 requires municipalities to collect ICR or Industrial Cost Recovery charges from industries discharging to municipal systems. These charges are designed to help the municipality and the Federal Government recover that portion of the costs which are attributable directly to the discharge of the industrial plant. Presently, under the 1977 Water Act Amendments, there is a moratorium on the collection of ICR charges. The costs are too variable to guess what any individual plant would be charged.

Close

In conclusion, your plants *will* probably face the issues discussed herein within the next several years. It would be to your benefit to be ready to assist them in these most serious negotiations. You must tell them to be alert to any indication that a sewer use ordinance is being developed or revised.

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DIRECT DISCHARGE

Introduction

Dairy plants that discharge wastewaters directly to streams, bays, sounds, rivers, creeks and/or estuaries must have a permit for this discharge. In most cases, even plants that have septic tanks for process wastewaters must also have a permit. Dairy plants that use non-discharge systems such as land disposal will also need a permit. Permits for discharge are usually obtained from the state environmental control agency.

Effluent Guidelines and Limitations

Introduction

In response to widespread public concern about the condition of the Nation's waterways, Congress enacted the Federal Water Pollution Control Act Amendments of 1972. The 1972 act built upon the experiences of earlier water pollution control laws. The 1972 act brought dramatic changes.

What the 1972 law says, in essence, is that nobody - no city or town, no industry, no government agency, no individual - has a right to pollute our water. What was acceptable in some areas in the past - the free use of waterways as a dumping ground for our wastes - is no longer permitted. From now on, under the 1972 law, we must safeguard our waterways even if it means fundamental changes in the way we manufacture products, produce farm crops, and carry on the economic life of our communities. Congress declared that the objective of the 1972 law is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."

- The law required EPA to establish national "effluent limitations" for industrial plants - including dairy products plants. An "effluent limitation" is simply the maximum amount of a pollutant that anyone may discharge into a water body.

- By July 1, 1977, the law required existing industries to reduce their pollutant discharges to the level attainable by using the "best practicable" water pollution control technology (BPT). BPT is determined by averaging the pollution control effectiveness achieved by the best plants in the industry.

- By July 1, 1983, the law requires existing industries to reduce their pollutant discharges still more - to the level attainable by using the "best available" pollution control technology (BAT). BAT was based on the best pollution control procedures economically achievable. If it is technologically and economically feasible to do so, industries were required to completely eliminate pollutant discharges by July 1, 1983. EPA studies concluded that this was not feasible for the dairy industry.

- The law requires new industrial plants to limit pollutant discharges to the level attainable by meeting national "standards of performance" established by EPA for new plants. A new plant was required to meet these standards immediately, without waiting for 1977 or 1983. Congress directed that these new plant standards may require greater reduction of pollutant discharges than the 1977 and 1983 standards for existing plants. Where practicable, zero discharge of pollutants can be required.

- The law requires industrial facilities that send their wastes to municipal treatment plants - as many dairies do - to make sure the wastes can be adequately treated by the municipal plant and will not damage the municipal plant. In some industries, discharges to municipal plants may thus have to be "pre-treated." That is, the portion of the industrial waste that would not be adequately treated or would damage the municipal plant must be removed from the waste before it enters the municipal system. EPA has determined that dairy wastes are compatible, that they will not damage municipal systems and that they do not require pretreatment.

- The law does not tell any industry what technology it must use. The law only requires industries to limit pollutant discharges to levels prescribed by law.

- The law also says that if meeting the 1977 and 1983 requirements is not good enough to achieve water quality standards, even tougher controls may be imposed on dischargers.

- And while the law requires industries to meet the national discharge standards set for 1977, 1983 and for new plants, the law also allows a state or community to impose stricter requirements if it wishes. The national standards are thus minimum requirements that all industries must meet.

The key to applying the effluent limits to industries - including the dairy industry - is the national permit system created by the 1972 law. (The technical name is the "national pollutant discharge elimination system," or NPDES.) Under the 1972 law it is illegal for any industry to discharge any pollutant into the Nation's waters without a permit from EPA or from a state that has an EPA-approved permit program.

