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A Study of the Untreated Wastewater Discharges from Five Dairy Plants in the Lower Mainland of British Columbia

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A STUDY OF THE UNTREATED WASTEWATER DISCHARGES FROM FIVE DAIRY PLANTS IN THE LOWER MAINLAND OF BRITISH COLUMBIA

by

G. Thompson

Environmental Protection Branch
Environmental Protection Service
Pacific Region

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LIST OF ABBREVIATIONS

BOD_5	five-day biochemical oxygen demand
TOC	total organic carbon
COD	chemical oxygen demand
T. Alkalinity	total alkalinity
NO_3	nitrates
NH_3	ammonia
$T.PO_4$	total phosphates
TR	total residue
TVR	total volatile residue
NFR	non-filterable residue
T.Cu	total copper
T.Mg	total magnesium
T.Pb	total lead
T.Zn	total zinc
T.Cr	total chromium
T.Hg	total mercury
HNO_3	nitric acid
H_2SO_4	sulfuric acid
Conc.	concentrated
cc	cubic centimetre
96 hr. LC_{50}	96 hour bioassay test (lethal concentration)
mg/ℓ	milligrams per litre
°C	degrees Celsius
°F	degrees Fahrenheit
CIP	clean in place
HTST	high temperature short time
GF/C	Glass Filter type C
IBC	International Biophysics Corporation
LAS	linear alkylate sulfonate
nm	nanometer

CONCLUSIONS

1. The untreated effluent from the five dairies studied is acutely toxic as indicated by the 96 hour LC_{50} values presented in Table 15.

2. The toxicity of the effluent as determined using the 96 hour LC_{50} toxicity test is due in part to low dissolved oxygen concentrations in the test vessels. The low dissolved oxygen concentration resulted from high levels of oxygen demand material in the effluent samples.

3. The effluent from the five plants studied is subject to wide variations in volume, strength and pH as shown in Tables 8 to 12.

4. The wastewater load could be reduced if products such as whey and curd wash were dried rather than discharged to the wastewater line and if dry cleanup was used more frequently.

5. The fluctuation of pH and wastewater strength could be lessened if spent detergents and similar discharges were stored and released slowly over a 24 hour period rather than in batch discharges.

1 INTRODUCTION

There are eleven large dairy plants in the Lower Mainland of British Columbia, five of which were studied in this report. This study was carried out in order to gather information on the characteristics of the wastewater generated by dairy operations. The information obtained will be useful in developing regulations and guidelines pertaining to the wastewater discharges from all dairy operations in Canada.

Dairies produce a wide range of products, including: several grades of fluid milk; cream cheeses and other culture products; ice creams, frozen desserts, and other frozen products; and powdered and condensed milk. No single plant studied in this report produces all of these products but each plant produces at least two of them. Table 1 outlines the final products, raw products, daily and annual quantities of raw products used, average monthly water consumption, treatment facilities, and the wastewater receiver for each dairy studied.

The type and amount of raw and final product varies considerably as does the water consumption and the resultant wastewater volume. Excess raw or partially processed products are usually shipped to other dairy plants for processing. The raw milk is often received on a non-operating day since some dairies receive milk seven days a week but only operate five or less. Consequently, most dairies have refrigerated milk storage facilities where the milk can be stored for up to 100 hours, although it is rarely held for more than 48 hours.

Only one dairy considered in this report has a secondary treatment facility and the discharge from it is released into a freshwater course. The other four plants have only preliminary treatment facilities and they discharge to municipal sewers which empty into one of several sewage treatment plants offering a minimum of primary treatment. The data presented in this report represents the analysis of the untreated effluent from each plant.

The dairies studied in this report were chosen on the basis of the following criteria: (1) size and accessibility of the dairy plant, (2) type of raw and final products handled, (3) accessibility of sampling points, and (4) the operational techniques employed in the plant. The five plants chosen represent a cross-section of the various dairy plant operations and processes employed in British Columbia.

1.1 General Dairy Plant Operations

A flow sheet showing general dairy operations is presented in Figure 1. There are many variations to the procedure described, depending on the types of raw materials handled, the final products made, and the age of the plant.

The dairy production line begins with the arrival of the milk via refrigerated tanker trucks. Milk cans are no longer used to transport milk at any of the dairies studied in this report. This milk is pumped from the trucks into refrigerated storage silos where it is normally held for 10 to 30 hours at a temperature between 0° - 4.5°C (32° and 40°F), but it may be stored for up to 100 hours during some periods. From the storage tanks, the milk is pumped to the HTST pasteurizer. The HTST process involves raising the temperature of the milk in two stages to 74°C (165°F), holding at this temperature for 16 seconds, and rapidly cooling the milk. At some point before the cooling is complete, the milk is passed through a centrifugal clarifier (standardizing clarifier) for cream, milk, and sludge separation. The milk and cream are then recombined to the required butterfat concentrations and homogenized. The sludge, which contains leucocytes bacteria and other undesirable material, is discharged to the wastewater line. The milk and cream then proceed to a point where they are further processed or made into secondary products. The finished products are stored at appropriate temperatures until they are shipped.

Sour cream, yogurt, buttermilk, and cottage cheese production all require either a culture or enzyme addition to cream or skim milk. To obtain the desired results, the enzyme or culture activity is limited by controlling the temperature and pH. The end products are mixed with flavourings, thickeners, or other additives and then packaged.

Ice cream and related products are made in many grades, types, and flavours. The liquid milk or cream is fortified to the desired solids and butterfat concentration, then pasteurized, flavoured, aerated, packaged, and frozen. Most of the ice cream is put into containers of various capacities, while a lesser proportion is made into frozen products such as Revels and Drumsticks. These products are sold through grocery stores and similar retail outlets. Some dairy plants also sell bulk ice cream and ice cream mix to restaurants, ice cream parlours, and similar retail outlets.

There are many other minor products produced in dairies, such as Popsicles, juices, and eggnog, and although these products make some contribution to the wastewater loading, it is relatively insignificant and will not be considered further in this report.

In all plants considered in this report, a CIP system is used. This is a system where the various cleansing solutions and rinses are released to the equipment to be cleaned by a programmed central control.

