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Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the

DAIRY PRODUCT PROCESSING

Point Source Category

May 1974

U.S. ENVIRONMENTAL PROTECTION AGENCY
Washington, D.C. 20460

DEVELOPMENT DOCUMENT

for

EFFLUENT LIMITATIONS GUIDELINES

and

NEW SOURCE PERFORMANCE STANDARDS

for the

DAIRY PRODUCTS PROCESSING POINT SOURCE CATEGORY

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Abstract

This document presents the findings of an extensive study of the dairy products processing industry by A. T. Kearney, Inc. for the Environmental Protection Agency for the purpose of developing effluent limitations guidelines, Federal standards of performance, and pretreatment standards for the industry, to implement Sections 304, 306, and 307 of the "Act."

Effluent limitations guidelines contained herein set forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through application of the best available technology economically achievable which must be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively. The Standards of Performance for new sources contained herein set the degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives.

The development of data and recommendations in the document relate to the twelve subcategories into which the industry was divided on the basis of the levels of raw waste loads and appropriate control and treatment technology. Separate effluent limitations were developed for each subcategory on the basis of the raw waste load as well as on the degree of treatment and control achievable by suggested model systems.

Supportive data and rationales for development of the proposed effluent limitations guidelines and standards of performance are contained in this report. Potential approaches for achieving the limitations levels and their costs are discussed.

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SECTION I

CONCLUSIONS

Size and Nature of the Industry

The basic function of the dairy products processing industry is the manufacture of foods based on milk or milk products. However, a limited number of non-milk products such as fruit juices are processed in some plants.

There are over 5,000 plants in the dairy products industry located all over the United States. Plants range in size from a few thousand kilograms to over 1 million kilograms of milk received per day.

There are about 20 different basic types of products manufactured by the industry. A substantial number of plants in the industry engage in multi-product manufacturing, and product mix varies broadly among such plants.

Industry Categorization

For the purpose of establishing effluent limitations guidelines and standards of performance the dairy products industry can be logically subcategorized in relation to type of product manufactured. Available information permits a meaningful segmentation into the following subcategories at this time:

- 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

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. However, a collateral economic study (conducted for the Environmental Protection Agency by Development Planning and Research Associates, Inc.) indicates that the costs of comparable treatment facilities impose a severe economic impact on the smaller plants in each subcategory. Thus, the subcategories should be further segmented by size to permit employment by the smaller plants of lesser technology that is within their financial capabilities.

Pollutants and Contaminants

The most significant pollutants contained in dairy products plant wastes are organic materials which exert a biochemical oxygen demand and suspended solids. Raw waste waters from all plants in the industry contain quantities of these pollutants that are excessive for direct discharge without appreciable reduction. The pH of many individual waste streams within a plant are outside the acceptable range, but there is generally a tendency for neutralization with commingling of waste streams. However, adjustment of pH is easily accomplished and the final discharge(s) from a plant should be kept within an acceptable range.

Additional contaminants found in dairy plant wastes include: phosphorus, nitrogen, chlorides, and heat. In general, control and treatment of the primary pollutants (organics and suspended solids) will hold these lesser pollutants to satisfactory levels. In isolated cases where these pollutants may be critical they should be handled on a case by case basis.

A major contributor to dairy waste BOD_5 is dairy fat, which is being treated successfully biologically. This is in contrast to mineral based oil which inhibits the respiration of microorganisms. The standard hexane soluble FOG (fats, oils, and grease) test used presently does not differentiate between mineral oil and dairy fat. Separate standards and tests should be developed for these two parameters.

Control and Treatment of Waste Water

In-plant controls, including management and engineering improvements, that are readily available and economically achievable can substantially reduce waste loads in the dairy industry. In many cases these controls can produce a net economic return through by-product recovery or reduced cost of waste treatment.

Conventional end-of-pipe treatment technology is capable of achieving a high degree of reduction when applied to the raw wastes of dairy plants. Attainment of zero discharge by complete recycle of waste waters, though a technical possibility through employment of reverse osmosis, carbon filtration and other advanced treatment techniques, is beyond the realm of economic feasibility for most if not all plants in the industry.

SECTION II

RECOMMENDATIONS

It is recommended that effluent limitation guidelines for existing sources and standards of performance for new sources in the dairy products industry be established for BOD5, suspended solids and pH. These limitations and standards are recommended only for dairy plants discharging to navigable waters. For dairies discharging to sanitary systems, municipalities should adopt other standards that reflect their own particular requirements.

BOD5 and Total Suspended Solids

Recommended effluent limitations guidelines and standards of performance for BOD5 and total suspended solids in terms of the average value for any consecutive thirty day period are set forth in Table 1.

pH

It is recommended that the pH of any final discharge(s) be within the range of 6.0-9.0.

Method of Application

Calculation of BOD5 Received.

It is recommended that in applying the guidelines and standards the waste load of a particular plant be determined and compared to the guidelines and standards. In doing so, it is imperative that consistency be maintained in regard to the basis on which the waste loads are developed.

To maintain consistency the calculation of the BOD5 received (going into processes in the case of multi-product plants) must be done 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 BOD5 input must be computed by applying factors of 1.031 0.890 and 0.691 to inputs of proteins, fats and carbohydrate 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. Compositions of some common raw materials are given in Table 8.

Table 1

Effluent Limitation Guidelines for BOD5 and TSS

Subcategory (1)	Limitations in kg/kkg BOD5 Input (2)					
	Level I(3)		Level II(4)		Level III(5)	
	BOD5	TSS	BOD5	TSS	BOD5	TSS
Receiving Stations						
Small	0.313	0.469	0.075	0.094	0.050	0.063
Other	0.190	0.285	0.050	0.063	0.050	0.063
Fluid Products						
Small	2.250	3.375	0.550	0.688	0.370	0.463
Other	1.350	2.025	0.370	0.463	0.370	0.463
Cultured Products						
Small	2.250	3.375	0.550	0.688	0.370	0.463
Other	1.350	2.025	0.370	0.463	0.370	0.463
Butter						
Small	0.913	1.369	0.125	0.156	0.080	0.10
Other	0.550	0.825	0.080	0.10	0.080	0.10
Cottage Cheese						
Small	4.463	6.694	1.113	1.391	0.740	0.925
Other	2.680	4.020	0.740	0.925	0.740	0.925
Natural Cheese						
Small	0.488	0.731	0.125	0.156	0.080	0.10
Other	0.290	0.435	0.080	0.10	0.080	0.10
Ice Cream Mix						
Small	1.463	2.194	0.363	0.454	0.240	0.30
Other	0.880	1.320	0.240	0.30	0.240	0.30
Ice Cream						
Small	3.063	4.594	0.70	0.875	0.470	0.588
Other	1.840	2.760	0.470	0.588	0.470	0.588
Condensed Milk						
Small	2.30	3.450	0.575	0.719	0.380	0.475
Other	1.380	2.070	0.380	0.475	0.380	0.475
Dry Milk						
Small	1.088	1.638	0.275	0.344	0.180	0.225
Other	0.650	0.975	0.180	0.225	0.180	0.225
Condensed Whey						
Small	0.650	0.975	0.163	0.204	0.110	0.138
Other	0.40	0.60	0.110	0.138	0.110	0.138
Dry Whey						
Small	0.650	0.975	0.163	0.204	0.110	0.138
Other	0.40	0.60	0.110	0.138	0.110	0.138

NOTES:
(1) See Table 7 for definition of products included in each subcategory.
(2) See calculation of BOD5 below for derivation of values for BOD5 received.
(3) Best practicable control technology currently available.
(4) Best available technology economically achievable.
(5) Standards of performance for new sources.

Multi-Product Plants

The guidelines and standards set forth in Table 1 apply only to single-product plants. It is recommended that limitations for any multi-product plant be derived from Table 1 on the basis of a weighted average, i.e., weighting the single-product guideline by the BOD5 processed in the manufacturing line for each product. That is:

$$\text{Multi-product Limitation} = \sum \left(\begin{array}{l} \text{Guideline (in kg/kkg or lb/100 lb)} \\ \text{For each single product sub-} \\ \text{category present in the plant} \end{array} \times \begin{array}{l} \text{Number of kkg or 100 lb} \\ \text{units of BOD5 input} \\ \text{for each single product} \\ \text{subcategory present} \end{array} \right)$$

Examples of application of guidelines to multi-product plants are as follows:

Type of Plant: Fluid Products, Cottage Cheese and Ice Cream

Raw Materials Processed (Avg. per Day)

Purchases

1.	Whole Milk	400,000 lb (41,560 lb of BOD5)
2.	40% Cream	20,000 lb (7,750 lb of BOD5)
3.	30% Condensed Skim	16,000 lb (3,520 lb of BOD5)
4.	Nonfat Dry Milk	2,000 lb (1,480 lb of BOD5)
5.	Sugar	6,500 lb (4,490 lb of BOD5)

Intra-Plant Transfers (For Further Processing)

1.	Skim Milk	50,000 lb (3,660 lb of BOD5)
2.	36% Cream	3,000 lb (1,100 lb of BOD5)

Determination of BOD5 Multi-Product Guideline, Level I (BPCTCA)

Subcategory and Input	Guideline Value	Guideline Discharge
1. Fluid Products 400,000 lb Whole Milk (41,560 lb of BOD5) Total BOD5 Input 41,560 lb	0.135 lb/100 lb	56.11 lb
2. Cottage Cheese 50,000 lb Skim Milk (3,660 lb of BOD5) 3,000 lb 36% Cream (1,100 lb of BOD5) Total BOD5 Input 4,760 lb	0.268 lb/100 lb	12.76 lb

3. Ice Cream 16,000 lb 30% Condensed Skim (3,520 lb of BOD5) 20,000 lb 40% Cream (7,750 lb of BOD5) 2,000 lb Nonfat Dry Milk (1,480 lb of BOD5) 6,500 lb Sugar (4,490 lb of BOD5) Total BOD5 Input 17,240 lb	0.184 lb/100 lb	31.72

Recommended Discharge for Total Plant = 100.59 lb of BOD5.

Type of Plant: Natural Cheese and Dry Whey

Raw Materials Processed (Avg. per Day)

Purchases

1. Whole Milk 500,000 lb (51,950 lb of BOD5)
2. 40% Solids Whey 30,000 lb (8,210 lb of BOD5)

Intra-Plant Transfers (For Further Processing)

1. Sweet Whey 455,000 lb (21,476 lb of BOD5)
2. 40% Solids Whey 75,860 lb (20,760 lb of BOD5)

Determination of BOD5 Multi-Product Guideline, Level I (BPCTCA)

Subcategory and Input	Guideline Value	Guideline Discharge
1. Natural Cheese 500,000 lb Whole Milk (51,950 lb of BOD5) Total BOD5 Input 51,950	0.029 lb/100 lb	15.07 lb
2. Condensed Whey 455,000 lb Sweet Whey (21,476 lb of BOD5) Total BOD5 Input 21,476 lb	0.040 lb/100 lb	8.59 lb
3. Dry Whey 105,860 lb 40% Solids Whey (28,970 lb of BOD5) Total BOD5 Input 28,970	0.040 lb/100 lb	11.59 lb

Recommended Discharge for Total Plant = 35.25 lb

A second decision to be made in regard to multi-product plants is that of size designation for determination of which guideline limitation values, those for small or those for other, should apply. If any single subcategory representation in a multi-product plant exceeds the size limitations suggested for designation as a small single product plant of that subcategory, irrespective of the size of the remaining subcategory representations the multi-product plant should not be designated as small. If none of the individual subcategory representations exceed the size limitations for their corresponding subcategories, it is recommended that each representation be expressed as a fraction of the corresponding subcategory limitation, and if the sum of the fractions does not exceed 1.5, the facility should be designated a small multi-product plant. That is.....

$$\sum \left(\frac{\text{Subcategory Representation}}{\text{Subcategory Size Limitation}} \right) \leq 1.5 \quad \text{Facility is a Small Multi-Product Plant}$$

For subcategory size limitations see Section IV.

Time Factor for
Enforcement of the Guidelines

The proposed effluent limitations and performance standards are based on thirty-day averages. For purposes of enforcement and determination of violations, daily maximums as multiples of the thirty-day average should apply, reflecting variability attributable to the reliability of technology. In the case of best practicable control technology currently available, daily maximum values of two times and two and one-half times the thirty-day averages are recommended for small plants and larger plants respectively. For best available technology economically achievable and new source performance standards daily maximum values of two times the thirty-day averages are recommended for all plants.

Because of the hourly and daily fluctuations of waste concentrations and waste water flows in the dairy products industry, waste loads should be measured on the basis of daily proportional composite sampling. This is particularly true for plants utilizing treatment facilities with relatively short retention times (e.g., activated sludge) which result in a greater tendency for influent fluctuations to be reflected in the effluent.

SECTION III

INTRODUCTION

Purpose and Authority

Section 301 (b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301 (b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304 (b) of the Act. Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology,, processes, operating methods, or other alternatives. including where practicable, a standard permitting no discharge of pollutants.

Section 304 (b) of the Act requires the Administrator to publish within one year of enactment of the Act, regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices economically achievable including treatment techniques, process and procedure innovations, operation methods and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304 (b) of the Act for the dairy products processing industry.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306 (1) (A) of the Act to propose regulations establishing Federal standards of performances for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973 (38 F.R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the dairy industry which was included within the list published January 16, 1973.

Summary of Methods Used for Development of the Effluent Limitations Guidelines and Standards of Performance

The effluent limitations guidelines and standards of performance proposed herein were developed in the following manner. The dairy products processing industry was first analyzed for the purpose of determining whether separate limitations and standards are appropriate for different segments within the industry. Such analysis was based upon raw material used, product produced, manufacturing process employed, and other factors. The raw waste characteristics for each subcategory were then identified. This included an analyses of (1) the source and volume of water used in the process employed and the sources of waste and waste waters in the plant; and (2) the constituents (including thermal) of all waste waters including toxic constituents and other constituents which result in taste, odor, and color in water or aquatic organisms. The constituents of waste waters which should be subject to effluent limitations guidelines and standards of performance were identified.

The full range of control and treatment technologies existing within each subcategory was identified. This included an identifaciton of each distinct control and treatment technology, including both in-plant and end-of-process technolgies, which are existent or capable of being designed for each subcategory. It also included an identification in terms of the amount of constituents (including thermal) and the chemical, physical, and biological characteristics of pollutants, of the effluent level resulting from the application of each of the treatment and control technologies. The problems, limitations and reliability of each treatment and control technology and the required implementation time were also identified. In addition, the non-water quality environmental impact, such as the effects of the application of such technologies upon other technology and the required implementation time were also identified. In addition, the non-water quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, noise and radiation were also idenitified. The energy requirements of each of the control and treatment technologies were identified as well as the cost of the application of such technologies.

The information, as outline above, was then evaluated in order to determine what levels of technology constituted the "best practicable control technology currently available," "best available technology, processed, operating methods, or other alternatives." In identifying such technologies, various factors were considered. These included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, non-water quality environmental impact (including energy requirements) and other factors.

The data for identification and analyses were derived from a number of sources. These sources included EPA research information, published literature, a voluntary questionaire issued by the Dairy Industry Committee, qualified technical consultation, and on-site waste sampling, visits, and interviews at dairy food processing plants throughout the United States. All references used in developing the guidelines for effluent limitations and standards of performance for new sources reported herein are included in Section XIV of this document.

Basic Sources of Waste Load Data

Prior Research

At the outset of this study, it was recognized that most of the information on dairy food plant wastes available as of 1971 had been collected and reviewed in two studies prepared for EPA:

1. "Study of Wastes and Effluent Requirements of the Dairy Industry," July 1971, by A.T. Kearney, Inc., for the Water Quality Office, EPA.

2. "Dairy Food Plant Wastes and Waste Treatment Practices, "March 1971, by Department of Dairy Technology, The Ohio State University, for the Office of Research and Monitoring, EPA.

The purpose of the 1971 Kearney study was to establish an informational background and recommend preliminary effluent limitation guidelines for the dairy industry. The Ohio State University study was a "state-of-the-art" report that set forth in great detail practically all available technical knowledge on dairy products processing. Dr. W. James Harper, the lead investigator for the Ohio State University study, served as a consultant to A. T. Kearny for the preparation of its report for the Water Quality Office, and essentially the same data base was utilized in both studies.

Sources of Data For This Study

Although many of the key factors affecting waste loads had been identified in the aforementioned reports and other technical literature, it was recognized that an expanded and refined data and informational base was needed to meet requirements associated with development of effluent limitations guidelines for the dairy products industry. Furthermore, it is imperative that all data used for development of guidelines be of a "verifiable" nature (i.e., the result of testing in identified plants that could be available for verification of data if necessary), and much of the data in the technical literature is not identified as to specific source. A concerted effort was devoted to a program to develop new and verifiable data that would supplement or even supplant the data available in the technical literature.

The body of quantitative data on wastes available for development of effluent limitations guidelines that resulted from this program was an aggregate of portions obtained from the following sources;

1. In-plant sampling of waste streams at selected dairy plants undertaken by independent certified laboratories under the direction of A.T. Kearney and with the assistance of dairy plant managements.

2. In-plant sampling at selected plants performed by the dairy companies utilizing contractors or company technical personnel, and with quality control assured by direction and observation of A.T. Kearney or EPA.

3. Data obtained from State and Municipal agencies (e.g., the Metropolitan Sanitary District of Greater Chicago) which have monitored the waste of selected dairy plants for regulatory purposes.

4. Data supplied by dairy companies which are the result of sampling programs conducted by the companies since the time of Kearney's 1971 study.

5. Plant waste survey data developed by independent research organizations (e.g., North Carolina Sate University) at selected dairy operations in the last two years.

6. Data furnished by the dairy industry to Kearney and Ohio Stae University during the 1971 studies for EPA in coded Form, but through company cooperation now identified as to specific plant source with pertinent operational parameters furnished.

Quality of the Data

Because of the high variability of dairy plant wastes in hydraulic load and strength, both during a day and from day to day, it is recognized that a composite made up of samples taken at hourly intervals or over a few days may yield values that depart considerably from true average loads. However, the variance that may exist because of low frequency of sampling or insufficient number of days in the sampling period decreases as the number of data points (one-day composites) in the data base increases.

While the approximately 150 plants included in the verifiable data base constitute only 3% of the total number of plants within the dairy products industry, it should be noted that the data base is the most extensive one of its nature compiled to date. The number of individual product manufacturing lines represented in aggregate is much greater than the number of plants, since many of the facilities are multi-product plants. Moreover, two additional factors should be borne in mind. The major thrusts in developing the data base were directed toward obtaining information on exemplary operations and securing representation of the range of size, age and other variables encountered in plants manufacturing each type of finished product.

Several control measures were imposed on the sampling program to maintain the quality of the waste load data. All analyses employed approved standard methods conducted under acceptable laboratory quality control. Flow-weighted composite sampling was used in all but a few cases, with the time interval between taking all aliquots ranging from 2 to 60 minutes. Exceptions were made only when information from a particular plant was highly desirable and installation of flow-proportioned composite sampling equipment was not possible. Constant volume sampling at set intervals was accepted in some cases when there was indication that variation of flow was within the limits of error of many field-flow measurement devices.

The number of days in any one sampling period at a plant ranged from 1 to 10 days, with the vast majority of the cases entailing 3 or more days. In a number of cases the data on plants that was furnished by the companies covered a long-term monitoring program.

General Description of the Industry

Production Classification

The industrial category covered by this document comprises all manufacturing establishments included in Standard Industrial Classification (SIC) Group No. 202 ("Dairy Products"), and "milk receiving stations primarily engaged in the assembly and reshipment of bulk milk for the use of manufacturing or processing plants" (included in SIC Industry No. 5043).

The common characteristic of all plants covered by this definition is that milk or milk by-products, including whey and buttermilk, are the sole or principal raw materiasl employed in the production processes. A comprehensive list of the types of products manufactured by the industry, as classified by the Office of Statistical Standards, appear in Table 2.

TABLE 2

STANDARD INDUSTRIAL CLASSIFICATION OF THE DAIRY INDUSTRY

(AS DEFINED BY THE OFFICE OF STATISTICAL STANDARDS)

Group	Industry	
202		DAIRY PRODUCTS
		This group includes establishments primarily engaged in; (1) manufacturing creamery butter;natural cheese; condensed and evaporated milk; ice cream and frozen desserts; and special dairy products, such as processed cheese and malted milk: and (2) processing (pasteurizing homogenizing, vitaminizing, bottling fluid milk and cream

retail for wholesale or retail distribution. Independently operated milk receiving stations primarily engaged in the assembly and reshipment of bulk milk for the use of manufacturing or processing plants are included in Industry 5043.*

2021 Creamery Butter

Establishments primarily engaged in manufacturing creamery butter.

Anhydrous milkfat
Butter, creamery and whey

202 2022 Cheese, Natural and Processed

Establishments primarily engaged in manufacturing all types of natural cheese (except cottage cheese--Industry 2026), processed cheese, cheese foods, and cheese spreads.

Cheese, all types and varieties except cottage cheese
Cheese, natural
Cheese, processed
Cheese spreads, pastes, and cheeselike preparations
Processed cheese
Sandwich spreads

2023 Condensed and Evaporated Milk

Establishments primarily engaged in manufacturing condensed and evaporated milk and related products, including ice cream mix and ice milk mix made for sale as such and dry milk products.

Baby formula, fresh, processed and bottled
Buttermilk; concentrated, condensed, dried, evaporated, and powdered
Casein, dry and wet
Cream; dried, powdered, and canned
Dry milk products; whole milk; nonfat milk;buttermilk; whey and cream
Ice milk mix, unfrozen; made in condensed and evaporated milk

plants
Lactose, edible
Malted milk
Milk; concentrated, condensed, dried evaporated and powdered
Milk, whole; canned
Skim milk: concentrated, dried, and powdered
Sugar of milk
Whey: concentrated, condensed, dried evaporated, and powdered

202 2024 <u>Ice Cream and Frozen Desserts</u>

Establishments primarily engaged in manufacturing ice cream and other frozen desserts.

Custard, frozen
Ice cream: bulk, packaged, molded, on sticks, etc.
Ice milk: bulk, packaged, molded, on sticks, etc.
Ices and sherberts
Mellorine
Mellorine-type products
Parfait
Sherberts and ices
Spumoni

2026 <u>Fluid Milk</u>

Establishments primarily engaged in processing (pasteurizing, homgenizing vitaminizing bottling) and distributing fluid milk and cream, and related products.

Buttermilk, cultured
Cheese, cottage
Chocolate milk
Cottage cheese, including pot, bakers', and farmers' cheese
Cream, aerated
Cream, bottled
Cream, plastic
Cream, sour
Kumyss
Milk, acidophilus
Milk, bottled
Milk processing (pasteurizing, homogenizing, vitaminizing, bottling) and distribution: with or without manufacture of

dairy products
Milk products, made from fresh milk
Route salemen for dairies
Whipped cream
Yoghurt
Zoolak

Source: Standard Industrial Classification Director

In recent years, many establishments classified within the dairy industry have also engaged in manufacturing other than products based on milk or milk by-products. Such is the case of fluid milk plants in which filling lines are also utilized for processing fruit juices, fruit drinks and other flavored beverages. The guidelines developed in this study are not intended to cover processes where other than milk-based products are involved.

Effluent limitations for those cases involving non-dairy products are more logically handled by application of guidelines developed for appropriate industries (e.g., beverages or fruits) or on an individual basis with consideration given to the BOD_5 of the raw materials, the loss of materials and the hydraulic load that is consistent with levels of treatment and control established for the dairy products industry.

Number of Plants and Volume Processed

In 1970, there existed approximately 5,350 dairy plants in the United States, which processed about 51 billion kg of milk, or 96% of the milk produced at the farm. The utilization of milk to manufacture major types of products was as given in Table 3.

TABLE 3

Utilization of Milk by Processing Plants (1970)

Use	Percent of Total Milk Produced
Fluid Products	45.1
Butter	22.2
Natural Cheese	17.0
Ice Cream and other Frozen Products	11.4
Evaporated Milk	2.8
Cottage Cheese	1.0
Dry Milk	.5
	100.0

The dairy industry comprises plants that receive anywhere from a few thousand to over 1 million kg of milk and milk by-products per day. The plants are located throught the country, with regional concentrations in Minnesota, Wisconsin, New York, Iowa and California.

Trends

Significant trends in the U.S. dairy industry which bear on the waste disposal problem include: (a) a marked decrease in the number of plants and increased production per plant (b) changes in the relative production of various types of dairy foods, (c) increasing automation of processing and handling facilities, and (d) changes in location of the plants.

Plants and Production

Over the past 25 years, dairy food processing plants in the United States have been decreasing in number and increasing in size. The main reasons for this trend are economic and technolgical, including unit cost reductions attainable by processing larger volumes and improvements in transportation,storage facilities and product shelf-life which allow the products to be handled over longer distances and longer periods.

The change in number of plants and processsing capacity in the past decade is reflected in Table 4 below.

TABLE 4

Number of Dairy Plants and Average Production

Type of Product	Number of Plants		Average Annual Production Per Plant Million kg (lb) of Product			
	1963	1970	1963		1970	
Fluid Products & Cottage Cheese	4,619	2,824	5.6	(12.3)	9.7	(21.3)
Butter	1,320	619	0.5	(1.1)	0.7	(1.5)
Cheese	1,283	963	0.5	(1.1)	1.0	(2.2)
Evaporated & Dry milk	281	257	18.0	(39.6)	19.1	(42.0
Ice Cream & Frozen Dessert	1,081	689	3.0	(6.6)	6.7	(14.7)
	8,584	5,352	28.3	(62.3)	37.2	(81.8)

Table 5 reflects the trends in production of dairy products. While production of butter and condensed products has been on the decline, the production of natural cheese, cottage cheese, ice cream, and fluid products has been increasing:

TABLE 5

Production of Major Dairy Products, 1963 and 1970

Type of Product	Total Production Millions of Kilograms (Pounds)				
	1963		1970		Percent Change
Butter	636	(1,399)	500	(1,050)	-21%
Condensed and Dry Products	5,050	(11,110)	4,910	(10,802)	-3%
Cheese	730	(1,606)	1,000	(2,200)	37%
Ice Cream & Frozen Desserts	4,050	(8,910)	4,590	(10,098)	13%
Cottage Cheese	410	(902)	450	(990)	11%
Fluid Products	25,550	(56,110)	27,050	(59,510)	6%
	36,416		36,500		

It is important to note that those sectors of the dairy products industry that are experiencing the highest rates of growth (ice cream, frozen deserts, and cottage cheese) are also those which have been shown to produce proportionally the largest waste.

Because it is produced in such large volumes and is relatively low in solids content, whey has long posed a utilization problem for the industry. The problem has increased as plants have become larger and more distant from farming areas where whey can be used directly as feed. Cottage cheese whey represents the more serious problem because its acid nature limits its utilization as feed or food.

It is estimated that between 30% to 50% of the whey produced is not processed into a finished product, but fed raw to livestock or discarded in various ways as waste, some of which goes to municipal treatment plants. Because of its microbial inhibiting effect, unless whey is diluted with other wastes it can potentially shock the receiving treatment system.

Plant Automation

As plants have increased in size there has been a tendency to mechanize and automate many processing and handling operations. This is reflected by the decreasing employment in the industry as shown in Table 6..

TABLE 6

Employment in the Dairy Industry

Type of Plant	(Thousands) Total Employment		Employment per million kkg. Produced Annually	
	1963	1970	1963	1970

Butter	12.0	7.2	18.7	14.3
Cheese	17.9	21.1	24.6	20.9
Condensed & Dry Products	12.2	10.7	2.4	2.2
Ice Cream & Frozen Desserts	29.1	22.4	7.3	4.8
Fluid Products & Cottage Cheese	185.0	140.7	7.0	5.1

The principal technoligical developments that are being widely applied throughout the industry and which have significance in relation to waste loads include:

1. Receiving milk in tank trucks, with automated rinsing and cleaning of the tanks at the plant.

2. Remote-controlled, continous-flow processing of milk at rates up to 45,000 kilograms per hours, with automatic standardizing of fat content.

3. Use of cleaned-in-place (CIP) systems that do not require daily dismantling of the equipment and utilize contolled amounts of detergents and sanitizing chemicals.

4. High speed, automatic filling and packaging operations

5. Automated materials handling by means of conveyors, casers and stackers

Although automation can theoretically provide for lower waste loads through in-plant waste control engineering, at the present time other factors have greater influence in the waste loads, as discussed later in this report.

Plant Location

As dairy plants have increased in size, the trend has been to receive milk from and distribute products to larger areas. As a result, the location of a plant has become independent of the immediate market place. Quite often, the prevailing factor has been to select a site with covenient access to major highway system covering the area serviced, usually at some distance from the larger urban centers.

The problem of waste disposal has frequently been given little attention in selecting the location of large new plants. A number of facilities with waste loads up to 3,500 kg BOD_5/day have been constructed in suburban areas of cities of under 50,000 population. Where such plants utilize the municipal sewage treatment facility they may become the largest contributor to the municipal system, imposing on it the problems that are typically associated with dairy wastes, such as highly variable hydraulic and BOD_5 loads and the risk of shock-loads when whey is discharged without equalization.

Processing Operations

A great variety of operations are encountered in the dairy products industry, but in oversimplication they can be considered a chain of operations involving receiving and storing 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 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 is not a major source of waste load.

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 common to most plants and products.

Clarification (removal of suspended matter) and separation (removal of cream, or for whole milk standardization to 3.5% 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 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 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 freezers. The processes employed for manufacture of various products are indicated in Figure 1 through 11. The Finished products are then packaged, cased and sent to storage for subsequent shipment.

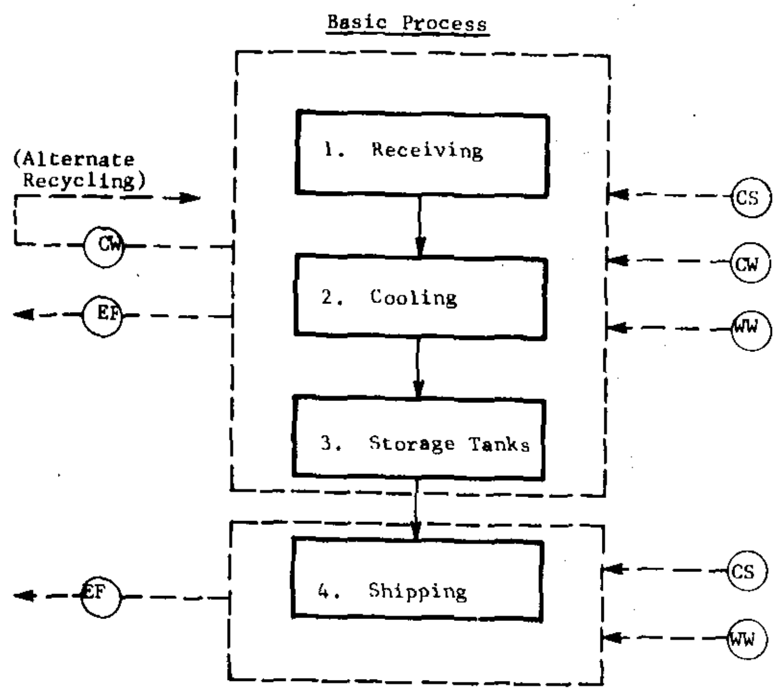
The product fill lines employed in the dairy products industry are typical liquids and solids packing units, much like those employed in many industries, with only minor modifications to adapt them to the products and containers of the industry. Storage is in refrigerated rooms with a range of temperaturs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

The product manfacture 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 in such as freezers and fillers, product washing (e.g., curd washing for cheese) and removal of adhering materials during cleaning and sanitizing of equipment. Wastes from storage and shipping result from rupture of containers due to mishandling and should be minimal.

It should be noted that most plants are multi-product facilities, and thus the process chain for a product may differ from the single product chain indicated in Figures 1 through 11. 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 of special design and constructed of stainless steel, is quite expensive.