This combination of national effluent standards and limits, applied to specific sources of water pollution by individual permits with substantial penalties for failure to comply, constitutes the first effective nationwide system of water pollution control.

Now what does all this mean to the dairy industry? How does one determine the NPDES permit limitations for a plant discharging into a receiving stream?

The U. S. Environmental Protection Agency prepared standards for dairy plants under the 1972 law. EPA did so, after considering many factors: the nature of dairy plant raw materials and wastes; manufacturing processes; the availability and cost of pollution control systems; energy requirements and costs; the age and size of plants in the industry; and the environmental implications of controlling water pollution. (For instance, we would gain nothing if, in controlling water pollution, we created a new air or land pollution problem.)

The proposed regulations were issued December 20, 1973. They were sent to the industry and other interested organizations for review and comments. They were made public by publication in the Federal Register. Comments were submitted by dairy companies and dairy industry organizations, by State agencies, and by Federal agencies. EPA then carefully analyzed the comments and made selected changes in the standards.

On May 28, 1974, EPA issued the final standards for dairy plants to follow in order to meet the requirements of the 1972 law.

The standards are contained in an official government regulation published in the Federal Register. This regulation is supported by a detailed technical document called the "Development Document for Effluent Limitations, Guidelines and New Source Performance Standards for the Dairy Product Processing Point Source Category."

In brief, here is what the regulation does for dairy facilities that are direct dischargers:

- Sets limits on identified pollutants that can be legally discharged by small and large plants in twelve sub-categories of the dairy products industry:" milk receiving stations; producers of market milk; cultured products; butter; cottage and cream cheese; natural and process cheese; fluid mix for ice cream and other frozen desserts; ice cream and frozen desserts and novelties; condensed milk; dry milk; condensed whey; and dry whey.

- Zeroes in on the major dairy industry pollutants, it establishes maximum limitations for BOD and suspended solids that dairy plants can discharge during any one day, and on an average over a thirty-day period based on the BOD input to the plant.

- Sets limits that can be met by using the "best practicable control technology currently available" - the 1977 requirement (Table 29).

- Sets more stringent limits that can be met by using the "best available technology economically achievable" - the 1983 requirment (Table 30). (For an example of the difference between the 1977 and 1983 standards, consider this: By July 1, 1977, a large milk receiving station must limit its discharge of organic waste (BOD) to 0.048 of a pound per pounds BOD taken into the plant (Table 29). By July 1, 1983, the BOD discharge must be lowered to 0.010 of a pound per 100 pounds BOD taken into the plant (Table 30).

- The economic impact on small dairy plants was lessened by easing their BPT control requirements - a major change from the originally proposed limits.

- Requires that the pH (acidity or alkalinity) of dairy plant discharges be within the range of 6.0 to 9.0.

- Establishes performance standards that new dairy plants must meet without waiting for 1977 or 1983. For the dairy industry, the new plant standard is the same as the 1983 standards for existing plants. (In some industries, the new plant standard may require greater control of pollutants, based on new technology not readily applicable to existing plants.)

- Does not require zero discharge of any pollutant by a dairy plant. Zero discharge is technically possible in the industry. However, the cost would be prohibitive for most if not all plants in the industry.

- Does not tell dairy companies what technology to use to meet regulations. The standards only require dairy companies to limit

Table 29. 1977 Effluent Guidelines (BPT) for the Dairy Industries.

