United States
Environmental Protection
Agency

Industrial Environmental Research
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Cincinnati OH 45268

EPA 600 2-78-203
September 1978

Research and Development

Reuse of Treated Fruit Processing Wastewater in a Cannery

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EPA-600/2-78-203
September 1978

REUSE OF TREATED FRUIT PROCESSING WASTEWATER IN A CANNERY

by

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Grant No. S803280

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly efficient pollution control methods be used. The Industrial Environemental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This document reports the results of two years of investigation of the reclamation and reuse of fruit processing wastewater in a fruit cannery. The conclusions contained herein are applicable to wastewater reclamation and reuse in plants producing high acid processed foods in hermetically sealed containers. They may be of limited applicability for plant operators producing low acid hermetically sealed processed foods or frozen processed foods.

The conclusions and recommendations have been reviewed by technical staff members of the U.S. Environmental Protection Agency's Health Effects Research Laboratory and Industrial Environmental Research Laboratory (Food and Wood Products Branch), the U.S. Department of Agriculture Food Safety and Quality Service's Fruit and Vegetable Quality Division, the U.S. Department of Health, Education and Welfare Food and Drug Administration's Division of Food Technology, and the Western Research Laboratory of the National Food Processors Association. These groups concur with the publication of the conclusions and recommendations presented in this report.

Further information may be obtained from the Food and Wood Products Branch of the Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio, 54268.

David G. Stephan
Director
Industrial Environmental Research Laboratory
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ABSTRACT

The Snokist Growers' Cannery at Yakima, Washington, has conducted a 2-year investigation of processing wastewater reclamation and reuse. Snokist's wastewater is generated from processing approximately 250 metric tons (kkg) of pears or peaches per day during a 9-to 12-week season beginning the last week in August, and 100 to 150 kkg of apples per day during a 10-to 15-week season beginning in October. The seasons overlap slightly. No sanitary wastes enter the processing wastewater, which is treated by screening and an activated sludge system. The treatment system was installed in 1968 with direct discharge to the Yakima River. The effluent consistently meets the Cannery's discharge permit, which was based on U.S. Environmental Protection Agency (EPA) guidelines for 1977.

Reclamation of the biologically treated effluent by filtration through mixed media pressure filters and disinfection with chlorine was investigated for two processing seasons. The reclaimed water was put to several trial uses: (a) initial product conveying, (b) equipment, floor and gutter wash, (c) direct contact container cooling, and (d) boiler feed. Steam generated from the reclaimed water was used on a trial basis for equipment cleaning, exhausting, cooking and blanching. No degradation of the product was produced as a result of reclaimed water use during these trial runs.

The cannery wastewaters and the biological treatment system were monitored during the study period for comparison with results from a 1967-1968 evaluation. Unit waste emission rates for flow, COD, and BOD from the cannery were lower than during the earlier study because of more efficient in-plant controls. The biological treatment system performance was approximately equivalent to that observed earlier except that the endogenous respiration rate of the biological sludge was lower. The treatment system was influenced adversely by chlorine discharges from the cannery cleaning operations during portions of both the 1975 and 1976 seasons.

The reclaimed water turbidity was consistently maintained at 15 nephelometric turbidity units (NTU) or less during the 1976 processing season through the end of pear processing except for 1-week of biological treatment system upset caused by chlorine toxicity. Overall during the 1976 season, 20 NTU or less was maintained 87% of the time including extreme cold weather periods. During 74% of the 1975 processing season, 20 NTU or less was maintained in spite of recurring chlorine discharges that caused mild upset to the activated sludge system for much of the season. Disinfection to less than 1-total coliform per 100 ml and less than 500 total aerobic bacteria per ml (total plate count) was consistently achieved by chlorination to 3 mg/l residual chlorine or greater with detention time at approximately 1 hour. Cost for the wastewater reclamation will be approximately 20 cents per cubic meter including capital costs. Snokist Growers' Cannery wastewater discharge reduction will be over 50% at full utilization of the reclaimed effluent in the areas of cooling, initial product conveying and floor and gutter wash. The EPA BATEA effluent guidelines can be achieved during peach and pear processing, but may not be met during apple processing.

This report was submitted in fulfillment of EPA RD&D Grant S 803280 by Snokist Growers. The project was conducted under partial sponsorship of the U.S. Environmental Protection Agency. The report covers the period of October 1974 through May 1977 when investigations were completed.