At the end of each production operation, the necessary pipes and hoses are connected and the various clean-up solutions are pumped through the equipment. The cleansing solutions are usually recirculated and are discharged on an irregular basis. However, the final rinses are discarded after each clean-up operation.

In some plants there are more than one of these units and in others the CIP system is used together with less automated clean-up methods, where some of the equipment is disassembled, cleaned, then reassembled for use.

In most plants the clean-up operations are carried on continuously throughout the day, but there is usually an increase in clean-up activity during the evening and night shifts (after 4:00 p.m.).

1.2 Sources of Wastewater

The principal sources of contaminated wastewater from dairies are spills from the production line and storage areas to the floor drains, clean-up operations, and in some instances the whey from the production of cottage cheese. The sludge from the clarifier also accounts for some of the wastewater loading.

The floor drains pick up contaminants from many sources, including ruptured product and ingredient containers, conveyor belt lubrication and overflow or spillage from processing machinery. In most cases these wastes are washed down the drains and only rarely is dry clean-up attempted.

In addition to the floor wash, the production equipment storage tanks and vats and the tanker trucks are washed during or at the end of the day and these cleaning operations result in large volumes of contaminated wastewater.

In some dairy plants where cottage cheese is produced, the whey and the curd wash are discharged. The whey, the fluid portion of the milk, is a high strength waste and if discharged, contributes high levels of nitrogen and phosphorus compounds, suspended and total solids, and BOD_5 and COD.

TABLE 1 DAIRY PLANT DESCRIPTION

	PLANT A	PLANT B	PLANT C	PLANT D	PLANT E
Product	Fluid Milk and Cream, Yogurt, Ice Cream, Sour Cream and Puddings	Fluid Milk and Cream, Yogurt and Cottage Cheese	Ice Cream Products	Canned Evaporated Milk	Condensed Skim, Powdered Skim, Cottage, Cheese, Powdered Whey, Butter
Type of Raw Products Received	Unprocessed Milk	Unprocessed Milk	Cream, Butter, Powdered Milk, Condensed Milk	Unprocessed Milk, Cream, Skim Milk	Unprocessed Milk, Cream
Average Daily Raw Products Utilized during Sampling Period (lbs)	744,200	477,500	57,300	208,800	218,000
Approximate Annual Milk Products Rec'd for Processing (lbs)	219,000,000	113,500,000	2,090,000	78,350,000	9,926,000
Average Monthly Water Consumption Based on 1975 Municipal Records (Imperial Gallons)	12,692,887	1,391,599	231,406	-	-
Treatment Facilities	Grease Trap	Grease Trap	Grease Trap	Grease Trap	Primary and Secondary Treatment
Wastewater Receiver	Municipal Sewer	Municipal Sewer	Municipal Sewer	Municipal Sewer	Receiving Water Stream
Comments	Milk is received 7 days a week but production occurs only 5 days a week. Glass and plastic reusable milk containers are still being used at this plant but these containers will be phased out in late 1976.	The whey from the production of cottage cheese is discharged.	The milk products received at this dairy are all partially preprocessed at other dairies.	Some of the raw products received at this plant are preprocessed at other dairies and some of the raw milk received is forwarded to other dairies.	Whey from cottage cheese production is powdered and sold. Some of the raw milk received is forwarded to other dairy plants.