FIGURE 1

RECEIVING STATION



Legend

CS = Cleaning and Sanitizing Solutions
WW = Wash Water (cold or hot)
CW = Cooling Water
EF = Effluent to drain

FIGURE 2

FLUID MILK

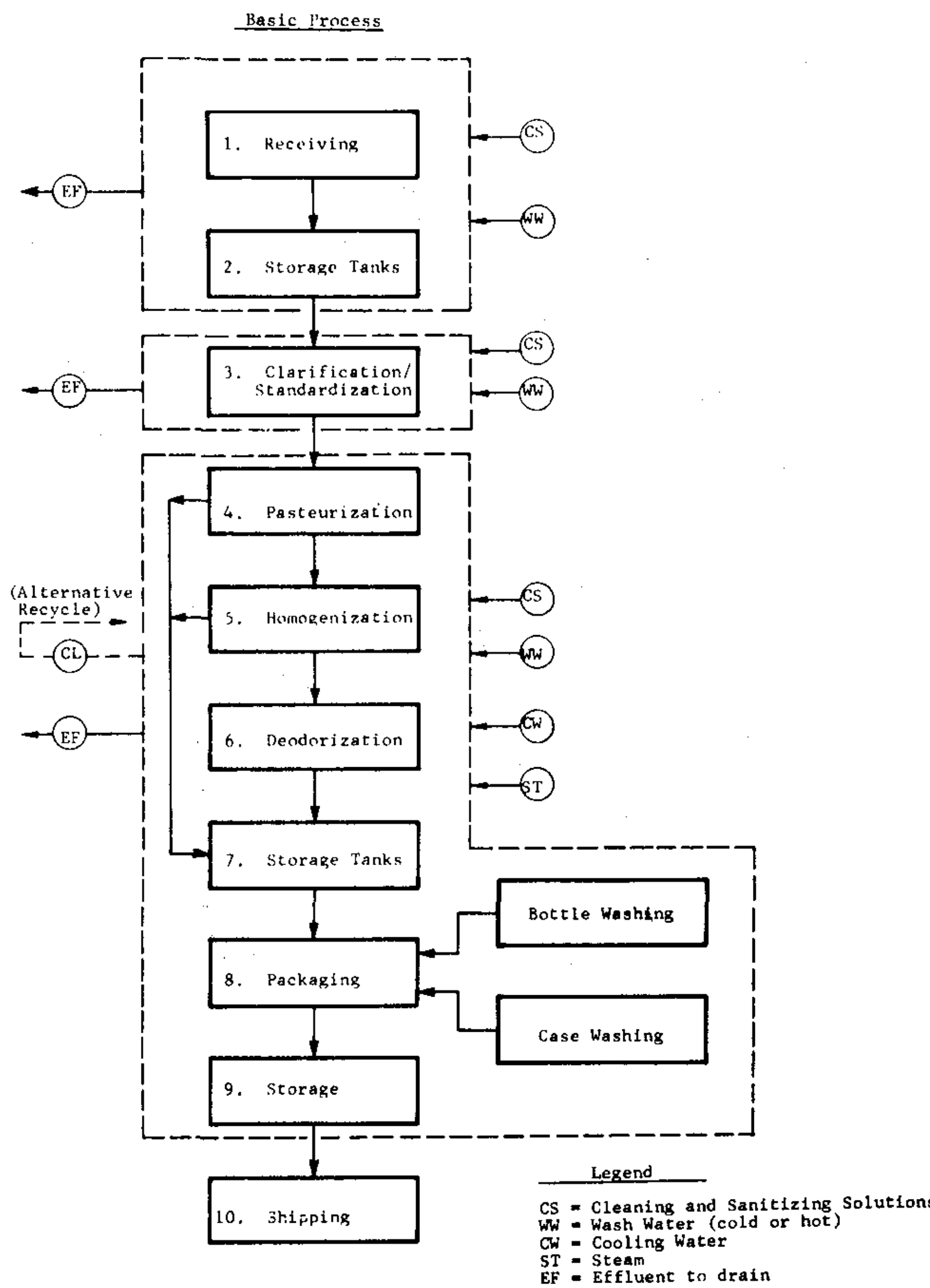
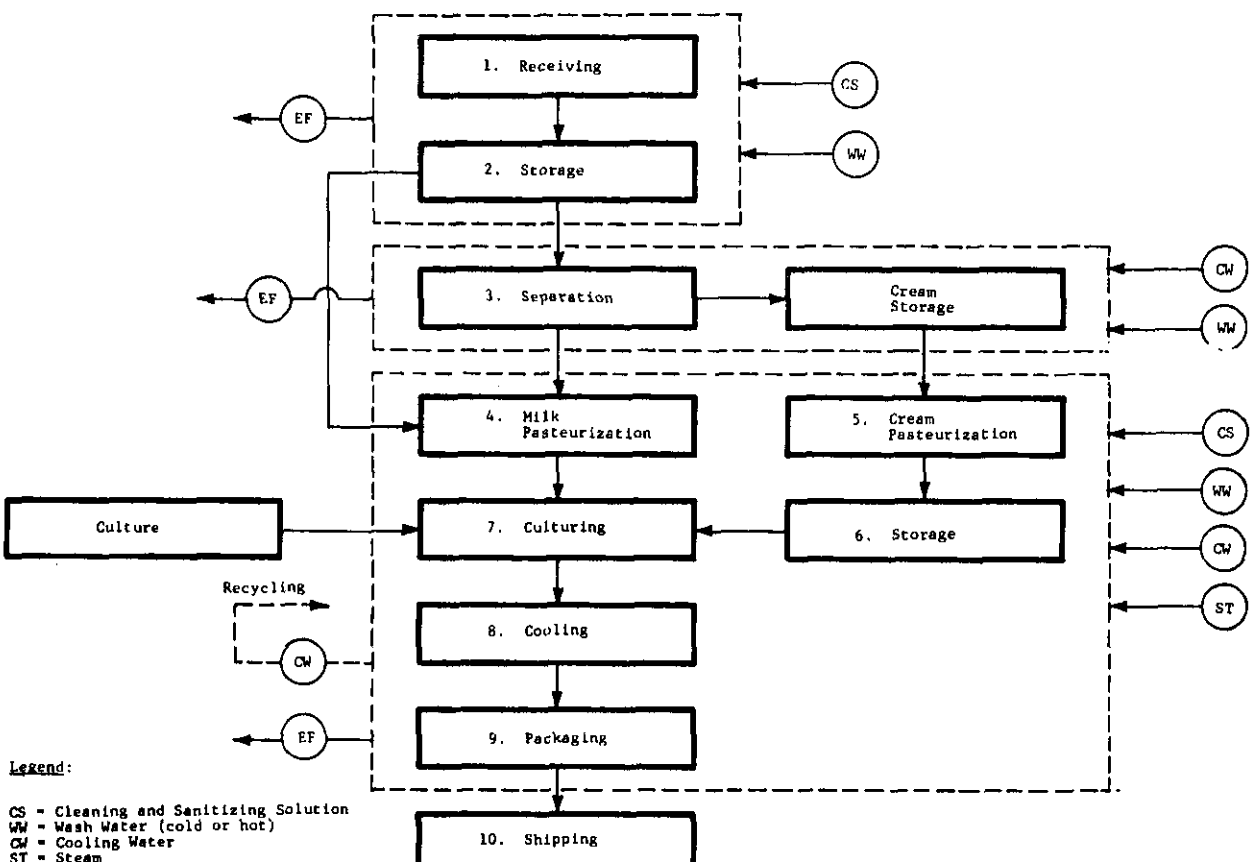


FIGURE 3

CULTURED PRODUCTS

Basic Process

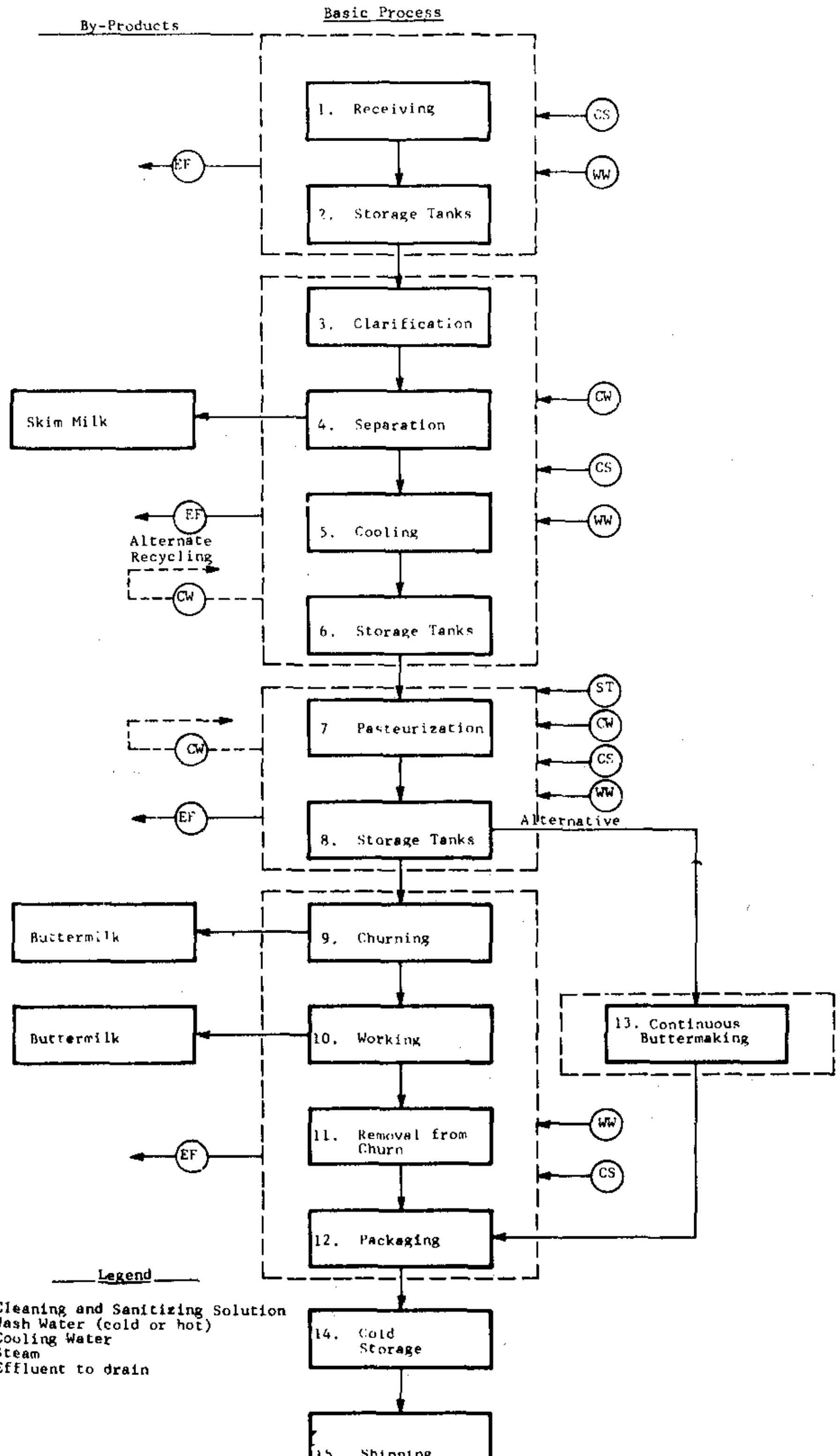


Legend:

CS - Cleaning and Sanitizing Solution
WW - Wash Water (cold or hot)
CW - Cooling Water
ST - Steam
EF - Effluent to drain

FIGURE 4

BUTTER



Legend

CS = Cleaning and Sanitizing Solution
WW = Wash Water (cold or hot)
CW = Cooling Water
ST = Steam
EF = Effluent to drain

FIGURE 5

NATURAL AND PROCESSED CHEESE

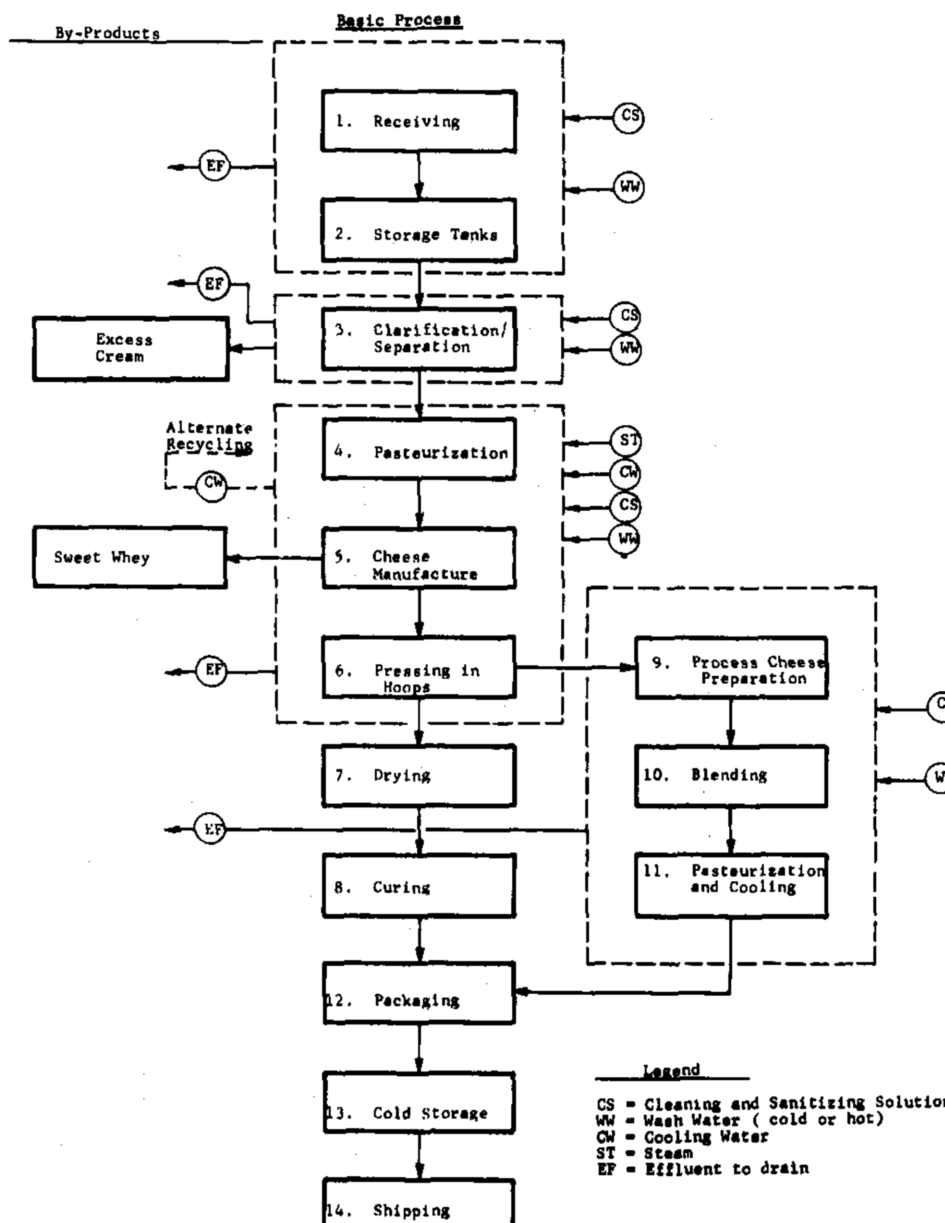


FIGURE 6

COTTAGE CHEESE

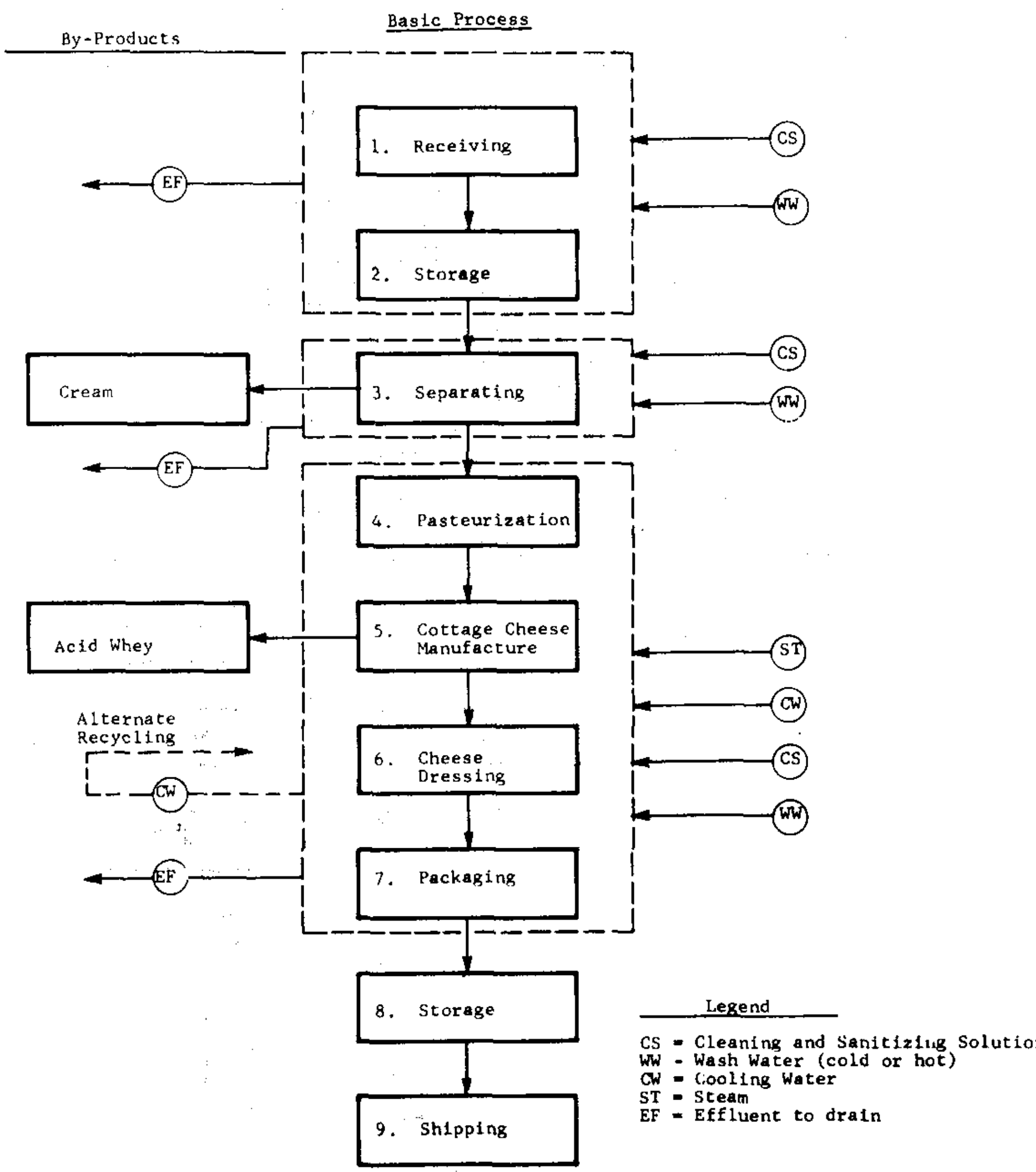


FIGURE 7

ICE CREAM

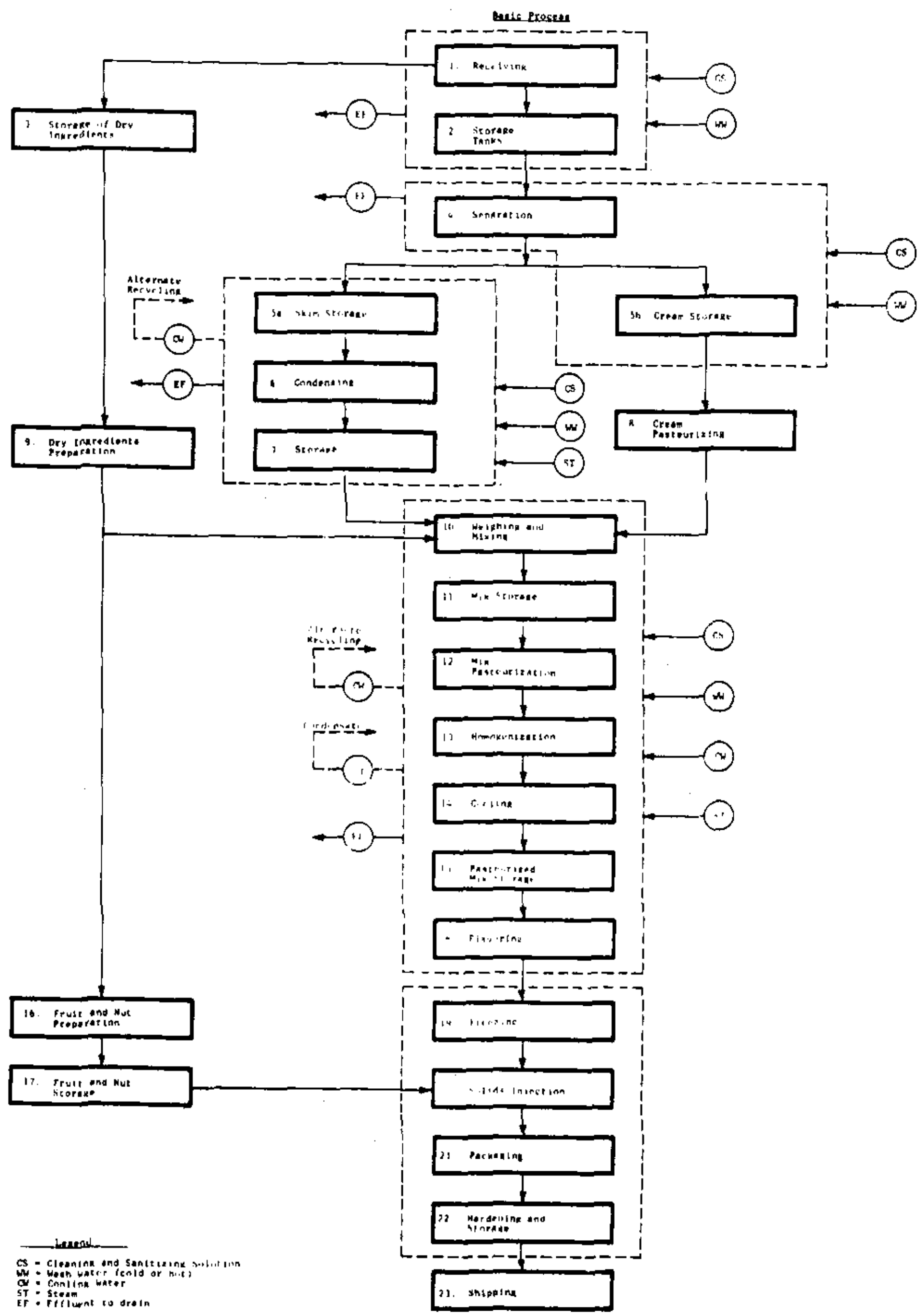


FIGURE 8

CONDENSED MILK

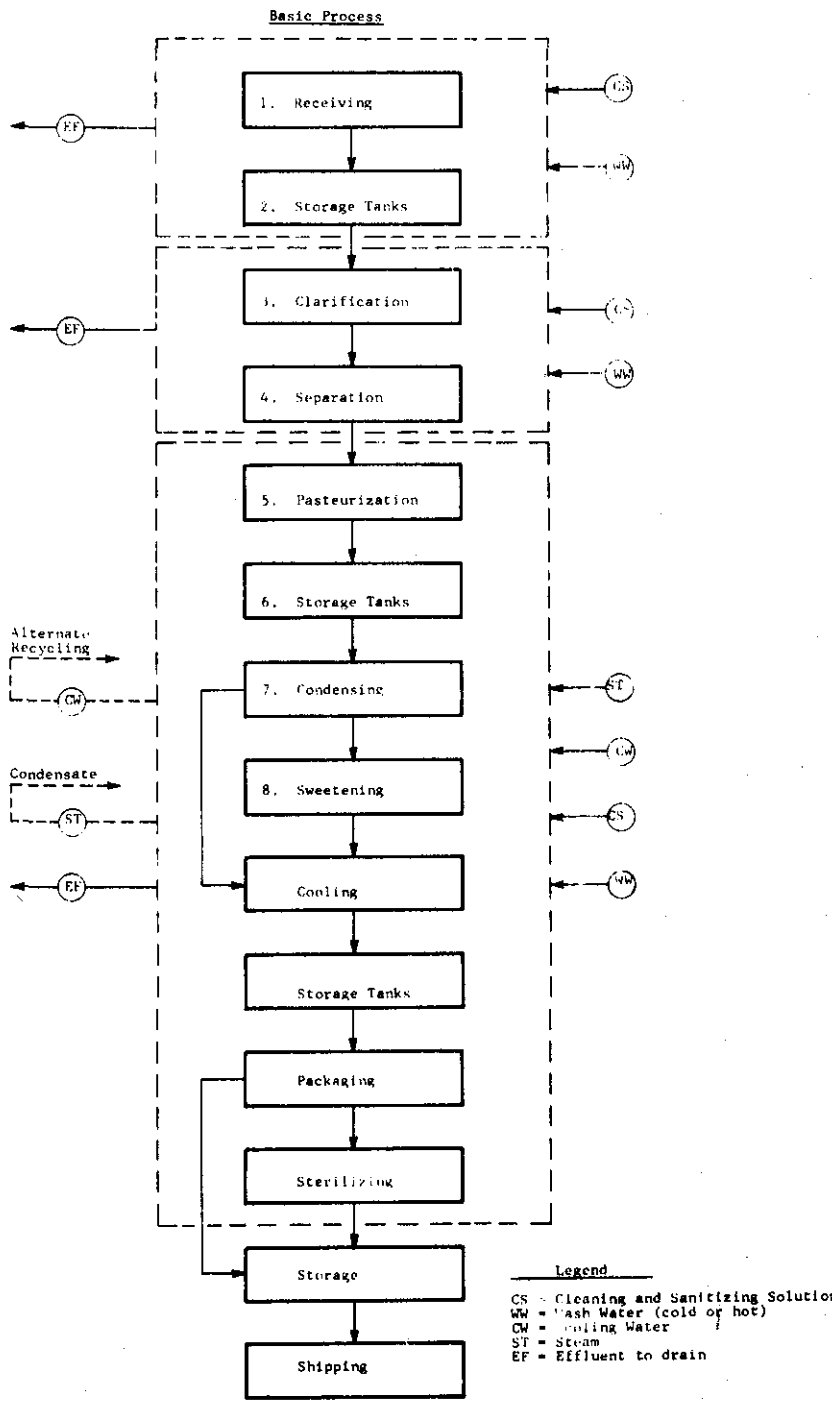


FIGURE 9

DRY MILK

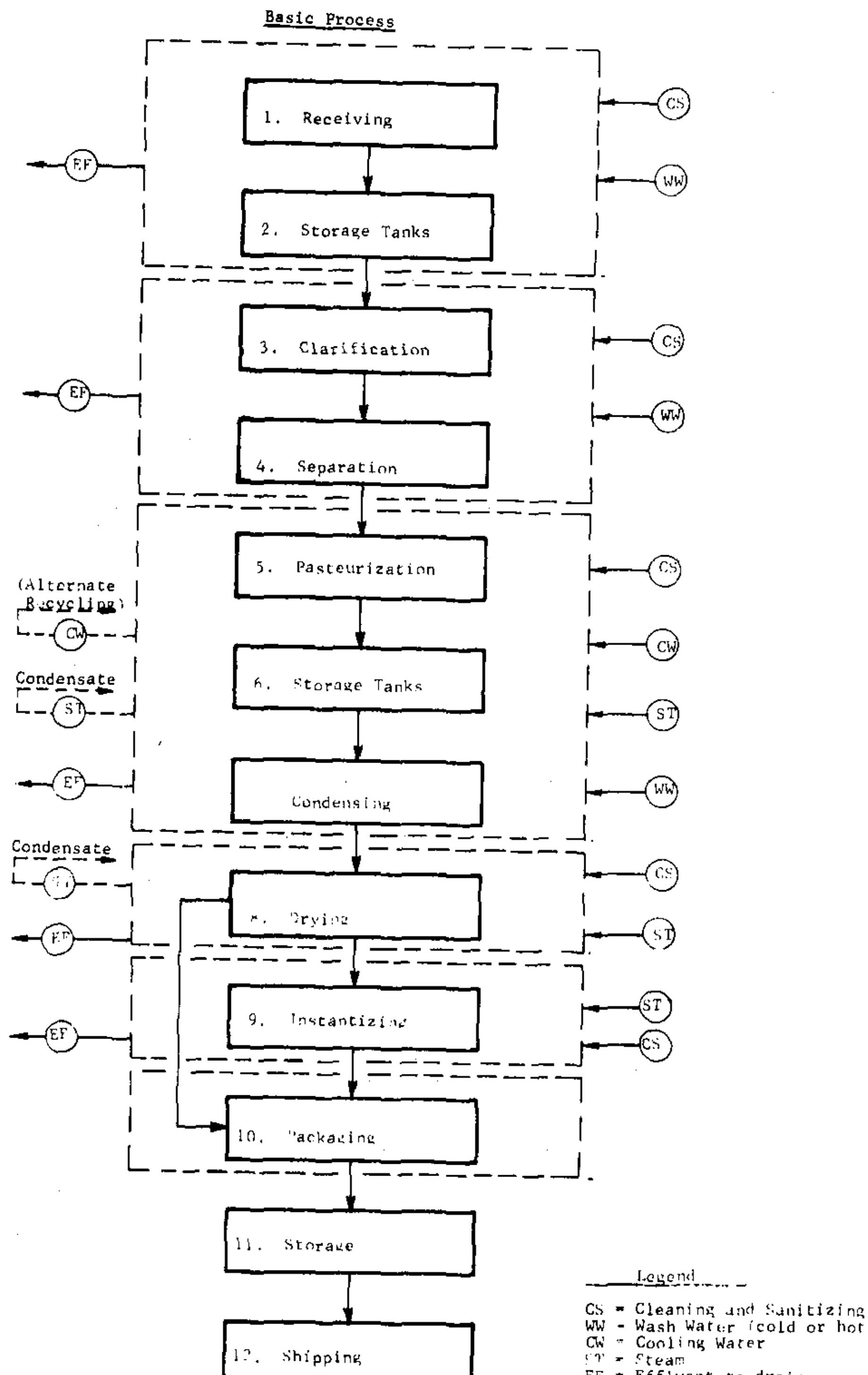
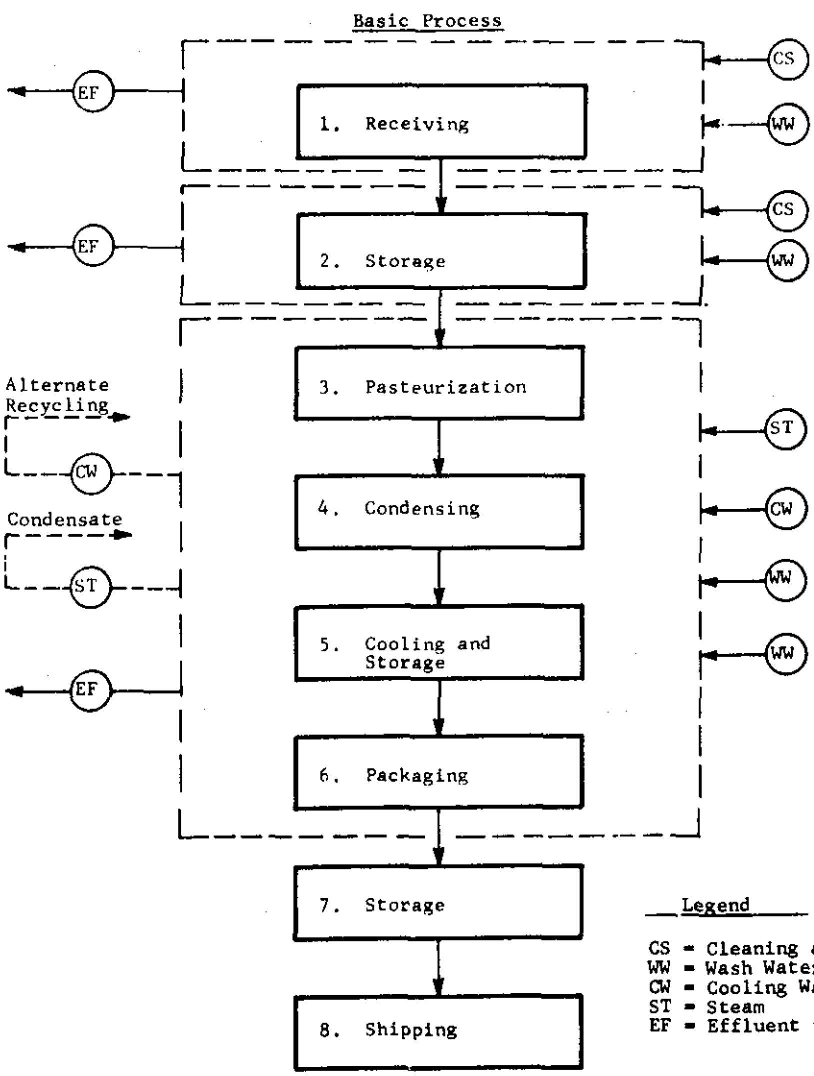


FIGURE 10

CONDENSED WHEY

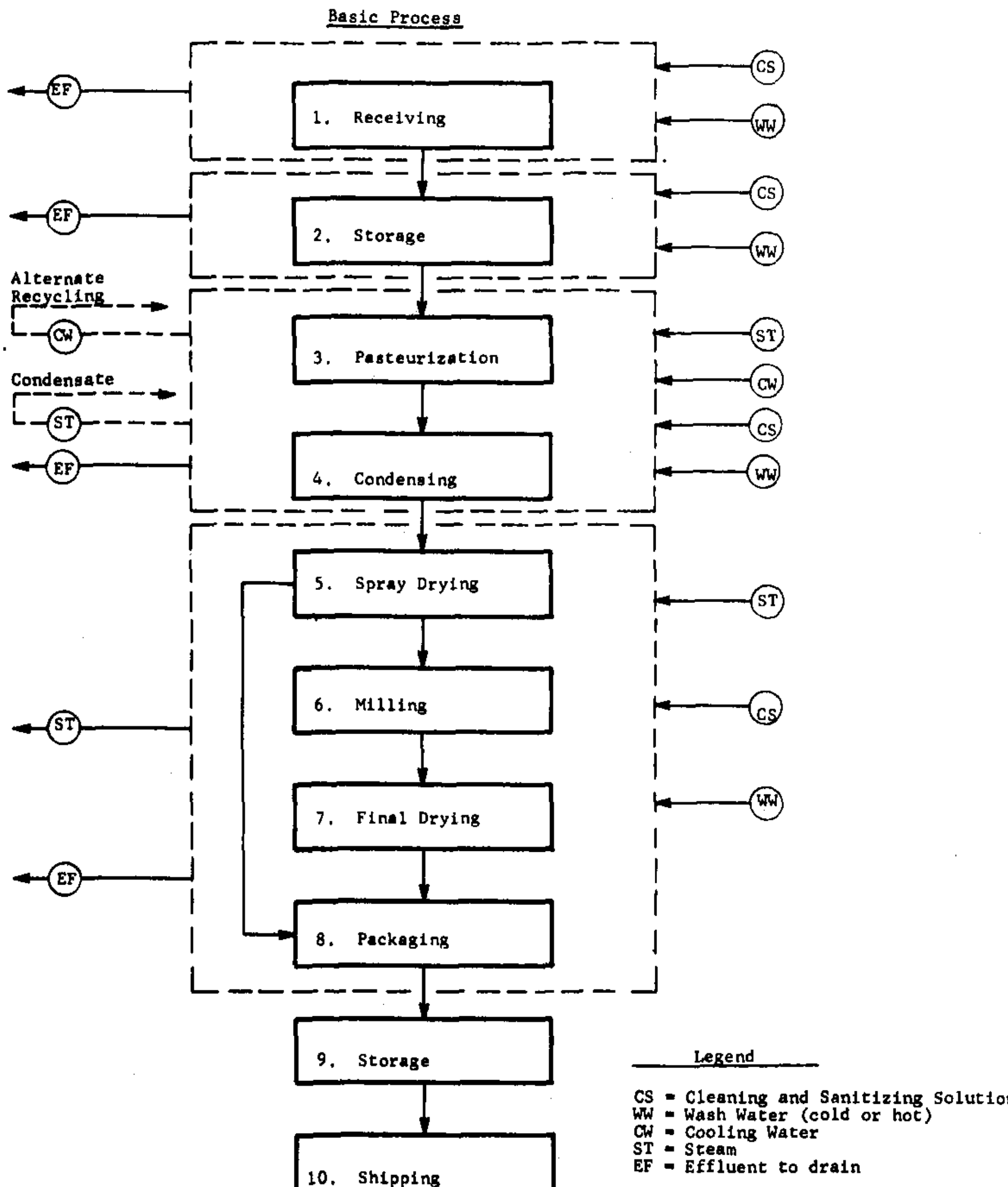


Legend

CS = Cleaning and Sanitizing Solution
WW = Wash Water (cold or hot)
CW = Cooling Water
ST = Steam
EF = Effluent to drain

FIGURE 11

DRY WHEY



SECTION IV

INDUSTRY CATEGORIZATION

Introduction

In developing the effluent limitations guidelines and standards of performance, a judgement must be made as to whether the dairy products industry should be treated as a single entity or divided into subcategories for the application of these guidelines and standards. The most cursory examination, especially if augmented by even minimal data, indicates the inadvisability of attempting to apply a single set of guidelines and standards to segments of an industry displaying such wide variation in raw material input, processes employed, end products manufactured, and levels of waste generation. The problem then becomes one of developing a logical subcategorization that will facilitate orderly development of effluent limitations and standards, taking into account the affect of factors such as raw materials input, processes employed, finished products manufactured, wastes discharged, age and size of plants, and other factors.