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ACKNOWLEDGMENTS

This study was conducted by Snokist Growers of Yakima, Washington at their cannery and cannery wastewater treatment facilities. Mr. Frank Coleman, General Manager, and the Board of Directors for Snokist Growers, are acknowledged for their recognition of the need to investigate reclamation as an alternate source of water supply and a means for pollutant discharge reduction. The project director for this study was Mr. Jule Graff. Mr. Mel Christenson and Mr. Darwin Finch, cannery Manager and Assistant Manager, respectively, coordinated the study with cannery operations. Mr. Don Peterson directed construction necessary for the in-plant distribution of the reclaimed water and for its in-plant control.

Mr. Herb H. Hart, Director of Pollution Control at Snokist Growers Cannery managed the treatment system operations and data collection. He was assisted in the laboratory by Mrs. Nina Wright, Mrs. Jeanne Rippy, Mrs. Veatrice Jossi, Mr. Dave Bybee, Miss Steva Ames, Mr. Ken Hegland and Mrs. Sharon Hill.

Dr. Larry A. Esvelt of Esvelt Environmental Engineering was Principal Investigator for this project. During project and facilities design, he was employed by Bovay Engineers, Inc.

Mr. Harold W. Thompson of EPA's Food and Wood Products staff, Corvallis, Oregon, was the project officer. He, Mr. Ken Dostal, and Dr. Martin Knittel of the EPA Corvallis staff are acknowledged for their technical assistance.

The National Food Processors Association, Western Research Laboratory, provided assistance in the form of heavy metals analysis, organoleptic evaluations and product grading during the course of the study. Additional outside analysis were performed by the Region X EPA laboratory in Seattle, by Foremost Foods laboratory in Dublin, California, by Columbia Laboratories, Inc. of Corbett, Oregon, and by Dohrmann Corporation of Santa Clara, California.

Mountain States Construction Company of Sunnyside, Washington, constructed the effluent polishing facilities. The pressure filter system was provided by Neptune Microfloc, Inc. Chlorination equipment was provided by Wallace and Tiernan, Inc. Pumps were provided by Aurora.

A Technical Advisory Committee reviewed the work plan and progress of this project. The committee consisted of:

- Mr. David A. Patton, Acting Director, U.S.D.A. Fruit and Vegetable Quality Division
- Mr. Herbert R. Pahren, P.E., Physical Science Administrator, EPA Health Effects Research Laboratory
- Dr. Reginald L. Handwerk, FDA Fruit and Vegetable Products Branch, Division of Food Technology
- Mr. Allen Katsuyama, National Food Processors Association, Western Research Laboratory
- Mr. Harold W. Thompson, P.E., Project Officer, EPA IERL Food and Wood Products Branch
- Mr. Herbert H. Hart, Project Manager, Snokist Growers
- Dr. Larry A. Esvelt, P.E., Principle Investigator, Esvelt Environmental Engineering

SECTION 1

INTRODUCTION

PURPOSE

This study was conducted to establish the technical and economical feasibility of reusing treated processing effluent from a cannery to supplement or replace a portion of the raw water supply. This report describes the results of treatment of fruit processing wastewater for reclamation and reuse. The quality of the reclaimed effluent and the results of pilot reuse studies within a fruit cannery are reported. These investigations were aimed at establishing parameters for reclaimed water quality and determining suitable uses within the fruit processing cannery for the reclaimed waters. These results may be used to determine whether reclamation and reuse projects are economically and technically viable at other locations for supplementing limited water supplies and/or reducing the quantity of wastewater and pollutants in discharges from food processing plants.

The purpose of this project was to supplement the water supply of the Snokist Growers' cannery by reclaiming processing wastewater so limitations on groundwater withdrawal for the cannery would not limit their fruit processing capabilities. The project will also reduce effluent emission rates with Snokist Growers' cannery to the Yakima River and result in water quality improvements, especially during low flow periods.

Processing wastewaters from Snokist Growers' fruit cannery contain no sanitary wastes. Treatment is by a biological treatment system (activated sludge). This project evaluated polishing of the biological effluent with multi-media filters and disinfection for reclamation and reuse in the cannery. Uses within the cannery included fairly continuous floor and gutter wash and pilot use for equipment wash down, steam generation and direct contact container cooling.