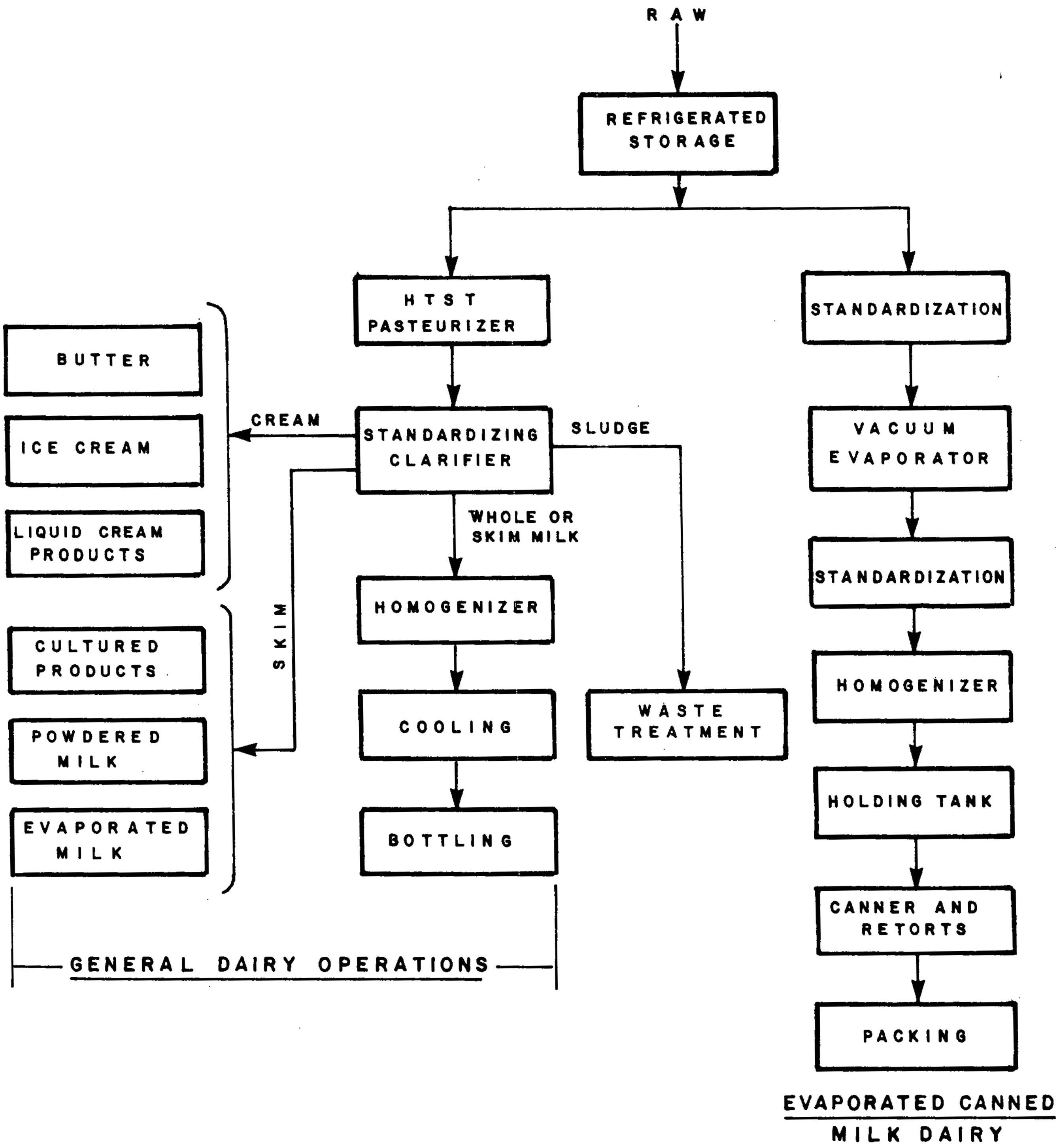

FIGURE I DAIRY PLANT OPERATIONS

2 METHODS AND MATERIALS

2.1 Sampling

Time proportional composite and grab samples were collected throughout the operating day for a minimum of two days at each of the five dairy plants considered in this report. The samples were collected from a point in the effluent line before any treatment was carried out.

The aliquots for the time proportional composite sample were taken every hour of the operating day and placed in a 40-gallon plastic barrel. At the end of each operating day, the composite sample was mixed thoroughly and divided into the portions necessary for the analysis of each parameter. Each portion was placed in the appropriately sized glass or plastic container and preserved as outlined in the Environment Canada Sampling Handbook.[1] Table 2 describes the size and type of container used and preservation technique employed for each analysis performed on the composite and grab samples obtained.

At each plant on one day of the program a series of grab samples were also taken at regular intervals of one or two hours depending on the plant. The samples collected were analyzed for pH, biochemical oxygen demand, residues, and nutrients. The sample containers and preservation techniques were the same as those used for the composite samples discussed previously.

Grab samples were also taken for oil and grease analysis at irregular intervals throughout each operating day and the results of the analysis of these grab samples are presented as a daily average.

At the end of each operating day, the samples for chemical analysis and bioassay determination were transported to the appropriate Environment Canada laboratory facility. Analytical determinations were carried out as outlined in the Environment Canada Laboratory Manual.[2]

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1 Environment Canada, Pacific Region, Pollution Sampling Handbook, Revised, January, 1976

2 Environment Canada, Pacific Region, Laboratory Manual, Revised

2.2 Analysis

An explanation and a brief description of the laboratory analysis procedure for each of the parameters noted in Table 2 follows. A more detailed description of the analysis methods is available in the Environment Canada Laboratory Manual.[1]

a) pH is a measure of the H^+ ion concentration. The pH scale is a series of numbers which express the acidic or basic properties of a solution. Numbers above seven indicate increasing basic conditions with increasing numerical value. Numbers below seven indicate increasing acidic conditions with decreasing numerical value. pH 7 is neutral.

   All pH values quoted in this report were the results of measurements taken with a Fisher 401 Accumet pH meter with a precision of ± .02 pH units under normal operating conditions.

b) The five-day biochemical oxygen demand determination measures the quantity of oxygen required for the stabilization of organic matter by micro-organisms within a period of five days at a temperature of 20°C. The BOD_5 test gives an indication of the amount of oxygen that will be consumed during the decomposition of the biodegradable portion of the sample.

   The sample to be analyzed was first neutralized to a pH range of 6 to 8.5. Any known toxins in the sample were also neutralized and then at least three different dilutions were prepared. The dilution water was treated with buffer solutions prior to the test. An initial dissolved oxygen concentration reading was taken on each sample using an I.B.C. 500-051 Dissolved Oxygen Meter and the samples were then incubated at 20°C for five days. At the end of the five-day period, the dissolved oxygen concentration was again measured and the approximate oxygen demand was calculated and reported as the BOD_5 expressed in mg/ℓ. In cases where the results were given as a range, the average

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[1] Environment Canada Laboratory Manual

value was reported. The minimum detectable concentration is 2 mg/ℓ. The precision of this test cannot be assessed.

c) Total organic carbon determination measures the organic carbon concentration of the sample. The TOC results, when compared to the BOD_5 results for a wastewater, give valuable information concerning the characteristics of the organic constituents in the sample.

A Beckman Total Carbon Analyzer Model 915 was used for TOC determinations. For these determinations, the procedure as outlined by the manufacturer for the Model 915 analyzer was followed.

The results are reported as mg/ℓ TOC. The minimum detectable concentration is 1 mg/ℓ and the precision is $\pm$ 1% to 2% or 1 to 2 mg/ℓ, whichever is greater.

d) Chemical oxygen demand is an estimate of that portion of the sample which is susceptible to oxidation by a strong chemical oxidant.

The sample was refluxed in a 50% sulfuric acid solution using potassium dichromate as the oxidizing agent. Mercuric sulfate and silver sulfate were added as catalysts. The excess potassium dichromate was titrated with ferrous ammonium sulfate and the COD was calculated and expressed as mg/ℓ COD.

The minimum detectable concentration is 20 mg/ℓ and the precision is 14 mg/ℓ on a 1000 mg/ℓ COD sample.

e) Total alkalinity in concentrations above background levels gives an indication of the presence of polluting substances and is a measure of the power of a solution to neutralize hydrogen ions. Substances which contribute to alkalinity include the salts of strong or weak bases, and weak acids.

The sample was potentiometrically titrated with 0.02N H_2SO_4 to the methyl orange end point (pH 4.5) and the total alkalinity was computed using tables and reported as mg/ℓ $CaCO_3$.

The minimum detectable concentration is 1 mg/ℓ and the precision is ± 1 mg/ℓ.

f) Surfactants make up 20 to 40% of the active part of detergents and soaps. Anionic surfactants, of which linear alkylate sulfonate is the most widely used, constitute the largest group of surfactants.

The sample was reacted with azure A which forms a blue anionic salt with the surfactant. The anionic salt was extracted with chloroform and the colour intensity was measured spectrophotometrically between 620 and 630 nm and compared with a sodium lauryl sulfate standard. The results were reported as mg/ℓ LAS.