Raw Materials Input

Raw materials for dairy products processing typically consist of milk and milk products (cream, condensed or dried milk and whey, etc.). Non-dairy ingredients (sugar, fruits, flavors, nuts, and fruit juices) are utilized in certain manufactured products such as ice cream, flavored milk, frozen desserts, yogurt, and others.

A raw material may be involved in manufacture of a number of finished products; for example, cream may serve as a raw material for such varied finished products as fluid milk and cream, butter, ice cream, and cultured products. Moreover, considerable variation is encountered in the raw materials employed in manufacture of a single product such as ice cream. Hence, raw materials input is poorly adapted to use as a single criterion for subcategorization, as it would require a separate subcategory for most individual plants.

Processes Employed

The processes employed in the dairy products industry can be divided into two groups, those essentially common to the entire industry such as receiving, storage, transfer, separation, pasteurization and packaging, and these employed in more limited segments of the industry such as churning, flavoring, culturing, and freezing.

In attempting to base subcategorization primarily or solely on processes employed several problems are encountered. The physical setup of dairy products plants is seldom if ever such that it is possible to isolate the waste discharge from a single process and thus generate the data base necessary for development of valid effluent limitations and standards applicable to processes. In addition, subcategorization based on process alone fails to account for the differences in potential waste generation that result from application of a common process (e.g., pasteurization) to a variety of materials such as milk, cream, ice cream mix, and whey.

Wastes Discharged

Pollutants contained in the wastes discharged by dairy products plants represent materials lost through direct processing of raw materials into finished products and materials lost from ancillary operations. The former group consists of milk, milk products and non-dairy ingredients (sugar, fruits, nuts, etc.), while the latter consist of cleaners and sanitizers used in cleaning equipment, lubricants (primarily soap and silicone-based) used in certain handling equipments, and sanitary and domestic sewage from toilets, washrooms and kitchens.

These wastes with the possible minor exceptions of some lubricants, cleaners, sanitizers, and concentrated wheys (especially acid wheys from production of cottage cheese), are readily degradable in typical biological treatment systems. Any refractive materials that are represented are generally present in such low concentrations as to pose no taste and odor problems.

Since there are no clear cut differences (other than their concentrations) in wastes discharged by dairy products plants, subcategorization based on wastes dicharged would be arbitrary and questionable.

Finished Products Manufactured

The finished products manufactured in dairy products plants are the results of application of specific sets of processes to selected groups of raw materials; hence, waste discharges associated with production of specific finished products reflect all variations attributable to raw materials, direct production processes, and associated ancillary operations. Therefore, a subcategorization based on finished products has been adopted. The subcategories proposed and their associated finished products are given in Table 7. Multiple-product plants should be treated as weighted composites of the subcategories.

One would expect age and size of plant, modifications of process and other miscellaneous factors to affect the raw waste loads generated by plants, especially for those manufacturing the same finished products, but in general, no such correlation is borne out by the data compiled during the course of this study. In fact, tests in several of the newer, highly-automated plants of large size yielded higher than average waste loads for their subcategories. Apparently any minor variations attributable to age and size of plant, raw materials input and process modifications are overshadowed by variations caused by "quality of management" (housekeeping, maintenance, personnel attitudes, etc.). Refinement of guidelines on a technology basis for size and age must await greater standardization of intangibles such as management, which should result from implementation of guidelines.

The exceptions to the foregoing that were noted and documented fall within the subcategories of receiving stations and natural cheese plants, the least complex operations in the industry and ones in which variation of intangibles is minimal. Here the data indicates a consistent difference in the waste loads generated by stations receiving milk in cans versus those receiving milk in bulk and large versus small cheese plants. Since these exceptions are accommodated within the segmentation of the subcategories by plant size that is based on economic considerations (i.e., receiving stations that receive appreciable portions of milk in cans and the affected natural cheese plants all fall within the small size designation), they have not resulted in further modification of the categorization or guidelines.

With the two minor exceptions noted in the preceeding paragraph, there is no justification for further segmentation of the dairy industry on the basis of the degree of effluent reduction that is technically feasible. However, when the economic impact of the guidelines (determined in a collateral economic study conducted by Development Planning and Research Associates, Inc.) is utilized as a basis for judgment, the converse is true and a need for further segmentation of the subcategories by plant size is indicated. The DPRA study concludes that costs imposed on small plants by implementation of a uniform level of control technology across the industry (e.g., equivalency of activated sludge as end-of-pipe treatment for all point sources) would result in closure of about 573 small plants. This severe impact on small plants is the result of both lower profitability of small operations, many of which are of questionable long-term viability even without imposition of high waste treatment costs, and their higher per unit of production waste control costs attributable to the economics of size in waste treatment. To lessen the economic impact of the guidelines a small plant segment has been designated in each subcategory; and for these segments less stringent effluent limitations based on the pollutant reduction attainable utilizing treatment technology with much lower associated costs are recommended. The upper input limitations for designation as a small plant that are recommended by economists are shown in Table 8.

Conclusion

On the basis of the preceeding discussion it can be concluded that, for the purpose of establishing effluent limitations guidelines and standards of performance for new sources, the dairy industry can logically be subcategorized on the basis of the type of products manufactured.

Subcategorization can be meaningful only to the extent that a valid basis (such as quantitive data, clearly identifiable technical, considerations, or economic considerations) exist for developing a sound guideline or standard for each category defined. On the basis of existing data and knowledge it is suggested that the dairy industry be subcategorized as indicated in Table 7, and that the subcategories be further segmented by size as indicated in Table 8.

The typical manufacturing processes for the products that characterize the proposed subcategories are illustrated in Figures 1 through 11.

The proposed subcategories represent single-product plants. Because of the large number of product combinations manufactured by individual plants in the industry and their varying proportions in relation to total plant production, further subcategorization for multi-product plants is impractical. Rather, it is proposed that guidelines and standards for multi-product plants be the summation of weighted averages of the guidelines for the corresponding single product processes (plants), using the total BOD input for each manufacturing subcategory representation as the weighing factor to which the appropriate limitation value is applied.

TABLE 7

Proposed Subcategorization for the Dairy Products Industry.

Name of Subcategory	Products Included
Receiving Station	Raw Milk
Fluid Products	Market milk (ranging from 3.5% to fat-free), flavored milk (chocolate and other) and cream (of various fat concentrations, plain and whipped).
Cultured Products	Cultured skim milk ("cultured buttermilk") yoghurt, sour cream and dips of various types.
Butter	Churned and continuous-process butter.
Natural and Processed Cheese	All types of cheese foods except cottage cheese and cultured cream cheese.
Cottage Cheese	Cottage cheese and cultured cream cheese
Ice cream, Frozen Desserts, Novelties and other Dairy Desserts	Ice cream, ice milk, sherbert, water ices, stick confections, frozen novelty products, frozen mellorine, puddings, other dairy-based desserts.
Ice Cream Mix	Fluid mix for ice cream and other frozen products.
Condensed Milk	Condensed whole milk, condensed skim milk, sweetened condensed milk and condensed buttermilk.
Dry Milk	Dry whole milk, dry skim milk, and dry buttermilk.
Condensed Whey	Condensed sweet whey and condensed acid whey.
Dry Whey	Dry sweet whey and dry acid whey.

Table 8

Upper Input Limitations
For Designation As A Small Plant

Subcategory	Units of Input	Corresponding BOD5 Input
Receiving Stations	150,000 lb/day M.E.	15,600 lb/day
Fluid Products	250,000 lb/day M.E.	25,900 lb/day
Cultured Products	60,000 lb/day M.E.	6,200 lb/day*
Butter	150,000 lb/day M.E. (40,000 lb 40% Cream)	18,800 lb/day
Cottage Cheese and Cultured Cream Cheese	25,000 lb/day M.E.	2,600 lb/day
Natural and Processed Cheese	100,000 lb/day M.E.	10,390 lb/day
Fluid Mix for Ice Cream & Other Frozen Desserts	Dairy Products Input of 85,000 lb/day M.E.	8,830 lb/day*
Ice Cream and Frozen Desserts	Dairy Products Input of 85,000 lb/day M.E.	8,830 lb/day*
Condensed Milk	100,000 lb/day M.E.	10,390 lb/day
Dry Milk	145,000 lb/day M.E.	15,070 lb/day
Condensed Milk	300,000 lb/day Fluid Raw Whey (20,700 lb/day of Solids)	14,160 lb/day
Dry Whey	57,000 lb/day 40% Solids Whey (22,800 lb/day of Solids)	15,620 lb/day

*BOD5 of dairy products only; does not include BOD5 of sugar, fruits, nuts and other non-dairy ingredients.

SECTION V

WASTE CHARACTERIZATION

Sources of Waste

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

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

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

3. Processing losses, including:

   (a) Sludge discharges from CIP clarifiers;
   (b) Product wasted during HTST pasteurizer 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, and;
   (f) Product change-over in filling machines.

4. Wastage of spoiled products, returned products, or by-products such as whey.

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

6. Entrainment of lubricants from conveyors, stackers and other equipment in the waste water from cleaning operations.

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

8. Waste constituents that 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 Dairy Plant Wastes

Materials 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 be wasted 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 waste water. Such water is recycled in many plants. If wasted, it increases the volume of the effluent and has an effect on 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 principle 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 9.

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 9

Composition of Common
Dairy Products Processing Materials

Material	% Protein	% Fat	% Carbohydrate	BOD_5 Kg/100Kg (lb/100 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 waste waters 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 waste waters is illustrated in Table 10.

Table 10

Estimated Contribution of Wasted Materials to the BOD_5 Load of Dairy Waste Water. (Fluid Milk Plant).

	kg BOD_5/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%

The inorganic constituents of dairy waste waters 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).

Variability of Dairy Wastes

A significant characteristic of the waste streams of practically all dairy plants is the marked fluctuations in flow, strength, temperature and other characteristics. Wide variations of such parameters frequently occur within minutes during the day, depending on the processing and cleaning operations that are taking place in the plant. Furthermore, there are usually substantial daily and seasonal fluctuations depending on the types of products manufactured, production schedules, maintenance operations, and other factors. Typical hourly variations in flow, BOD_5 and COD of a plant manufacturing cottage cheese is illustrated in Figure 12. Figure 13 illustrates daily variations in BOD_5 strength of the waste from the frozen products drain of another dairy plant.

It is important to recognize the highly variable nature of the wastes when a sampling program is undertaken in a dairy plant. Unless the daily samples are a composite of subsamples taken at frequent intervals and proportioned in accordance with flow, results could depart considerably from the true average values. Furthermore, the sampling period should ideally cover enough days at various times of the year to reduce the effect of the daily and seasonal variations.

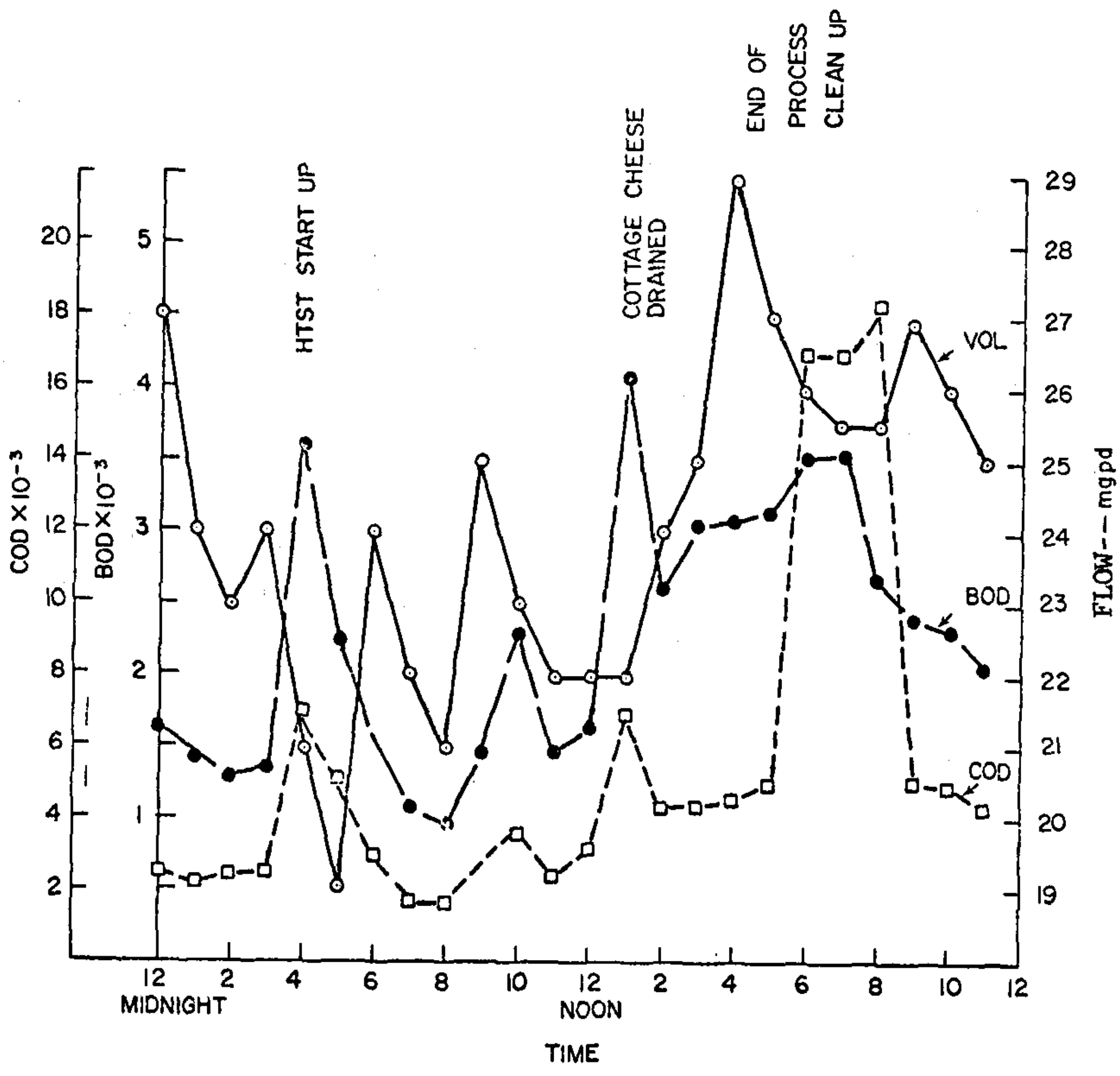
Waste Load Units

Waste loads have frequently been reported in terms of concentration or "strength" of a given parameter in the waste stream, such as parts per million (ppm) or milligrams per liter (mg/l). Although a unit of concentration can be significant as a loading factor for waste treatment systems and for water quality analysis, it is not meaningful for control purposes because any amount of water added to the waste stream will result in a lower concentration, while the volume of polluting material discharged remains unchanged. For pollution control purposes, the total weight of pollutant discharged in a unit of time is a more meaningful factor.

Researchers have long recognized a direct relationship in the dairy industry between the total weight of pollutant discharged and the weight or volume of material processed. Waste loads of different plants can be meaningfully compared on the basis of a unit load, such as kg (lb) of a given waste parameter per kkg (1000 lb) of raw material or product.

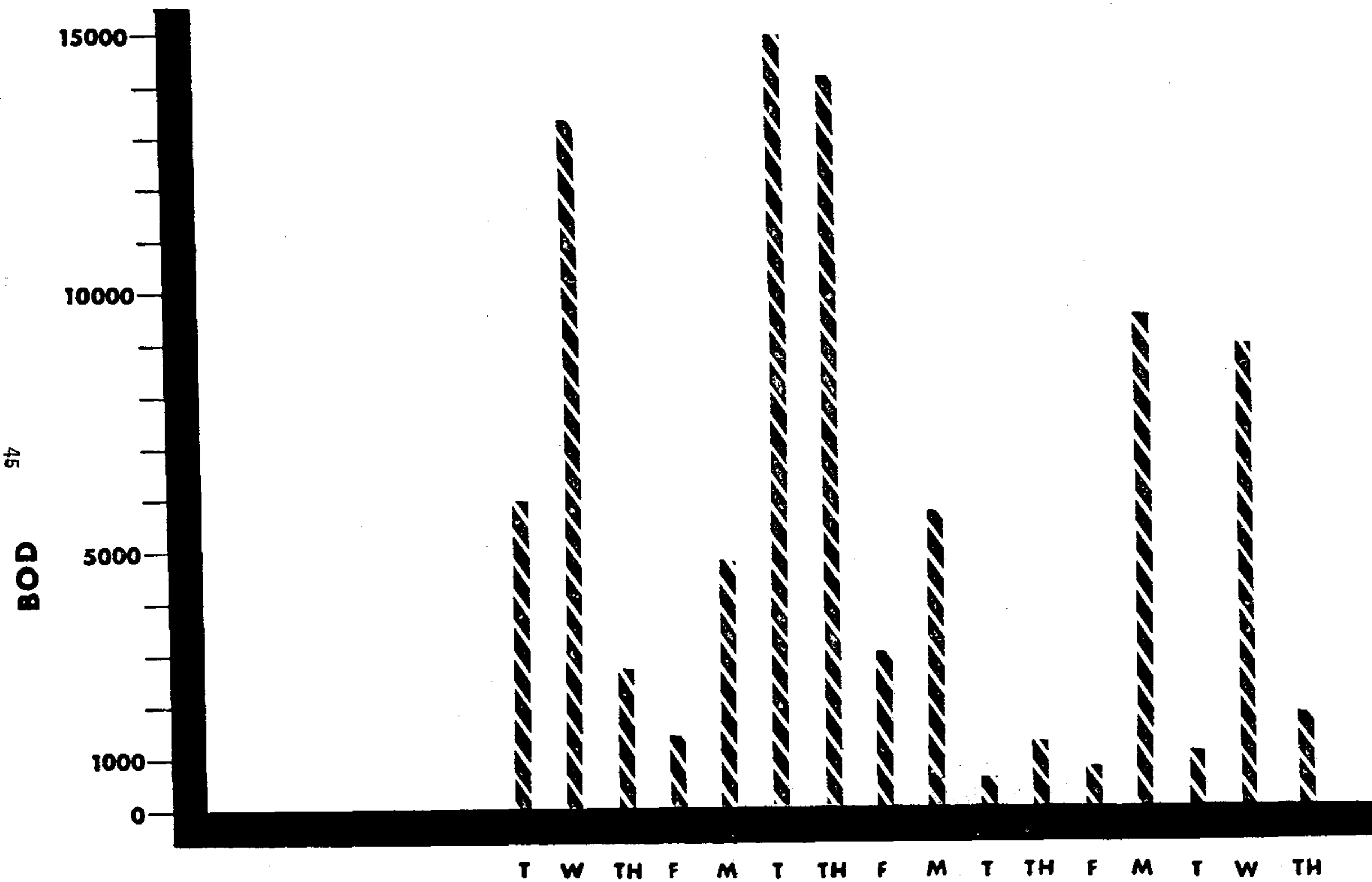
Up until this time, it has been the accepted practice to characterize the raw wastes of dairy plants in relation to the number of pounds of milk or "milk equivalent" received or processed. During this study it was found that the "milk

FIGURE 12



Hourly variations in ppm BOD_5, COD and waste water for a dairy plant

FIGURE 13



Variation in waste strength of frozen products drain for consecutive sampling days in one month.

equivalent" concept has been defined differently by various sources, has often been applied inconsistently, and has at least been confusing to many people that have used waste load data for research, management, or control purposes.

Some of the inconsistencies between definitions or applications of the milk equivalent concept are a result of arbitrary decisions that must be made in its definition, including the following:

1. The milk equivalent of a milk product can be referred either to raw milk as received from the farms, or to "whole milk" as standardized for sale in the market.

2. Raw milk varies in composition, and therefore a conventional solids content must be agreed upon if the definition is to be consistent.

3. The milk equivalent can be defined in terms of the fat solids the non fat solids or the total solids of the whole milk and of the product in question.

4. Milk products to which other than milk solids have been added (such as ice cream or sweetened condensed milk) further complicate the definition of a milk equivalent based on total solids as opposed to fat or non fat milk solids.

Because of this situation, it is proposed that the unit waste loads defining the effluent limitation guidelines (significantly BOD) be expressed in terms of the total BOD_5 input contained in the dairy and other raw materials utilized in the production processes. This approach has the following advantages:

1. The many arbitrary decisions involved in establishing a definition of the "milk equivalent" concept are eliminated.

2. The BOD_5 content (in lb BOD_5 per lb of raw material) of any given daily raw material can be determined by standard laboratory analysis. Values for most of the typical dairy and other raw materials have been published and are reasonably consistent.

Accordingly, the waste load data presented in the report have been expressed in or converted to units relating to the quantity of BOD_5 in the raw materials received or processed.

To maintain consistency in the application the waste load data and guidelines set forth in this report it is essential that the procedures set forth in this report be adopted as standards to calculate the waste load of any particular plant. For simplicity, only the <u>process</u> raw materials are considered in the computations; it must be remembered, however, that BOD_5 can also be contributed by lubricants, detergents, sanitizers, and in some cases, sanitary sewage. However, the contribution from these latter materials should be of such low magnitude as to be of no consequence in relation to the load borne in a treated final effluent, particularly when the precision of sampling and analytical methods are considered.

BOD

Available data indicates that the daily average BOD5 strength of dairy plant wastes varies over a broad range, from as low as 40 mg/l to higher than 10,000 mg/l, with the great majority of plants falling within 1,000 to 4,000 mg/l. A summary of available raw waste BOD5 data appears in Table 11.

In expressing BOD5 loss per BOD5 received (processed) it is convenient and useful to express the unit load as kg (lb) BOD5 of waste discharge per 100 kg (lb) received processed for two reasons.

1. kg BOD5/100 kg (lb/100 lb) can be read directly as per cent BOD5 loss, i.e., for ice cream plants the mean loss is 14.8 kg/100 kg (14.8 lb/100 lb) or directly, 14.8 percent.

2. kg BOD5/100 kg BOD5 (lb BOD5/100 lb BOD) is approximately equal to kg BOD5/1000 milk equivalent when the raw material is whole milk, since the BOD5 of whole milk is approximately 10 percent by weight.

Mean unit BOD5 loads for plants range from 0.41 kg/100 kg BOD5 or 0.41 kg/1000 kg M.E., (0.41 lb/100 lb BOD5 or 0.41 lb pr 1000 lb M.E.) for receiving stations to 16.8 kg/100 kg BOD5 or 14.6 kg/1000 kg M.E. (16.8 lb/100 lb BOD5 or 14.6 lb/1000 lb M.E.) for cottage cheese plants. In general, the relative magnitudes of the mean unit BOD5 loads for the various subcategories are as would be expected when considering the viscosity and BOD5 content of the product and the nature of the processes.

COD

Chemical Oxygen Demand (COD) is the amount of equivalent oxygen required for oxidation of the organic solids in an effluent, measured by using chemical oxidizing agents under certain specified conditions instead of using microorganisms as in the BOD test. It can be used alternatively to BOD5 as a measure of the strength of the waste water. The advantages of the COD test over the BOD5 is that it can be completed in a relatively short time and there is generally a lesser chance for error in performing the test.

There is disagreement, however, on the accuracy and relative merits of each test in determining the oxygen demand of a dairy effluent. In spite of being more cumbersom, and inherently

TABLE 11

Summary of Calculated, Literature Reported and Identified Plant Raw Waste BOD_5 Data

Type of Plant	Calculated kg BOD_5 per 1,000 kg Milk Equivalent Received(1)	Literature Reported Plant Sources: Number of Plants Reporting	Literature Reported Plant Sources: Kg BOD_5 per 1,000 kg Milk Equivalent Received: Range	Mean	Identified Plant Sources: Number of Plants Reporting	Identified Plant Sources: Kg BOD_5 per 1,000 kg Milk Equivalent Received: Range	Mean	Identified Plant Sources: Kg BOD_5 per 100 kg BOD_5 Received: Range	Mean
A. Single Product									
Receiving Station (Cans)	0.47	7	0.02-1.13	0.28	5	0.30-0.70	0.46	0.30-0.70	0.46
Receiving Station (Bulk)	0.33	1	-	0.10	1	-	0.17	-	0.17
Fluid Products	0.96-1.32	16	0.14-17.06	3.60	6	0.30-7.16	3.21	0.30-7.16	3.21
Cultured Products	-	-	-	-	-	-	-	-	-
Butter	1.11	11	0.19-1.91	0.86	1	-	0.80	-	0.80
Cottage Cheese	8.69	5	1.30-42.00	14.64	-	-	-	-	-
Natural Cheese	1.77	21	0.30-4.04	2.00	5	0.24-0.93	0.54	0.35-9.33	0.60
Ice Cream	1.81	7	1.90-21.04	5.54	10	0.68-19.60	6.75	1.33-40.50	13.45
Ice Cream Mix	-	-	-	-	1	0.63	0.63	-	0.99
Condensed Milk	0.67-1.26	5	0.18-13.30	3.67	2	0.41-4.00	2.20	0.41-4.00	2.20
Dry Milk	0.94-1.91	9	0.40-13.50	6.06	3	0.41-2.44	1.18	0.60-3.52	1.62
Condensed Whey	1.22-1.35	3	0.27-0.31	0.29	7	0.24-0.88	0.43	0.58-2.19	1.05
Dry Whey	1.12-1.85	3	3.40-57.20	22.33	5	0.02-1.16	0.60	0.05-2.88	1.44
B. Multi-Products									
Fluid-Cottage	2.14	10	0.66-7.87	2.90	5	2.26-6.94	4.54	2.26-6.94	4.54
Fluid-Cultured	-				5	0.35-7.84	3.00	0.80-7.84	3.10
Fluid-Butter	1.66	8	0.30-3.26	1.21	-	-	-	-	-
Fluid-Natural Cheese	1.40	1	-	2.14					
Fluid-Ice Cream Mix-Cottage-Cultured	-				-	-	-	-	-
Fluid-Ice Cream Mix-Cond. Milk-Cultured	-				1	-	1.80	-	1.80
Fluid-Cultured-Juice	-				1	-	7.21	-	16.70
Fluid-Cottage-Cultured	-				4	0.95-10.10	3.80	0.95-10.10	3.80
Fluid-Cottage-Ice Cream	2.17	10	0.90-12.90	6.79	1	-	6.24	-	6.24
Fluid-Butter-Natural Cheese	1.79	9	0.07-2.22	0.81					
Fluid-Cottage-Dry Milk	1.11	1	-	2.46					
Fluid-Cottage-Cultured-Dry Whey(2)	-				1	-	2.21	-	2.21
Fluid-Cottage-Cultured-Ice Cream	-				3	2.09-4.78	3.44	2.80-4.78	3.72
Fluid-Cottage-Cultured-Cond. Milk	-				1	-	1.70	-	1.70
Fluid-Cottage-Butter-Ice Cream-Dry Milk(2)	-				1	-	0.93	-	0.98
Butter-Dry Milk	1.59	6	1.30-320	2.54	4	0.39-1.14	0.68	0.39-1.24	0.83
Butter-Cond. Milk	1.32				1	-	0.85	-	1.04
Butter-Dry Milk-Dry Whey	-					-	5.41	-	8.29
Butter-Natural Cheese	2.11	19	0.30-3.88	1.32					
Butter-Dry Milk-Ice Cream	1.30	1	-	2.21					
Cottage-Cond. Milk	1.46				1	-	3.61	-	3.61
Cottage-Cultured-Dry Milk-Dry Whey-Fluid	-				1	-	0.28	-	0.31
Cottage-Natural Cheese	-				1	-	6.43	-	6.43
Natural Cheese-Dry Whey	3.49		-	3.00	3	1.28-20.10	8.62	1.28-20.10	8.62
Natural Cheese-Cultured-Rec. Sta.	-				1	-	2.15	-	2.15
Natural Cheese-Cond. Whey	-				3	1.06-4.20	2.12	1.10-4.20	2.29

Notes: (1) Using SMP standard loads as developed in the "Study of Wastes and Effluent Requirements of the Dairy Industry, Section III, July 1971."

(2) Excludes Whey dumping.

providing a greater chance of error, the BOD5 test has been much more widely used in the past. The results of the BOD5 test have been regarded as more significant, because it was considered to more nearly parallel what is actually taking place in natural waters. Many dairy companies in the United States have reportedly attempted to use the COD test but have discontinued the practice because of the wide variation in BOD:COD ratios measured.

More recently, the need for the COD test as a supplement the BOD5 test has been recognized, and many investigations consider it a better method for assessing the strengths of dairy effluents.

A summary of BOD:COD data appears in Table 12. Significant variations of the ratio are evident; the overall range of the BOD:COD ratio for raw effluents reported from all sources is 0.07 to 1.03. The mean for identified plants is 0.57. This figure can be used as a conversion factor.

Suspended Solids

The concentrations of suspended solids in raw dairy plant wastes vary widely among the different dairy operations. The greatest number of plants have suspended solids concentrations in the 400 mg/l to 2000 mg/l range.

The data on the suspended solids content of raw wastes of identified plant sources are summarized in Table 13. The mean suspended solids loads range from a low of 0.03 kg/100 kg BOD5 (0.03 kg/1,000 kg M.E.) for milk receiving stations to a high of 3.50 kg/100 kg BOD5 1.78 kg/kkg M.E.) for ice cream plants. Data were not available for dry milk, cultured products, cottage cheese, and can receiving stations operations as single product categories. The suspended solids would be composed primarily of coagulated milk, fine particles of cheese curd and pieces of fruits and nuts from ice cream operations.

In all but two cases the suspended solids content of raw wastes was lower than the BOD5 value. Further, there did seem to be a significant correlation between the suspended solids content of raw wastes and the type of plant operation. This fact is supported by an analysis of suspended solids to BOD5 ratios for identified plant source data. The values of the suspended solids - BOD5 ratio were found to be distributed about a mean of 0.415 with a standard deviation of 0.32. This yields a coefficient of variance of 77 percent. With 3 highest and lowest values eliminated from the sample, the mean and standard deviation become 0.368 and 0.155 respectively, giving a correlation of variance of 42 percent. Further, a regression analysis of the data the suspended solids and BOD5 data pairs resulted in the following relationship with a correlation coefficient of 0.92. Suspended solids = 0.529 BOD5 - 152.2.