Evaluation of reclaiming and reusing the cannery's treated processing effluent was predicated on historically low suspended solids levels. A low suspended solids level is necessary for reuse to allow adequate disinfection and to prevent contamination of equipment or product by foreign materials. Both turbidity and suspended solids of the reclaimed water were monitored during this study to determine its suitability for reuse.

It is essential to have a water of good bacteriological quality for use in a cannery. Thus one of the most important criteria for reclamation of a wastewater is the capability for producing a good quality water from a bacteriological standpoint. Organisms of interest include those which can damage the product, cause failure of the product or its packaging during storage and those organisms which can transmit disease. Since disease transmitting organisms (pathogens) occur in extremely low densities even in poor quality water, indicator organisms, more numerous in quantity, are measured to indicate potential threat from these pathogens. Indicator organisms normally used are of the coliform and fecal coliform groups. Total bacteriological content of waters for cannery use is also of interest since many other types of bacteria can cause problems with a product or its packaging during storage. Total coliform organisms, fecal coliform organisms and total bacterial plate count were used as indicators of bacteriological quality for the reclaimed water for this study. Their removal was used as an indication of disinfection performance in the treatment system.

OBJECTIVES

The project was divided into two phases. The first phase evaluated the feasibility of reusing treated process wastewater within the processing plant. Phase one is reported in this document. Phase two which has not been initiated to date would be the commercial demonstration of reusing the treated wastewater in those areas found feasible during phase one. The specific phase one objectives were as follows:

1. To determine the feasibility of fruit processing wastewater treatment to achieve a water quality suitable for reuse; and to develop operational procedures to insure consistant performance of the treatment system.

2. To determine the feasibility of reusing the treated processing wastewater for:

    A. Equipment cleaning;

    B. Product cleaning and conveying;

    C. Boiler feed to produce steam for:

        (1) Cleaning,

        (2) Exhausting,

        (3) Cooking,

        (4) Blanching; and

D. Direct contact container cooling.

3. To document the reduction of pollutants being discharged to the environment resulting from reuse of treated processing wastewater; and evaluate the economics of wastewater reuse for achieving EPA's 1983 effluent standards.

Phase two objectives if undertaken, would be to demonstrate on a commercial scale and continuous production basis, the reuse of treated wastewater in areas determined feasible during phase one.

TECHNICAL ADVISORY COMMITTEE

A Technical Advisory Committee representing various agencies interested in wastewater reuse in the food processing industry was formed to review the work plans, project activities and finally the conclusions and recommendations. The committee members were charged with representing the interests of their agencies during the project and with reviewing and making recommendations for the project Conclusions and Recommendations to allow their endorsement by the agencies. The committee consisted of:

Mr. David A. Patton representing the U.S. Department of Agriculture Food Safety and Quality Services' Fruit and Vegetable Quality Division,

Mr. Herbert R. Pahren representing the Environmental Protection Agency's Health Effects Research Laboratory,

Dr. Reginald L. Handwerk representing the U.S. Department of Health, Education and Welfare Food and Drug Administration's Division of Food Technology,

Mr. Allen Katsuyama representing the National Food Processors Association's Western Research Laboratory,

Mr. Harold W. Thompson, Project Office representing the EPA Industrial Environmental Research Laboratory's Food and Wood Products Division,

Dr. Larry A. Esvelt, Principle Investigator, and

Mr. Herbert H. Hart, Project Manager representing Snokist Growers.

BACKGROUND

Snokist Growers is a grower's cooperative located in the Yakima valley of Washington. The cooperative operates a fruit cannery near Yakima to process pears, apples, peaches, plums, crab apples, cherries and other products of the growers. The principle annual pack consists of canned pears and canned apple products. During a typical season, the cannery processes approximately 250 metric tons (kkg) of pears per day for about two months, about 250 kkg of peaches per day for about one week, and 100 to 150 kkg of apples per day for two to four months. Cherries, plums and crab apples are processed for limited periods during the season.