	(Contaminant levels per 100 lb BOD_5 Input)			
	BOD		TSS	
Industrial Category (Production)	maximum daily	average 30 days	maximum daily	average 30 days
(lb/day)	(lb)	(lb)	(lb)	(lb)
Receiving Stations				
Small ≤ 150,000	.063	.031	.094	.047
Other > 150,000	.048	.019	.071	.029
Fluid Products				
Small ≤ 250,000	.450	.225	.675	.338
Other > 250,000	.338	.135	.551	.203
Cultured Products				
Small ≤ 60,000	.450	.225	.675	.338
Other > 60,000	.338	.135	.506	.203
Butter				
Small ≤ 175,000	.183	.091	.274	.137
Other > 175,000	.138	.055	.206	.083
Cottage Cheese				
Small ≤ 25,000	.893	.446	1.339	.669
Other > 25,000	.670	.268	1.005	.402
Natural Cheese				
Small ≤ 100,000	.098	.049	.146	.073
Other > 100,000	.073	.029	.109	.044
Ice Cream Mix				
Small ≤ 85,000	.293	.146	.439	.219
Other > 85,000	.220	.088	.330	.132
Ice Cream				
Small ≤ 85,000	.613	.306	.919	.459
Other > 85,000	.460	.184	.690	.276
Condensed Milk				
Small ≤ 100,000	.460	.230	.690	.345
Other > 100,000	.345	.138	.518	.207
Dry Milk				
Small ≤ 145,000	.218	.109	.328	.164
Other > 145,000	.163	.065	.244	.098
Condensed Whey				
Small ≤ 300,000	.130	.065	.195	.098
Other > 300,000	.100	.040	.150	.060
Dry Whey				
Small ≤ 57,000(40%)	.130	.065	.195	.098
Other > 57,000(40%)	.100	.040	.150	.060

≤ = less than or equal to weight of milk equivalents.

> = greater than weight of milk equivalents.

Table 30. 1983 Effluent Guidelines (BAT) for the Dairy Industries.

	(Contaminant levels per 100 lb BOD_5 Input)			
	BOD		TSS	
Industrial Category (Production)	maximum daily	average 30 days	maximum daily	average 30 days
(lb/day)	(lb)	(lb)	(lb)	(lb)
Receiving Stations				
Small ≤ 150,000	.015	.008	.019	.009
Other > 150,000	.010	.005	.013	.006
Fluid Products				
Small ≤ 250,000	.110	.055	.138	.069
Other > 250,000	.074	.037	.093	.046
Cultured Products				
Small ≤ 60,000	.110	.055	.138	.069
Other > 60,000	.074	.037	.093	.046
Butter				
Small ≤ 175,000	.025	.013	.031	.016
Other > 175,000	.016	.008	.020	.010
Cottage Cheese				
Small ≤ 25,000	.223	.111	.278	.139
Other > 25,000	.148	.074	.185	.093
Natural Cheese				
Small ≤ 100,000	.025	.013	.031	.016
Other > 100,000	.016	.008	.020	.010
Ice Cream Mix				
Small ≤ 85,000	.073	.036	.091	.045
Other > 85,000	.048	.024	.060	.030
Ice Cream				
Small ≤ 85,000	.140	.070	.175	.088
Other > 85,000	.094	.047	.118	.059
Condensed Milk				
Small ≤ 100,000	.115	.058	.144	.072
Other > 100,000	.076	.038	.095	.048
Dry Milk				
Small ≤ 145,000	.055	.028	.069	.034
Other > 145,000	.036	.018	.045	.023
Condensed Whey				
Small ≤ 300,000	.033	.016	.041	.020
Other > 300,000	.022	.011	.028	.014
Dry Whey				
Small ≤ 57,000(40%)	.033	.016	.041	.020
Other > 57,000(40%)	.022	.011	.028	.014

≤ = less than or equal to weight of milk equivalents

> = greater than weight of milk equivalents.

pollutant discharges to levels found attainable by using best practicable control technology.

An amendment to the regulation issued February 11, 1975, says this: Existing dairy products plants that send their wastes to publicly-owned treatment plants may do so without pre-treating the wastes. A municipal plant may establish its own requirements however, to prevent problems. For example, equalization may be required so as to prevent the discharge of a heavy surge of whey which may upset or interfere with the operation and efficiency of a public treatment plant.