TABLE 12

Summary of Literature Reported and Identified Plant Source BOD_5: COD Ratios for Raw Dairy Effluents

Type of Plant	Literature Reported Plant Sources: Number of Plants Reporting	Literature Reported Plant Sources: BOD_5: COD Ratios for Raw Effluent – Range	Literature Reported Plant Sources: BOD_5: COD Ratios for Raw Effluent – Mean	Identified Plant Sources: Number of Plants Reporting	Identified Plant Sources: BOD_5: COD Ratios for Raw Effluent – Range	Identified Plant Sources: BOD_5: COD Ratios for Raw Effluent – Mean
A. Single Product						
Receiving Station (Cans)	-	-	-	-	-	-
Receiving Station (Bulk)	-	-	-	1	-	0.55
Fluid Products	-	-	-	1	-	0.57
Cultured Products						
Butter	1	-	0.66			
Cottage Cheese	-	-	-	-	-	-
Natural Cheese	-	0.31-0.66	0.45	1	-	0.53
Ice Cream	-	-	-	2	0.55-0.59	0.57
Ice Cream Mix	-	-	-	-	-	-
Condensed Milk	-	-	-	-	-	-
Dry Milk	-	-	-	-	-	-
Condensed Whey	-	-	-	3	0.50-0.79	0.66
Dry Whey	-	-	-	-	-	-
B. Multi-Products						
Fluid-Cottage Cheese	4	0.44-0.97	0.70	-	-	-
Fluid-Cultured Products	-	-	-	1	-	1.03
Fluid-Butter	-	-	-	-	-	-
Fluid-Natural Cheese	-	-	-	-	-	-
Fluid-Ice Cream Mix-Cottage-Cultured	-	-	-	-	-	-
Fluid-Ice Cream Mix-Cond. Milk-Cultured	-	-	-	-	-	-
Fluid-Cultured-Juice	-	-	-	-	-	-
Fluid-Cottage-Cultured	-	-	-	-	-	-
Fluid-Cottage-Ice Cream	3	0.40-0.51	0.44	3	0.63-0.72	0.67
Fluid-Butter-Natural Cheese	-	-	-	-	-	-
Fluid-Cottage-Dry Milk	-	-	-	-	-	-
Fluid-Cottage-Cultured-Dry Whey	-	-	-	-	-	-
Fluid-Cottage-Cultured-Ice Cream	-	-	-	-	-	-
Fluid-Cottage-Cultured-Cond. Milk	-	-	-	-	-	-
Fluid-Cottage-Butter-Ice Cream-Dry Milk	-	-	-	1	-	0.50
Butter-Dry Milk	-	-	-	-	-	-
Butter-Cond. Milk	-	-	-	-	-	-
Butter-Dry Milk-Dry Whey	-	-	-	-	-	-
Butter-Natural Cheese	-	-	-	-	-	-
Butter-Dry Milk-Ice Cream	-	-	-	-	-	-
Cottage-Cond. Milk	-	-	-	-	-	-
Cottage-Cultured-Dry Milk-Dry Whey-Fluid	-	-	-	1	-	0.07
Cottage-Natural Cheese	-	-	-	-	-	-
Natural Cheese-Dry Whey	-	-	-	1	-	0.60
Natural Cheese-Cultured-Rec. Sta.	-	-	-	1	-	0.51
Natural Cheese-Cond. Whey	-	-	-	3	0.49-0.56	0.53
C. Not Available	-	0.11-0.80	-	-	-	-

TABLE 13

Summary of Identified Plant Source Raw Suspended Solids Data

Type of Plant	Number of Plants Reporting	Identified Plant Sources: Kg Suspended Solids per 1,000 kg Milk Equivalent Received — Range	Mean	Suspended Solids per 100 kg BOD_5 Received — Range	Mean
A. Single Product					
Receiving Station (Cans)	-	-	-	-	-
Receiving Station (Bulk)	1	-	0.03	-	0.03
Fluid Products	5	0.13-3.36	1.50	1.36-3.36	1.50
Cultured Products	-	-	-	-	-
Butter	1	-	0.40	-	0.40
Cottage Cheese	-	-	-	-	-
Natural Cheese	5	0.10-0.27	0.17	0.14-0.27	0.19
Ice Cream	10	0.23-2.76	1.62	0.46-5.86	3.20
Ice Cream Mix	1	-	0.19	-	0.30
Condensed Milk	2	0.17-1.48	0.82	0.17-1.48	0.82
Dry Milk	-	-	-	-	-
Condensed Whey	3	0.13-0.70	0.34	0.33-1.74	0.86
Dry Whey	2	0.19-0.56	0.38	0.47-1.40	0.94
B. Multi-Products					
Fluid-Cottage	-	-	-	-	-
Fluid-Cultured	4	0.20-11.60	2.88	0.46-11.6	2.94
Fluid-Butter	-	-	-	-	-
Fluid-Natural Cheese	-	-	-	-	-
Fluid-Ice Cream Mix-Cottage-Cultured	-	-	-	-	-
Fluid-Ice Cream Mix-Cond. Milk-Cultured	1	-	1.10	-	1.10
Fluid-Cultured-Juice	1	-	1.80	-	4.17
Fluid-Cottage-Cultured	2	0.21-1.08	0.65	0.21-1.08	0.65
Fluid-Cottage-Ice Cream	1	-	1.64	-	1.64
Fluid-Butter-Natural Cheese	-	-	-	-	-
Fluid-Cottage-Dry Milk	-	-	-	-	-
Fluid-Cottage-Cultured-Dry Whey	1	-	1.65	-	1.65
Fluid-Cottage-Cultured-Ice Cream	3	0.33-6.90	2.90	0.44-7.16	3.02
Fluid-Cottage-Cultured-Cond. Milk	1	-	0.70	-	0.70
Fluid-Cottage-Butter-Ice Cream-Dry Milk	1	-	1.52	-	1.61
Butter-Dry Milk	1	-	1.00	-	1.56
Butter-Cond. Milk	-	-	-	-	-
Butter-Dry Milk-Dry Whey	1	-	2.56	-	3.92
Butter-Natural Cheese	-	-	-	-	-
Butter-Dry Milk-Ice Cream	-	-	-	-	-
Cottage-Cond. Milk	-	-	-	-	-
Cottage-Cultured-Dry Milk-Dry Whey-Fluid	1	-	0.57	-	0.64
Cottage-Natural Cheese	1	-	1.20	-	1.20
Natural Cheese-Dry Whey	3	0.80-2.01	1.45	0.80-2.01	1.45
Natural Cheese-Cultured-Rec. Sta.	1	-	1.70	-	1.70
Natural Cheese-Cond. Whey	3	0.22-1.34	0.68	0.33-1.34	0.72

This relationship between suspended solids and BOD5 seems to hold over the range of BOD5 normally found in raw dairy plant wastes, i.e., 1,000 mg/l to 4,000 mg/l. Using the above equation and the lower and upper limits of range of 1,000 mg/l, and 4000 mg/l, suspended solids - BOD5 ratios of 0.38 and 0.49 respectively are found.

Despite the relatively constant ratio of suspended solids to BOD5 of about .40 for the dairy industry as an aggregate, there is some evidence that the ratio may be somewhat higher for cottage cheese, ice cream, and drying operations where large amounts of fines could potentially be wasted. Substantiation of this hypothesis must await further data and analysis.

It should be noted that the amount of suspended solids in treated effluent from dairy products processing is as much or more dependent on the characteristics of the floc created in biological treatment than on the suspended solids in the raw waste. The former tends to have somewhat poor settling characteristics.

pH

The pH of raw dairy wastes of a total of 33 identified plants varies from 4.0 to 10.8 with an authentic mean of 7.8. The main factor affecting the pH of dairy plant wastes is the types and amount of cleaning and sanitizing compounds discharged to waste at the plant. Commingling of waste streams tend to neutralize the final discharge.

Temperature

Values reported by 12 identified plants for temperatures of raw dairy wastes vary from 8° to 38°C (46°F to 100°F) with a mean of 24°C (76°F). In general the temperature of the waste water will be affected primarily by the degree of hot water conservation, the temperature of the cleaning solutions, the relative volume of cleaning solution in the waste water. Higher temperatures can be expected in plants with condensing operations, when the condensate is wasted. Commingling and treatment tend to reduce the higher temperature encountered.

Phosphorus

Phosphorus concentrations (as PO_4) of dairy waste waters reported by 29 identified plants range from 9 mg/l to 210 mg/l, with a mean of 48 mg/l.

Part of the phosphorus contained in dairy waste water comes from the milk or milk products that are wasted. Waste water containing 1% milk would contain about 12 mg/l of phosphorus (3). The bulk of the phosphorus, however, is contributed by the wasted detergents, which typically contain significant amounts of phosphorus. The wide range of concentrations reported reflect varying practices in detergent usage and recycling of cleaning solutions.

Nitrogen

Ammonia nitrogen in the waste water of 9 identified plants varied between 1.0 mg/l and 13.4 mg/l, with a mean of 5.5 mg/l. Total nitrogen in 10 plants ranged from 1.0 mg/l to 115 mg/l, with a mean of 64 mg/l.

Milk alone would contribute about 55 mg/l of nitrogen at a 1% (10,000 mg/l) concentration in the waste water. Quaternary ammonium compounds used for sanitizing and certain detergents can be another source of nitrogen in the waste water.

Chloride

Six identified plants reported chloride concentrations ranging from 46 mg/l to 1,930 mg/l; the mean was 483 mg/l. The principal sources of chloride in the waste stream may include brine used in refrigerator systems and chlorine based sanitizers. Milk and milk products are responsible for part of the load; at a 1% concentration in the waste water, milk would contribute 10 mg/l of chloride.

Waste Water Volume

Waste water volume data are shown in Tables 14 (in metric units) and 14A (in English units). Waste water volumes consistent with good in-plant practices are shown in Table 14B.

Waste water flow for identified plants covers a very broad range from a mean of 542 l/kkg milk equivalent (65 gal per 1,000 lb, M.E.) for receiving stations to a mean of over 9,000 l/kkg milk equivalent (over 1,000 gal pr 1,000 lb M.E.) for certain multiproduct plants. It should be noted that waste water flow does not necessarily represent total water consumed, because many plants recycle condenser and cooling water and/or use water as a necessary ingredient in the product.

Principal Factors Determining Dairy Waste Loads

Prior research has shown that a major controlling factor of the raw waste loads of dairy plants is the degree of knowledge, attitude, and effort displayed by management towards implementing waste control measures in the plant. This conclusion was reaffirmed by the investigations carried out in this study.

Good waste management is manifested in such things an adequate training of employees, well defined job description, close plant supervision, good housekeeping, proper maintenance, careful production scheduling, finding suitable uses or disposal methods for whey and returned products other than discharge to drain, salvaging products that can be reused in the process or sold as

TABLE 14

Summary of Literature Reported and Identified Plant Source Raw Waste Water Volume Data

Type of Plant	Literature Reported Plant Sources: Number of Plants Reporting	Literature Reported Plant Sources: Liters Waste Water per 1,000 kg Milk Equivalent Received: Range	Literature Reported Plant Sources: Liters Waste Water per 1,000 kg Milk Equivalent Received: Mean	Identified Plant Sources: Number of Plants Reporting	Identified Plant Sources: Liters Waste Water per 1,000 kg Milk Equivalent Received: Range	Identified Plant Sources: Liters Waste Water per 1,000 kg Milk Equivalent Received: Mean	Identified Plant Sources: Liters Waste Water per 100 kg BOD_5 Received: Range	Identified Plant Sources: Liters Waste Water per 100 kg BOD_5 Received: Mean
A. Single Product								
Receiving Station (Cans)	6	525-1,251	676	5	317-1,868	826	317-1,868	826
Receiving Station (Bulk)	1	-	83	1	-	542	-	542
Fluid Products	16	108-9,091	3,077	11	434-8,507	3,870	434-8,507	3,886
Cultured Products	-	-	-	-	-	-	-	-
Butter	10	1,334-6,547	2,602	1	-	801	-	2,093
Cottage Cheese	5	834-12,543	7,740	-	-	-	-	-
Natural Cheese	20	200-5,846	2,135	5	275-959	567	275-1,384	676
Ice Cream	7	776-5,563	2,977	12	525-7,039	4,053	767-13,144	7,427
Ice Cream Mix	-	-	-	1	-	1,251	-	1,968
Condensed Milk	4	1,000-3,336	1,985	2	801-7,289	4,045	801-7,289	4,045
Dry Milk	8	984-12,835	4,720	3	751-3,836	1,810	917-5,529	2,502
Condensed Whey	3	909-1,026	967	7	917-1,151	992	2,285-2,852	2,444
Dry Whey	3	5,079-7,081	5,396	5	509-2,152	1,076	1,259-5,534	2,669
B. Multi-Products								
Fluid-Cottage	10	975-2,135	1,193	6	234-4,645	2,177	234-4,645	2,177
Fluid-Cultured	-	-	-	7	459-7,948	3,453	709-7,948	3,536
Fluid-Butter	8	751-3,336	1,676	-	-	-	-	-
Fluid-Natural Cheese	1	-	7,106	-	-	-	-	-
Fluid-Ice Cream Mix-Cottage-Cultured	-	-	-	-	-	-	-	-
Fluid-Ice Cream Mix-Cond. Milk-Cultured	-	-	-	1	-	3,678	-	3,678
Fluid-Cultured-Juice	-	-	-	1	-	5,980	-	13,861
Fluid-Cottage-Cultured	-	-	-	6	617-2,819	2,002	617-2,819	2,002
Fluid-Cottage-Ice Cream	12	801-11,518	3,545	1	-	2,319	-	2,319
Fluid-Butter-Natural Cheese	9	500-4,253	2,002	-	-	-	-	-
Fluid-Cottage-Dry Milk	1	-	1,618	-	-	-	-	-
Fluid-Cottage-Cultured-Dry Whey	-	-	-	1	-	2,210	-	2,210
Fluid-Cottage-Cultured-Ice Cream	-	-	-	3	1,134-3,753	2,783	1,518-3,886	2,955
Fluid-Cottage-Cultured-Cond. Milk	-	-	-	1	-	5,921	-	5,921
Fluid-Cottage-Butter-Ice Cream-Dry Milk	-	-	-	1	-	2,619	-	2,769
Butter-Dry Milk	6	834-2,519	1,735	4	542-1,126	851	709-1,126	984
Butter-Cond. Milk	-	-	-	1	-	2,685	-	3,286
Butter-Dry Milk-Dry Whey	-	-	-	1	-	2,802	-	4,287
Butter-Natural Cheese	19	417-6,505	2,777	-	-	-	-	-
Butter-Dry Milk-Ice Cream	1	-	1,526	-	-	-	-	-
Cottage-Cond. Milk	-	-	-	1	-	1,084	-	1,084
Cottage-Cultured-Dry Milk-Dry Whey-Fluid	-	-	-	1	-	1,368	-	1,535
Cottage-Natural Cheese	-	-	-	1	-	6,297	-	6,297
Natural Cheese-Dry Whey	1	-	2,085	3	1,401-20,333	9,207	1,401-20,333	9,207
Natural Cheese-Cultured-Rec. Sta.	-	-	-	1	-	6,572	-	6,572
Natural Cheese-Cond. Whey	-	-	-	3	3,786-8,040	5,271	3,987-8,040	5,880

TABLE 14 A

Summary of Literature Reported and Identified Plant Source Raw Waste Water Volume Data (FPS Units)

Type of Plant	Literature Reported Plant Sources: Number of Plants Reporting	Literature Reported Plant Sources: Gallons Waste Water per 1,000 Pounds Milk Equivalent Received: Range	Mean	Identified Plant Sources: Number of Plants Reporting	Identified Plant Sources: Gallons Waste Water Per 1,000 Pounds Milk Equivalent Received: Range	Mean	Gallons Waste Water per 100 Pounds BOD_5 Received: Range	Mean
A. Single Product								
Receiving Station (Cans)	6	63-150	81	5	30-224	99	38-224	99
Receiving Station (Bulk)	1	-	10	1	-	65	-	65
Fluid Products	16	13-1,090	369	11	52-1,020	464	52-1,020	466
Cultured Products	-	-	-	-	-	-	-	-
Butter	10	160-785	312	1	-	96	-	251
Cottage Cheese	5	100-1,504	928	-	-	-	-	-
Natural Cheese	20	24-701	256	5	33-115	68	33-166	81
Ice Cream	7	93-667	357	12	63-844	486	92-1,576	890
Ice Cream Mix	-	-	-	1	-	150	-	236
Condensed Milk	4	120-400	238	2	96-874	485	96-874	485
Dry Milk	8	118-1,539	566	3	90-460	217	110-663	300
Condensed Whey	3	109-123	116	7	110-138	119	274-342	293
Dry Whey	3	609-849	647	5	61-258	129	151-642	320
B. Multi-Products								
Fluid-Cottage	10	69-256	143	6	28-557	261	28-557	261
Fluid-Cultured	-	-	-	7	55-953	414	85-953	424
Fluid-Butter	8	90-400	201	-	-	-	-	-
Fluid-Natural Cheese	1	-	852	-	-	-	-	-
Fluid-Ice Cream Mix-Cottage- Cultured	-	-	-	-	-	-	-	-
Fluid-Ice Cream Mix-Cond. Milk-Cultured	-	-	-	1	-	441	-	441
Fluid-Cultured-Juice	-	-	-	1	-	717	-	1,662
Fluid-Cottage-Cultured	-	-	-	6	74-338	240	74-338	240
Fluid-Cottage-Ice Cream	12	96-1,381	425	1	-	278	-	278
Fluid-Butter-Natural Cheese	9	60-510	240	-	-	-	-	-
Fluid-Cottage-Dry Milk	1	-	194	-	-	-	-	-
Fluid-Cottage-Cultured-Dry Whey	-	-	-	1	-	265	-	265
Fluid-Cottage-Cultured-Ice Cream	-	-	-	3	136-450	334	182-466	354
Fluid-Cottage-Cultured-Cond. Milk	-	-	-	1	-	710	-	710
Fluid-Cottage-Butter-Ice Cream-Dry Milk	-	-	-	1	-	314	-	332
Butter-Dry Milk	6	100-302	208	4	65-135	102	85-135	118
Butter-Cond. Milk	-	-	-	1	-	322	-	394
Butter-Dry Milk-Dry Whey	-	-	-	1	-	336	-	514
Butter-Natural Cheese	19	50-780	333	-	-	-	-	-
Butter-Dry Milk-Ice Cream	1	-	183	-	-	-	-	-
Cottage-Cond. Milk	-	-	-	1	-	130	-	130
Cottage-Cultured-Dry Milk-Dry Whey-Fluid	-	-	-	1	-	164	-	184
Cottage-Natural Cheese	-	-	-	1	-	755	-	755
Natural Cheese-Dry Whey	1	-	250	3	168-2,438	1,104	168-2,438	1,104
Natural Cheese-Cultured-Rec. Sta.	-	-	-	1	-	788	-	788
Natural Cheese-Cond. Whey	-	-	-	3	454-964	632	478-964	705

Note: *Including whey dumping.

Table 14B

Raw Waste Water Volume Attainable Through Good In-Plant Control

Subcategory	l/kkg M.E.	l/kg BOD5	gal/1000 lb M.E.	gal/1000 lb BOD5
Receiving Stations	999	9.6	120	115.5
Fluid Products	4663	44.9	560	539.0
Cultured Products	4663	44.9	560	539.0
Butter	999	9.6	120	115.5
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
Ice Cream	5413	52.1	650	625.6
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

feed, and establishing explicit waste reduction programs with defined targets and responsibilities. Improvement in those areas generally will not require inordinate sums of money nor complex technologies to be implemented. In fact, most waste control measures of the type indicated will have an economic return as a result of saving product that is otherwise wasted.

The other principal factors determining the raw waste load, including BOD_5 of the inputs and products, viscosity of materials, and processes employed have been discussed elsewhere in the report.

Polluting Effects

It has been generally recognized that the most serious pollutional problem caused by dairy wastes is the depletion of oxygen of the receiving water. This comes about as a result of the decomposition of the organic substances contained in the wastes. Organic substances are decomposed naturally by bacteria and other organisms which consume dissolved oxygen in the process. When the water does not contain sufficient dissolved oxygen, the life of aquatic flora and fauna in the water body is endangered.

SECTION VI

POLLUTANT PARAMETERS

Waste water Parameters of Potential Pollutional Significance

On the basis of all evidence reviewed, it has been concluded that the waste water parameters of potential pollutional significance include BOD, COD, suspended solids, pH, temperature, phosphorus in the form of phosphates, nitrogen in various forms (e.g., ammonia nitrogen and nitrate nitrogen), and chlorides. The significance of these parameters and the rationale for selection or rejection of each as a factor for which an effluent guideline should be established are discussed below.

BOD

The majority of waste material in dairy plant waste waters is organic in nature, consisting of milk solids and organic components of cleaners, sanitizers and lubricants. The major pollutional effect of such organics is depletion of the dissolved in receiving waters. The potential of a waste for exerting this effect most commonly has been measured in terms of BOD, the laboratory analysis which most closely parallels phenomena occurring in receiving waters.

The BOD_5 concentration of raw waste waters in the dairy products processing industry typically ranges from 1,000 mg/l to 4,000 mg/l and the total daily loads within the industry have been observed to range from 8.2 kg/day (18.0 lb) to 3,045 kg/day (6,699 lb). This is equivalent to raw waste discharge for municipalities of 100 to 40,000 population. Such concentrations of BOD_5 are considered excessive for direct discharge to receiving waters, and unless the receiving waterbody is a large, well-mixed lake or stream, the upper segment of the range of loads poses a hazard to aquatic wildlife as a result of oxygen depletion.

The BOD_5 level of dairy wastes can be reduced by in-plant controls and end-of-pipe treatment (including disposal on land) that are well demonstrated and readily available. Therefore, effluent limitations guidelines for this parameter are justifiable and recommended for point source discharges for each subcategory within the dairy products industry.

Biochemical oxygen demand (BOD) is a measure of the oxygen consuming capabilities of organic matter. The BOD does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Sewage and other organic effluents during their processes of decomposition exert a BOD, which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD can kill all inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations.

COD

In theory, the Chemical Oxygen Demand test (an analytical procedure employing refluxing with strong oxidizing agents) measures all oxidizable organic materials, both non-biodegradable and biodegradable, in a waste water. It thus has an advantage, when compared to the BOD_5 test, of measuring the refractive organics which may cause toxicity or taste and odor problems. An additional advantage (especially for employment as an operational waste management tool) is that COD can be determined in a relatively short period of time, at most a matter of several hours not days, and thus is a measure of current operations, not those of days past as is true for BOD. Conversely, COD has two major disadvantages. It does not closely parallel phenomena in receiving waters and it does not distinguish between non-biodegradable and biodegradable materials. Thus, it does not indicate the potential that a waste water may have for causing an oxygen depletion in receiving waters.

Data compiled during the course of this study indicate a COD to BOD_5 ratio of approximately 2:1 for raw wastes and 4:1 for biologically treated (e.g., activated sludge) wastes. Both of these ratios are fairly close to those noted for typical municipal wastes and do not indicate wastes abnormally high in refractive organics.

The decision of whether or not to include COD as a parameter to be controlled under effluent guidelines should be based on the answers to two questions. What is the significance of the materials measured by COD and not by other parameters, and what are the facts associated with treatment for removal of COD?

Historically there is little or no information to indicate environmental problems associated with an inherent toxicity of dairy plant wastes, the impacts on aquatic life having been mediated through oxygen depletion attributable to biodegradable organics. Similarly, the limited taste and odor problems have been associated primarily with intermediate products resulting from biological breakdown (especially under anaerobic conditions) of the degradable organic constituents of milk. Thus, from the standpoint of environmental effects there is little or no reason to adopt COD as a control parameter for dairy products processing.

Removal of refractive organics from dairy products wastes would require utilization of special treatment techniques, such as chemical-physical approaches designed for specific substances, carbon adsorption and reverse osmosis. These techniques are high in cost and subject to a number of operational problems, for example, membrane fouling and carbon regeneration. The significance of refractive organics in the dairy industry's wastes does not justify imposition of such treatment.

Dairy product plants that can establish reasonably consistent correlation between COD and BOD_5 could, in the future, substitute COD for BOD as a monitoring measurement for determining the effectiveness of control and treatment. This is especially true for small isolated operations that could not afford Total Organic Carbon or Total Oxygen Demand determinations at some later date.

Total Suspended Solids

Suspended solids in waste water have an adverse affect on the turbidity of the receiving waters. This is particularly noticible for waste water from dairy products due to the color of the solids and their extreme opacity. An additional effect of suspended solids in quiescent waters is the build-up of deposits on the botton. This is especially objectionable when the suspended solids are primarily organic materials, as is the case in dairy wastes. The resulting sludge beds may exert a heavy oxygen demand on the overlying waters, and under anaerobic conditions their decomposition produces intermediate products (e.g., hydrogen sulfide) which cause odor problems and are toxic to aquatic life.

Dairy products waste waters typically contain up to 2,000 mg/l of suspended solids, most of which are organic particulates derived from the milk and other materials processed. The level of solids in raw waste waters can be reduced by good in-plant control and with adequate end-of-pipe biological treatment and clarification can be reduced to acceptable concentrations in final discharge waste waters. It is recommended, therefore, that suspended solids be included in the parameters to be controlled under effluent guidelines and standards.

Suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair, and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, state and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water for textile industries; paper and pulp; beverages; dairy products; laundries; dyeing; photography; cooling systems, and power plants. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a seemingly inexhaustible food source for sludgeworms and associated organisms.

Turbidity is principally a measure of the light absorbing properties of suspended solids. It is frequently used as a substitute method of quickly estimating the total suspended solids when the concentration is relatively low.

pH, Acidity and Alkalinity

pH outside of an acceptable range may exert adverse effect either through direct impact of the pH or through their role of influencing other factors such as solubility of heavy metals. Among the potential adverse effects of abnormal pH are direct lethal or sub-lethal impact on aquatic life, enhancement of the toxicity of other substances, increased corrosiveness of municipal and industrial water supplies, increased costs for water supply treatment, increased staining problems associated with greater solubility of substances such as iron and manganese, and rendering water unfit for some processes such as canning or bottling of certain foods and beverages.

Though a number of individual waste streams within a dairy products plant may exhibit undesirably high or low pH, the available data show that the combined discharge from dairy plants generally fall with the acceptable range. However, monitoring and adjustment of pH are relatively simple and inexpensive, so there is no real reason for discharge of waste water that is outside the acceptable range of pH.

In view of the many potential adverse effects of abnormally high or low pH, and the ease of measurement and control, it is recommended that pH be included in the parameters for effluent guidelines and standards.

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH water tastes "sour". The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

Temperature

Available data (Table 15) indicates that temperature of raw waste waters range between 8°C (46°F) and 38°C (100°F), with 90 percent of the discharges ranging between 15°C (59°F) and 29°C (85°F). These values, coupled with volumes of discharge in the industry, indicate that neither temperature nor total heat discharge constitute serious problems. Furthermore, there will be a tendency for the waste waters to approach ambient temperature as they pass through the treatment facilities that must be installed for point source discharges to meet BOD_5 limitations. Thus, temperature has not been included in the parameters subject to guidelines and standards.

Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present; it activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development. Warmer water generally accelerates activity and may be a primary cause of aquatic plant nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances and the decay rate increases as the temperature of the water increases reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F. Predominant algal species change, primary production is decreased, and bottom associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperatures may cause aquatic plant nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Given amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers more rapidly deplete oxygen in water at higher temperatures, and the respective toxicities are likewise increased.

When water temperatures increase, the predominant algal species may change from diatoms to green algae, and finally at high temperatures to blue-green algae, because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperatures increase above 90°F, which is close to the tolerance limit for the population. This could seriously affect certain fish that depend on benthic organisms as a food source.

The cost of fish being attracted to heated water in winter months may be considerable, due to fish mortalities that may result when the fish return to the cooler water.

Rising temperatures stimulate the decomposition of sludge, formation of sludge gas, multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus affecting the esthetic value of a water course.

In general, marine water temperatures do not change as rapidly or range as widely as those of freshwaters. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas, because of the nursery and replenishment functions of the estuary that can be adversely affected by extreme temperature changes.

Phosphorus

Phosphorus is of environmental concern because of the role it plays in eutrophication, the threshold concentration for stimulation of excessive algal growth generally being considered as approximately 0.01 mg/l to 0.25 mg/l.

Phosphorus concentrations in raw waste waters in the dairy industry have been found to range from 12 mg/l to 210 mg/l with a mean of 49 mg/l. With the reduction of phosphorus concentrations that result from implementation of adequate in-plant control, and the further reduction that accompanies biological treatment (approximately 1 part per 100 parts of BOD_5 removed), the phosphorus levels associated with point source discharges in the industry will be consistent with those in discharges from municipal secondary treatment plants. Effluent guidelines and standards for phosphorus are not recommended at this time.

During the past 30 years, a formidable case has developed for the belief that increasing standing crops of aquatic plant growths, which often interfere with water uses and are nuisances to man, frequently are caused by increasing supplies of phosphorus. Such phenomena are associated with a condition of accelerated eutrophication or aging of waters. It is generally recognized that phosphorus is not the sole cause of eutrophication, but there is evidence to substantiate that it is frequently the key element in all of the elements required by fresh water plants and is generally present in the least amount relative to need. Therefore, an increase in phosphorus allows use of other, already present, nutrients for plant growths. Phosphorus is usually described, for this reasons, as a "limiting factor."

When a plant population is stimulated in production and attains a nuisance status, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating and water skiing and sometimes fishing may be eliminated because of the mass of vegetation that serves as an physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Plant nuisances emit vile stenches, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a desired substrate and breeding ground for flies.

Phosphorus in the elemental form is particularly toxic, and subject to bioaccumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues. Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1 ug/l.

Nitrogen

Nitrogen is another element whose major cause for environmental concern stems from its role in excessive algal growth. In addition, very high levels of nitrogen are undesirable in water supplies and are toxic to aquatic life especially when present in the form of ammonia.

Nitrogen is present in dairy waste waters primarily as protein and ammonia nitrogen. Based on very limited data (Table 15), ammonia nitrogen concentrations have been found to vary from 1.0 mg/l to 13.2 mg/l and average 5.4 mg/l. As is the case for phosphorus, reductions attained through in-plant controls and biological treatment required to meet limitations for other parameters will result in nitrogen concentrations in point source discharges that are consistent with those found in discharges from municipal secondary treatment plants. Effluent limitations for nitrogen are not recommended for application to the dairy products industry at the present time.

Chloride

Excessive concentrations of chloride interfere with use of waters for municipal supplies by imparting a salty taste, for industrial supplies by increasing corrosion, for irrigation through phytotoxicity, and for propagation of freshwater aquatic life (if levels are in thousands of mg/l and variable) through disturbance of osmotic balance.

Very limited data (Table 15) show that chloride concentrations in raw waste waters range between 46 mg/l and 1,930 mg/l and average 482 mg/l. If one eliminates the very high value of 1,930 mg/l, possibly attributable to leakage of brine from refrigeration lines, the chloride concentrations are well below limits for any use other than irrigation of the most sensitive plants. Chloride is a conservative pollutant, i.e., it is not subject to significant reduction in biological treatment systems. Appreciable reduction of chloride would require advanced treatment such as reverse osmosis or ion exchange.

TABLE 15

SUMMARY OF pH, TEMPERATURE, AND CONCENTRATIONS OF NITROGEN, PHOSPHORUS, AND CHLORIDE IONS --LITERATURE REPORTED AND IDENTIFIED PLANT SOURCES

		LITERATURE PLANT SOURCE			IDENTIFIED PLANT SOURCE	
Parameter	**No. of Plants**	**Range**	**Mean**	**No. of Plants**	**Range**	**Mean**
Ammonia Nitrogen (mg/l)				9	10-13.4	5.5
Total Nitrogen (mg/l)	11	15-180	73	10	1-115	64
Phosphorus as PO_4 (mg/l)	12	12-205	53	29	9-210	48
Chlorides (mg/l)	8	48-559	297	6	46-1930	483
Temperature (°C)	13	18-42	33	12	8-38	24
(°F)	--	65-108	92	--	46-100	76
pH	33	4.4-12.0	7.2	33	40-10.8	7.8

In view of the relatively low levels of chlorides encountered and the difficulty of their removal, effluent guidelines and standards are not recommended for chlorides.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

In-Plant Control Concepts

The in-plant control of water resources and waste discharges in all types of dairy food plants involve two separate but interrelated concepts:

1. Improving management of water resources and waste materials.

2. Engineering improvements to plant, equipment, processses, and ancillary systems.

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; it must clearly understand the relative role of engineering and management supervision in plant losses.

The best modern engineering design and equipment cannot alone provide for the control of water resources and waste within a dairy plant. This fact was clearly evident again during this study. A new (six-month old), high-capacity, highly automated multi-product dairy plant, incorporating many advanced waste reduction systems, was found to have a BOD_5 level in its waste water of more than 10 kg/kkg (10 lb/1000 lb) of milk equivalent processed. This unexpected and excesssive waste could be related directly to lack of management control of the situation and poor operating practices.

Management control of water resources and waste discharges should involve all of the following:

- Installation and use of a waste monitoring system to evaluate progress.

- Utilization of an equipment maintenance program to minimize all product losses.

- Utilization of a product and process scheduling system to optimize equipment utiliztion, minimize distractions of personnel, and assist in making supervision of the operation possible.

- Utilization of a planned quality control program to minimize waste.

- Development of alternative uses for a wasted products.

- Improvement of processes, equipment and systems as rapidly as economically feasible.

Waste Monitoring

The collection of continuous information concerning water usage and waste water discharge is essential to the development of any water and waste control program in a dairy plant. Much of the excess water and high solids waste discharges to sewer result from lack of information to plant personnel, supervisors and management. In many instances, large quantities of potentially recoverable milk solids are discharged to the drain without the knowledge of management. Accounting systems utilized to account for fat and solids within a dairy plant are frequently inaccurate because of many inherent errors in sampling, analysis, measurement of product, and package filling. The installation of water meters and of a waste monitoring system has generally resulted in economic recovery of lost milk solids. Recovery is usually sufficient to pay for costs of the monitoring equipment within a short time.

Water meters may be be installed on water lines going to all major operating departments in order to provide water use data for the different major operations in the plant. Such knowledge can be used to develop specific water conservation programs in a more intelligent manner. Some plants have found it advantageous to put in water meters to each major process to provide even more information and to fix responsibility for excessive water use.

Waste monitoring equipment generally should be installed at each outfall from the plant. Wherever possible in older plants, multiple outfalls should be combined to a common discharge point and a sampling manhole installed in this location. Where sampling manholes are being installed for the first time in old or new locations, attention should be given to insuring that there is easy and convenient access to the sampling point.

Monitoring equipment generally would include, a weir to measure flow volume and a continuous sampling device. Two types of samplers may be utilized: (a) a proportional flow, composite sampler such as the Trebler, or (b) a time-activated sampler that can provide hourly individual samples. For plant control purposes the latter can provide the waste control supervisor and and employees with a visual daily picture of the wastes from the plant even without sampling the turbidity, color, presence of free fat, or sediment. Such a daily evaluation can readily point out problem areas. In the case of the time sampler it is necessary to utilize flow data to make up a flow proportioned composite sample for analysis.

Engineering Improvements for In-Plant Waste Control

Many equipment, process, and systems improvements can be made within dairy food plants to provide for better control of water usage and waste discharges. In many cases significant engineering changes can be made in existing plants at a minimal expense. The application of engineering improvements must be considered in relationship to their effect on water and waste discharges and also on the basis of economic cost of the changes. Many engineering improvements should be considered as "cost recovery" expenditures, since they may provide a basis for reclaiming resources with a real economic value and eliminating the double charges that are involved in treating these resources as wastes.

New plants or extensive remodeling of existing plants provide an even greater opportunity to "engineer" water and waste reduction systems. Incorporation of advanced engineering into new plants provides the means for the greatest reduction in waste loads at the most economical cost.

Existing Plants

- Equipment improvements
- Process improvements
- System improvements

New Plants or Expandsion of Existing Plants

- Plant layout and equipment selection

<u>Waste Mangement Through Equipment Improvements</u>

Waste management control can be strengthened by upgrading existing equipment in plant operations. These can be divided into: (a) improvements that have been recommended for many years and (b) these that are new and not widely used or evaluated.

Standard Equipment Improvement Recommendations

1. Put automatic shut-off valves on all water hoses so that they cannot run when not in use.

2. Cover all drains with wire screens to prevent solid materials such as nuts, fruits, cheese curd from going down the drain.