For several years prior to 1966, Snokist Growers was subject to increasing pressure from regulatory agencies to upgrade the quality of wastewater discharged to the Yakima River. In 1967 the cannery constructed an aerated lagoon treatment facility. In 1968 it was upgraded to an activated sludge treatment system with capability for limited sludge reaeration. These facilities were evaluated under a Federal Water Pollution Control Administration Research, Development and Demonstration Grant. The results were highly gratifying and were made available through the literature to processors throughout the United States, Canada and the rest of the world for application on similar wastewaters.[1,2,3] The activated sludge system was effective in reducing BOD and suspended solids levels in the processing effluent on an efficient and consistent basis. Snokist Growers' cannery wastewater treatment system was selected as being exemplary during the development of guidelines for best practicable technology for wastewater treatment according to provisions in the Federal water quality amendments of 1972 (Public Law 92-500).[4,5]

The wastewater treatment system performed adequately from 1968 to 1973 and consistently produced a very clear effluent. In 1973 Snokist Growers began consideration of reclaiming and reusing the treated effluent in the cannery. The consideration was prompted by a low water year in the northwest and a decreasing water table in the vicinity of the plant. The ground water level decrease resulted in one of the cannery's three wells becoming unuseable and cannery personnel became concerned about the integrity of the remaining two wells in the water supply system. An investigation of the feasibility of an additional well versus reclaiming a portion of the biological treated process effluent for use in the cannery indicated that the lower cost alternative was development of a new well supply. Results of the feasibility analysis and the fact that Snokist was considering reclaiming effluent, reached EPA officials in charge of evaluating the possibility of reducing food processing wastewater emissions through reclamation and reuse in compliance with the goals of Public Law 92-500 for limitation of pollutant discharges.

The national pollutant discharge elimination system administered by the EPA and by the States, requires that the discharge of pollutants from a processing plant be limited to a certain quantity per unit of product processed. The emission quantities recommended allowable for fruit processing wastewaters were developed and presented for two stages of implementation. The first stage intended for implementation by July 1, 1977, was mandated to be "best practicable control technology currently available" (BPCTCA). The second stage developed for implementation by July 1, 1983, is to be the "best available technology economically achievable" (BATEA). Limitations on emission rates for these two levels of technology were developed for each fruit processed and presented in the development documents for proposed effluent limitation guidelines and new source performance standards.[4,5]

Research, Development and Demonstration (RD&D) funds were appropriated by Congress to assist in developing technology for reduction of pollutants. The possible availability of these funds induced Snokist Growers to submit an application for the funds which would overcome the economic disadvantage of wastewater reclamation and reuse when compared with the alternative of a new well water supply. An EPA RD&D Grant S803280 was awarded in late 1974, for the investigation of reuse of treated fruit processing wastewater within the cannery. The grant allowed for payment of a fee to Snokist to partially offset the cost differential between wastewater reclamation and reuse and the alternative solution to their water supply problem, providing a new well. In addition, the investigative activities and operating cost for the reclamation system during the grant period were to be covered by the grant.

SECTION 2

CONCLUSIONS

The study of Snokist Growers' Cannery wastewater treatment, reclamation and reuse has resulted in the conclusions contained in this Section. In considering the widespread application of technology based on these conclusions, it must be remembered that they are applicable to treatment and reclamation of a fruit processing wastewater with no sanitary wastes, and reused in areas of processing high-acid (fruit) products preserved by heat treatment for storage in hermetically sealed containers. Since high-acid products inherently inhibit the growth of many microorganisms, caution should be exercised in application of these conclusions to any other class of food, such as low-acid canned foods and foods not subjected to a terminal thermal process. These conclusions must not be considered applicable to any wastewater containing sanitary wastes.

Conclusions have been divided into two categories, those relating to the feasibility for reuse of Snokist's fruit processing wastewater, and those relating to the processing wastewater and its treatment. Conclusions in the first category, reuse feasibility, have been reviewed and approved by members of the technical advisory committee for the project and their organizations: The EPA Health Effects Research Laboratory; the EPA Industrial Environmental Research Laboratory; the FDA Food Technology Division; the USDA Food Safety and Quality Service; and the National Food Processors Association Western Research Laboratory.

FEASIBILITY OF WASTEWATER REUSE

1. Snokist Growers biologically treated wastewater can be polished by filtration and disinfected by chlorination to a quality suitable for reuse within their cannery, except during periods of high suspended solids discharge from biological treatment.