In 1978, EPA reviewed the BAT standards in light of Section 304 (b)(4) of the Clean Water Act which established "best conventional pollutant control technology" (BCT). BCT was intended to replace BAT. Congress directed EPA to consider the:

> . . . reasonableness of the relationship between the costs of attaining a reduction in effluents and the effluent reduction benefits derived, and the comparison of the cost and level of reduction of such pollutants from the discharge of publically owned treatment works to the cost and level of reduction of such pollutants from a class or category of industrial sources

The dairy processing industry was studied and regulations were proposed in the August 23, 1978, Federal Register. The results of these studies indicated to EPA that-they should establish BCT = BAT regulations. Thus, no change resulted for the dairy industry although many changes occurred for the food industry.

Despite the voluminous amount of material available in regard to the regulations, many dairy processors will find they are facing state regulations more stringent than the BPT, BAT or BCT standards. Discharge into certain waters is often restricted and stringently controlled. When facing a permit situation, prompt contact with the proper regulatory officials is recommended.

The key to applying the effluent limits to industries - including the dairy industry - is the national permit system created by the 1972 law. (The technical name is the "National pollutant discharge elimination system," or NPDES.) Under the 1972 law it is illegal for any industry to discharge any pollutant into the Nation's waters without a permit from EPA or from a State that has an EPA-approved permit program. Every industrial plant that discharges pollutants to a waterway must therefore apply for a permit. Even truck wash facilities for dairy trucks discharging to storm sewers are required to have a permit.

When issued, the permit regulates what may be discharged and the amount of each identified pollutant. It sets specific limits on the effluent from each plant. It commits the discharger to comply with all applicable national effluent limits and with any State or local requirements that may be imposed. If the industrial plant cannot comply immediately, the permit contains a compliance schedule - firm target dates by which pollutant discharges will be reduced or eliminated as required. The permit also requires dischargers to monitor their wastes and to report the amount and nature of wastes put into waterways. The permit, in essence, is a contract between a company and the government. Complete details of the permit can be found in the Legal Spinoff.

NPDES - Effect of Limitations on Discharge

The values in Table 31 were arrived at by using the BPT and BAT effluent guidelines for subcategories in the dairy industry from Tables 29 and 30 and appropriate coefficients contained in the Development Document for Dairy Product Processing. The objective of Table 31 is to show approximately the allowable concentration (mg/l) and the total load (lb/day) of a pollutant discharged by a processing plant with a NPDES permit. The following example details the calculations necessary to obtain some of the values in Table 31.

Example 1 - A receiving station that receives 15,600 lbs of BOD_5 per day from the input of whole milk. What are the BPT and BAT one day maximum allowable load and concentration of BOD_5.

Step 1 - Find the wastewater volume, Q, in gallons.

Q = (BOD_5 received/100) (wastewater flow coefficient)

Q = (15,600# BOD_5/100) (65 gal/100# BOD_5)

Q = 10,140 gal.

Table 31. Effect of Effluent Limitations On Large Dairy Processing Facilities.[f]

Category	Parameter	BOD Received[e] (lb/day)	Wastewater Flow - gal per 100 lbs BOD Input	Wastewater Volume (gal)	Raw Waste Load - lb/100 lbs BOD Input	Raw Waste Load (lb)	Raw Waste Conc. (mg/l)
A) Receiving Station-bulk	BOD[d]	15600	65c	10140	0.17a	26.5	313.6
	TSS	15600	65	10140	0.03b	4.7	55.6
B) Fluid Products	BOD	25900	466	120694	3.21	831.4	826.0
	TSS	25900	466	120694	1.5	388.5	386.0
D) Butter	BOD	18180	251	45632	0.80	145.4	382.2
	TSS	18180	251	45632	0.40	72.4	190.4
F) Natural Cheese	BOD	10390	81	8416	0.60	62.3	888.2
	TSS	10390	81	8416	0.19	19.7	281.3
H) Ice Cream	BOD	8830	890	78587	13.45	1187.6	1812.0
	TSS	8830	890	78587	3.20	282.6	431.1
G) Ice Cream Mix	BOD	8830	236	20839	0.99	87.4	503.0
	TSS	8830	236	20839	0.30	26.5	152.4
I) Condensed Milk	BOD	10390	485	50392	2.20	228.6	543.9
	TSS	10390	485	50392	0.82	85.2	202.7
J) Dry Milk	BOD	15070	300	45210	1.62	244.2	647.5
	TSS	15070	300	45210	-	-	-
K) Condensed Whey	BOD	14160	293	41489	1.05	148.7	429.7
	TSS	14160	293	41489	0.86	121.8	351.9
L) Dry Whey	BOD	15620	320	49984	1.44	224.9	539.6
	TSS	15630	320	49984	0.94	146.8	352.2