3. Mark all hand operated valves in the plant, especially multiport valves, to identify open, closed and directed flow positions to minimize errors in valve operation by personnel.

4. Identify all utility lines.

5. Install suitable liquid level controls with automatic pump stops at all points where overflow is likely to occur (filler bowls, silo tanks, process vats, etc.). In very small plants, liquid level detectors and an alarm bell may be used.

6. Provide adequate temperature controls on coolers, especially glycol coolers, to prevent freezing-on of the product and subsequent product loss. In some instance high-temperature limit controls may be installed to prevent excessive burn-on of milk which not only increase solids losses but also increase cleaning compound requirements.

7. All CIP lines should be checked for adequate support. Lines should be rigidly supported to eliminate leakage of fittings caused by excessive line vibrations. All lines should be pitched to a given drain point.

8. Where can receiving is practiced in small plants, an adequate drip saver should be provided between can dumping and can washing. This should be equipped with the spray nozzle to rinse the can with 100 ml (3-4 oz) of water. A two minute drain period should be utilized before washing.

9. All piping around storage tanks and process areas where pipelines are taken down for cleaning should be identified to eliminate misassembly and damage to parts and subsequent leaking of product.

10. Provide proper drip shields on surface coolers and fillers so that no spilled product can reach the floor.

11. All external tube chest evaporators should be designed with a tangential inlet from the tube chest to the evaporating space. All coil or colandria evaporators should be equipped with efficient entrainment separators.

12. "Splash discs" on top of the evaporators can prevent entrainment losses through improper pan operation.

13. Evaporators and condensers should be equipped, wherever possible, with full barometic leg to eliminate sucking water back to the condenser in case of pump or power failure.

New Concepts For Consideration In Equipment Improvement for 1983 Control and New Source Standards

1. Install drip shields on ice cream filling equipment to collect frozen product during filling machine jams. Such equipment would have to be specially designed and built at the present time.

2. Install a system for collecting novelties from frozen dessert novelty machines and packaging units. At the

present time numerous types of failures, especially on stick novelty machines, cause defective novelties to be washed down the drain. Such defects include bad sticks, no sticks, poor stick clamping, overfilling, and poor release. The "defective product collection system" would have to be specially designed and custom built at the present time.

3. Since recent surveys have shown that case washers may use up to 10% of the total water normally utilized in a total plant operation, automatic shut-off valves on the water to the case washer should be installed so that the case washer sprays would shut-off when the forward line of the feeder was filled. Many cases are exposed to long term sprays because of relatively low rate of stacking and use of washed cases in many operations. Another alternative to be shut-off valve would be an integrated timer coupled to a trip switch in which the trip switch would activate the washer sprays which would automatically shut-down after a specified washing cycle.

4. Install a product recovery can system, attached to a pump and piped to a product recovery tank. Such a system should be installed near filling machines (including ice cream) to provide a system for recovering the product from damaged cartons or non-spoiled product return. Such product could be sold for animal feed.

5. Develop a "non-leak" portable unit for receiving damaged product containers. Currently used package containers are not liquid tight and generally leak products onto the floor. This is particularly undersiable for high solids products materials such as ice cream.

6. Install an electrical interlock between the CIP power cut-on switch and the switch for manual air blow down, so that the CIP pump cannot be turned on until after the blow down system has purged the line of product.

7. Equip filling machines for most fluid products with a product-capture system to collect products at time of change over from one product to another. Most fillers have a product by-pass valve. An air-acutated by-pass valve interlocked with a low level control could be piped to the filler product recovery system or the container collecting the product from drip shields; so designed that when the product in the filler bowl reaches the minimal low level the product by-pass systems would open, the product would drain, followed by a series of short flushing rinses. Filler bowls could be equipped with small scale spray devices for this purpose. The entire system could be operating through a sequence timer. All the components of such a system are readily available but the system would have to be designed and built for each particular filler at the present time.

8. In the future, there is a need to give attention to the design of equipment such as fillers and ice cream freezers to permit them to be fully CIP cleaned.

Waste Management Through Systems Improvements

In the context of this report a "system" is a combination of operations involving a multiplicity of different units of equipment and integrated to a common purpose which may involve one or more of the unit processes of the dairy plant. Such systems can be categorized into: (a) those that have been put in use in at least one or more dairy plants, and (b) those that have not yet been utilized but are technolgically feasible and for which component equipment parts now exist.

(a) Waste Control Systems Now In Use:

Systems which are currently in use that have a direct impact on decreasing dairy plant wastes include the following:

- CIP cleaning systems
- HTST product recovery systems (for fluid products and ice cream)
- Air blow down
- Product rinse recovery systems
- Automatic processes

1. CIP - The management of cleaning systems for dairy plants has significance to waste discharges in three respects: (a) the amount of milk solids discharged to drain through rinsing operations, (b) the concentration of detergents in the final waste water, and (c) the amount of milk solids discharged to drain as the result of the cleaning opertion itself. The cleaning of all dairy equipment, whether done by mechanical force or hand cleaning, involves four steps: pre-rinse, cleaning, post-rinse, and sanitizing.

Wherever possible, circualtion cleaning procedures are replacing the hand-cleaning operations, primarily because of their greater efficiency and concomitant result in improving product quality. Since cleaning compounds have been shown to be deleterious to the microflora of dairy waste treatment systems, all cleaning systems should take into account both water utilization and cleaning compound utilization.

In small plants where hand-cleaning cannot be economically avoided, a system should be developed to pre-package the cleaning compounds in amounts just sufficient to do each different type of cleaning job in the plant. This will avoid the tendency of plant personnel to use much more cleaning compound than necessary. A wash vat for hand cleaning should be provided that has direct connection to the plant hot water system and incorporates a thermostatically controlled heater to maintain the tank temperature at or around 50°C (120°F). High-pressure spray cleaning units should be used for hand cleaning of storage tanks and process vessels to improve efficiency and reduce cleaning compound usage.

Cleaning compounds should be selected for a specific type of operation and the different types of compounds kept at a minimum to eliminate confusion, loss of materials, and utilization of improper substances.

Small parts such as filler parts, homogenizer parts and separator parts from those machines needing to be hand-cleaned should be cleaned in a well-designed COP (cleaned-out-of-place) circulation tank cleaner equipped with a self-contained pump and a thermostically controlled heating system.

For maximum efficiency, minimum utilization of cleaning compounds and maximum potential use of rinse recovery systems, as much of the plant equipment as possible should be CIP. Two types of CIP systems are currently in use in the dairy industry:

-Single-use: the cleaning compound is added to the cleaning solution and discharged to drain after a single cleaning opeation.

- Multiple-use: the cleaning compound is circulated through the equipment to be cleaned and returned to a central cleaning tank for reutilization. The cleaning compound concentration is maintained at a desired level either by "recharging" or by using contactivity measurements and automatic addition of detergent as required.

There is a conflict within industry as to which method is best from the viewpoint of cleaning compound (detergent) and water usage. In principle it would appear that the reutilization of the detergent solution should be the most economical in respect to water and cleaning compound requirements. Under actual practice this has not always been the case and in some instance the highest water and cleaning compound utilization has been in plants equipped with mutiple-use CIP systems. On the average, single-use systems use less cleaning compound and slightly more water than multiple or reuse systems.

Automation of a CIP system provides for maximum potential waste control, both in respect to product loss and detergent utilization. An automated CIP system is composed of necessary supply lines, return lines, remote operated valves, flow control pumping system, temperature control system and centralized control unit to operate the system.

These systems have to be designed with safety in mind as well as efficiency. A major problem in most current designs is inadequate air capacity to completely clear the lines of product and dependency upon plant personnel to make sure that they are used prior to initiation of the CIP cleaning operation.

2. Product Rinse Recovery - The automated CIP system and product recovery system for the HTST pasteurizer can also be expanded to include rinse recovery for all product lines and receiving operations.

3. Post Rinse Utilization System - Final rinses and sanitation water may be diverted to a holding tank for utilization in prerinsing and wash water make-up for single use CIP application.

4. Automated Continuous Processing - Fluid products,including ice cream mix, can be prepared in a continuous, sequential manner eliminating the need for special processing vats for various products, eliminating the need to make a change-over in water between products that are being pasteurized. Such systms are curently in use for milk products and could be developed for ice cream operations.

(b) New Waste Control Concepts

A number of new waste control systems using existing components and electrical and electonic control systems may be developed in the future to further reduce waste loads in dairy plants.

<u>Waste Management Through Proper Plant Layout and Equipment Selection</u>

Proper layout and installation of equipment designed to mimimize waste are important factors to achieve low waste and low water consumption in new or expanded plants.

(a) Plant Layout

Whereas the principles involved apply to all dairy food plants, they are most critical for large ones. The point is approaching when 80% of the dairy products will be produced in less than 30% of the plants. Thus, major waste discharges will be associated with a relatively few very large plants. For such operations, attention to plant layout is essential.

Some major features in plant design which will minimize waste loads include:

1. The use of a minimum number of storage tanks. A reduction in the number of tanks reduces the number of fittings, valves, pipe length, and also reduces the amount of wash water and cleaning solution required. Also, the loss due to product adhering to the sidewalls to tanks is minimized by using fewer

and larger tanks.

2. Locating equipment in a flow pattern so as to reduce the amount of piping required. Fewer pipes mean fewer fittings, fewer pumps and fewer places for leakage.

3. Segregation of waste discharge lines on a departmental basis. Waste discharge lines should be designed so that the wastes from each major plant area can be identified and, ideally, diverted independently of other waste discharges. This would permit identification of problems and later application of advanced technology to divert from the sewer all excessive discharges - such as accidental spills.

4. Storage tanks should be elevated and provide for gravity flow to processing and filling equipment. This allows for more complete drainage of tanks and piping, and reduces pumping requirements.

5. Space for expansion should be provided in each departmental areas. This will permit an orderly expansion without having to install tanks and equipment at remote points from existing equipment. Only the equipment needed for current production (or production for the next three years) should be installed at the time of building the plant. This eliminates the tendency to operate a number of different pieces of related equipment under-capacity to "justify" their presence in the plant. Such surplus equipment, especially pasteurizers, tends to increase waste loads and require additional maintenance attention.

6. Hand-cleaned tanks should be designed to be high enough from the floor to permit draining and rinsing.

(b) Equipment Selection

In new or remodeled plants, attention must also be given to the selection of equipment, processes and systems to minimize water usage and waste discharge. The following considerations are applicable to these concepts and may be beneficial to overall plant efficiencies and operations.

1. Evaluation of equipment for ease of cleaning. Equipment should be designed to elimate dead space, to permit complete draining, and be adaptable to CIP (clean in place). Use of 3A-approved equipment is to be encouraged, since these cleanability factors are included in the approval process.

2. Use CIP air-actuated sanitary valves in place of plug valves. They fall shut in case of actuator failure, reduce leaks in piping systems, are not taken down for cleaning and therefore receive less damage and require less maintenance. Such valves are the key to other desirable waste management features

such as automated CIP systems, automated process control, rinse recovery systems, and air blowdown systems.

3. Welded lines should be used wherever possible to reduce leaks by eliminating joints and fittings.

4. For pipes that must be disconnected, use CIP fittings that are designed not to leak and require minimum maintenance.

5. CIP systems should be used wherever possible. In all new installations, these should be automated to eliminate human errors, to control the use of cleaning compounds and waters, to improve cleaning efficiencies and to provide basic systems for use in future engineering proceesses for waste control.

6. Install a central hot water system. Do not use steam "T mixers", as they waste up to 50% more water than a central heating system for hot water.

7. Evaluate all available processes and systems for waste mangement concepts.

<u>Waste Reduction Possible Through Improvement of Plant Management and Plant Engineering</u>

Assessment of the extent to which in-plant controls can reduce dairy plant wastes is difficult, because of the many different types of plants, the variability of management, and the lack of an absolute model on which to base judgement. Based on limited data, it would appear probable with current management, equipment, processes and systems that have been utilized anywhere in the industry, the best that could be achieved in most plants would be a water discharge of 830 l/kkg (100 gal/ 1,000 lb) of milk equivalent processed, and a BOD_5 discharge of 0.05 kg/kkg (0.5 lb/100lb) of milk equivalent processed. This would be equivalent to a BOD_5 waste strength minimum of 600 mg/l. The achievement of such levels have been demonstrated only in a few instances in the industry and in all cases these have been in single-product plants not involving ice cream and cottage cheese.

Waste Reduction Possible Through Management

The extent to which management can reduce water consumption and and waste loads would depend upon a number of factors that do not lend themselves to objective evaluation, such as the initial quality of management, the current water and waste loads in the operation, and the type and effiency of implementation of control programs within the plant. No absolute values can be ascertained. Nor is it possible to assign individual water and waste discharge savings to specific aspects of the plant management improvement program; rather, the problem can only be looked at subjectively in the context of its whole. The consensus among those who have studied dairy plant waste control recently (Harper, Zall, and Carawan) is that under many circumstances mangement improvement can result in a reduction equivalent to 50% of current load, see Table 16.

Although there are exceptions, there has been a general relationship found between waste water volume and BOD_5 concentrations in dairy plant waste waters. For most plant operations the waste discharge could be reduced to a rate of 1,660 l/ kkg (200 gal/1000 lb) of milk equivalent processed and 2.4 kg BOD_5. The reductions achievable represent a real economic return to the operation. Each kilogram of BOD_5 saved represents a savings of up to 10 cents on treatment cost and 70 cents in cost value of raw milk. (Grade A milk at a farm price of $7 per 100 lb.) For a 227,000 kg/day (500,000 lb) milk plant, this would represent a potential return of $400/day or $120,000/year (based on 300 processing days).

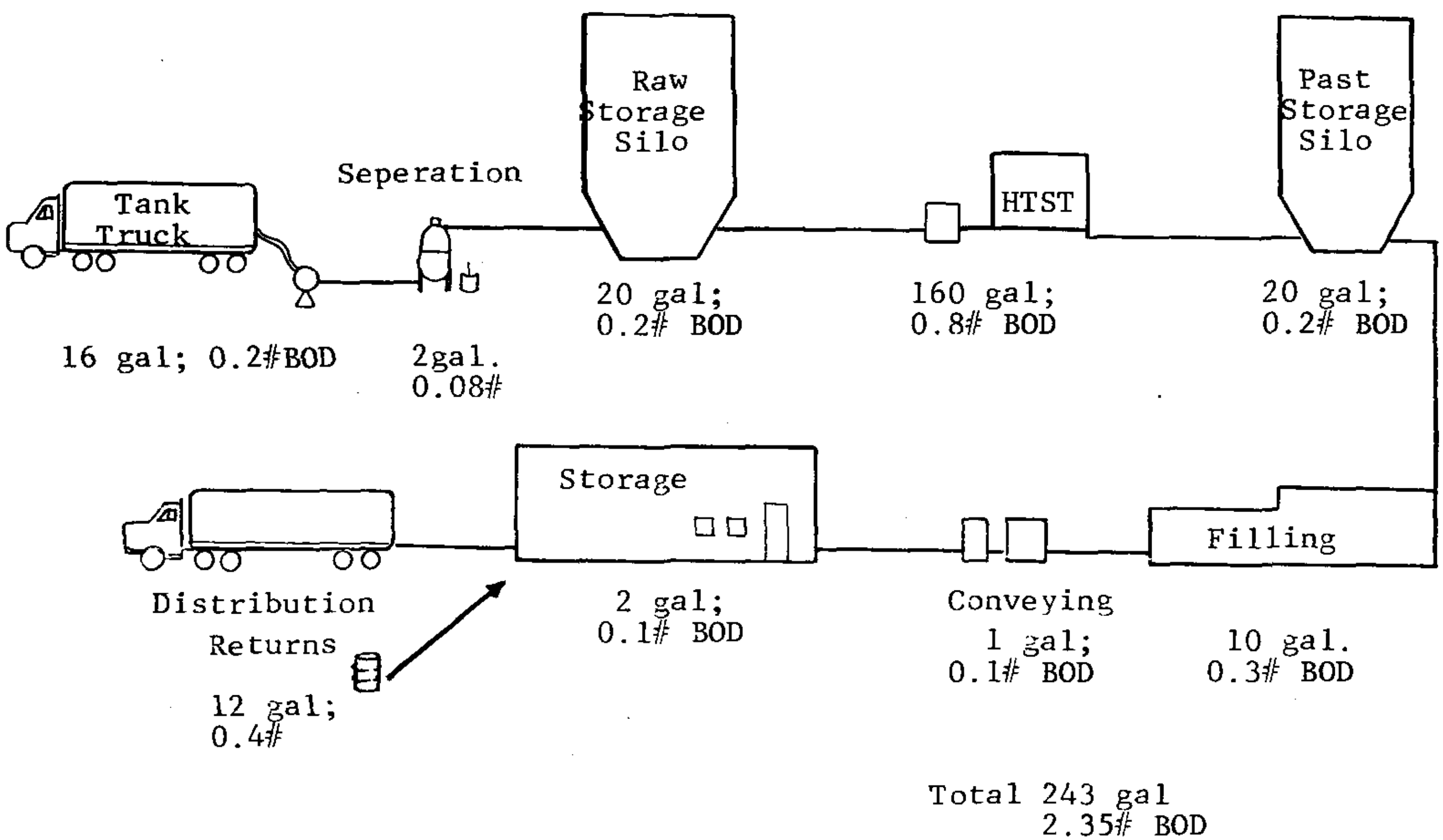
Waste Reduction Through Engineering

Assignment of values to water and waste reduction through engineering is very difficult because of the multiplicity of variable factors that are involved. The values arrived at in this report are based on subjective judgment. It is assumed that an overall reduction of about 2 kg BOD_5/kkg of milk equivalent processed is achievable in a well-managed plant through the application of presently available equipment, processes and systems. The values used as a base line for unit operations are the "standard manufacturing process" waste loads based on "good management," reported in the 1971 Kearney report. It should be recognized that these values were obtained on relatively limited data and may not be generally achievable in the dairy industry as a whole at the present time.

An example of what can be achieved through application of engineering is shown in Figures 14 and 15. Figure 14 shows the waste load for a fluid milk operation under normal practices of relatively good mangement. Figure 15 shows the values for unit operations and the plant after the following engineering changes:

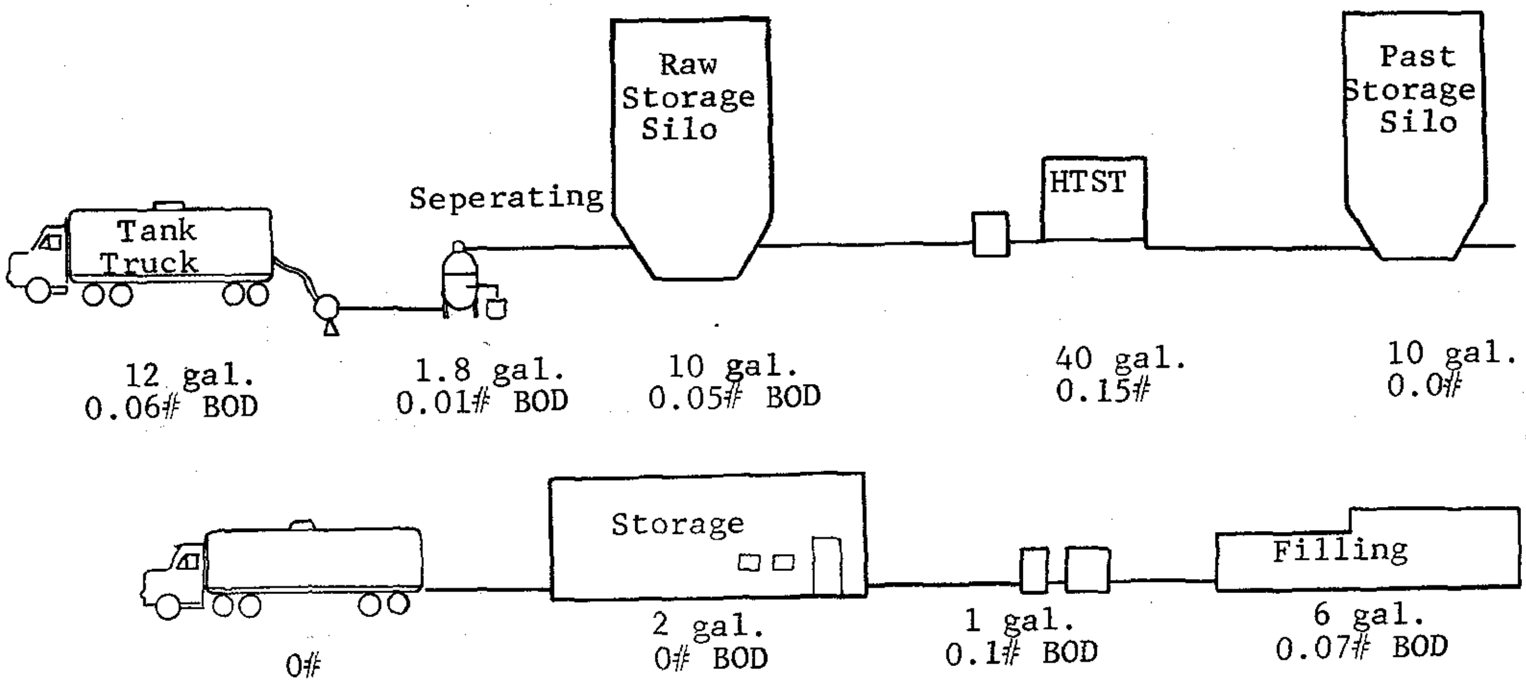
- Installation of drip shields on all fillers.
- A central water heating system with shut-off valves on all hoses
- A product recovery for the HTST operation for start-up, change-over, and shut-down.
- Air blown down of lines.
- A rinse recovery system.
- Collection of CIP separator sludge as solid waste.

FIGURE 14



Waste Coefficients for a Fluid Milk Operation Normal Operation.
(#BOD/1000# Milk processed gal waste water/1000#Milk processed)

FIGURE 15



Total 102.8 gal./1000#
0.5# BOD/1000#

Waste Coefficients After Installation of Engineering Advances in a Fluid Milk Operation (#BOD/1000 milk processed, gal. waste water/1000# milk processed)

TABLE 16

The Effect of Management Practices on Waste Coefficients

Plant No.	Products Manufactured	Milk Processed Lb/Day	Lb BOD/1000 Lb Milk Processed	Lb Waste Water/ Lb Milk Processed	Level of Management Practices	Explanation of Practices
1	Milk	400,000	0.3	0.4	Excellent	Rinses saved, hoses off, out of use, filler drip pans
42	Milk	150,000	7.8	5.2	Poor	No steps taken to reduce waste
43	Milk	500,000	0.2	0.1	Excellent	Rinses saved, returns excluded, filler drip pans, cooling tower
6	Cottage Cheese	600,000	2.0	0.8	Good	Whey excluded, fines screened out, wash water to drain
36	Cottage Cheese	300,000	1.3	4.7	Good	Whey excluded, spilled curd handled as solid waste
37	Cottage Cheese	650,000	71	12.4	Poor	Whey included
9	Ice Cream	17,000	32.2	5.3	Poor	Rinses to drain leaks, drips; water running-not in use
26	Ice Cream	34,000	2.1	0.8	Good	Freezer rinses segregated
48	Milk	250,000	0.7	1.0	Good	Whey & wash water excluded, rinses segregated, returns to feed use
8	Milk, Cottage Cheese	1,000,000	8.6	2.0	Poor	Whey excluded; many drips, leaks, returns included
10	Milk, Cottage Cheese	900,000	3.3	1.1	Fair	Whey excluded, good water volume control

Plant No.	Products Manufactured	Milk Processed Lb/Day	Lb BOD/1000 Lb Milk Processed	Lb Waste Water/ Lb Milk Processed	Level of Management Practices	Explanation of Practices
40	Milk, Cottage Cheese	1,000,000	4.12	1.2	Good	Whey included, rinses saved
52	Milk, Cottage Cheese	465,000	1.8	1.1	Good	Returns excluded, good water control
3	Milk Ice Cream Cottage Cheese	400,000	3.9	1.4	Fair	Whey & wash water excluded, rinses excluded
30	Milk Ice Cream Cottage Cheese	800,000	7.7	3.5	Poor to fair	Whey excluded, sloppy operations, spillage, leaks, hoses running
33	Milk Ice Cream Cottage Cheese	600,000	12.9	3.3	Poor	Whey included
34	Milk Ice Cream Cottage Cheese	900,000	9.1	2.8	Poor	Whey excluded, many leaks, drips, etc.
44	Milk, Butter	300,000	0.87	0.8	Good	Buttermilk excluded, few leaks, dry floor conditions
50	Whey powder	500,000	0.2	5.9	Good-fair	No entrainment losses, all powder handled as solid waste, no leaks or drips
56	Milk powder, Butter	200,000	3.0	2.5	Fair	Continuous churn, hoses running, numerous leaks and drips

From Harper et al, 1971

- Utilization of all returns for hog feed.

- Utilization of a water-tight container for all damaged packaged products.

The reductions achieved would appear to be as great as could be conceivably possible under any currently available engineering equipment process or systems.

The estimated reduction of waste water volume and BOD5 concentration for the various engineering aspects cited in this report are summarized in Table 17 along with the various suggested improvements in equipment processes and systems. In some cases it is not possible to estimate a potential waste reduction in value. In many instances the systems are being installed to eliminate dependence upon people and therefore savings relate to management aspects of the plant operation. As in the case of waste control through management improvement, the extent of decrease in overall waste loads would depend to a large extent upon the current utiliztion of recommended equipment processing systems. It must be emphasized that the incorporation of engineering improvements without concomitant management control can and has resulted in water and waste discharges that are in excess of those of the dairy plant with less modern equipment but planned management waste control.

The data in Table 17 must be considered as engineering judgement values subject to confirmation through additional analyses that are not available at the present time.

In a well-operated dairy plant one of the most visible sources of organic waste is the start-up and shut-down of the pasteurizing unit. In this respect, the utilization of a product recovery system merits particular mention in terms of potential waste savings. Figure 16 shows the fat losses and product loss as a function of time during the start-up and shut-down of a 27,300 kg/hour (60,000 lb/hour) high temperature short-time pasteurizer. To go from complete water to complete milk or from complete milk to complete water generally requires approximately two minutes with the discharge of approximately 910 kg (2,000 lb) of product and water every time the unit is started, stopped,or changed over in water between products. The utilization of the product recovery system for HTST units can result in a 75% reduction in product going to drain.

Table 17
Effect of Engineering Improvement of
Equipment, Processes and Systems on Waste Reduction

Engineering Improvement	Estimated Waste Reduction Potential Water	BOD
Equipment		
Cone-type silo Tank	760 1 (200 gal.)	73 kg (160 lb)
Water Shut Off Valves	Up to 50% of water used	
Drain Screens	None	Not estimable - waste represents spillage in most cases
Drip Saver	None Require water for operation	0.3 kg per 38 liter can (0.8 lb/ 10 gal. 1.5 kg per 38 liter can (3.2 lb/10 gal. can) for heavy cream
Filler Drip Shield	Variable; water saved equivalent to about 10 1/1 about 10 1 (10 gal/ gal) of product	Variable - can save up to 0.25 kg BOD5/ kkg (0.25 lb/1000 lb) of milk packaged; 1.0 kg BOD5/kkg (1.0 lb/1000 lb) of cream packaged. In cases of poor management and maintenance, reduction could be 2 to 3 times these values.
Interlock Control	Variable	Not calulable. Loss without control would be caused only by employee error. Such error could result in discharge of 1 kg BOD5 per kkg (1 lb/1000 lb) of milk processed, or 4 kg BOD5 per kkg (4 lb/1000 lb) of heavy cream processed.

Engineering Estimated Waste Reduction Potential

Improvement	Water	BOD
Equipment		
Ice Cream Filler Drip Shields	Variable - up to 20 l per liter (20 gal/gal) ice cream saved	Variable. At 6,800 l/hr, a one-minute spill is equivalent to 113 l (30 gal) of ice cream, 57 kg (125.4 lb) of ice cream, or 23 kg (50.6 lb) of BOD_5
Novelty Collection System	Variable - up to 1,900 liters 500 gallons) of water to wash frozen novelties down the drain	Variable - reduction in loss depends on efficiency of machine On an average machine savings should average 5-10 kg (11-22 lb) BOD/day.
Product Recovery Can System	Variable; should save 8.3 l (2.2 gal) of water per kkg (2200 lb) of milk processed	Variable: Depends on machine jams. On an average operation, should save 0.1 kg BOD_5 per kkg (0.1 lb/1000 lb) milk processed.
"Non-Leak" Portable Damaged Package Unit	Variable	Variable; Depends on machine jams. Should save 0.1 kg BOD_5 per kkg (0.1 lb/1000 lb) of milk processed
Curd Saving Unit		Not calculable at present time.
Filler-Product Recovery System	-	Variable: probably save 0.05 kg/kkg BOD_5 (0.05 lb/1000 lb) processed.

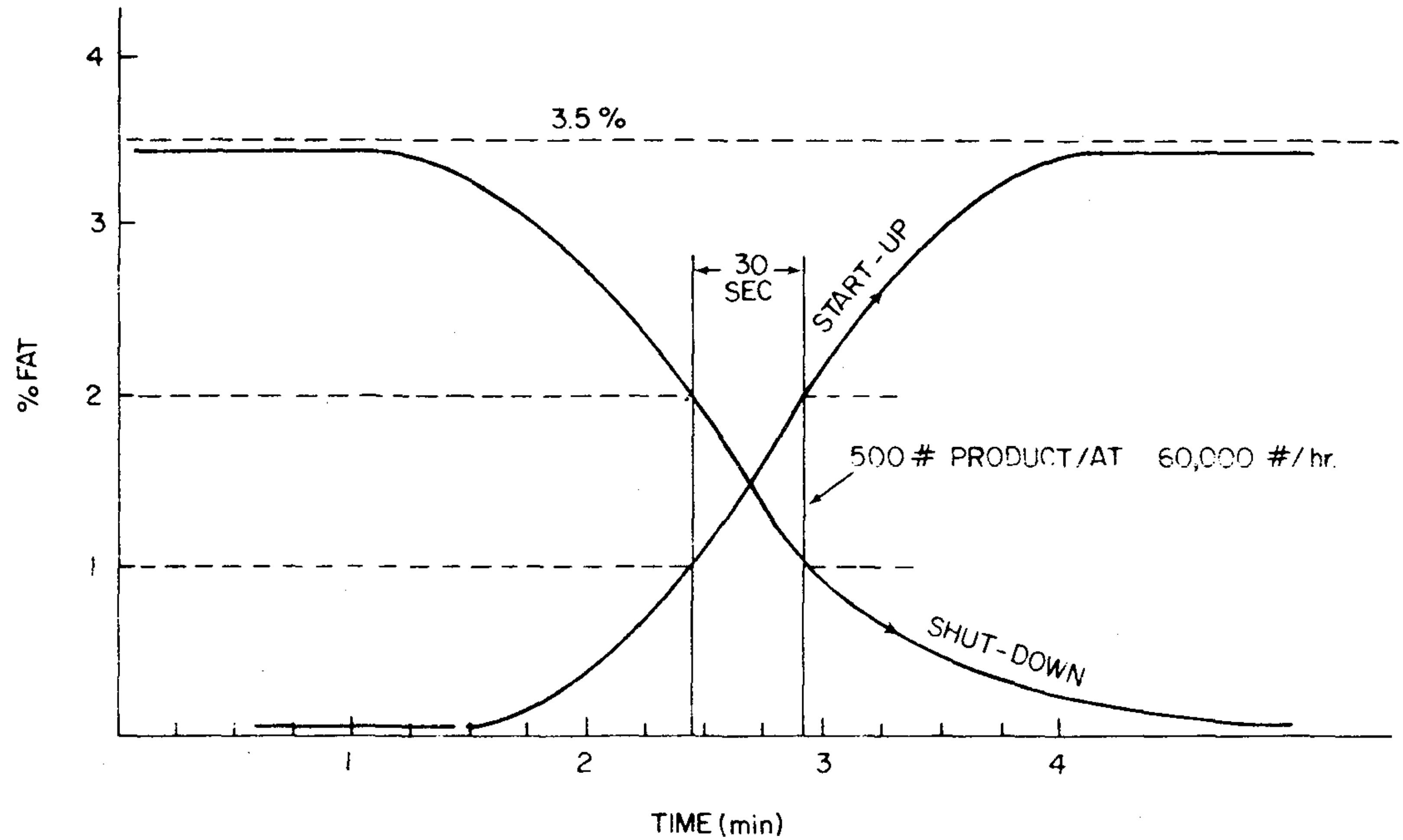
Engineering Improvement	Estimated Waste Reduction Potential Water	BOD

<u>Equipment</u>		
Case Washer Control	Should reduce water used about 170 l/kkg (20 gal/1000 lb) milk packaged	None
<u>Systems</u>		
CIP Systems - Re-use Type	10% over single use	20% over hand-cleaning
CIP Systems - Single Use	None (10% less cleaning compound under average use)	20% over hand-cleaning
Automated Continous Processing	Save 300 liters (80 gal) water on each product change over 6 change overs= (1800 l 480 gal)	Save 0.6 kg BOD5/kkg (0.6 lb/1000 lb) milk processed for each product change over. Change over = 910 kg/2 min x 6 = 5,460 kg (or 2002 lb/2 min x 6 = 12,011 lb) = 3.3 kg (7.26 lb) BOD5 saved per day
HTST Recovery System	600 l (160 gal) water/day	0.6 kg/kkg (0.6 lb/100 lb) milk processed
Product Rinse Recovery	About 2 liters of water/kg (1 qt/ lb) milk recovered	0.15 kg BOD/kkg (0.15 lb/1000 lb) milk processed
Post Rinse Utilization (5,000 gallon tanks, valves, pipes & controller)	Approximately 5% of water volume of plant	None
Air Blowdown	0.1 kg water/kkg (0.1 lb/1000 lb) of milk processed	0.2 kg BOD/kkg (0.2 lb/1000 lb) of milk processed

Engineering Improvement	Estimated Waste Reduction Potential Water	BOD
<u>Systems</u>		

Ice Cream Rerun System	2 1/1 (2gal/gal) ice cream saved (spilled ice cream is rinsed to drain)	Variable; in most operations, saving in BOD_5 should average 245 kg (540 lb) BOD_5/day.