2. The lack of consistency and the potential for equipment malfunctions requires that continuous monitoring of reclaimed water quality be sufficient to provide cannery operating personnel with early warning of deterioration. Residual chlorine monitoring at two points, turbidity monitoring of the reclaimed effluent and low chlorine residual and high turbidity alarms at

strategic locations in the cannery are necessary to allow the conversion to alternate water supplies for key cannery processes in the event of effluent quality deterioration.

3. Based on this study, neither the quality nor the safety of the final product is adversely affected by the use of reclaimed processing wastewater. Specific uses evaluated were equipment cleaning in the initial processing area, raw product conveying, container cooling and boiler feed for steam generation. Steam generated from the reclaimed water was used for equipment cleaning in the initial processing area, exhausting, cooking and blanching. Monitoring for volatile organics in the steam and product was not conducted so reclaimed water steam use for exhausting, cooking and blanching cannot be concluded as acceptable.

4. Toxic constituents tested for were not present in the reclaimed effluent in concentrations sufficient to cause public health concern for the final products. Heavy metals were at or below primary drinking water standard maximum permissable concentrations. Pesticides were undetectable or below primary drinking water standard levels. Halogenated organics were below levels found in many drinking water supplies. No buildup of these toxicants in the system with extended reuse was apparent at the testing schedule conducted although added testing would be desirable to confirm these results.

5. The reclaimed wastewater is suitable for full scale continuous use for initial raw product conveying, washdown of equipment in the initial processing area of the cannery (excluding peelers and peeled product conveyors), floor and gutter washdown and direct contact container cooling when the quality is maintained equal to:

Suspended solids $\leq$ 30 mg/l,

Turbidity $\leq$ 20 NTU,

Total coliform $\leq$ 1 organism/100 ml,

Fecal coliform $\leq$ 1 organism/100 ml,

Total plate count $\leq$ 500/ml.

6. The reclaimed effluent is suitable for continuous full scale boiler feed except that COD and dissolved oxygen were higher than recommended levels. When the suspended solids are higher in the reclaimed effluent than in the house tap water, it may be less desirable for this use because of potential solids buildup in the ion exchange boiler feed water treatment system. Use of the generated steam may be restricted to areas where it would not directly contact the product due to the

unknown extent of concentration of volatile organics into the steam.

WASTEWATER QUALITY AND TREATMENT

1. The cannery pollutant unit emission rates were lower during this study than during the 1967-68 period, primarily due to in-plant water use reduction and to preventing waste solids (cores, peels) from contacting the wastewater.

2. Biological treatment performance is keyed to sufficient nutrient (nitrogen and phosphorus) addition, control of chlorination practices in the cannery and adequate aeration, sludge return and clarification capacity.

3. Biological treatment kinetics during this study were comparable to those observed during 1967-68: COD and BOD soluble effluent concentrations were a function of the removal rate per unit of mixed liquor volatile suspended solids (MLVSS) and the temperature ($f_T = 0.019 \times 1.16^{T-20}$ g COD removed/g MLVSS-day-mg/l COD); the activated sludge production per unit COD or BOD removed was the same as reported earlier (Yield = 0.50 g VSS/g COD removed = 0.68 g VSS/g BOD removed); and the endogenous respiration rate of the MLVSS was apparently lower than observed earlier while still being equally temperature dependent ($k_d = 0.05 \times 1.15^{T-20}$ g VSS/g VSS-day).

4. The mixed liquor suspended solids (MLSS) composition was approximately as reported in 1967-1968 (MLVSS/MLSS = 0.89, COD/MLVSS = 1.38, BOD/MLVSS = 0.25, N/MLVSS = 0.074, P/MLVSS = 0.016).

5. Biological effluent quality deteriorated when chlorine was periodically applied in dry form during plant cleanup and flushed to the aeration system at startup, apparently due to selective killing of portions of the activated sludge organisms. The effluent deterioration occurred as high effluent suspended solids and, during extreme upset (i.e., 1976), as high COD, BOD and chlorine demand.

6. Direct biological effluent multimedia pressure filtration resulted in a normal reduction in suspended solids of 20 to 30 percent. Alum added ahead of direct filtration did not improve the suspended solids removal. The polymers investigated did not result in improvement either. Without upsets it is possible to maintain a reclaimed (filtered) effluent quality with a turbidity less than 15 NTU and a suspended solids concentration less than 20 mg/l.

7. Chlorination to 3 mg/l or above with approximately one hour contact, consistently provided bacteriological reduction to: total coliform $\leq$ 1/100 ml; fecal coliform $\leq$ 1/100 ml; total

plate count $\leq$ 500/ml.