[a]Development Document, p. 48 - mean values from Identified Plant Sources.
[b]Development Document, p. 51 - mean values from Identified Plant Sources.
[c]Development Document, p. 55 - mean values from Identified Plant Sources.
[d]BOD = BOD_5
[e]Milk received is approximatly equal to 10 x (BOD Received)

Continiued . . . . .

Table 31 continued . . . . .

	BPT Effluent Limitations[g] (lb/100 lbs)		BPT Load (lb/day)		BPT Cont. (mg/l)		BAT Effluent Limitations[h] (lb/100 lbs)		BAT Load (lb/day)		BAT Cont. (mg/l)	
	One Day Maximum	Consec-utive 30 Day Avg.	One Day Maximum	Consec-utive 30 Day Avg.	One Day Maximum	Consec-utive 30 Day Avg.	One Day Maximum	Consec-utive 30 Day Avg.	One Day Maximum	Consec-utive 30 Day Avg.	One Day Maximum	Consec-, utive 30 Day Avg.
A)	0.048	0.019	7.49	2.96	88.5	35.0	0.010	0.005	1.56	0.78	18.5	9.2
	0.071	0.029	11.08	4.52	131.0	53.5	0.013	0.006	2.03	0.94	24.0	11.1
B)	0.338	0.135	87.54	34.97	87.0	34.7	0.074	0.037	19.17	9.58	19.0	9.5
	0.551	0.203	142.71	52.58	141.7	52.2	0.093	0.046	24.09	11.91	23.9	11.8
D)	0.138	0.055	25.09	10.0	65.9	26.3	0.016	0.008	2.91	1.45	7.6	3.8
	0.206	0.083	37.45	15.09	98.4	39.6	0.020	0.010	3.64	1.82	9.5	4.8
F)	0.073	0.029	7.58	3.01	108.1	42.9	0.016	0.008	1.66	0.83	23.7	11.8
	0.109	0.044	11.33	4.57	161.3	65.1	0.020	0.010	2.08	1.04	29.6	14.8
H)	0.460	0.184	40.62	16.25	62.0	24.8	0.094	0.047	8.30	4.15	12.7	6.3
	0.690	0.276	60.93	24.37	93.0	37.2	0.118	0.059	10.42	5.21	15.9	7.9
G)	0.220	0.088	19.43	7.77	111.8	44.7	0.048	0.024	4.24	2.12	24.4	12.2
	0.330	0.132	29.14	11.66	167.7	67.1	0.060	0.030	5.30	2.65	30.5	15.2
I)	0.345	0.138	35.85	14.34	85.3	34.1	0.076	0.038	7.90	3.95	18.8	9.4
	0.518	0.207	53.82	21.51	128.1	51.2	0.095	0.048	9.87	4.99	23.5	11.9
J)	0.163	0.065	24.56	9.80	65.1	26.0	0.036	0.018	5.43	2.71	14.4	7.2
	0.244	0.098	36.77	14.77	97.5	39.2	0.045	0.023	6.78	3.47	18.0	9.2
K)	0.100	0.040	14.16	5.66	40.9	16.4	0.022	0.011	3.12	1.56	9.0	4.5
	0.150	0.060	21.24	8.50	61.4	24.5	0.028	0.014	3.96	1.98	11.5	5.7
L)	0.100	0.040	15.62	6.25	37.5	15.0	0.022	0.011	3.44	1.72	8.2	4.1
	0.150	0.060	23.431	9.37	56.2	22.5	0.028	0.014	4.37	2.19	10.5	5.3

[f]For example, a receiving station will have to reduce its raw waste concentration from 313.6 mg/l BOD_5 to an average of 9.2 mg/l BOD_5 to meet BAT standards - a reduction of 97.1%. Authors note - Although the calculations are from industry averages, each plant must meet limitations based on their own wastewater flow and raw waste load. Table serves to explain the process.