The minimum detectable concentration is 0.05 mg/ℓ and the precision is ± 5%.

g) Nitrates are an indication of the nutrient concentration in a water sample. For the purposes of this report, the concentrations of nitrites and nitrates are combined and reported as nitrates.

The combined nitrite-nitrate concentration was measured using a Technicon Autoanalyzer II with the nitrite manifold following the procedure recommended by the manufacturer. The results were reported as total nitrates in mg/ℓ nitrogen.

The minimum detectable concentration is 0.01 mg/ℓ nitrogen and the precision is ± 2.3%.

h) Ammonia is also an indication of nutrient concentration but the presence of ammonia may also indicate anaerobic activity. Ammonia is toxic to fish, particularly at high pH or under low dissolved oxygen concentrations.

The ammonia concentration was determined using the Berthelot reaction, which produces a blue-coloured compound related to indophenol, when an ammonium salt is added to sodium phenoxide in the presence of sodium hypochlorite. The analysis was then carried out using a Technicon Autoanalyzer II following the procedure recommended by the manufacturer. The results were reported as mg/ℓ nitrogen.

The minimum detectable concentration is 0.005 mg/ℓ nitrogen. No estimate of the precision of the test is available at the time of writing this report.

i) Total phosphates are another indication of the nutrient concentration in a water sample. High phosphate concentrations stimulate and support algae blooms and the growth of weeds. The phosphates themselves are not considered to be a source of toxicity but the depletion of the dissolved oxygen concentration as a result of the degradation of the phosphates could cause toxicity.

The total phosphate concentration was determined by first converting all phosphates to ortho-phosphates by sulfuric acid - persulfate digestion in an autoclave. The digested sample was then analyzed for ortho-phosphates using the Technicon Auto-analyzer II and the procedure outlined by the manufacturer. The results were reported as total phosphate in mg/ℓ phosphorus.

The minimum detectable concentration is 0.01 mg/ℓ. No estimate of the precision of the test is available at the time of writing this report.

j) Total residue refers to the material left in an evaporating dish after the evaporation of the sample.

100 cc of the sample were placed in a dried pre-weighed evaporating dish and evaporated at 90°C. The residue was then heated to 103°C for one hour. The dish was cooled, brought to constant weight and weighed and the increase in weight was used to calculate the TR concentration in the sample and reported as mg/ℓ.

The minimum detectable concentration is 10 mg/ℓ. The precision of this test is approximately $\pm$ 5%.

k) Total volatile residue refers to that portion of the total residue which is lost upon ignition.

The sample was analyzed for total residue and then the residue was incinerated in a muffle furnace at 550°C for 20 to 60 minutes. The evaporating dish was allowed to cool in a dessicator and weighed and this weight was used to calculate the total volatile residue and reported as mg/ℓ.

The minimum detectable concentration is 10 mg/ℓ. No estimate of the precision of the test is available at the time of writing this report.

l) Non-filterable residue is that portion of the total residue retained by a specific filter. NFR is also referred to as suspended matter or suspended solids.

The sample was filtered through a pre-weighed Gooch crucible containing a GF/C filter paper. The crucible was dried at 103°C, cooled, brought to constant weight, and re-weighed. The increased weight was used to calculate the NFR and the results were reported as mg/ℓ.

The minimum detectable concentration is 10 mg/ℓ. No estimate of the precision of the test is available at the time of writing this report.

m) Total Metals - The presence of high concentration of some metals may have serious consequences to the receiving environment. The analysis procedure used to determine the total concentrations of the trace metals in this report is the same for all except mercury.

The samples were digested with nitric acid and then analyzed using a Jarrell-Ash 810 Atomic Absorption Spectrophotometer using a procedure recommended by the manufacturer. The results were reported as mg/ℓ.

The mercury sample was treated with various chemical oxidants to destroy all organic matter. The mercuric ions were converted to mercury, vapourized into a cell, and analyzed using the Jarrall-Ash 810 Atomic Absorption Spectrophotometer and reported as mg/ℓ.

The minimum detectable concentration ranges from .0002 mg/ℓ for mercury to .02 mg/ℓ for lead and chromium. The precision is $\pm$ 1/2 the minimum detectable concentration.

n) Oils or petroleum ether extractable material may cause toxicity in fish by coating or plugging the gill membranes. Water soluble substances in the oils may also be toxic to fish and other aquatic organisms..

Oil and grease analysis was carried out in the following manner. The acidified sample was filtered and the residue dried. The oils and greases were extracted from the dried, filtered material using a Soxhlet extractor and petroleum ether solvent. The solvent was evaporated at 90°C, leaving the oils residue which was weighed and the results were expressed as mg/ℓ petroleum ether extractable oil.

The minimum detectable concentration is 5 mg/ℓ.

o) The static fish bioassay gives an approximate value of the biological toxicity of an effluent. It can be defined as the concentration or level of a measurable lethal agent required to kill the 50th percentile in a group of test organisms over the time period of 96 hours.

The bioassay test consisted of a series of 30 litre, all-glass test vessels containing different sample dilutions.. Samples where the pH value did not fall within the range of pH 6 to pH 8 were neutralized to approximately pH 7. The test vessels were placed into a controlled environment room where the temperature was maintained at 13° $\pm$ 1°C and the photo period was limited to 16 hours per 24 hours. The samples were continuously aerated throughout the 96 hour test period with oil-free compressed air. Eight to 10 underyearling Rainbow Trout (Salmo gairdnere) were placed in each test vessel. The fish-loading density in each test vessel did not exceed 0.60 grams of fish per litre of test water. The fish mortality versus sample dilution for each test vessel was plotted on a graph and a 96 hour LC_{50} was established.[1]

It is impossible to assess the precision or the accuracy of this test.