FIGURE 16



Fat losses as a function of time during start-up and shut-down of a 60,000 pound/hour HTST pasteurizer.

End-of-Pipe Waste Treatment Technology

The discussion that follows covers the technologies that can be applied to raw waste from dairy manufacturing operations to further reduce waste loads prior to discharge to lakes or streams. The subjects covered include current treatment practices in the industry, the range of technologies available, problems associated with treatment of dairy wastes, and the waste reductions achievable with treatment.

Current Practices

Dairy wastes are generally amenable to biological breakdown. Consequently, the standard practice to reduce oxygen demanding materials in dairy waste water has been to use secondary or biological treatment. Tertiary treatment practices in the dairy industry - sand filtration, carbon adsorption, or other methods - are almost nil. Systems currently used to treat dairy waste water include:

Activated Sludge

In activated sludge systems the waste water is brought into contact with microorganisms in a aeration chamber where thorough mixing and provision of the oxygen required by the concentrated population of organisms are accomplished by use of aerators. Aerations chambers are designed with sufficient capacity to provide a theoretical retention time that may vary with the concentration of the waste but is generally on the order of 36 hours. The discharge from the aeration chamber passes to a clarifier where the microorganisms are allowed to settle as a sludge under quiescent conditions. Most of the sludge is returned to the aeration chamber to maintain the desired concentration of organisms and the remainder is wasted, generally as a solid waste following dewatering. The supernatant liquid may be discharged as a final effluent or subjected to additional treatment such as "polishing" (e.g., filtration) or chlorination.

Trickling Filters

In trickling filters the waste water is sprayed uniformly on the surface of a filter composed of rock, slag or plastic media, and as it trickles through the filter the organic matter is broken down by an encrusting biological slime. Conventional rock or slag beds are 1.8 to 2.4 meters (6 to 8 feet) deep. Plastic filters are built taller and occupy less area. As the waste passes through the filter some of the slime sloughs is carried away, thus allowing continued exposure of a surface of active young biota and preventing clogging of the filter by excessive slime growth. Sloughed slime generally is settled, dewatered and disposed of as a solid waste. In the operation of most trickling filters a major portion (up to 95 percent) of the filtrate is recycled to increase efficiency of organic waste removal and assure proper wetting of the filter.

Aerated Lagoons

Aerated lagoons are similar in principle to activated sludge systems except that there is generally no return of sludge. Hence, the microbial population in the aerated basin is less than in activated sludge tanks and retention of waste water must be longer to attain high BOD_5 reduction. A settling lagoon usually follows the aerated lagoon to allow settling of suspended solids. Mixing intensities are usually not as great as in activated sludge tanks. This results in a suspended solids blanket covering the aerated and settling lagoons which is further attacked by aerobic and anaerobic bacteria. Periodically the sludge blanket has to be dredged out. A clarifier may be used between the first and second stage lagoons with the settled sludge returned to the first stage. This both reduces the sludge to be dredged from the second stage and improves the effiency of the first stage by increasing the density of microorganisms.

Stabilization Ponds

Stabilization ponds are holding lagoons, 0.6 to 1.5m (2 to 5 ft.) deep, where organic matter is biodegraded by aerobic and anaerobic bacteria. Algae utilize sun rays and CO_2 released by bacteria to produce oxygen which in return allows aerobic bacteria to breakdown the organic matter. In lower layers, facultative or anaerobic bacteria further biodegrade the sludge blanket.

Disposal On Land

Disposal on land of waste waters is an alternative which deserves careful consideration by small operations with a rural location. Land requirements are relatively large, but capital costs and operational costs are low. Typical procedures are:

1. Spray Irrigation - This consists of pumping and discharging the wastes over a large land area through system of pipes and spray nozzles. The wastes should be sprayed over grasses or crops to avoid erosion of the soil by the impact of the water droplets. Successful application depends on the soil characteristic - coarse, open-type soils are preferred to clay-type soils - the hydraulic load, and BOD_5 concentration. A rate of application of 56 cu m/ha per day (6,000 gal/ac per day) is considered typical.

2. Ridge and Furrow Irrigation - The disposal of dairy wastes by ridge and furrow irrigation has been successfully used by small plants with limited volume of wastes. The furrows are 30 to 90 centimeters (1 to 3 ft) deep, and 30 to 90 centimeters (1 to 3 ft) wide, spaced 0.9 to 4.6 m (3 to 15 ft) apart. Distribution to the furrows is usually from a header ditch. Gates are used to control the liquid depth in the furrow. To

prevent soil erosion and failure of the banks, a good cover of grass must be maintained. Odors can be expected in warm weather, and in cold weather the ground will not accept the same volume of flow. The need to remove the sludge which accumulates in the ditches is an additional problem which does not exist in spray irrigation.

3. Irrigation by Truck - The use of tank trucks for hauling and disposing of wastes on land is a satisfactory method for many dairy food plants. However, the cost of hauling generally limits the use of this method to very small plants. Disposal on the land may be done by driving the tank truck across the field and spraying from the rear, or by discharging to shallow furrows spaced a reasonable distance apart.

Anaerobic Digestion

Anaerobic digestion has been practiced in small dairies through the use of septic tanks. In the absence of air, anaerobic bacteria breakdown organic matter into acids then into methane and CO_2. Usually a reduction period of about three days is employed, since little added reduction takes place with more extended retention times. Anaerobic digestion is effective in attaining up to 50-60% reduction when initial waste concentrations are high, but it has serious limitations for producing a final effluent of very high quality.

Combined Systems

Waste treatment plants combining the features of some of the biological systems described in the preceding paragraphs have been constructed in some dairy plants in an attempt to assure high BOD_5 reduction efficiencies at all times. Examples and possibilities of such systems include: An activitated sludge system followed by an aerated lagoon; trickling filter followed by activated sludge system; activated sludge system followed by sand filtration; and anaerobic digestion followed by one of the aerobic techniques.

Design Characteristics

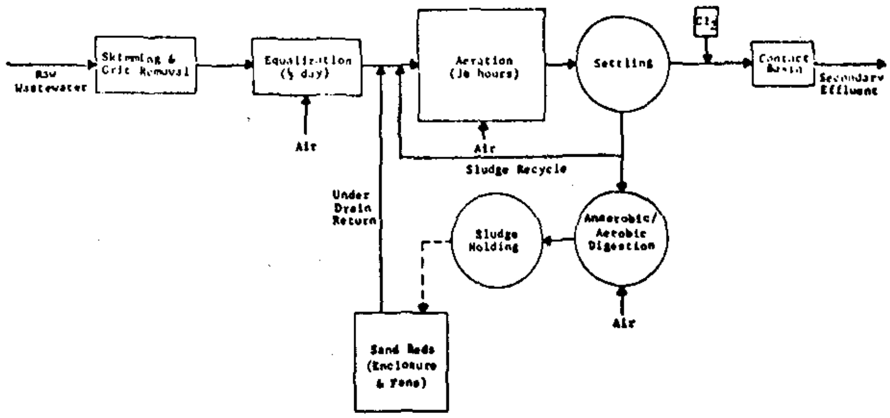
Figure 17 is a schematic flow diagram of activated sludge, trickling filter and aerated lagoons systems which should perform satisfactorily. Table 18 lists the recommended design parameters for the three types of biological treatment systems. Systems constructed in accordance with the suggested design characteristics should result in year-round BOD_5 reductions above 90 percent and are capable of producing an effluent containing 30 mg/l or less of BOD_5.

Problems, Limitations and Reliability

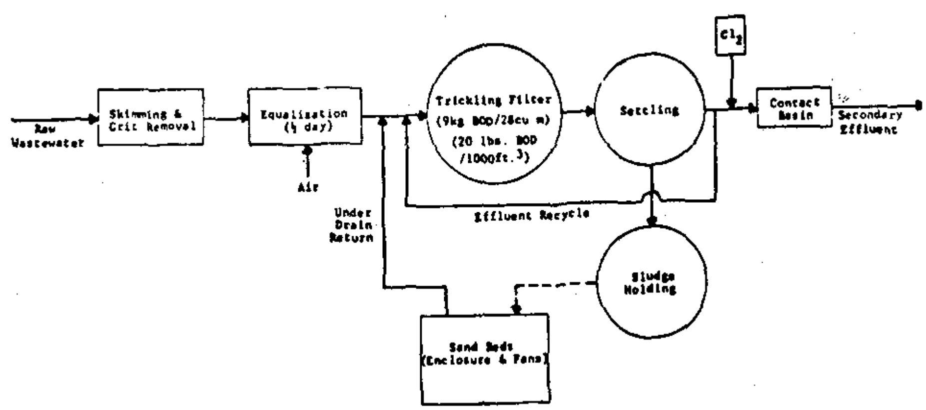
FIGURE 17

RECOMMENDED TREATMENT SYSTEMS FOR DAIRY WASTEWATER

ACTIVATED SLUDGE SYSTEM



TRICKLING FILTER SYSTEM



AERATED LAGOON SYSTEM

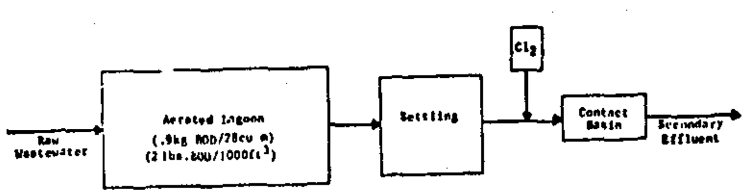


TABLE 18

RECOMMENDED DESIGN PARAMETERS
FOR BIOLOGICAL TREATMENT OF DAIRY WASTES

ACTIVATED SLUDGE	TRICKLING FILTER	AERATED LAGOON
1. Removal of floating substances.	1. Removal of floating substances.	1. Applied BOD_5 loading of 3.2 Kg per 100 m^3 (2 lbs./1,000 $ft.^3$.)
2. Twelve-hour equalization to buffer fluctuating BOD_5 and detergent loads. Diffused air supply to prevent acid fermentation.	2. Twelve-hour equalization to buffer fluctuating BOD_5 and detergent loads. Diffused air supply to prevent acid fermentation.	2. Air supply for sufficient oxygen dispersion.
3. Activated sludge tank to provide 36 hours retention.	3. Applied BOD_5 load of 32 Kg/100 m^3 (20 lb./1,000 $ft.^3$).	3. Nutrient nitrogen and phosphorus addition if below BOD:N:P ratio of 100:5:1.
4. Micro-organisms population in the aerated tank to maintain a maximum loading of 0.5 Kg BOD/Kg volatile mixed liquor suspended solids.	4. Rock size of 6 to 9 centimeters (2.5 to 3.5 inches) or equivalent plastic media to allow proper ventilation and prevent clogging. Diffused air supply is helpful. (3)	4. Settling basin to sediment suspended solids.
5. Air supply of 60 cubic meters per Kg (1,000 $ft.^3$ per pound) BOD_5 applied.	5. 100% recycle of treated effluent.	5. Segregation of whey and cheese wash water from wastewater.
6. Nutrient nitrogen and phosphorus addition if below BOD:N:P ratio of 100:5:1.	6. Nutrient nitrogen and phosphorus addition if below BOD:N:P ratio of 100:5:1.	6. Reduction of milk waste concentration to a minimum through in-plant control.
7. Use of defoamers to prevent foam.	7. Steam injection of equalization tank if temperature drop impairs BOD removal.	7. Chlorination of final effluent.
8. Steam injection of equalization and aerated tanks if temperature drop impairs BOD removal efficiency.	8. Winter enclosure of filter in cold regions.	
9. Segregation of whey and cheese wash water from wastewater.	9. Segregation of whey and cheese wash water from wastewater.	
10. Reduction of milk waste concentration to a minimum through in-plant control.	10. Reduction of milk waste concentration to a minimum through in-plant control.	
11. Chlorination of final effluent.	11. Continuous dosing of filter to prevent drying up of slime.	
	12. Chlorination of final effluent.	

It is recognized that biological waste treatment facilities do not operate at constant efficiencies. Variations of the BOD5 reduction efficiencies from day to day and throughout the year can be expected from any individual system. Factors such as BOD5 concentration, type of waste, flow, temperature, and inorganic constituents of the effluent may affect the rate of treatment of dairy wastes by living organisms, but the interaction of and correlation between such factors is not fully understood. Available data show that it is possible to achieve BOD5 reduction efficiencies greater than 99% part of the time with almost any of the types of biological waste treatment that are available. However, due to high variability of the composition of dairy effluents these same treatment systems can have BOD5 reduction efficiencies as low as 30% during other times, such as after sudden, highly concentrated loads are discharged or other causes of severe upset occur.

To obtain consistent high BOD5 removal, it is essential to allow microorganisms to biodegrade organic matter under favorable operating conditions. These include properly designed and operated treatment systems to prevent shock loads and to allow microorganisms to function under well balanced conditions; addition of nutrients if absent; exclusion of whey and cheese washes; in-plant reduction of waste water BOD5 to a minimum; and maintaining favorable temperature levels and pH whenever possible. With such practices, consistently high reductions should be attained and peak discharge loads should not be more than 2 to 2-1/2 times the long-term average.

Research indicates that percent BOD5 removal may decrease with increasing BOD5 influent concentration. In one experiment, the BOD5 reduction efficiency of an activated sludge system decreased significantly when influent BOD5 concentration increased beyond 2,000 mg/l. High BOD5 loading (in excess of 2000 mg/l) decreased the concentraticn of gram negative organisms and encouraged the development of a microflora that apparently could not utilize animo acids as a nitrogen source, but only inorganic nitrogen, such as ammonia nitrogen. Under these conditions the efficiency of the system decreased.

Detergents at concentrations above 15 mg/l begin to inhibit microbial respiration, with anionic detergents showing relatively less inhibitory effects than non-ionic and cationic surfactants. Quite understandably, high concentrations of sanitizer are inimical to efficient biological treatment.

Treatment of Whey

Whey constitutes the most difficult problem facing the dairy industry in respect to meeting effluent guidelines in two respects: (a) the supply of whey generally exceeds its market potential at the present time and (b) whey is difficult to threat by any of the common biological treatment methods. Generalization about whey handling and treatment can easily be misinterpreted. In no other instances is the fact more clear than with whey that each individual circumstance must be evaluated in light of the particular situation existing at the particular plant. The type of whey, accessibility to an existing whey processing facility, volume of whey produced, location of the plant, and the type of farm operations contingent to the processing facility are among the factors which must be taken into consideration in determining disposition of whey for a particular plant situation.

If whey is to be processed further for feed or food, a major factor in the handling of such whey is to prevent the development of further acidity in the product after manufacture. This is true of cottage cheese whey was well as sweet whey. It is a well recognized fact that the development of acidity in the product increases the diffiucly of drying the product. This effects is particularly well illustrated by the recent article by Pallansch (Proceedings Whey Products Conference, 1972) showing the temperature at which sticking occurred as a function of lactic acid content. Cottage cheese whey, which has long been recognized to be more difficult to dry than rennet whey, becomes impossible to dry at pH below 4.2 in most equipment.

Prevention of development of acidity and outgrowth of undersirable spoilage or potential pathogens requires that whey be cooled to about 40°F and maintained at this temperature until processed. Whereas this can generally be achieved in most plants where processing is conducted in the same plant as the whey is produced, lack of adequate cooling equipment in many small plants will require a considerable expenditure on the part of these plants to cool the whey. This becomes particularly a problem in respect to the shipment of whey over long distances both in respect to precooling and in recooling at the point of receipt. Another problem related to this general area is a lack of a really adequate procedure for concentrating the product at the point of manufacture in an economical manner. Membrane processing procedures are fine in principle and are approaching possible application. There remains the problem of sanitation that still is a limiting factor for almost all current membrane processing systems now on the market. In almost all cases further improvement in sanitation design is going to be required to make these pieces of equipment fully adequate for concentration of whey that is going to be subsequently used for food or feed. This is especially true in respect to possible fluid uses.

Whey for food use must be considered in an identical manner as Grade A milk from a microbiological viewpoint, and cannot be handled as a by-product. It is particularly a point for food use that whey be cooled and maintained at 40° from the time of manufacture until final processing to avoid the outgrowth of undesirable organisms. Alterations in the product due to residual proteases from the coagulant might develop into further acidity, and potential development of food poisoning organisms.

From a processing point of view there are a number of procedures that are potentially available to the whey manfacturers. However, at this point in time the only really proven method of processing whey is its concentration and drying for food or feed use. The market potential for whey is tied very closely to the availability and price of skim milk powder on the commercial market. Several large scale whey drying plants have had to either shut down or to convert from food grade to feed grade powder as a result of increased importation of milk powder.

Alternatives in the Dispostion of Whey

The following are some of the more common methods of disposing of whey at the present time:

1. <u>Direct return to farmers supplying the milk as feed:</u> This approach is limited to very small plants whose suppliers are in the immediate locality of the plant and are engaged in livestock feeding. Whey generally can be fed at levels of up to 50% substitution without creating scours or other problems even in ruminant animals. Frequently lack of acceptability of whey as a feed to ruminants creates problems.

2. <u>Spray irrigation:</u> Where feasible, the best method of treatment of whey is through spray irrigation. Because of the low loading required for adequate spray irrigation, the approach is limited to plants that are located in rural areas with adequate land and generally limited to relatively small plants. Plants producing cottage cheese whey in excess of 100,000 lb who previously had utilized this method of disposal have been forced to desist from the use of spray irrigation in such states as Vermon, New York, and Ohio. The freezing of the ground surface in northern climates and the run-off in thawing has been a major reason for closing down large scale spray irrigation systems in the northern states.

3. <u>Transfer to municipal treatment systems:</u> For plants located in large municipalities, where the contribution of BOD_5 to the total plant load is low (less than 10%) joint treatment is a feasible method of treatment without interference with the efficiency of the municipal system, provided that shock loading is avoided. The installation of equalization tanks is generally required by the municipality. In a few instances it has been found desirable to cool the whey to prevent further acid production to facilitate its biological oxidation.

5. <u>Concentrating and drying:</u> At the present time this appears to be the most feasible procedure for the utilization of whey as a food or feed. In 1971 in the State of Wisconsin about 90% of all sweet whey was handled in this manner. Problems associated are the frequent necessity to haul non-concentrated whey long distances, lack of an adequate market

for the finished product, and large capital expenditure for the concentrating and drying equipment.

6. Electrodialysis: The electrodialysis process provides a product of high quality for special pharmaceutical applications, but the process is well covered by proprietory patent and the direct market is limited.

7. Ultrafiltration and reverse osmosis: While potentially a very promising development, especially for the recovery of a potentially marketable protein product, current commercialization of this process to its full potential is dependent upon more complete development of sanitary membrane processing equipment as cited earlier. New developments in sanitation and cleaning procedures plus development of operations that operate under lower fouling conditions lends possible promise for commercialization in the immediate future. At the present time it is much easier to sanitize ultrafiltration than reverse osmosis equipment.

8. Concentration and Plating for feed application: The utilization of film evaporators originally developed by the cirtus industry followed by plating of the concentrate on bran or citrus pulp may be a relatively low cost potential in development of an improved quality feed stuff. The competitive position of such a product depends upon the future economic situation in the feed grains, especially corn and soybeans.

9. Protein concentrates: In addition to ultrafiltration, various procedures for the preparation of protein concentrate including polyphosphate percipitation, iron product precipitation, CMC co-precipitation and gel filtration are all potential methods which remain unproven as viable commercial entities at the present time. The full commercialization of these procedures awaits the development of a better market for the protein product. The market for protein product is ironically limited at the present time because of inadequacies in economics of procedures for providing high quality protein. The greatest potential application, fortification of soft drinks, requires large quantities of whey protein that cannot be supplied at present. Therefore, soft drink manufacturers hesitate to enter the field, whey manfacturers hesitate to develop the processes, so that at the present time we have somewhat of a standoff in this area.

10. Fermentation products: The utilization of whey as a media for the production of yeast cells as a feed and potential food product is under commercialization at the present time. At this point there are no data indicating the relative economics of this process in respect to drying. The major use for the end product at the current time is feed, and again the market potential depends upon the comparative

costs of other feed supplements and feed products including corn and soybeans. The spent liquor from the fermentation does constitute a potentially difficult disposal problem at the present time. We have inadequate information in this area.

11. Lactose modification: Numerous investigators are currently studying the possibility of hydrolyzing lactose in whey by soluble and by immobilized enzymes. The overall development of this field is at least several years behind that of membrane processing and its success also will depend upon the solving of microbiological and sanitation aspects of the process. In addition, drying of lactose modified whey becomes more difficult because of the increased colligative property of the product and increased stickiness at the same acidity.

12. Lactose: A limited market for lactose is the major factor in the full utilization of this material at the present time. Much research is being done but a clear solution to the problem is not yet in sight. A solution to the the lactose utilization problem is of major concern. Even processes that recover valuable products in the form of whey protein result in residuals containing 80% as much BOD_5 as the original whey because of the lactose. Methylation, phosphorylation, polymerization are laboratory possibilities at the present time. However, until the market is developed for the finished product, commercialization of such technologies appears to be improbable and at the best uncertain.

Problems Associated With the Biological Oxidation of Whey:

Lagoons, trickling filters, and activated sludge systems are all upset by the incorporation of whey into the waste water.

Dairy plants manufacturing whey that operate their own treatment facilities have recognized for a long time the desirability of keeping whey out of the treatment system. The reason for problems with the biological oxidation of whey has been given as a BOD:N ratio that is undersirable and that whey is deficient in nitrogen. The BOD:N ratio, however, is near to 20:1, a value considered to be satisfactory. Two recent studies in the Ohio State University laboratories have some possible bearing on the problem of whey treatment.

1. High BOD_5 loading (in excess of 2000 mg/l BOD) decreases the concentration of gram negative organisms and encourages the development of a microflora that cannot utilize amino acides as a nitrogen source. The microflora that exist under high BOD_5 loading can use only inorganic nitrogen, such as ammonia nitrogen. Under these conditions the efficiency of the system decreases.

2. The constituents present in the highest concentration in milk wastes is lactose, and nearly all of the lactose (80%) in milk is present in whey. The first step in the degradation of lactose is:

$$\text{lactose} \xrightarrow{\text{lactase}} \text{glucose} + \text{galactose}$$

During the manufacture of cheese, a small amount of the lactose is degraded to glucose and galactose. Glucose is readily utilized by the bacteria to product lactic acid, but galactose is not as readily degraded. Studies in the Ohio State University laboratory have shown that whey contains about 0.05% glucose and 0.3-0.45% galactose. Galactose is about 20 times more effective as an inhibitor of lactase than lactose is as a substrate. Galactose at a concentration of 0.4% will inhibit lactase by more than 50%. At the same time there is some evidence, which needs further confirmation, that galactose also stops the organisms in the biomass from producing any more lactase enzyme.

Studies are needed under commercial conditions to confirm these findings.

If substantiated, methods could be developed to materially increase the efficiency of biological treatment of dairy wastes and permit the development of procedures to treat whey.

Studies are in progress under the auspices of the National Science Foundation to determine if lactase treatment of milk wastes will improve their treatability. Laboratory studies have been completed under this grant to prove that the addition of gram negative organisms to an activated sludge treatment system permits removal of up to 98% BOD_5 at a BOD_5 loading of 3000 mg/l. (Only about 80% reduction was possible in the absence of the organisms.) The organisms must be added on a regular basis, since they cannot compete with the gram positive organisms in the system. (A field study has shown that a treatment system for a one million pound milk-cottage cheese plant was materially improved by the bi-weekly addition of gram negative organisms. The BOD_5 reduction was increased from 85 to 96%; sludge age was decreased; sludge volume decreased by 40%; and the mixed liquor VSS were increased from 1500 to 5000 mg/l.

Advantages And Disadvantages Of Various Systems

The relative advantages, disadvantages and problems of the waste water treatment methods utilized in the dairy industry are summarized in Table 19.

Management Of Dairy Waste Treatment Systems

If biological treatment systems are to operate satifactorily, they must not only be adequately designed, but must also be

TABLE 19

Advantages and Disadvantages of Treatment Systems Utilized in The Dairy Industry

ACTIVATED SLUDGE (A.S.)	TRICKLING FILTERS (T.F.)	AERATED LAGOON (A.L.)	STABLIZATION PONDS (S.P.)	IRRIGATION	ANAEROBIC DIGESTION	COMBINED SYSTEMS
Advantages Good BOD reduction. Good operating flexibility. Good resistance to shock loads when properly designed. Minimum load requirements.	Advantages Good BOD reduction. Good resistance to shock loads when properly designed. Less operating cost than A.S.	Advantages Good BOD reduction. Good resistance to shock loads. Low capital cost. Less supervision than A.S. and T.F. Less sludge problems than A.S. and T.F.	Advantages Suitable as a pretreatment system. Prevents shock loads to proceeding treatment systems. Good resistance to shock loads. Low capital cost. Low operating cost. Less sludge problems than A.S. and T.F.	Advantages 100% treatment efficiency. Low capital cost. Low operating cost. No sludge problems (except for ridge and furrow). Suitable for disposal of whey.	Advantages Suitable as a pretreatment system. Prevents shock loads to proceeding treatment systems. Minimum capital cost. Minimum operating cost. Minimum sludge disposal problems. Minimum supervision	Advantages Good BOD reduction. Good resistance to shock loads. Good operating flexibility.
Disadvantages Substantial capital investment. High operating cost. Continous supervision. Upsets to shock loads. Sludge disposal problems. Performance drops with temp. drop.	Disadvantages Substantial capital investment. High operating cost. Continuous supervision. Long acclimation period after shock loads. Ponding of trickling filters when poorly designed and operated. Significant land requirements. Fly and odor problems when poorly designed and operated. Sludge disposal problems. Performance drop with temp. drop.	Disadvantages Large land requirements. High power cost. Performance drop with temp. drop.	Disadvantages BOD reduction below A.S., T.F., and A.L. Algae growth. Large land requirements. Insect problems. Odors. Ordinances restricting its location.	Disadvantages Amount of land required and in some cases, distance from the dairies. Surface run-off. Ponding. Seepage to ground water supplies. Health hazards to animals. Soil-clogging and compaction. Vegetation damage. Insect propagation. Odors. Spray carry-over. Maintenance problems-clogged nozzles, freeze-up, and the requirement that lines be relocated to allow "rest periods". Cold water surface icing. Sludge build-up (ridge and furrow only). State ordinances limiting its location.	Disadvantages Suitable only for low volume wastewaters BOD reduction below A.S., T.F., and A.L. Susceptible to shock loads. Methane odor and safety problems.	Disadvantages High capital cost. High operating cost. Significant land requirements. Constant supervision. Sludge disposal problems.

operated under qualified supervision and maintenance. Following are some key points that should be observed to help maintain a high level of performance.

(a) Suggestions Applicable To All Biological Systems

1. Exclude all whey from the treatment system and the first wash water from cottage cheese.

2. If it is impossible to exclude whey from the treatment system, a retention tank should be provided so that the whey can be metered into the treatment system over a 24-hour period. In this case it would be necessary to make sure that the pH of the whey does not fall below 6.0. Normally, this would require a neutralization process.

3. It would be beneficial to provide pre-aeration for all dairy food plant wastes.

4. A retention tank of sufficient size should be provided to hold the waste water from one processing day to equalize hydraulic and BOD5 loading. Such an equalizing tank might well be pre-aerated.

5. The treatment facility should be under the direct supervision of a properly trained employee. He should have sufficient time and sufficient training to keep the system in a total operating condition. It should be recognized that in the operation of a dairy food treatment plant there are two types of variations that cause operating problems. The first of these are the short term surges from accidental spillages that can be disastrous to a treatment facility if not checked immediately. In the hands of a skilled operator, immediate corrective measures can be taken. The second type is much more difficult to control and relates to the very slow acclimatization of the biological microflora to dairy food plant wastes. This appears to take a minimum of about 30 days so that changes in the composition of the waste may not show up in changes in operating characteristics of the treatment system for 30 to 60 days.

6. The operating personnel should keep daily records and operate a routine daily testing procedure which should include as a minimum; influent and effluent pH, influent and effluent BOD, influent and effluent suspended solids, calculaticn of BOD5 and hydraulic loading, and a log of observations on the operation of the treatment facility.

7. The dairy food plant should be operated in such a manner as to minimuze hydraulic and BOD5 shock loading.

8. Any accidental spillage in the dairy food plant should be immediately indicated to the engineer in charge of the treatment facility. This is particularly critical if there is inadequate equalization capacity ahead of the treatment facility.

9. All equipment should be kept in good operating condition.

10. Final treatment effluent may need to be chlorinated and checked for coliform organisms.

11. In the development stages of planning a new treatment facility or an expanded treatment facility, lab or pilot scale operation of the design type should be made for at least 60 days in the intended loading and process region.

(b) Recommendations in Respect to Spray Irrigation

1. Spray irrigation is generally not practical in dairy plants processing over 100,000 pounds of milk per day or discharging over 0.5 pounds of BOD_5 per thousand pounds of milk processed.

2. Regular inspection of the soil should be made to evaluate organic matter and microbial cell build-up in the soil that could lead to "clogging".

3. The land used for spraying should be rotated to minimize over-loading of the soil.

4. Regular inspection of the spray devices should be made to eliminate clogging and uneven soil distribution over the land surface.

5. A drain area should be located on the low side of the irrigation field and the run-off checked on a regular basis to determine the efficiency of the operation. If the irrigation field is adjacent to a stream, then regular monitoring of the stream should be made to insure adequate operation, since it is insufficient to assume that spray irrigation is 100% effective.

(c) Suggestions Concerning Oxidation Ponds

1. Aerated lagoons have limited application in areas where they are frozen for a period of time during the winter.

2. Normal loading of aerated lagoons is 2 pounds of BOD_5 per day per 1000 ft^3 for ponds with a 30-day retention time. This level of loading appears to provide an optimum ratio of microbial and algal balance in the ponds.

3. Diffusers should be regularly inspected to insure that inlets are not clogged.

4. Dissolved oxygen should be measured regularly in the first and second aeration ponds and correlated to the loading and to the air input to the lagoon.

(d) Suggestions in Respect to Trickling Filter Systems

1. The system should be loaded between 17 and 20 lb BOD_5 per thousand cu ft with a recirculation ratio of from 8 to 10.

2. In northern climates, the filter should be enclosed or otherwise protected for year-rcund operation.

3. The flow to the filter should run for 24 hours out of every 24-hour day.

4. All debris and solids should be prefiltered.

5. Inspection of the distribution system of the filter should be made regularly to insure a uniform distribution of the influent.

6. Pre-aeration is useful in the treatment of wastes by trickling filter procedures. Where blowers are used, they should have a capacity of 0.5 cu ft/gal of raw waste treated.

7. Filters should be inspected regularly for ponding. If ponding occurs, it may be desirable to decrease hydraulic flow and flush the filter with high pressure hoses.

(e) Suggestions with Relationship to the Operation of an Activated Sludge Treatment System

1. The operator should have dissolved oxygen data available in the pre-aeration and assimilation tanks. It would be desirable to have the measuring equipment integrated into the oxygenating equipment to serve as a controlling device. Frequently, problems in respect to dairy food plant activiated sludge treatment systems result from lack of close attention to trends in the system, and operation is always in reaction to changes that have already taken place. In the case of Type-2 (stable) foam, the operator frequently will cut the air level back to decrease the foam only to have the treatment system go anaerobic. Abrupt changes in aeration are to be avoided to prevent sharp changes in operating characteristics. One of the most difficult factors to control in dairy food plant waste activated sludge systems is proper aeration.

2. The operator should make regular inspection of the aerating devices to make sure that there is no clogging of the inlets.

3. There should be intentional sludge wastage, especially in the case of extended aeration type activated sludge treatment. The amount of wastage may be varied depending upon the characteristics of the sludge. One of the most serious problems in dairy food plant activated sludge treatment is the poor characteristics of the sludge formed. The reasons for poor sludge characteristics relate in part to the chemical nature of the waste, the microbial flora and the operating characteristics. The problem is highly complex and step-wise procedures for control or correction of the problem have not yet been developed.

4. The loading of the treatment plant should be in the range of 0.2 to 0.5 lb BOD/lb mixed liquor volatile suspended solids (MLVSS), and in the range of 35 to 50 lb BOD_5 per thousand cu ft.

(f) Suggestions for stabilization lagoons:

1. The depth of stabilization lagoons should not be more than three to five feet.

2. Organic loadings for northern areas should not exceed 20 lb/acre/day. For southern areas higher loadings may be applied, up to 40-50 lb/acre/day.

3. Theoretical retention times should be 90 to 120 days, depending on the climate.

4. In northern climates where ice coverage is encountered for extensive periods, supplementary aeration (possibly as simple as agitation with an outboard motor) should be available, to assist in odor control during the period of ice breakup.

(g) Recommendations for anaerobic digestion:

1. Retention time should approximate three days. Added retention times are not justified by the increase in organic reduction attained. Shorter retention times may not furnish sufficient equalization and may result in reduced efficiency of the methane- CO_2 stage.

2. Odor control must be practiced by using covers, and venting if impervious covers are employed. Venting may employ flaring or be as simple as passing the vented gases through a gravel-sand-loose earth filter. If pervious covers are employed (e.g., straw and grease

cover or natural biological scum), venting is not usually necessary.

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 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 waste water.

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 waste water 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 insoluable 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 collodial 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 waste water 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 waste water. Ion-exchange is used primarily for recovery of valuable constituents and to reduce specific inorganic salt concentration.

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 waste water 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.

Recycling System

Figure 18 gives a schematic diagram of a tertiary treatment system that could be used for treatment of secondary waste water for complete recycle.

For recycling of treated waste water, ammonia has no effect on steel but is extremely corrosive to copper in the presence of a few parts per billion of 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.