[g]From Table 29.

[h]From Table 30.

Step 2 - Find the raw waste load, W_L, in lbs.

W_L = (#BOD_5 received/100)(raw waste load coefficient)

W_L = (15,600# BOD_5/100)(0.17 lbs/100 lbs of BOD_5)

W_L = 26.5 lbs

Step 3 - Find the raw waste concentration, W_C, in mg/l.

Wc = (W_L/Q)(unit conversions)

W_C = (26.5 lbs/10,140 gal)(l ga1/3.81)(453.6 g/lb)(1000 mg/g)

W_C =313.4 mg/l

Step 4 - Find the one day maximum BPT load in lbs/day.

BPT load = (#BOD_5 received/100)(BPT effluent limitation)

load = (15,600# BOD/100)(0.048 lbs/100# BOD)

load = 7.49 lbs/day of BOD_5

Step 5 - Find the one day maximum BPT concentration in mg/l.

BPT cont. = (BPT load/Q)(unit conversions)

cont. = (7.49 lbs/10,140 gal)(1 ga1/3.81)(453.6 g/lb)(1000 mg/g)

cont. = 88.5 mg/l

Step 6 - Find the one day maximum BAT load in lbs/day.

BAT load = (# BOD_5 received/100)(BAT effluent guidelines)

load = (15,600# BOD_5/100)(0.010 lb/100 lbs)

load = 1.56 lbs/day

Step 7 - Find the one day maximum BAT concentration in mg/l.

BAT cont. = (BAT load/Q)(unit conversions)

cont. = (1.56 lbs/10,140 gal)(l ga1/3.8 1)(453.6 g/lb)(l1000 mg/g)

cont. = 18.4 mg/l

Calculation of NPDES Using Effluent Guidelines

Introduction

To determine the amount of pollutant which may be discharged according to a NPDES permit there are several prior factors to consider. The applicable effluent guideline needs to 'be determined. Is it BPT, BAT, BCT, or NSPS? Is the plant classified as a large or small plant? Has the effluent guideline, if challenged, been upheld or rejected by the courts? And, if the courts agreed with the plaintiff by suspending the effluent guidelines, what then are the enforceable standards that effect the plant? Has the receiving stream been classified by the state regulatory agency as a special water quality stream with stricter effluent guidelines? These are some of the initial questions which need to be answered before a reasonable estimate of the NPDES permit requirements can be made. A contact with state or federal regulatory personnel should help answer these questions.

Calculation of BOD_5 Received or Input to the Process

To establish the amount of BOD_5 received by a dairy plant it is imperative to maintain the same procedure that was used in the development of the effluent guidelines. BOD_5 received must be calculated on the following basis:

1. All dairy raw materials (milk and/or milk products) and other materials (e.g., sugar) must be considered.
2. The BOD_5 input must be computed by applying factors of 1.031, 0.890, and 0.691 to inputs of proteins, fats and carbohydrates respectively. Organic acids (such as lactic acid) when present in appreciable quantities should be assigned the same factor as carbohydrates. The composition of raw materials may be obtained from the U.S. Department of Agriculture Handbook No. 8, Composition of Foods and other reliable sources.

For example the calculation of BOD_5 in lb of BOD_5/gal of product or in mg/l for 1 gallon of raw milk would be:

Step 1 - Composition of raw milk.
fat = 3.8%; protein = 3.32%; lactose = 4.46%

Step 2 - Density of raw milk is approximately 8.6 lb/gal, but may vary depending on temperature, fat content, and solids content.

Step 3 - Individual contribution of components to BOD_5 of raw milk.
Component, (lb of BOD_5) = (weight of product)(% component/100) (component BOD_5 factor)

a. fat (lb of BOD_5) = (8.6 lb)(0.038)(0.890)
= 0.291 lb.

b. protein (lb of BOD_5) = (8.6 lb)(0.0332)(1.031)
= 0.2944 lb.

c. Lactose (lb of BOD_5) = (8.6 lb)(0.0466)(0.691)
= 0.2769 lb.