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[1] See bioassay records, Bioassay Laboratory, Environmental Protection Service, Pacific Region

TABLE 2   SAMPLE CONTAINERS AND PRESERVATION METHODS

	TYPE OF CONTAINER	PRESERVATION
pH BOD_5	1000 cc wide-mouth hard plastic bottle	temperature maintained at approximately 45°F
TOC	500 cc narrow-mouth hard plastic bottle	same as above
COD	100 cc wide-mouth glass bottle	2 drops conc. H_2SO_4
T. Alkalinity	500 cc wide-mouth hard plastic bottle	temperature maintained at approximately 45°F
Surfactant	200 cc wide-mouth hard glass bottle	temperature maintained at approximately 45°F
Nutrients - NO_3-N - NH_3-N - PO_4-P	1000 cc wide-mouth hard plastic bottle	same as above
Residues - TR - TVR - NFR	1000 cc wide-mouth hard plastic bottle	same as above
Metals - T.Cu - T.Mg - T.Pb - T.Zn - T.Cr	500 cc wide-mouth hard plastic bottle	2.5 cc conc. HNO_3 added to sample
Mercury - T.Hg	500 cc wide-mouth hard plastic bottle	2.5 cc conc. HNO_3 added to bottle before sample added
Oils - Petroleum Ether Extractable Material	900 cc wide-mouth glass bottle	2 cc conc. HNO_3 added to sample
96 hr - LC_{50}	Four 5-gallon hard plastic jerry cans	temerature maintained at approximately 40°F

3 RESULTS AND DISCUSSION

3.1 Composite Samples

Tables 3 to 7 outline the data obtained from the analysis of the composite samples collected from each dairy plant. Although the concentration of any one parameter may vary considerably from one day to the next, the variance is not out of line with what would be expected from a dairy operation. The changes that are evident are likely due to minor changes in the production line or other plant operations.

The static bioassay data indicates that the neutralized effluent is toxic to fish. This toxicity could be due to several factors, including high oxygen demand as well as the presence of toxic agents or chemicals. During the bioassay testing, the dissolved oxygen could not be stablized in many of the samples due to the high oxygen demand present. It should be noted that the toxicity would probably be more acute if the samples were unneutralized.

The concentrations of BOD_5, COD, TOC, $T.PO_4$, TR, TVR, NFR, and oils are significantly high when compared to acceptable discharges from other industrial operations. This is especially true considering the large volumes of effluent being discharged. The levels of ammonia encountered could be expected to cause increased toxicity under the conditions of high pH and low dissolved oxygen levels found in most samples.[1] The nitrates would be a concern only if these effluents were being discharged to a confined natural water course. The concentrations of the six metals, anionic surfactants, and total alkalinity are not considered significant.

3.2 Grab Samples

The data presented in Tables 8 to 12 outlines the results of the analysis of the grab samples collected at each dairy plant during one sampling day.

The data indicates very wide variations in the concentrations of biochemical oxygen demand, residues, and nutrients. The pH also

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[1] Water Quality Criteria, California State Water Resources Control Board, 1973.

fluctuates considerably from an acidic to alkaline condition. In addition, at each plant at least one set of grab samples shows a very large increase in concentration of most parameters. The fluctuations are due to operational changes within the plant during production and clean-up shifts and the large surges in concentration are attributed to the dumping of a raw or final product or more likely exhausted clean-up solutions. The fluctuations in the pH are attributed to the various clean-up and sterilizing solutions and rinses employed during clean-up operations.

3.3 Water Consumption

Tables 13 and 14 present the hourly water consumption at Plants A and B based on the readings taken from the municipal meters. This data is not available from Plants D, C, and E because the meters were not operating properly during the sampling period. However, based on information obtained from the plant personnel, it is estimated that Plant C discharges in excess of 20,000 Imperial gallons per day, Plant D discharges in excess of 10,000 Imperial gallons per day, and Plant E discharges in excess of 70,000 Imperial gallons per day. In all five plants studied, the volume of use-contaminated cooling water was insignificant.

The data from Plants A and B shows considerable variation in water consumption throughout the day. These variations in water consumption are attributed to operational changes within the plant. The water consumption is used as an estimate of the waste water flow.

The comparison of the daily water consumption to pounds of milk utilized at Plants A and B (Plant A, 0.547 gallons/pound of milk utilized; Plant B, 0.132 gallons/pound of milk utilized) indicates that Plant B uses water more conservatively than Plant A. The wastewater volumes must be taken into consideration when comparing the composite data obtained from the plants studied in the report.

3.4 Comparison of Composite Data

The calculated average of the composite sample data over the entire sampling period at each dairy plant is presented in Table 15. This data gives an indication of the quality of the wastewater to be expected from the different dairy operations.

Although Plant A appears to have the best quality of effluent, this is only because of the very heavy water consumption at this plant compared to other plants, particularly Plant B which is a similar type of operation. The higher strength of the waste water at Plant B can also be attributed to the fact that Plant B discharges the whey from the production of cottage cheese. Plant A does not produce cottage cheese.

The high concentrations of five-day biochemical oxygen demand and oils at Plant C are to be expected since this plant produces only ice cream, where both the initial materials and final products are very high in butterfat concentrations. The water usage at this plant is more closely controlled than at most other dairies studied.

The five day biochemical oxygen demand, total organic carbon, and residues are considerably lower at Plant D than most others because the plant produces canned, evaporated milk, which is less likely to be spilled from ruptured containers. The processing line is more enclosed as well and consequently less milk enters the wastewater line. The unproportionately high chemical oxygen demand at Plant D is difficult to explain with the information presently available but it is probably due to the discharge of a detergent compound (polyphosphate) from the clean-up operation. Although these products are used at all dairies studied, the estimated water consumption at Plant D is much lower than most and consequently the detergents and other cleaning agents would be far less diluted.

The effluent from Plant E is not unusual but it should be noted when examining the data that this plant produces powdered milk and cottage cheese. The whey and curd wash is not discarded but rather dried and sold. Since most of the final products from this plant are powdered, dry clean-up is used more frequently in this plant than in other dairies studied.