Pretreatment of Dairy Waste Discharged To Municipal Sanitary Sewers

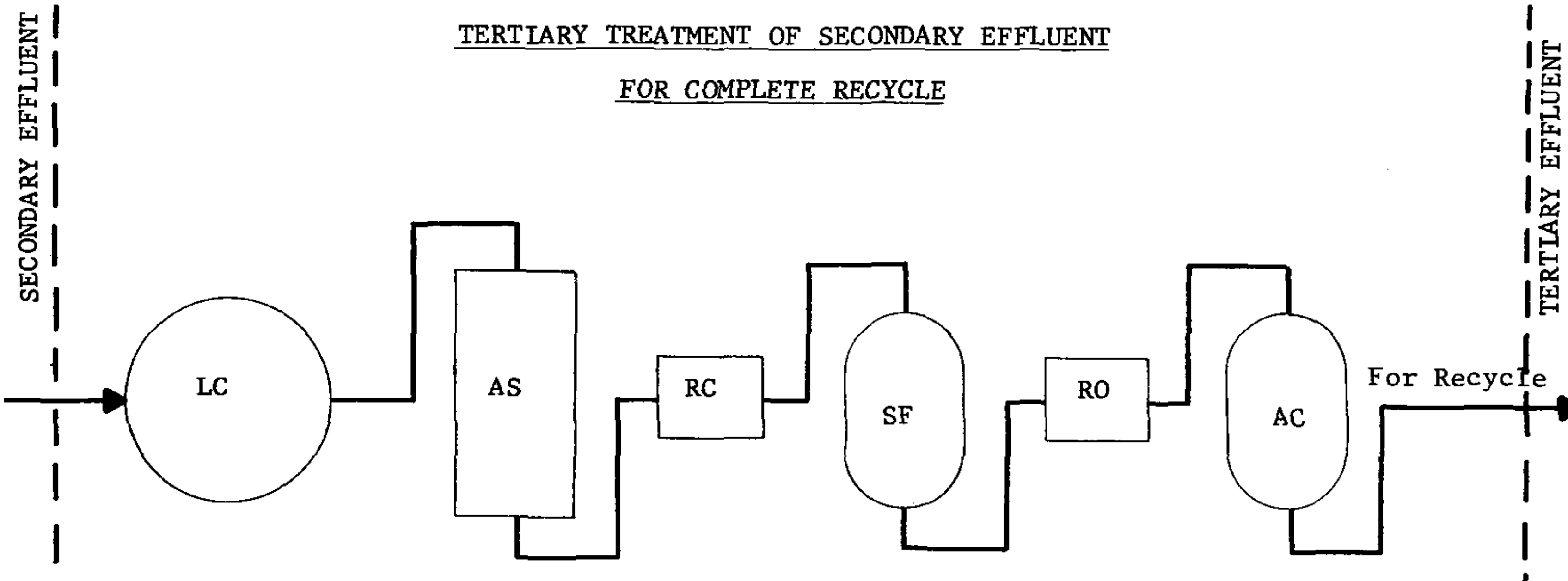
General

Dairy waste water, in contrast to many other industrial waste waters, does not contain quantities of readily settleable suspended solids and is generally near neutral. Hence, primary treatment practices such as sedimentation and neutralization have no necessary application in the case of dairy waste water. Equalization is recommended for activated sludge and trickling

FIGURE 18

TERTIARY TREATMENT OF SECONDARY EFFLUENT

FOR COMPLETE RECYCLE



LC= Lime Precipitation Clarification
AS= Ammonia Stripping
RC= Recarbonation
SF= Sand Filtration
RO= Reverse Osmosis
AC= Activated Carbon

filter systems; however, dairy waste loads discharged to municpal treatment plants will be equalized in the sewer lines if the dairy waste water does not constitute a very large proportion of the load on the municipal plant.

The best approach to reduce the load on municipal plants and excessive surcharges is good in-plant control to reduce BOD5 and recycling of cooling water.

However, if sanitary districts impose ordinances which can be met only through some degree of pretreatment, the following treatment methods are suggested:

1. Anaerobic digestion.

2. High-rate trickling filters and activated sludge systems.

3. Stabilization ponds.

4. Aerated ponds

5. Chemical treatment

Anaerobic digestion could be applicable to small plants discharging low volume waste. High-rate trickling filters and activated sludge systems require high capital outlay and have appreciable operating costs. Stabilization ponds and aerated ponds require considerable land and will usually be impractical for dairy plants located in cites. Chemical treatment will require a high capital outlay and extremely high operating cost, especially with sludge disposal. In regard to efficiency, anaeorbic digestion and stabilization ponds will attain less BOD5 reduction. However they could eliminate appreciable BOD5 at very long retention periods.

If the dairy waste is a significant part of the total load being treated by a municipal plant, it is necessary that whey be segregated to avoid the risk of upsetting the system.

Hexane Solubles

Some municipalities across the country are imposing tight restrictions on hexane soluble fats, oils and grease. Waste containing mineral oils discharged by the chemical and petrochemical industries and other sources inhibit the respiration of microorganisms. However, fat in dairy waste water does not exhibit such an inhibitory effect. Appreciable quantities of dairy fat are being treated successfully biologically with no noticeable effects on microorganisms (see Table 20).

Although large quantities of floating fats and grease could potentially clog or stick to the walls of sewer lines, dairy fat

TABLE 20

EFFECT OF MILK LIPIDS ON THE EFFICIENCY OF BIOLOGICAL OXIDATION OF MILK WASTES

Products Mfg.	Type of Waste Treatment	BOD Influent mg/1	Fat Influent mg/1	Percent Reduction of BOD	BOD Effluent mg/1	Fat Effluent mg/1
Milk, c.c., cond., milk p.	Activated sludge	1,750	496	98.0	35	1
Cheese	Aerated lagoon	1,200	350*	97.5	30	1
Milk	Activated sludge + lagoon	1,500	308*	99.9	20	1
Milk + c.c.	Activated sludge + lagoon	2,000	560*	99.0	20	1
Milk + c.c.	Activated sludge	2,250	787	96.0	90	1
Milk + ice c.	Activated sludge	3,000	1,250	98.0	60	1
Ice cream	Trickling filter	1,100	540	98.0	22	1
Italian Cheese	Septic tank and activated sludge	827	415	98.0	14	1

Note: * Fat values calculated as minimum levels based on type of operation and BOD loading. Values may vary ±10%.

No data.

<u>Nomenclautre</u>

c.c.: cottage cheese
cond.: condensed milk
milk p.: milk powder
ice c.: ice cream

does not contain inhibitory substances or toxic heavy metals that could upset a municipal treatment system. Sanitary districts should recognize the difference between the potential detrimental effects of mineral-based versus milk-based fats, oils and grease in applying their ordinances. A test that distinguishes between those sources of fatty matter should be developed, since mineral oil and dairy fat are both solubilized in the hexane test currently used for control purposes.

Performance Of Dairy Waste Treatment Systems

Biological Treatment

Performance data for some dairy treatment systems currently meeting recommended guideline limitations. It will be noted that a variety of systems is represented in Table 21.

One data source for sand filtration showed average reductions of 81.0% for BOD and 95.5% for suspended solids. Sand filtration removes not only suspended solids but also associated BOD, COD, turbidity, color, bacteria and other matter.

Tertiary Treatment

Table 22 gives a general comparison of tertiary treatment systems efficiency to remove specific pollution parameters.

Table 23 gives some further insight of the efficiencies of tertiary treatment systems. It shows reductions produced after passage of biological effluent through sand filtration and activated carbon at the South Tahoe, California, treatment plant. The effluent from the conventional activated sludge process is treated with alum and polyelectrolyte prior to its passage through a multi-media sand filter.

Table 21

Effluent Reductions Attained by Exemplary Operations and Corresponding Guidelines Limitations

Subcategories Present	Treatment	Plant Discharge lb/day		1977 Limitations lb/day		1983 Limitations lb/day	
		BOD5	TSS	BOD5	TSS	BOD5	TSS
Cottage Cheese, Cultured Products, Fluid Products	Equalization, Activated Sludge, Clarification	8.71	N/A	17.05	25.58	5.68	7.10
Fluid Products, Cultured Products, Cottage Cheese, Condensed & Dry Milk	Activated Sludge	19.99	N/A	59.76	89.64	19.92	24.90
Natural Cheese	Anaerobic Digestion, Activated Sludge, Sand Filtration	0.12	0.16	1.51	2.26	0.42	0.52
Natural Cheese, Condensed Whey, Dry Whey	Activated Sludge	11.97	N/A	12.85	19.06	4.28	5.35
Condensed Whey, Dry Whey (plus lactose processing)	Two Stage Trickling Filter	2.60	N/A	8.00*	12.00*	2.70*	3.40*
Condensed Whey, Dry Whey (plus lactose processing)	Two Stage Aerated Lagoon	11.55	109.50	12.00*	18.00*	4.00*	5.00*
Condensed Whey, Dry Whey	Two Stage Aerated Lagoon	10.98	N/A	14.40	21.60	4.80	5.00
Condensed Whey	Two Stage Aerated Lagoon	3.10	7.00	4.00	6.00	1.33	1.66
Butter, Condensed Milk, Dry Milk	Trickling Filter, Polishing Pond	4.45	4.45	45.30	67.95	10.41	13.01
Natural Cheese, Butter Condensed Whey, Dry Whey	Anaerobic Digestion, Stabilization Lagoon, Spray Irrigation	No Discharge		19.86	29.79	4.97	6.21

*Does not include any allowance for lactose processing.

TABLE 22

GENERAL COMPARISON OF TERTIARY TREATMENT SYSTEMS EFFICIENCY

Parameter	Lime Precipitation	Sand Filtration	Carbon Absorption	Ion Exchange	(140) Reverse Osmosis	Ammonia Air Stripping
BOD	**	**	***	*	***	*
COD	*	*	***	*	***	*
S.S.	**	***	**	**	***	*
T.D.S.	**	*	*	***	***	*
Nitrogen	*	*	*	*	**	*
Phosporus	***	***+	*	*	**	*
NH_3	*	*	*	***	**	***
Color	**	**+	***	*	**	*

Notes: *** Excellent

** Good

* Fair to Poor

+ Based on addition of chemicals (e.g. alum and polyelectrolyte).

(1) Total Dissolved Solids of Secondary Effluent.

TABLE 23

PLANT PERFORMANCE DATA FOR THE TERTIARY TREATMENT PLANT AT SOUTH TAHOE, CALIFORNIA (141)

Quality Parameter	Raw Waste-Water Effluent	Activated Sludge Plant Effluent	Water Reclamation Plant: Sand Bed Effluent	Water Reclamation Plant: Chlorinated Carbon Column Effluent
Biochemical oxygen demand (mg/liter)	200-400	20-40	Under 1	Under 1
Chemical oxygen demand (mg/liter)	400-600	80-160	30-60	3-16
Total organic carbon (mg/liter)	-	-	10-18	1-6
Suspended solids (mg/liter)	160-350	5-20	Under 0.5	Under 0.5
Turbidity (units)	50-150	30-70	0.5-3.0	Under 0.5
Phosphates (mg/liter)	15-35	25-30	0.1-1.0	0.1-1.0
ABS (mg/liter)	2-4	1.1-2.9	1.1-2.9	0.002-0.5
Coliforn bacteria (M.P.N./100 ml)	15,000,000	150,000	15	Under 2.2
Color (units)	High	High	10-30	Colorless
Odor	Odor	Odor	Odor	Odorless

SECTION VIII

COST,ENERGY AND NON-WATER QUALITY ASPECTS

Cost of In-Plant Control

An accurate assessment of the costs of in-plant improvement is not possible because of the following:

- broad variation in types and sizes of plants
- geographical differences in plant location
- difference among plants in respect to their current implementation of necessary management and engineering improvements
- management limitations

However, an estimate of costs is provided in this section for engineering improvement areas. These values should be used as general guidelines only; they could vary substantially in individual situations.

For the same reasons indicated above, it is not possible to relate costs incurred for in-plant control to specific reduction benefits achievable (as estimated in Section VII) on an industry or subcategroy basis. However, many of the in-plant improvements that have been suggested in this report as means to achieve the effluent limitation guidelines have been successfully implemented in a number of plants at a net economic return as a result of product saved. It may be reasonably assumed, therefore that the in-plant controls necessary to achieve the suggested effluent guidelines in many plants will cost little or no more than economic return they will achieve. Exceptional cases in all probability will involve the economic disposal of whey in plants producing cottage or natural cheese.

Cost of Equipment, Process and Systems Improvements

The costs involved in making the engineering improvements suggested in Section VII are equally difficult to ascertain with precision, and certainly will change with plant location, with size and type of plant, and with the supplier of the equipment. Estimated values are based on figures obtained from various major manufacturers of dairy plant equipment, and are presented in Table 24. They should be considered as guidelines values; the cost in individual situations could be as much as 20% higher than the quoted figures.

Table 24
ESTIMATED COST OF ENGINEERING IMPROVEMENTS OF EQUIPMENT, AND SYSTEMS TO REDUCE WASTE.

Item	Unit Cost	Total Cost for a 230,000 kg/day (500,000 lb/day) dairy plant
Standard Equipment		
Automatic Water Shut-Off Valves	$15-25 valve	$300
Drain Screens	$ 12	$150
(Note: Not recommended by equipment suppliers, because they plup-up too easily. New design needed for drain. Quick estimate of non-fouling drain system would be $150/drain).		
Liquid Level Control	$300/probe	$6,000 (min)
Temperature Controller	$1,000	$2,000
CIP Line Support	$330/100m ($100/100 ft.)	(Included in line installation cost of $2500/valve)
Drip Saver (can dumping)	$150	(Not applicable)
Evaporator Improvement	Included today in basic cost of equipment	
Filler Dripshield (Cost depends on size and type of filler)	$50-250	$1,500
(Drip shield Note: These items would have to be specially designed and may cause redesign in filler.)		
Evaporator Improvement	Included today in basic cost of equipment	
New Equipment Concepts		
Ice Cream Filler	$1,000	$3,000

Table 24 (con't)

Item	Unit Cost	Total Cost for a 230,000 kg/day (500,00 lb/day dairy plant
Novelty Collection System	Equipment manufacturers cannot estimate cost at this time. Would require special design.	
Case Washer Water Control	$ 550	$ 550
Product Recovery Can System (including 20 gallon container, piping, fittings, and controls)	$2,000/unit	$6,000
"Non-leak" Damaged Package Unit; complete with pump valve, level controller, spray device.	$2,500	$7,500
Interlock control between CIP and air blow down	$ 700	$4,200
Filler Product Recovery System	$2,700	$10,800
CIP Fittings and Controls	$ 25-30/ fitting $ 300-500/ control	--- ---
Improvement of Systems based on Existing Components		
CIP System - Revised type	$10,000/ unit	$30,000

Table 24 (con't)

Item	Unit Cost	Total Cost for a 230,000 kg/day (500,00 lb/day) dairy plant
CIP System -Single-Use type	$15,000 unit	$ 30,000
HTST Receiving System	$10,000	$ 20,000
Air Blow Down System Non-Lubricated	$ 5,000 $ 6,000	$ 7,800
Air Compression		
Air Blow Down Unit (filler, valve, etc.)	$ 300/unit	
Product Rinse Recovery	$10,000	$ 10,000
Post Rinse Utilization	$ 7,500	$ 7,500
Automated Continuous Processing	$10,500	$ 10,500
Application of New Systems Concepts		
High Solids Recovery System, including 2 valves 50,000 gal tank and turbidity inter controls		$104,000
Ice Cream Recovery System, including 250 gal tank and 2 valves/unit with piping & fitting		$ 13,000
Other new systems	Cost not determinable at present time	

Table 24 (con't)

Item	Unit Cost	Total Cost for a 230,000 kg/day (500,00 lb/day) dairy plant
Standard 190,000 1 (50,000 gal) Silo tank	$50,000	$100,000
Cone shaped 190,000 1 (50,000 gal) Silo tank	$60,000	$120,000
Standard 78,000 1 (20,000 gal) Silo Pasteurizer Surge Tank	$20,000	$100,000
Standard 78,000 1 (20,000 gal) Silo Pasteurizer Surge Tank	$24,000	$120,000
Welded pipelines, fittings, controls, installation;	$ 2,500 x No. of air-acutated valves	---
4 products only -- 30 valves		$ 75,000
Full product line-- 150 Valves		$375,000
Drain Segregation	Increase in Construction cost estimated at $.25/ square ft. include manholes for each department and drain junction.	$ 50,000
Air Actuated Valves	$700-800/valve	---
	$330-820/100m ($100-250/100 ft.)	---
Central Hot Water	$3,000-10,000	$ 7,500

Cost of End-Of-Pipe Treatment

Biological Treatment

A summary of the estimated capital costs and operating costs for activated sludge, trickling filter and aerated lagoon systems are shown in Figures 19 through 23. The data are based on 1971 costs. Operating costs include power, chlorine, materials and supplies, laboratory supplies, sludge hauling, maintenance, direct labor, and generally 10-year straight-line depreciation.

Cost estimates for biological waste treatment systems are based on model plants covering various discharge conditions representative of the dairy industry. Specifically, raw waste BOD_5 concentration of 500 mg/l, 1000 mg/l, 1500 mg/l and 2000 mg/l were selected, each at a flow volume of 187 cu m/day, 375 cu m/day, 935 cu m/day, 1872 cu m/day (50,000 gpd, 100,000 gpd, 250,000 gpd and 500,000 gpd). Cost analysis for waste water volumes of 187 cu m/day (50,000 gpd) and less were based on treatment by means of package plants. Package activated sludge was considered although packed towers could be as efficient.

Substantial savings could be realized through use of prefabricated plants for low volume discharge. Although field-instituted treatment systems cost more even at larger capacities, they would generally provide greater operational flexibility, greater resistance to shock loads and flow surges, better expansion possibilities and higher average treatment efficiencies. Cost estimates assume plants designed in accordance with the parameters specified in Table 16, Section VII.

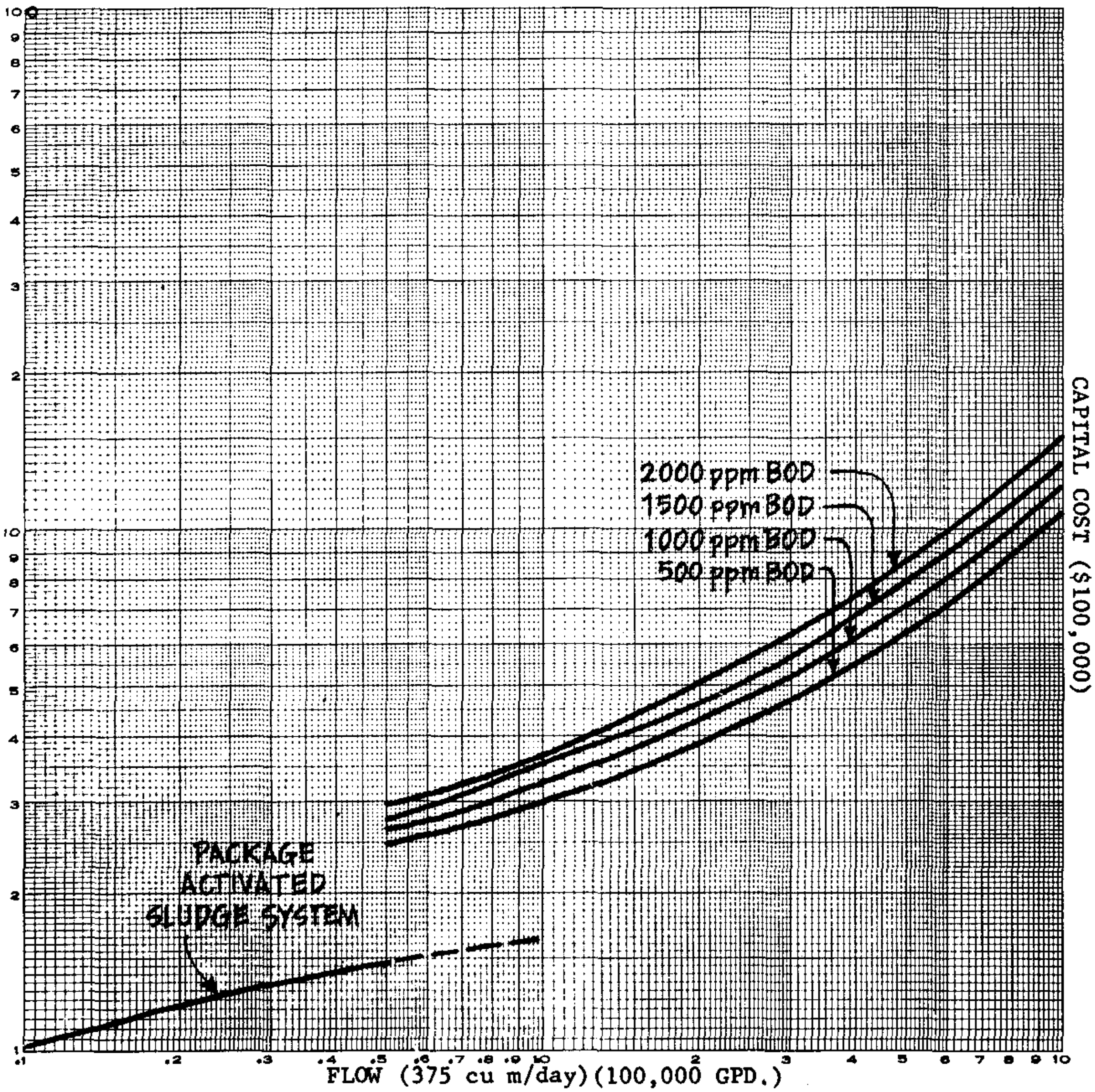
Capital cost estimates for aerated lagoons for the four BOD cases--500 mg/l, 1000,mg/l, 1500 mg/l and 2000 mg/l -- were almost identical. Therefore, one case is indicated, namely 2000 mg/l BOD_5 at 187 cu m/day, 375 cu m/day, 935 cu m/day, 1872 cu m/day (50,000 gpd, 100,000 gpd, 250,000 gpd and 500,000 pgd). Also operating cost estimates for the four BOD_5 concentrations were almost identical and only the operating cost for the model lagoons receiving 2,000 mg/l BOD_5 is indicated. Fig. 22 shows operating costs including 10-year straight line depreciation. Fig. 23 shows operating costs excluding depreciation.

Capital cost estimates for a treatment system consisting of anaerobic digestion followed by a stabilization lagoon were based on the following design parameters: retention times of 3-day and 120-days respectively, for anaerobic digestion and stabilization, an average depth of 3 feet for the stabilization lagoon, and an organic loading limit of 20 lb BOD_5/acre/day for the stabilization lagoon. The estimates incorporate land at $1000/acre, the costs of mechanical equipment (pumps, a 5 or 10 horsepower aeration at the discharge point from anaerobic digestion, and piping), and the costs of construction. Investment is estimated at $7,600, $13,000 and $21,000 for

FIGURE 19

CAPITAL COST (AUGUST, 1971)

ACTIVATED SLUDGE SYSTEMS (FOR DAIRY WASTEWATER)

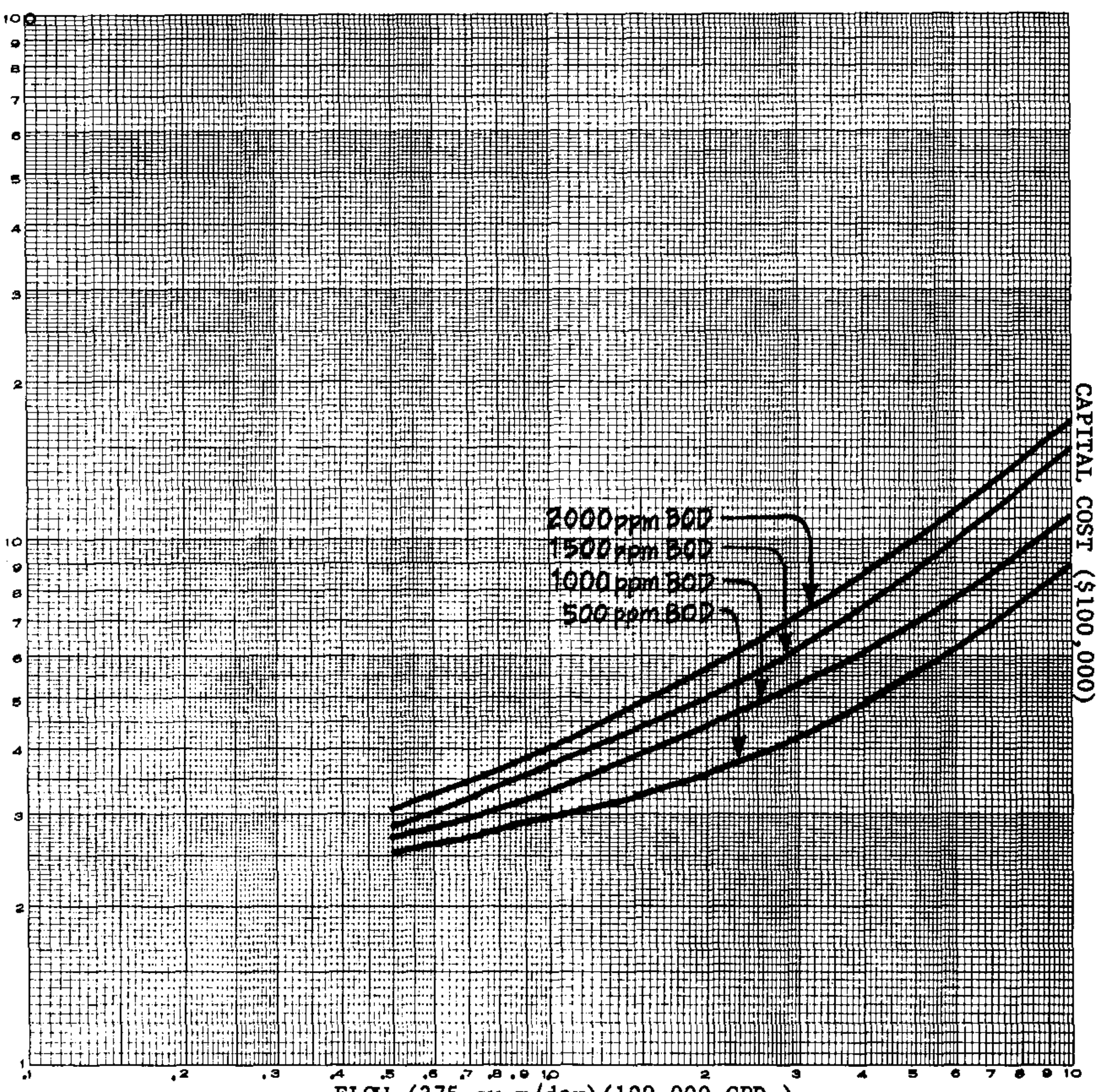


Includes: Raw wastewater pumping, half-day equalization with diffused air, aeration basin (36 hours) with diffused air supply system, settling, chlorination feed system, chlorination contact basin, sludge recycle, aerobic sludge digestion, sludge holding tank, sand-bed drying with enclosure and fans, under-drain sand-bed pumping, laboratory, garage and shop facilities, yardwork, engineering and land. Package treatment system does not include sand beds, laboratory, garage and land cost.

FIGURE 20

CAPITAL COST (AUGUST, 1971)

TRICKLING FILTER SYSTEM (FOR DAIRY WASTEWATER)

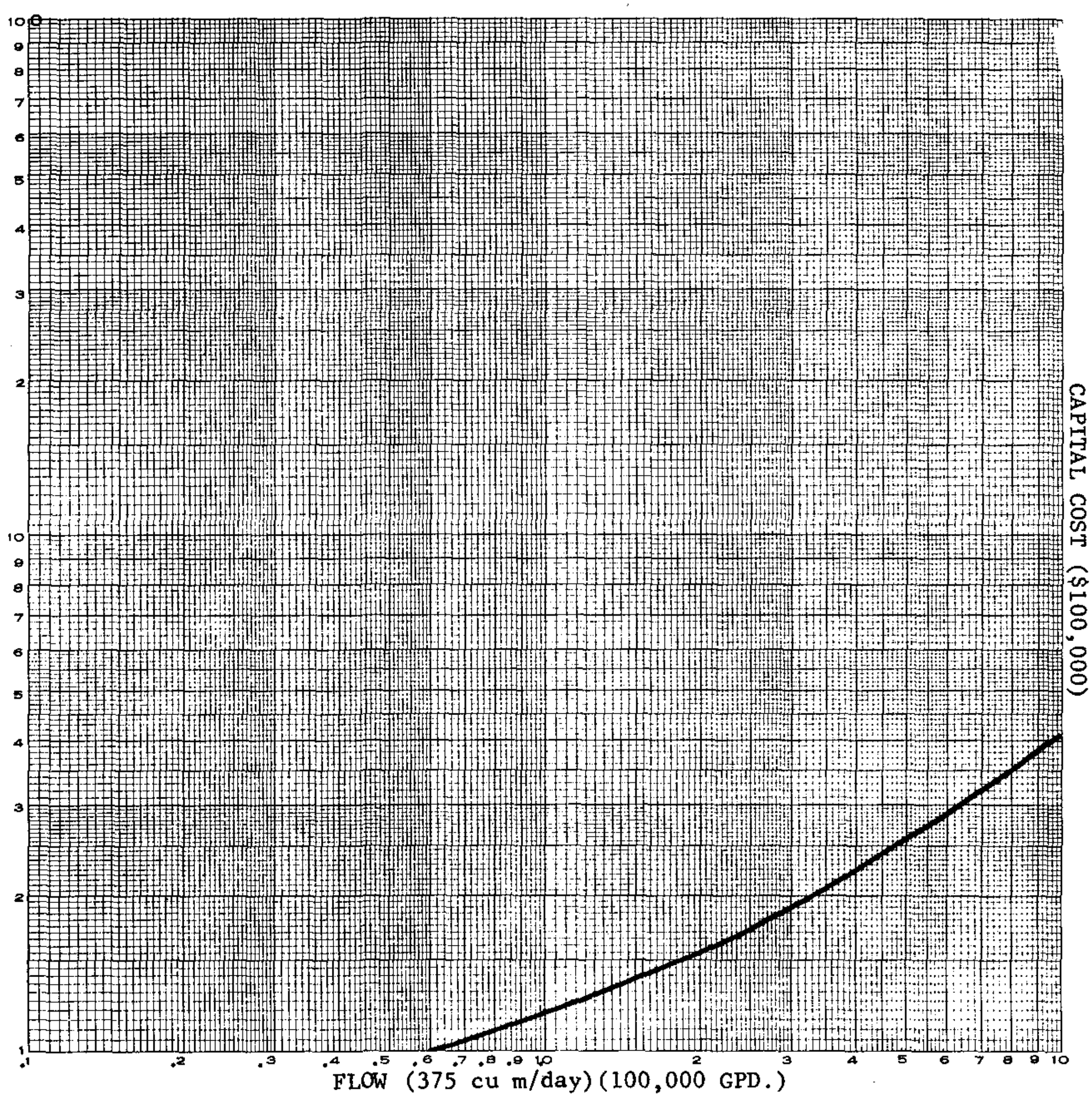


Includes: Raw wastewater pumping, half-day equalization with diffused air, trickling filter, settling chlorination feed system, chlorination contact basin, recirculation pumping, sludge pumping, sludge holding tank, sand bed drying with enclosure and fans, garage and facility, yardwork, engineering and land.

FIGURE 21

CAPITAL COST (AUGUST, 1971)

AERATED LAGOON (FOR DAIRY WASTEWATER)

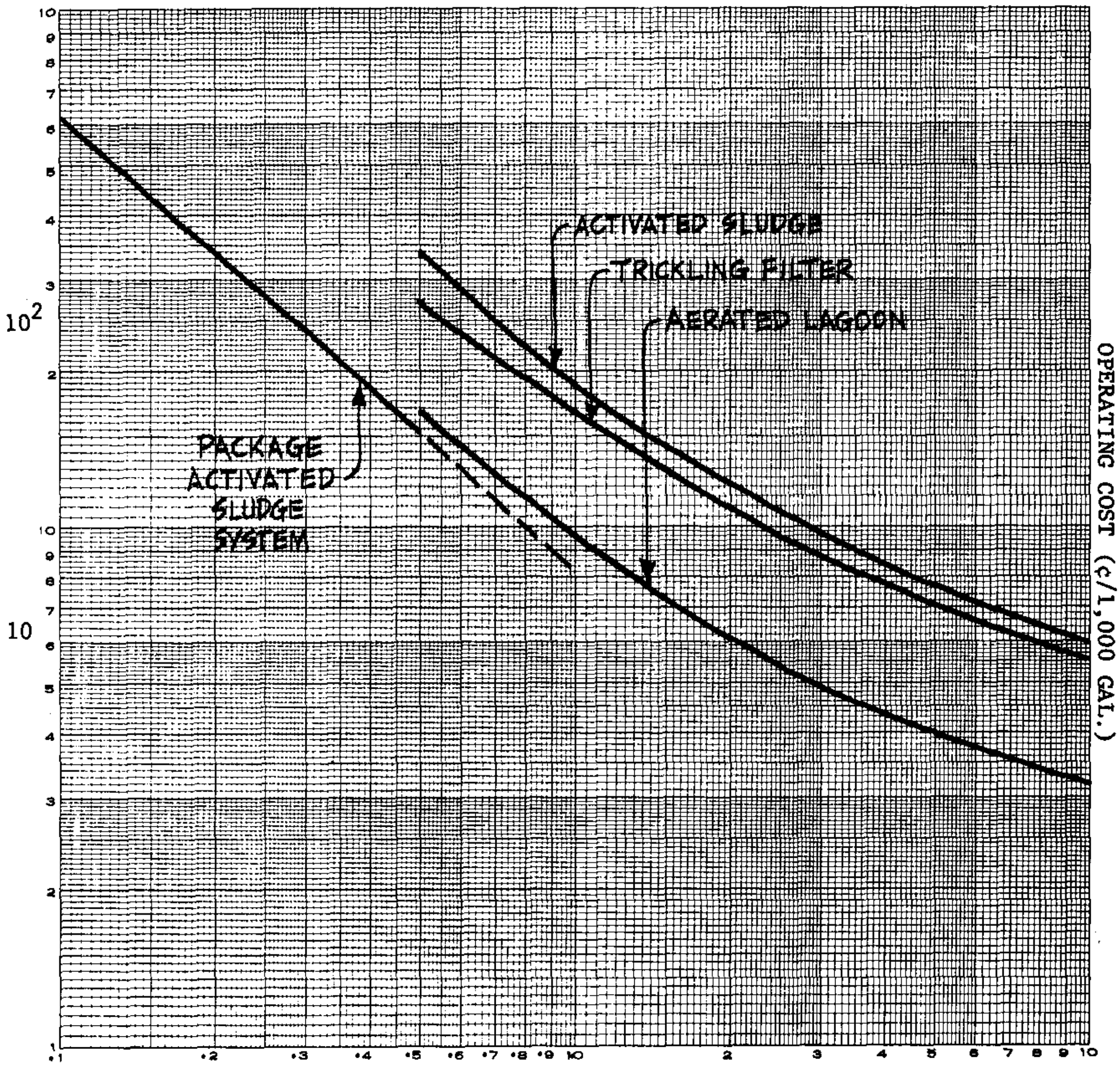


Includes: Raw wastewater pumping, aeration lagoon with high-speed floating surface aerators, concrete embankment protection, settling basin, chlorination contact basin, engineering and land.