Step 4 - E of components to find lb of BOD_5/gal of raw milk.
E = 0.291 + 0.2944 + 0.2769
E = 0.8623 lb of BOD_5/gal of raw milk.

Step 5 - Unit conversion to express BOD_5 in mg/l.
BOD_5 (mg/l) = (lb BOD_5/gal)(1 ga1/3.81)(453.6 g/lb)(1000 mg/g)
BOD_5 (mg/l) = 102,931 mg/l

Thus using the composition of the product and the appropriate BOD_5 factor the BOD_5 input for the plant can be determined. Plants are classified as either "small" or "other" plants by the amount of BOD_5 input. Each class of plant has a different effluent guideline with the small plants having a higher allowable discharge per lb of BOD_5 input to the process. Then by using the effluent guideline value and the BOD_5 input the amount of discharge can be found.

Single-Product Plant

To derive the amount of discharge allowable for a single-product one simply multiplies the effluent guideline value by the BOD_5 input to the plant. For example a receiving station that handles 50,000 gallons of raw milk the one day maximum BAT discharge of TSS would be:

Step 1 - Weight of raw milk.
= (50,000 ga1)(8.6 lb/gal) = 430,000 lb.

Step 2 - Raw milk composition.
3.8% fat; 3.32% protein; 4.46% lactose.

Step 3 - Individual contribution of components to BOD_5 of raw milk.

a. fat = (430,600 lb)(0.038)(0.890)
= 14,542.6 lb of BOD_5

b. Protein = (430,000 lb)(0.0332)(1.031)
= 14,718.6 lb of BOD_5

c. Lactose = (430,000 lb)(0.0446)(0.691)
= 13,252.0 lb of BOD_5

Step 4 - Total BOD_5 input.

E component of BOD_5 = 14,542.6 + 14,718.6 + 32,252.0
BOD_5 = 42,513.2 lb.

Step 5 - One day maximum BPT discharge of TSS.

TSS discharge (lb/day) = (BOD_5 input)(effluent guideline for an "other" plant)
= (42,513.2 lb)(0.071 lb/100 lb)
= 30.18 lb of TSS

Multiproduct Plant

The multiproduct plant limitation can be derived on the basis of a weighted average. A weighted average is calculated by weighing the single-product guideline by the BOD_5 processed in the manufacturing line for each product.

Discharge limitation = E (guideline limitation x (BOD_5) input for each process)

Type of Plant: Natural cheese and Dry Whey

Purchases

Whole Milk .	500,000 lb (51,950 lb of BOD_5)
40% Solids Whey	30,000 lb (8,210 lb of BOD_5)

Intra-Plant Transfers (For Further Processing)

1.	Sweet Whey	455,000 lb (21,476 lb of BOD_5)
2.	40% Sol ids Whey	75,860 lb (20,760 lb of BOD_5)

Determination of BOD_5 multiproduct BPT effluent limitation for consecutive 30 day average.

Subcategory and Input	Effluent Limitation	Guideline Discharge
1. Natural Cheese		
500,000 lb Whole Milk		
(51,950 lb of BOD_5)		
Total BOD_5)	0.029 lb/100 lb	15.07 lb
2. Condensed Whey		
455,000 lb Sweet Whey		
(21,476 lb of BOD_5)		
Total BOD_5	0.040 lb/100 lb	8.59 lb
3. Dry Whey		
105,860 lb 40% Solids		
Whey		
(28,970 lb of BOD_5)		
Total BOD_5 Input 28,970	0.040 lb/100 lb	11.59'lb
Discharge Limitation for Total Plant =		35.25 lb

Impact of Effluent Guidelines

What does all this mean - to the dairy companies, to those of you who work in or with a dairy plant. Consider some questions that you may very well be asking yourself at this point about the impact of pollution control on the dairy industry.‘

1. Can dairy plants meet the 1977 limitations? That is technologically, can they reduce their discharges of pollutants to the levels required by 1977?