TABLE 3 ANALYTICAL RESULTS FOR 24-HOUR COMPOSITE SAMPLES TAKEN AT PLANT A

	Day 1	Day 2	Day 3	Day 4	Day 5
pH	8.7	7.8	7.3	10.2	10.2
BOD_5 (mg/l)	1350	555	-	1100	620
TOC (mg/l)	547	291	762	551	446
COD (mg/l)	2300	1900	2300	2100	2100
T.Alkalinity (mg/l)	81.2	75.9	148.5	151	149
Anionic Surfactant (mg/l)	-	0.17	0.17	0.32	0.20
NO_3-N (mg/l)	0.26	0.10	0.555	0.14	0.16
NH_3-N (mg/l)	0.68	1.25	1.0	0.63	0.67
T.PO_4-P (mg/l)	31	35	91	40	65
TR (mg/l)	570	660	1300	1200	1100
TVR (mg/l)	470	450	950	940	810
NFR (mg/l)	370	210	370	200	320
T.Cu (mg/l)	0.06	0.06	0.06	0.05	0.07
T.Mg (mg/l)	0.84	0.67	1.19	0.90	0.78
T.Pb (mg/l)	0.03	<0.02	<0.02	<0.02	<0.02
T.Zn (mg/l)	0.20	0.23	0.20	0.13	0.17
T.Cr (mg/l)	0.07	0.07	<0.02	0.04	0.33
T.Hg (mg/l)	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Oils* (mg/l)	190	40	-	91	461
96 hr LC_{50} (%)	24	13.5	13.5	13.5	16.25
Total Water Usage/day (Imp.gal)	429,844	438,579	371,509	376,908	429,158

* The samples taken for Oils Analyses (Petroleum Ether Extractable Material) were collected as grab samples every three hours throughout the sampling period and the results shown represent the average of the eight samples taken each day.

TABLE 4 ANALYTICAL RESULTS FOR 21-HOUR COMPOSITE SAMPLES TAKEN AT PLANT B

	Day 1	Day 2
pH	8.5	10.3
BOD_5 *mg/l	3950	2850
TOC (mg/l)	2959	1826
COD (mg/l)	7600	5600
T.Alkalinity (mg/l)	290	280
Anionic Surfactant (mg/l)	1.1	0.95
NO_3-N (mg/l)	1.3	0.25
NH_3-N (mg/l)	8.3	4.1
T.PO_4-P (mg/l)	75	65
TR (mg/l)	5700	4100
TVR (mg/l)	4600	3400
NFR (mg/l)	530	570
T.Cu*(mg/l)	-	-
T.Mg (mg/l)	-	-
T.Pb (mg/l)	-	-
T.Zn (mg/l)	-	-
T.Cr (mg/l)	-	-
T.Hg (mg/l)	-	-
Oils**(mg/l)	472	108
96 hr LC_{50} (%)	4.2	7.5
Total Water Usage/day (Imp.gal)	65,789	60,800

* Due to a sampling error, no analyses for metals is available for this plant.

** The samples taken for Oils Analyses (Petroleum Ether Extractable Material) were collected as grab samples every three hours throughout the sampling period and the results shown represent the average of the eight samples taken each day.

TABLE 5 ANALYTICAL RESULTS FOR 16-HOUR COMPOSITE SAMPLES TAKEN AT PLANT C

	Day 1	Day 2
pH	9.7	10
BOD_5 (mg/l)	3600	3600
TOC (mg/l)	1870	2808
COD (mg/l)	6200	5900
T.Alkalinity (mg/l)	258	355
Anionic Surfactant (mg/l)	0.15	0.86
NO_3-N (mg/l)	0.6	1.4
NH_3-N (mg/l)	1.3	0.85
T.PO_4-P (mg/l)	40	60
TR (mg/l)	4400	5400
TVR (mg/l)	320	4500
NFR (mg/l)	1500	790
T.Cu (mg/l)	0.17	0.24
T.Mg (mg/l)	2.3	2.0
T.Pb (mg/l)	0.07	0.17
T.Zn (mg/l)	0.24	0.29
T.Cr (mg/l)	<0.05	<0.05
T.Hg (mg/l)	0.0004	<0.0002
Oils* (mg/l)	3400	9500
96 hr LC_{50} (%)	10	10
Total Water Usage/day (Imp.gal)	NOT AVAILABLE	

* The samples taken for Oils Analysis (Petroleum Ether Extractable Material) were collected as grab samples every two hours throughout the sampling period and the results shown represent the average of the eight samples taken each day.

TABLE 6 ANALYTICAL RESULTS FOR 17-HOUR COMPOSITE SAMPLES TAKEN AT PLANT D

	Day 1	Day 2
pH	10.0	11.8
BOD_5 (mg/l)	1300	1100
TOC (mg/l)	854	610
COD (mg/l)	6800	7400
T.Alkalinity (mg/l)	320	7200
Anionic Surfactant (mg/l)	1.6	0.08
NO_3-N (mg/l)	0.4	4.01
NH_3-N (mg/l)	0.96	1.4
T.PO_4-P (mg/l)	63	79
TR (mg/l)	1800	2100
TVR (mg/l)	1200	1200
NFR (mg/l)	18	74
T.Cu (mg/l)	0.06	0.02
T.Mg (mg/l)	5.8	6/2
T.Pb (mg/l)	0.06	0.04
T.Zn (mg/l)	0.08	0.08
T.Cr (mg/l)	0.02	0.02
T.Hg (mg/l)	<0.0002	<0.0002
Oils* (mg/l)	28	73
96 hr LC_{50} (%)	7.5	7.5
Total Water Usage/day (Imp.gal)	NOT AVAILABLE	

* The samples taken for Oils Analysis (Petroleum Ether Extractable Material) were collected as grab samples every two hours throughout the sampling period and the results shown represent the average of the eight samples taken each day.

TABLE 7 ANALYTICAL RESULTS FOR 24-HOUR COMPOSITE SAMPLES TAKEN AT PLANT E

	Day 1	Day 2	Day 3
pH	8.1	11.2	7.8
BOD_5 (mg/l)	3650	1800	2750
TOC (mg/l)	1800	720	1200
COD (mg/l)	5300	2200	3700
T.Alkalinity (mg/l)	350	520	910
Anionic Surfactant (mg/l)	0.12	0.10	0.33
NO_3-N (mg/l)	<0.01	0.55	0.6
NH_3-N (mg/l)	1.5	1.3	0.9
T.PO_4-P (mg/l)	130	45	83
TR (mg/l)	4800	2600	3800
TVR (mg/l)	3900	1600	3000
NFR (mg/l)	850	220	280
T.Cu (mg/l)	0.16	0.16	0.22
T.Mg (mg/l)	6.0	4.4	6.7
T.Pb (mg/l)	0.04	<0.02	0.03
T.Zn (mg/l)	0.23	0.16	0.38
T.Cr (mg/l)	<0.02	<0.02	<0.02
T.Hg (mg/l)	-	<0.0002	0.0004
Oils* (mg/l)	266	37	130
96 hr LC_{50} (%)	7.5	7.5	7.5
Total Water Usage/day (Imp.gal)	NOT AVAILABLE		

* The samples taken for Oils Analysis (Petroleum Ether Extractable Material) were collected as grab samples every two hours throughout the sampling period and the results shown represent the average of the eight samples taken each day.