FIGURE 22

OPERATING COSTS (AUGUST, 1971)

ACTIVATED SLUDGE SYSTEM, TRICKLING FILTER SYSTEM,
AND AERATED LAGOON.
(FOR DAIRY WASTEWATER)

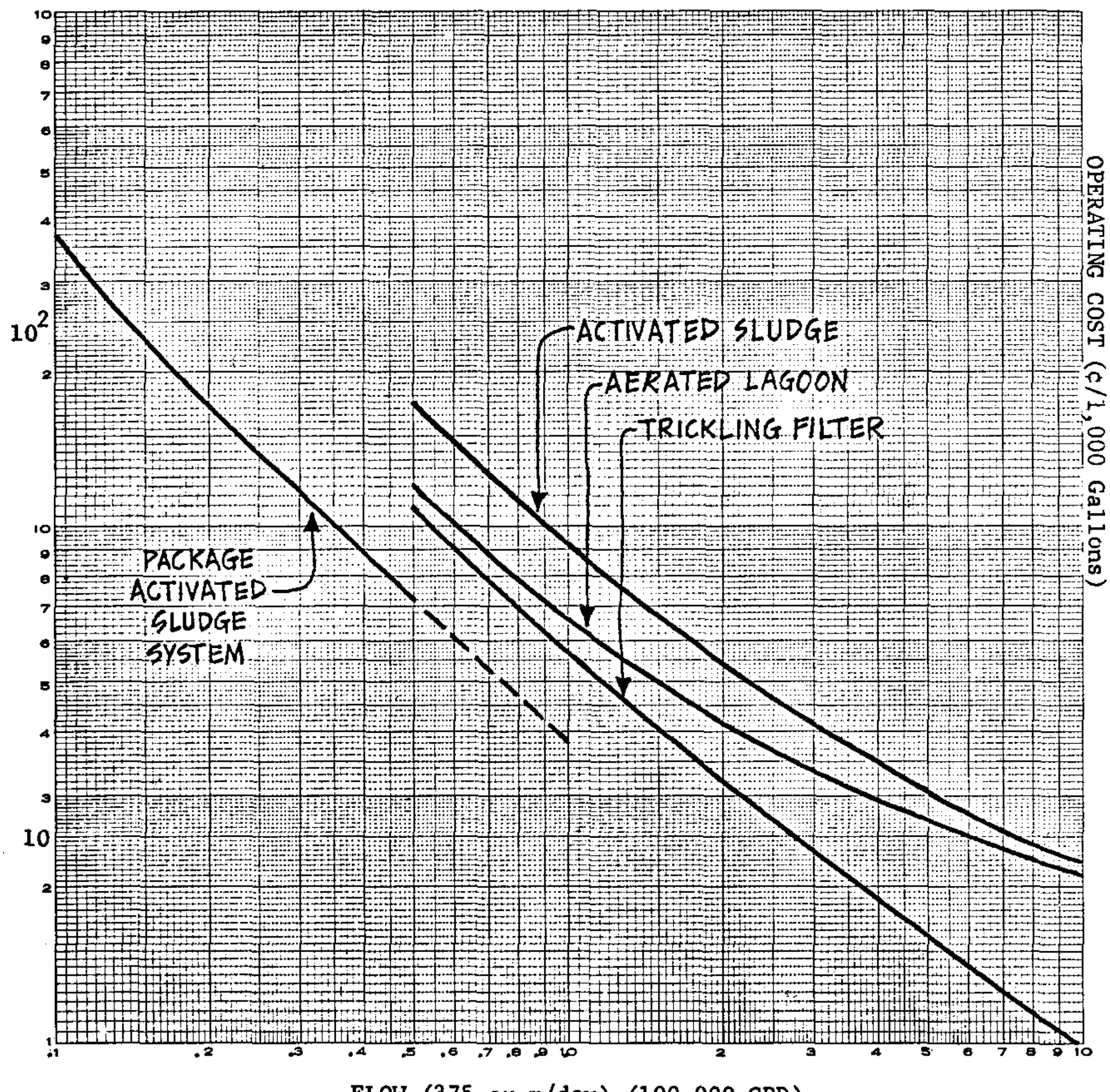


(Includes 10-year straight-line depreciation.)
Package treatment system does not include sludge sand beds, laboratory and shop facilities.

FIGURE 23

OPERATING COSTS (AUGUST 1971)

ACTIVATED SLUDGE, TRICKLING FILTER
AND AERATED LAGOON SYSTEMS
(FOR DAIRY WASTEWATER)



(Excluding Depreciation or Amortization.)
Package treatment system does not include sand beds, laboratory and shop facilities.

discharges of 10,000 gal/day (50 lb/day BOD5 raw waste), 40,000 gal/day (200 lb/day BOD5 BOD5 raw waste), 40,000 gal/day (200 lb/day BOD5) respectively. Annual operating costs (power, sludge removal and general maintenance) for these discharges are estimated to be $2,500 and $3,500 and $6,000.

Irrigation

Investment and costs were developed for three levels of waste water discharge: 10, 40 and 80 thousand gallons per operating day. It is assumed that the maximum daily discharge per acre is 20,000 gallons (0.062 ft or 0.74 in/day) or 150 pounds BOD5. 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 BOD5/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 waste water-BOD application per acre, particularly in the Lake States region where many plants are located.

Other assumptions are (1) minimum in-plant changes to reduce waste water or BOD discharge, (2) waste water and BOD discharge coefficients per 1,000 pounds of M.E. are those used in the DPRA study (phase II, table V-1), (3) and 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 $7,000-$8,000. If whey is discharged with the cheese plant waste water, 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 waste water, the annual total cost are $1,600, $3,100, and $5,200 respectively. About 70 percent of these costs are variable and the remainder fixed.

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 30 cents per 1,000 pounds of M.E. throughput to 14 cents 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 waste water including whey is 70 cents, 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 percent 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 7 cents for fluid, evaporated milk and ice cream plants regardless of the size. The cost is 8 cents per 1,000 pounds M.E. for butter-powder, 3 cents per 1,000 pounds M.E. for cheese plants without whey discharge, and 55 cents 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.

Tertiary Treatment

For further reduction of BOD, suspended solids, phosphorus, and other parameters which biological systems cannot remove, tertiary treatment systems would have to be used.

The capital and operating costs for such tertiary systems are given in Table 25. The operating costs include ten-year straight line depreciation costs. The total capital and operating cost represent the costs required for treatment of secondary waste water for use in a complete recycle process. Of the procedures in Table 25, only sand filtration is predicted for compliance with the guidelines; and that only for 1983 limitations and new source performance standards.

Economic Considerations

Today many waste water treatment plants of approximately the same BOD-removal capacity vary as much as five fold in installed capital investment. If due consideration is not given to economic evaluation of various construction and equipment choices, an excessive capital investment and high operating expense usually result. The engineer is faced with defining the problem, determining the possible solutions, economically evaluating the alternatives and choosing the individual systems that, when combined, will yield the most economical waste water treatment process. Both capital investment and operating cost must be considered carefully since it is sometimes more economical to invest more capital initially in order to realize a reduced yearly operating cost.

Of the three biological systems, that provide refined treatment, namely, activated sludge, trickling filters and aerated lagoons, the aerated lagoon system provides the most economical approach. Investment can be minimized by providing weatherproof equipment rather than buildings for equipment protection. Where buildings are required, prefabricated steel structures set on concrete slabs are economically used. Plants discharging less than 375 cu m/day (100,000 GPD) should consider using package treatment systems. Such treatment systems could result in capital and operating costs savings.

Small plants in rural locations should consider the more land oriented approaches (irrigation or a combined anaerobic digestion - stabilization lagoon system) as a solution for waste water treatment. If suitable land is readily available, satisfactory waste discharge levels may be attained at lower capital investment and operating costs, and without the operational problems and adjustments associated with the more sophisticated systems that require employment of a skilled waste treatment operator.

Table 25

Tertiary Treatment Systems Cost

Estimated Capital Cost (1971 Cost)

	Flow (mgd)		
	0.1	0.5	1.0
	($ 1000)		
Lime precipitation clarification	49	80	120
Ammonia air stripping	53	94	125
Recarbonation	28	39	49
Sand filtration	28	79	125
Reverse osmosis	111	467	858
Activated carbon	139	347	528
Total	408	1,106	1,805

Estimated Operating Cost* (1971 Cost)

	Flow (mgd)		
	0.1	0.5	1.0
	(¢/1,000 gal)		
Lime precipitation clarification	17.8	9.1	7.8
Ammonia air stripping	16.1	8.9	6.2
Recarbonation	10.9	4.5	3.5
Sand filtration	19.9	15.9	13.6
Reverse osmosis	70.7	50.5	42.6
Activated carbon	58.8	34.8	29.6
Total	194.2	123.7	103.3

*Includes 10-year depreciation cost.

Plant layout should always receive careful consideration. Simple equipment rearrangement can save many feet of expensive pipe and electrical conductors as well as reducing the distances plant operators must travel. Maintenance costs are reduced by providing equipment-removal devices such as monorails to aid in moving large motors and speed reducers to shop areas for maintenance. When designing pumping stations and piping systems, an investigation should be made to determine whether the use of small pipe, which creates large headlosses but which is low in capital investment, is justified over the reverse situation. Often a larger capital investment is justified because of lower operating costs.

Table 26 depicts the relative costs of the three biological treatment systems as practiced in the chemical industry based on consistent unit land and construction costs for each process.

Table 26

Biological System Cost Comparisions As Applied in the Chemical Industry

	Cost Ratio (relative to 1.0 as lowest cost system)		
	Activated Sludge	Trickling Filter	Aerated Lagoons
Land requirement	1.0	1.0-1.4	2.0-100
Capital Investment	1.8-2.5	1.8-5.5	1.0
Operating Cost			
Manpower	2.5-5.5	2.2-5.0	1.0
Maintenance	6.0-12.0	4.0-8.0	1.0
Chemical Usage	1.2+	1.1+	1.0
Power	40-100	1.0	50-300
Sludge Disposal	50-150	50-150	1.0

Non-Water Quality Aspects of Dairy Waste Treatment

The main non-water pollutional problem associated with treatment of dairy wastes is the disposal of sludge from the biological oxidation systems. Varying amounts of sludge are produced by the different types of biological systems. Activated sludge systems and trickling filters produce sludge that needs to be handled almost daily.

Waste sludge from activated sludge systems generally contains about 1% solids. The amount of sludge produced ranges between 0.05 to 0.5kg solids per kg BOD_5 removed. For extended aeration systems about 0.1 kg solids will be produced per kg BOD_5 removed.

Sludge from trickling filters consists of slime sloughed off the filter bed. This sludge settles faster than activated sludge and compacts at solids concentrations greater than 1% solids. The amount of sludge generated will be less than that produced by activated sludge systems.

Aerobic and anaerobic digestion of sludge generated from activated sludge systems is recommended to render it innocuous, thicken it, and improve its dewatering characteristics. Sludge thickening can preceed digestion to improve the digestion operations. Digested activated sludge and thickened trickling filter sludges can be vacuum-filtered, centrifuged or dried on sand beds to increase their sclids content for better "handleability" before final disposal.

Energy Requirements

The energy required to comply with the effluent guidelines and standard of performance is largely that for pumping and aeration associated with treatment facilities. The energy requirements associated with in-plant control are so negligible as to be virtually undetectable in the over all power consumption in dairy products processing plants.

Based on biological treatment (e.g., extended aeration) for the portion of the industry that constitutes point source discharges, and including operation of treatment facilities presently in place, the power demand to meet the 1977 limitations is estimated to be 145,000 kwh/day. An additional 3100 kwh/day would be required for compliance with 1983 limitations. Depending on the size of the plant, a new source would require 79 to 380 kw/mgd (1896 to 9120 kwh/mgd) discharged. These estimates may be reduced if a number of plants opt for treatment practices with lower power requirements such as irrigation or a combination of anaerobic digestion and stabilization lagoons.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE (LEVEL I EFFLUENT LIMITATIONS GUIDELINES)

Introduction

The effluent limitations which must be achieved July 1, 1977 are to specify the degree of effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available", The Environmental Protection Agency has defined the best practicable control technology currently available as follows.

Best Practicable Control Technology Currently Available is generally based upon the average of the best existing performance by plants of various sizes, ages and unit processes within the industrial category and/or subcategory. This average is not based upon the entire range of plants within the dairy products processing industry, but based upon performance levels achieved by exemplary plants.

Consideration must also be given to:

1. The total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;

2. the size and age of equipment and facilities involved;

3. the processes employed;

4. the engineering aspects of the application of various types of control techniques;

5. process changes;

6. non-water quality environmental impact (including energy requirements.

Also, Best Practicable Control Technology Currently Available emphasizes treatment facilities at the end of a manufacturing process but includes the control technologies within the process itself when the latter are considered to be normal practice within an industry.

A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of commencement of construction or installation of the control facilities."

Effluent Reduction Attainable Through the Application of The Best Practicable Control Technology Currently Available

BOD

Based upon the information contained in Sections III through Section IX of this report, and the results that are attained by the better plants, it has been estimated that the degree of BOD_5 reduction attainable through the application of the best practicable control technology currently available in each industry subcategory is as indicated in Table 27.

Suspended Solids

End-of-pipe biological treatment is primarily designed for removal of BOD_5, but it is generally effective in reducing the level of suspended solids. Such is the case with dairy products waste waters. The level of suspended solids in a treated effluent is a result of the combined effect of the concentration and nature of the suspended solids in the raw waste and the settling characteristics of the biological sludge generated in the treatment facility. In general, it is expected that the concentration of suspended solids in the effluent will be equal to or less than that of the BOD_5. However, the somewhat poor settling qualities of treated effluents from dairy products processing is well documented, and this is reflected in the values in Table 27. While the suspended solids levels in raw waste waters were found to be approximately 40% of those of BOD_5, the guidelines limitations for suspended solids are higher than those for BOD_5.

Identification of Best Practicable Control Technology

The suggested effluent limitations are currently being achieved by a number of "exemplary" plants in the industry. Other plants can acheive them by implementing some or all of the following waste control measures:

(a) In-Plant Control

1. Establishment of a plant management improvement program, as described in detail in Section VII. Such a plan would cover adoption of water conservation practices, installation of waste monitoring equipment, improvement of plant maintenance, improvement of production scheduling practices, quality control improvement, finding alternate uses for products currently wasted to drain, and improvement in housekeeping and product handling practices.

Specific attention should be given to recovery and use of whey and other by-products rather than discharge to the treatment system.

2. Improving plant equipment as described specifically under "Standard Equipment Improvement Recommendations", items 1 through 13, in Section VII.

(b) End-of-Pipe Control

1. For large plants, installation of a biological treatment system (activated sludge, trickling filter, or aerated lagoon), designed generally in accordance with the suggested parameters set forth in Section VII and operated under careful management.

2. For small plants, installation of an anaerobic digestion - stabilization lagoon system in accordance with suggested parameters set forth in Section VII.

3. Where land is available, irrigating the waste water by spray or ridge and furrow, if this can be done economically and satisfactorily. This option is of limited feasibility for the very large plant.

<u>Rationale For Selection Of Best Practicable Control Technology Currently Available</u>

In view of the biodegradable nature of dairy processing wastes and the current limited development of chemical-physical treatment for organic wastes, conventional biological treatment was considered to be the logical choice for end-of-pipe technology. Evaluation of the application of biological treatment within the dairy processing industry indicated that a variety of systems (i.e., activated sludge and its variations, trickling filters, or aerated lagoons) were capable of producing high quality effluents consistent with those generally expected from efficient "secondary treatment". This was true even for those subcategories beset by the greatest problems of waste concentration, waste volume and waste treatability. Accordingly, technical feasibility indicated that effluent guidelines should be in keeping with reductions attained by the better biological treatment systems within the industry.

Late in the guidelines development period the issue of economic impact on small plants arose. It was noted that the economics of size associated with any single treatment approach (e.g., activated sludge) resulted in much higher "per unit of production treatment costs" for small plants, and that the financial status of small plants in general was poor. Economic analysis indicated that the burden imposed by such high treatment costs would force closure of many small plants. To ameliorate this effect, guidelines based on a lesser degree of reduction attained by a relatively low-cost system (anaerobic digestion followed by stabilization lagoons) are applied to plants within the size ranges in which severe economic impact was expected. While no field data was obtained on performance of such a system during the course of the dairy technical study, information in the literature and field data obtained by EPA in other technical studies on wastes of a similar nature (i.e., high BOD_5 and suspended solids) indicate that compliance with the guidelines is readily attainable using the design criteria specified in Section VII.

Since the effluent discharged from a treatment facility is dependent to some degree on the influent hydraulic and organic load, some consideration must be given to in-plant control for development of effluent guidelines. In-plant controls incorporated into the development cf best practicable control technology guidelines have been limited to those housekeeping and management practices (e.g., automatic shut-off valves on hoses and spill control) that materially reduce hydraulic and organic loads but do not require extensive plant modification or large capital investment.

The effluent limitations values contained in Table 27 are based on discharges expected from application of the appropriate end-of-pipe treatment to the raw waste from a well-run dairy products processing operation.

Table 27

Effluent Reduction Attainable Through Application of Best Practicable Control Technology Currently Available

Subcategory/Segment	Effluent in kg/kkg of BOD5 Received or Processed	
	BOD5	TSS
Receiving Stations		
Small	0.313	0.469
Other	0.190	0.285
Fluid Products		
Small	2.250	3.375
Other	1.350	2.025
Cultured Products		
Small	2.250	3.375
Other	1.350	2.025
Butter		
Small	0.913	1.369
Other	0.550	0.825
Cottage Cheese		
Small	4.463	6.694
Other	2.680	4.020
Natural Cheese		
Small	0.488	0.731
Other	0.290	0.435
Ice Cream Mix		
Small	1.463	2.194
Other	0.880	1.320
Ice Cream		
Small	3.063	4.594
Other	1.840	2.760
Condensed Milk		
Small	2.30	3.450
Other	1.380	2.070
Dry Milk		
Small	1.088	1.638
Other	0.650	0.975
Condensed Whey		
Small	0.650	0.975
Other	0.40	0.60
Dry Whey		
Small	0.650	0.975
Other	0.40	0.60

SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE CONTROL TECHNOLOGY ECONOMICALLY ACHIEVABLE

Introduction

The effluent limitations which must be achieved by July 1, 1983 are to specify the degree of effluent reduction attainable through the application of the "Best Available Control Technology Economically Achievable" The Environmental Protection Agency has defined this level of in the following terms:

"This level of technology is not based upon an average of the best performances within an industrial category, but is to be determined by identifying the very best control and treatment technology employed by a specific point source whin the industrial category or subcategory; where a technology is readily transferable from one industry or process to another, such technology may be identified as applicable. A specific finding must be made as to the availability of control measures and practices to eliminate the discharge of pollutants, taking into account the cost of such elimination, and:

1. the age of equipment and facilities involved;
2. the process employed;
3. the engineering aspects of the application of various types of control techniques;
4. process changes;
5. cost of achieving the effluent reduction resulting from application of technology;
6. non-water quality environmental impact (including energy requirements).

In contrast to the best practicable control technology currently available, the best available control technology economically achievable assesses the availability in all cases of in-process controls as well as control or additional treatment techniques employed at the end of a production process. In-process control options available which should be considered in establishing control and treatment technology include, but need not be limited to, the following:

1. Alternative Water Uses
2. Water Conservation
3. Waste Stream Segregation

4. Water Reuse

5. Cascading Water Uses

6. By-Product Recovery

7. Reuse of Waste Water Constituent

8. Waste Treatment

9. Good Housekeeping

10. Preventive Maintenance

11. Quality Control (raw material, product, effluent)

12. Monitoring and Alarm Systems

Those plant processes and control technologies which at the pilot plant, semi-works, or other level, have demonstrated both technological performances and economic viability at a level sufficient to reasonably justify investing in such facilities may be considered in assessing technology. Best available technology control economically achievable is the highest degree of control technology that has been achieved or has been demonstrated to be capable of being designed for plant scale operation up to and including "no discharge" of pollutants. Although economic factors are considered in this development, the costs for this level of control is intended to be the top-of-the-line of current technology subject to limitations imposed by economic and engineering feasibility. However, it may be characterized by some technical risk with respect to performance and with respect to certainty of costs. Therefore, attainment of this technology may necessitate some industrially sponsored development work prior to its application.

<u>Effluent Reduction Attainable Through the Application of the Best Available Control Technology Economically Achievable</u>

BOD_5

Based on the information contained in Section VII and the data base of this report, it has been estimated that the degree of effluent reduction attainable through the application of the best available technology economically achievable in each industry subcategory is as indicated in Table 28. The BOD_5 loads are the suggested monthly average effluent limitations guidelines to be met by July 1, 1983.

Suspended Solids

Table 28

Effluent Reduction Attainable Through Application of Best Available Control Technology Economically Achievable

Subcategory/Segment	Effluent in kg/kkg of BOD5 Received or Processed	
	BOD5	TSS
Receiving Stations		
Small	0.075	0.094
Other	0.050	0.063
Fluid Products		
Small	0.550	0.688
Other	0.370	0.463
Cultured Products		
Small	0.550	0.688
Other	0.370	0.463
Butter		
Small	0.125	0.156
Other	0.080	0.10
Cottage Cheese		
Small	1.113	1.391
Other	0.740	0.925
Natural Cheese		
Small	0.125	0.156
Other	0.080	0.10
Ice Cream Mix		
Small	0.363	0.454
Other	0.240	0.30
Ice Cream		
Small	0.70	0.875
Other	0.470	0.588
Condensed Milk		
Small	0.575	0.719
Other	0.380	0.475
Dry Milk		
Small	0.275	0.344
Other	0.180	0.225
Condensed Whey		
Small	0.163	0.204
Other	0.110	0.138
Dry Whey		
Small	0.163	0.204
Other	0.110	0.138

Based on the same analyses and rationale described under "Suspended Solids" in Section IX of this report, and limited dairy industry data on sand filtration, it is suggested that the effluent limitation guidelines for suspended solids be as shown in Table 28.

Identification of Best Available Control Technology Economically Achievable

The suggested raw waste loads and end-of-pipe waste reduction are currently being achieved by a few "exemplary" plants in the industry. Other plants can achieve them by implementing some or all of the following waste control measures:

(a) In-Plant Control

1. Establishment of a plant management improvement program, as described in Section VII. Such a plan would cover a water use conservation program, installation of waste monitoring equipment, improvement of plant maintenance, improvement of production scheduling practices, quality control improvement, finding alternate uses for products currently wasted to drain, and improvement in product handling practices.

2. Improving plant equipment as described specifically under "Standard Equipment Improvement Recommendations", items 1 through 13, in Section VII.

3. Improving plant equipment as described specifically under "New Concepts for Equipment Improvement" items 1 to 8, in Section VII.

4. Applying process improvements, as described specifically under "Waste Management Through Process Improvements". Items 3 and 4 are included only as possible approaches to meeting guidelines limitations without installation of end-of-pipe treatment improvements. The economics of individual cases will determine whether or not this is the best approach to compliance.

(b) End-Of-Pipe Control

1. Installation of a biological treatment system (activated sludge, trickling filter, or aerated lagoon) designed generally in accordance with the suggested parameters set forth in Section VIII, and operated under good managment.

2. Installation of a sand filter or other polishing steps of adequate capacity.

3. Where land is available, irrigating the waste water by spray or ridge and furrow, if this can be done economically and satisfactorily.

Rationale for Selection of Best Available Control Technology Economically Achievable

The effluent limitation values for best available control technology economically achievable have been based on the further waste discharge reduction attainable by adding an efficient polishing operation (e.g., sand filtration) to the treatment facilities of a plant complying with best practicable control technology limitations. The feasibility of the potential alternative for attaining the specified limitation (through in-plant modifications detailed in Section VII) is dependent on the cost of in-plant controls, the cost of additional waste treatment, the value of recovered materials, and other factors that must be evaluated on a case-by-case basis.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

Introduction

In addition to guidelines reflecting the best practicable control technology currently available and the best available control technology economically achievable, applicable to existing point source discharges July 1, 1977 and July 1, 1983 respectively, the Act requires that performance standards be established for "new sources." The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance."

The Environmental Protection Agency has defined the appropriate technology in the following terms: "The technology shall be evaluated by adding to the consideration underlying the identification of the best available control technology economically achievable a determination of what higher levels of pollution control are available through the use of improved production processes and/or treatment techniques. Thus, in addition to considering the best in-plant and end-of-process control technology, the technology is to be based upon an analysis of how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods or other alternatives must be considered. However, the end result of the analysis will be to identify effluent standards which reflect levels of control achievable through the use of improved production processes as well as control technology, rather than prescribing a particular type of process or technology which must be employed. A further determination which must be made for the technology is whether a standard permitting no discharge of pollutants is practicable."

At least the following factors should be considered with respect to production processes which are to be analyzed in assessing the technology:

1. the type of process employed and process changes

2. operating methods

3. batch as opposed to continuous operations

4. use of alternative raw materials and mixes of raw materials

5. use of dry rather than wet processes (including substitution of recoverable solvents for water)

6. recovery of pollutants as by-products

Effluent Reduction Attainable in New Sources

Because of the large number of specific improvements in management practices and design of equipment, processes and systems that have some potential of development for application in new sources, it is not possible to determine, within reasonable accuracy, the potential waste reduction achievable in such cases, However, the implementation of many or all of the in-plant and end-of-pipe controls described in Section VII should enable new sources to achieve the waste load discharges defined in Section X.

The short lead time for application of new source performance standards (less than a year versus approximately 3 and 9 years for other guidelines) affords little opportunity to engage in extensive development and testing of new procedures. The single justification that could be made for more restrictive limitations for new sources than for existing sources would be one of relative economics of installation in new plants versus modification in existing plants. There is no data to indicate that economics of new technology in dairy products processing is significantly weighted in favor of new plants.

The attainment of zero discharge of pollutants does not appear to be feasible for dairy product plants other than those with suitable land readily available for irrigation. Serious problems of sanitation are associated with complete recycle of waste waters and the expenses associated with the complex treatment system that would permit complete recycle (see Figure 18) are excessive.

In view of the foregoing, it is recommended that the effluent limitations for all new sources be the same as those for best available control technology economically achievable for larger plant found in Section X.

No distinction is recommended for the smaller plant. With minimization of raw waste loads (both hydraulic and organic) through in-plant control (a necessity for economic viability of smaller plants) and application of end-of-pipe treatment suggested in Section X, the smaller plant should be able to meet the recommended limitations.

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SECTION XIV

GLOSSARY

Biochemical Oxygen Demand - (Or five-day BOD5). Is the amount of oxygen consumed by microorganisms to assimilate organics in waste water over a five day period at 20° C. BOD5 is expressed in mg/l (or ppm) and is the most common yardstick at present to measure pollutional strength in water.

Biological Oxidation - The process whereby living organisms in the presence of oxygen convert the organic matter contained in waste-water into a more stable or a mineral form.

Churned Buttermilk - Byproduct resulting from the churning of cream into butter. It is largely defatted cream and its typical composition is 91% water. 4.5% lactose, 3.4% nitrogenous matter, 0.7%ash and 0.4% fat. Churned or "true" buttermilk is distinguished from cultured buttermilk, which is a fermentation product of skim milk. The latter is sold in the retail market and referred to simply as "buttermilk".

Chemical Oxygen Demand - Is the amount of oxygen provided by potassium dichromate for the oxidation of organics present in waste water. The test is carried out in a heated flask over a two hour period. One of the chief limitations of the COD test is its inability to differentiate between biologically oxidizable and biologically inert organic matter. Its major advantage is the short time required for evaluation when compared with the five-day BOD test period. COD is expressed in mg.l or ppm.

Chlorine Contact - A detention basin where chlorine is diffused through the treated effluent which is held a required time to provide the necessary disinfection.

Condensed - The term "condensed" as used in this report, applies to any liquid product which has been concentrated through removal of some of the water it normally contains, resulting in a product which is still in the liquid or semi-liquid state. When applied to milk, the term "condensed" is used interchangeably with "evapoprate" to designate milk which has been concentrated milk. Commercially, however, the term "evaporate milk" is commonly used to define unsweetened concentrated milk.

Cultured Products - Fermentation-type dairy products manufactured by innoculating different forms of milk with a bacterial culture This designation includes yogurt, cultured buttermilk, sour cream, and cultured cream cheese, among other products.

Effluent - Waste containing water discharged from a plant. Used synonymously with "waste water" in this report.

Endogenous - An auto oxidation of cellular material that takes plance in the absence of assimilable organic material to furnish energy required for the replacement of worn-out components of protoplasm.

Food to Microorganism Ratio - An aeration tank loading parameter. Food may be expressed in pounds of suspended solids, COD, or BOD_5 added per day to the aeration tank, and microorganisms may be expressed as mixed liquor suspended solids (MLSS) or mized liquor volatile suspended solids (MLVSS) in the aeration tank. The flow (volume per unit time) applied to the surface area of the clarification or biological reactor units (where applicable).

Hydraulic Loading - The flow (volume per unit time) applied to the surface area of the clarification or biological reactor units (where applicable).

Influent - Waste water or other liquid - raw or partially treated; flowing into a reservoir, basin, treatment process or treatment plant.

Ice Cream - Applied in a general sense, this term refers to any milk-based product sold as frozen food. Food regulatory agencies define ice-cream in terms of composition, to distinguish the product from other frozen dessert-type products containing less milk-fat or none at all, such as sherbert, water ices and mellorine.

Milk Equivalent M.E. - Quantity of milk (in pounds) to produce one pound of product. A milk equivalent can be expressed in terms of fat solids, non-fat solids or total solids, and in relation to standard whole milk or milk as received from the farm: the many definitions possible through the above alternatives has resulted in confusion and inconsistent application of the The most widely used milk equivalents are those given by the U.S. Department of Agriculture, Statistical Bulletin No. 362 "Conversion Factors and Weights and Measures for Agricultural Commodies and Their Products."

Mixed Liquor - A mixture of activated sludge and waste water undergoing activated sludge treatment in the aeration tank.

pH - A means of expressing the degree of acidity or basicity of a solution, defined as the logarithm of the reciprocal of the hydrogen ion concentration in gram equivalent per liter of solution. Thus at normal temperature a neutral solution such as pure distilled water has a pH of about 7, a tenth-normal solution of hydrochloric acid has a pH near 1 and a normal solution of strong alkali such as sodium hydroxide has a pH of nearly 14.

Raw Milk - Milk as received from the farm or of standardized composition that has not been pasteurized.

Raw Waste Load - Numerical value of any waste parameter that defines the characteristics of a plant effluent as it leaves the plant, before it is treated in any way.

Recirculation Rate - The rate of return of part of the effluent from a treatment process to the incoming flow.

Sanitary Sewer System - A sewer intended to carry waste water from home, businesses, and industries. Storm water runoff sometimes is collected and transported in a separate system of pipes.

Skim Milk - In common usage, skim milk (also designated non-fat, defatted, or "fat-free" milk) from which that fat has been separated as completely as commercially practicable. The maximum fat content is normally established by law and is typically 0.1% in the United States. There is also a common but not universal requirement that non-fat milk contain a minimum quantity of milk solids other than fat, typically 8.25%. In many states the meaning of the term skim milk is broadened to include milk that contains less fat that the legal minimum for whole milk, such as the low-fat sold in the retail market. The term skim milk used in this study refers to non-fat milk.

Sloughings - Trickling filter slimes that have been washed off the filter media. They are generally quite high in BOD_5 and will degrade effluent quality unless removed.

Standard Manufacturing Process (SMP) - An operation or a series of operations which is essential to a process and/or which produced a waste load that is substantially different from that of an alternate method of performing the same process. The concept was developed in order to have a flexible "building block" means for characterizing the waste from any plant within an industry.

Suspended Solids - Particles of solid matter in suspension in the effluent which can normally be removed by settling or filtration.

Waste - Potentially polluting material which is discharged or disposed of from a plant directly to the environment or to a treatment facility which eliminates its undesirable polluting effect.

Waste Load - Numerical value of any waste parameter (such as BOD content, etc.) that serves to define the characteristics of a plant effluent.

Waste Water - Waste-containing water discharged from a plant. Used synonymously with "effluent" in this report.

Whey - By-product in the manufacture of cheese which remains after separating the cheese curd from the rest of the milk used in the process. Whey resulting from the manufacture of natural cheese is termed "sweet whey" and its composition is somewhat different to "acid whey" resulting from the manufacture of cottage cheese. Typically, whey is composed of 93% water and 7% solids, including 5% lactose.

Whole Milk - In its broad sense, the term whole milk refers to milk of composition such as produced by the cow. This composition depends on many factors and is seasonal with fat content typically ranging between 3.5% and 4.0%. The term whole milk is also used to designate market milk whose fat content has been standardized to conform to a regulatory definition, typically 3.5%.

METRIC UNITS

CONVERSION TABLE

MULTIPLY (ENGLISH UNITS) by TO OBTAIN (METRIC UNITS)

ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram-calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555(°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	ton	0.907	kkg	metric tons (1000 kilograms)
yard	yd	0.9144	m	meters

* Actual conversion, not a multiplier

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