Based on all available information, the answer is yes. Most existing dairy plants have met the 1977 standards. EPA estimated that by meeting the 1977 standards, dairy plants will reduce their discharges of organic materials by about 90-95 percent, and of suspended solids by about 85-90 percent. And in meeting the 1983 standards, dairy plants will have to achieve even greater reductions in pollutant discharges.

Moreover, existing dairy plants that do not want to invest in pollution control equipment may have the option, depending on where they

Here the answer is no. No additional plant closings are expected as a result of the 1983 standards.

8. How will the 1977 and 1983 standards affect consumers? What impact will they have on the price of dairy products? Here are some estimates for several dairy products:

Butter - It's estimated that meeting the 1977 and 1983 standards may cause a 1.1 percent increase in the wholesale price of butter. If that increase is passed on to consumers, it would mean an increase in the retail price of butter of less than one cent a pound.

Cheese - It's estimated that there may be a 0.4 percent increase in the wholesale price of cheese. If passed on to consumers, that would mean an increase of three-tenths of a cent per pound of cheese.

Milk - About 90 percent of the large milk processors are already linked to municipal treatment systems. For the remaining large milk plants that discharge their wastes directly into water bodies, it's estimated that meeting the 1977 and 1983 standards may cause the price of milk to increase by one-tenth of 1 percent. For a half-gallon of milk that now retails for 75 cents, that would mean a price hike of less than a tenth of a penny.

Ice Cream - About 90 percent of large ice cream plants are already linked to municipal treatment systems. For the remaining plants that are direct dischargers, it's estimated that meeting the 1977 and 1983 standards may raise the prices by 0.9 to 1.2 percent. For a half-gallon of ice cream that retails for $1.69, that could mean a price increase of up to two cents.

Canned Milk - It's estimated that there may be a 0.6 percent increase in the price of canned milk. If passed on to consumers, that would mean an increase of one-tenth of a cent per twenty-cent can of milk.

Thus, water pollution control requirements for the dairy industry will have a negligible impact on the price of dairy products. However, one must note that these price increases do not include the increased costs noted for plants considering discharging to municipalities. Considering these plants, EPA estimated cost increases for consumers 4 to 5 times the increases predicted using only the direct discharges. Thus, water pollution control may add a price increase at the supermarket of 5 cents per pound of butter and 10 cents for a half-gallon of ice cream.

9. What about the productive capacity that will be lost if about one hundred dairy plants do indeed shut down? It was estimated that those plants account for only 0.2 percent of the industry's production. The slight drop in the industry's production was predicted as being able to be more than made up by other plants, which were found not to be operating at full capacity.

Thus, water pollution control requirements for the dairy industry were predicted to have no long-range repercussions in terms of supplies of dairy products or industry growth. And the standards were predicted to not affect the Nation's balance of trade with other countries; they will not affect exports of dairy products and will not cause an increase in imports of dairy products.

In summary, except for about 100 small plants that are already having trouble staying in business, the U. S. dairy industry can meet the water pollution control requirements mandated by the 1972 law. The result will be cleaner water for all of us to enjoy and less waste of usable dairy products. Subsequent amendments by Congress have not altered the requirements for the dairy industry.

However, the full impact of the 1972 law and subsequent amendments including the Clean Water Act have not yet been felt by the dairy industry. For example, many plants are not and may not be able to meet the 1983 standards or more rigorous state water quality standards within the time frame proposed by EPA. In fact, the hypothetical reuse and recovery systems proposed have not been fully developed or accepted by the industry and regulatory officials. The variability that will be experienced by biological treatment systems has not been accepted by the current regulations. For example, many plants may meet the BCT standards 90% of the time. Will EPA action force closure of these plants? Much research and engineering needs to go into process equipment, recovery systems and treatment processes before the dairy industry can fully meet all current regulations. Perhaps with your help, the dairy industry not discharging into municipal systems will be able to develop the needed technology to help meet all environment regulations necessary to protect our waters.

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