TABLE 8 ANALYTICAL RESULTS FOR GRAB SAMPLES TAKEN AT PLANT A

Time	pH	BOD_5 mg/l	TR mg/l	TVR mg/l	NFR mg/l	NO_3-N mg/l	NH_3-N mg/l	T.PO_4-P mg.l
0030	6.3	72	360	100	25	0.17	0.26	94
0130	9.9	120	200	45	20	0.19	0.37	13
0430	7.3	-	95	15	20	0.18	0.13	3.8
0530	7.9	42	65	30	20	0.19	0.13	2.5
0630	7.8	45	70	40	20	0.15	0.11	4.8
0730	8.9	288	620	490	35	0.25	0.29	6.0
0830	7.8	18000	9800	9700	5500	1.66	2.8	5.0
0930	7.4	335	340	270	150	0.24	0.43	4.0
1030	9.3	345	250	160	65	0.20	0.30	4.8
1130	6.8	1375	1100	1000	170	0.25	0.78	3.3
1230	6.8	1100	940	870	250	0.12	0.29	3.8
1330	5.2	330	280	160	170	0.18	0.29	38
1430	9.7	735	760	520	1900	0.22	1.3	13
1530	9.5	365	570	450	110	0.22	0.88	10
1630	8.4	1000	800	570	160	0.18	0.90	33
1730	10.3	855	250	200	330	0.15	0.95	24
1830	2.9	250	330	130	80	0.15	0.28	180
1930	2.3	160	1000	310	55	0.14	0.33	480
2030	11.1	7950	1300	1100	1800	0.80	5.1	240
2130	9.9	95	170	110	30	0.18	0.23	10
2230	10.8	615	1810	640	40	0.18	1.40	110
2330	8.9	1300	1900	1600	1100	0.23	1.00	19
Average*	7.9	1685	1043.2	841.4	546.4	0.2832	0.8423	59.18

* Calculated Average

TABLE 9 ANALYTICAL RESULTS FOR GRAB SAMPLES TAKEN AT PLANT B

Time	pH	BOD_5 mg/l	TR mg/l	TVR mg/l	NFR mg/l	NO_3-N mg/l	NH_3-N mg/l	T.PO_4-P mg.l
0700	11.4	570	830	330	440	0.35	0.53	5.5
0800	4.7	4150	5700	5100	1700	0.95	1.1	87
0900	5.9	1275	2200	1900	74	0.38	0.83	36
1000	4.8	2750	3900	3500	1400	0.15	5.5	51
1100	4.8	1940	3400	3000	480	0.10	3.8	14
1200	6.0	975	1400	1200	300	1.3	1.3	20
1300	11.3	1840	2600	1700	320	1.5	2.0	47
1400	8.0	2450	2400	2100	350	1.2	1.0	30
1500	11.3	1950	3200	2000	290	1.4	1.6	44
1600	10.7	540	1000	680	260	1.0	1.8	16
1700	10.0	1350	1600	1400	330	0.70	0.85	17
1800	4.8	15600	26000	23000	960	0.75	45	370
1900	11.1	1120	1400	930	180	0.83	0.88	27
2000	5.2	1770	18000	17000	11000	0.70	5.0	88
2100	4.9	5500	9200	8000	600	0.65	16	160
2200	7.2	520	730	590	45	0.05	0.73	20
2300	12.1	445	1700	490	85	0.55	0.65	55
2400	10.6	300	400	250	32	0.55	0.15	16
0100	11.8	162	1200	290	150	2.1	0.33	13
0200	11.2	126	500	180	77	0.90	0.43	2.7
0300	11.8	206	740	210	72	0.75	0.48	2.9
Average*	8.6	2168	4195	3517	912	0.80	4.28	53.4

* Calculated Average

TABLE 10 ANALYTICAL RESULTS FOR GRAB SAMPLES TAKEN AT PLANT C

Time	pH	BOD_5 mg/l	TR mg/l	TVR mg/l	NFR mg/l	NO_3-N mg/l	NH_3-N mg/l	T.PO_4-P mg.l
0800	9.3	850	1000	700	250	0.30	0.30	0.097
1000	7.7	1100	1700	1200	560	0.43	0.38	0.10
1200	7.5	1350	3100	2600	1200	0.48	0.40	0.11
1400	6.5	3000	4300	3800	1000	0.33	0.50	25
1600	5.7	6900	11000	10500	1200	0.45	1.0	25
1800	10.9	3800	9400	7600	1100	0.55	0.98	160
2000	10.7	4950	7000	3900	850	0.48	1.4	150
2200	10.6	2150	3600	2600	440	0.70	0.75	90
Average*	8.6	3012	5138	4112	825	0.46	0.71	56.29

* Calculated Average

TABLE 11 ANALYTICAL RESULTS FOR GRAB SAMPLES TAKEN AT PLANT D

Time	pH	BOD_5 mg/l	TR mg/l	TVR mg/l	NFR mg/l	NO_3-N mg/l	NH_3-N mg/l	T.PO_4-P mg.l
0700	8.7	200	400	280	79	3.41	0.13	4.4
0800	7.5	195	470	380	16	3.53	0.05	3.3
0900	9.9	1030	1500	1100	130	3.44	0.69	40
1000	10.5	680	1400	780	220	3.16	0.81	68
1100	7.9	100	320	210	70	3.43	0.49	4.5
1200	7.6	420	560	450	14	3.46	1.0	4.3
1300	9.5	150	450	300	270	3.34	0.49	13
1400	9.3	250	430	290	310	3.54	0.40	7.5
1500	9.1	90	640	100	5	3.52	0.26	9.5
1600	11.3	<5	1000	210	72	3.23	0.68	93
1700	7.9	18	210	80	110	3.32	0.64	0.80
1800	10.7	590	1700	390	430	4.03	0.31	29
1900	6.1	350	2800	670	140	3.96	1.1	63
2000	7.9	100	540	220	76	3.84	0.05	4.3
2100	9.6	<5	340	110	54	4.02	0.21	13
2200	12.8	2900	15000	5100	7500	2.96	12	480
2300	7.8	1300	900	740	530	3.45	0.13	7.3
2400	7.1	15000	15000	14000	330	3.00	5.2	120
Average*	9.0	1299	2426	1412	575	3.48	1.37	53.6

*Calculated Average

TABLE 12 ANALYTICAL RESULTS FOR GRAB SAMPLES TAKEN AT PLANT E

Time	pH	BOD_5 mg/l	TR mg/l	TVR mg/l	NFR mg/l	NO_3-N mg/l	NH_3-N mg/l	T.PO_4-P mg.l
0800	11.6	930	1800	800	180	0.50	0.90	24
0900	12.0	445	1900	590	200	0.55	0.97	90
1000	9.6	905	1600	1200	45	0.48	0.64	17
1100	11.3	530	1400	600	130	0.46	0.70	44
1200	4.7	3450	5000	4300	420	0.50	0.75	40
1300	4.4	3700	3100	2500	1400	0.42	2.2	78
1400	4.1	3700	4800	3800	330	0.06	1.9	32
1500	4.3	2600	3200	2700	89	0.20	2.0	100
1600	4.2	2600	2400	2100	1100	0.38	0.12	33
1700	10.5	1300	2300	1400	110	0.23	1.1	50
1800	10.0	1800	2700	1900	150	0.27	0.58	32
1900	9.7	660	980	600	16	0.46	1.6	46
2000	12.5	4000	13000	5200	930	0.49	0.97	140
2100	12.2	50	2300	390	140	0.48	0.78	34
2200	11.6	700	1800	760	210	1.4	7.6	120
2300	11.5	100	960	250	35	0.73	1.6	13
2400	11.8	93	1100	240	200	0.52	1.2	47
0100	11.9	60	1100	190	80	0.50	1.5	63
0200	7.7	4500	6800	5500	550	0.55	0.77	27
0300	6.4	6600	11000	9000	610	0.61	0.20	20
0400	9.8	2200	3400	2700	560	0.62	0.04	4
0500	9.7	58	500	160	60	0.90	3.8	130
0600	6.3	420	570	360	85	1.7	2.6	26
0700	4.7	520	960	660	160	0.90	3.2	17
Average*	8.9	1747	3111	1996	325	0.58	1.57	51

* Calculated Average

TABLE 13 HOURLY WATER CONSUMPTION (IMPERIAL GALLONS) - PLANT A

	Day 1	Day 2	Day 3	Day 4	Day 5
0100	-	12522	13519	8052	11718
0200	9553	9093	11775	7414	10441
0300	8062	7829	10910	7011	9630
0400	8062	8033	10910	7011	9630
0500	12714	11490	11577	9700	11373
0600	11935	13697	12963	10447	14738
0700	22733	15747	15779	15498	17561
0800	11169	18959	15300	13582	17906
0900	21750	21201	14240	16003	19502
1000	25313	20530	16309	20090	18251
1100	14119	21680	19872	22216	22574
1200	20128	22880	17752	18583	19260
1300	21418	22280	16546	19477	20294
1400	24968	23161	20109	20524	20275
1500	20971	21731	19975	19796	23927
1600	27318	21443	19949	18902	19815
1700	19706	23621	17682	19106	21744
1800	23321	27880	14604	19196	21233
1900	19726	16788	14630	18506	21999
2000	16826	16954	15179	15888	20441
2100	27012	20677	16565	17580	19802
2200	22752	25517	14272	19438	19291
2300	22408	18167	10741	17574	21214
2400	17880	16699	10351	15313	16539
Total	429844	438579	361509	376908	429158
Average/Hour	18689	18274	15063	15704	17882

(25% added to correct for 2nd meter head)

TABLE 14 HOURLY WATER CONSUMPTION (IMPERIAL GALLONS) - PLANT B

	Day 1	Day 2
0800	2411	1452
0900	847	1857
1000	1975	1396
1100	2187	2579
1200	2804	1146
1300	3433	2349
1400	2349	2268
1500	2181	2523
1600	2685	1614
1700	3695	2380
1800	6367	7040
1900	4542	5644
2000	2342	941
2100	3775	10460
2200	6504	5208
2300	5320	5158
2400	1258	2860
0100	2716	1283
0200	7738	2156
0300	660	486
Total	65789	60800
Average/Hour	3289	3040

TABLE 15 AVERAGE COMPOSITE SAMPLE ANALYSIS OVER ENTIRE SAMPLING PERIOD AT EACH DAIRY

	Plant A	Plant B	Plant C	Plant D	Plant E
pH	8.4	9.4	9.8	10.9	9.0
BOD_5 (mg/l)	906	3400	3600	1200	2733
TOC (mg/l)	519	2392	2339	732	1240
COD (mg/l)	2140	6600	6050	7100	3733
T.Alkalinity (mg/l)	121	285	306	3760	593
Anionic Surfactant (mg/l)	0.22	1.02	0.51	0.84	0.18
NO_3-N (mg/l)	0.24	0.78	1.0	2.2	0.39
NH_3-N (mg/l)	0.85	6.20	1.08	1.18	1.23
$T.PO_4$-P (mg/l)	52	70	50	71	86
TR (mg/l)	966	4900	4900	1950	3733
TVR (mg/l)	724	4000	2410	1200	2833
NFR (mg/l)	294	550	1145	46	450
T.Cu (mg/l)	0.06	-	0.205	0.04	0.18
T.Mg (mg/l)	0.88	-	2.2	6.0	5.7
T.Pb (mg/l)	<0.02	-	0.12	0.05	0.03
T.Zn (mg/l)	0.09	-	0.26	0.08	0.26
T.Cr (mg/l)	0.11	-	0.05	<0.02	<0.02
T.Hg (mg/l)	<0.0002	-	<0.0002	<0.0002	0.0003
Oils (mg/l)	195	290	6450	50	144
96 hr LC_{50} (%)	16.2	5.8	10	7.5	7.5
Avg. Water Usage/day (Imp.gal)	407,200	63,294	NOT AVAILABLE		

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