8. The cost of reclaiming wastewater for reuse at Snokist Growers' Cannery was about $0.20 per cu. meter, including the cost of capital investment amortization. A new well development would have resulted in a cost of about $0.085 per cu. meter of water including capital investment amortization. The operating cost of the two systems would be similar.

9. Snokist Growers can reduce its effluent emission rate by more than 50% by using its reclaimed wastewater for initial product conveying, container cooling and floor and gutter wash. The BATEA discharge standards can be met during peach and pear processing with this amount of reclamation and reuse.

SECTION 3

RECOMMENDATIONS

Recommendations based on the results of this study are divided into categories, those specifically pertaining to Snokist Growers future operations of the wastewater reclamation system and use of reclaimed water, and those pertaining to the entire food processing industry. These recommendations have been reviewed and approved by the technical advisory committee.

INDUSTRYWIDE RECOMMENDATIONS

1. It is recommended that the food processing industry consider wastewater reclamation and reuse as demonstrated at Snokist Growers' Cannery as a viable alternative for reducing pollutant emissions. It should be considered in concert with other pollutant reduction measures such as in-plant controls.

2. It is recommended that industry and regulatory agency representatives consider means for validating these results to include low acid and non-thermally processed foods by confirming key results through further studies at appropriate facilities.

SNOKIST GROWERS' CANNERY RECOMMENDATIONS

1. Further demonstration of consistent performance for reclamation is recommended. Funding of Phase 2 of the project to demonstrate reclamation and reuse on a full scale basis for a two year period should be obtained. Full scale use for can cooling,for initial product conveying and for initial processing area (prior to peeling) washdown would give full use of the reclaimed effluent.

2. Monitoring of the reclaimed effluent during the demonstration seasons should include: coliform, fecal coliform and total plate count analyses to demonstrate sanitary quality; suspended solids and turbidity to demonstrate aesthetic quality; heavy metals, pesticides, polychlorinated biphenyls (PCBs) and halogenated organics to demonstrate whether there is a buildup of toxic or carcinogenic substances during prolonged reuse. The methodology, detection limits, frequency and quality assurance program for all of these tests should be reviewed by concerned regulatory agencies to assure that they will be able to

apply the results on an industry wide basis.

3. Reclaimed water quality criteria for reuse in critical areas such as direct contact container cooling should be set at:

Coliform	Conform to the National Interim Primary Drinking Water Regulations
Fecal Coliform	Conform to the National Interim Primary Drinking Water Regulations for Coliform
Total Plate Count	Equal to or less than 500/ml Average, Equal to or less than 1000/ml max.
Turbidity	Equal to or less than 20 NTU
Suspended Solids	Equal to or less than 30 mg/l
Chlorine Residual	Measurable residual at the point of use.

4. It will be necessary to chlorinate to a residual of approximately 3 mg/l with one hour of contact to achieve adequate bacterial kill. An alarm system for low chlorine residual and for high turbidity in the reclaimed water should be extended to appropriate locations for monitoring at all times that wastewater is being reused in critical areas. In the event of a chlorine residual or turbidity alarm during processing, water supply to critical areas such as direct contact container cooling should be converted to house water until the problem is corrected.

5. Continued in-plant diligence to prevent chlorine discharges toxic to the biological treatment system should be maintained and to assure the protection of the biological system and a consistent high quality effluent, the wastewater should be equalized. The existing sludge reaeration basin should be used for an equalization basin which would require inlet and outlet structure modifications and addition of a pump in the existing sludge pump building.

6. In-plant revisions are recommended to take full advantage of reclaimed water and to reduce the cannery discharge. Principally, this should consist of a collection and repumping system for cooler overflows to allow further use at the floor and gutter wash areas. The remaining coolers should be plumbed into the reclaimed water system.

SECTION 4

FACILITIES AND CONDUCT OF THE STUDY

This study was conducted at the Snokist Growers cannery. Reclaimed wastewater for reuse was produced from the cannery's processing wastewater by biological treatment and effluent polishing facilities. Biological treatment was monitored during the 1974 processing season and reclamation with pilot reuse was evaluated during the 1975 and 1976 processing seasons. The overall evaluation followed a detailed work plan which was developed by the principal investigator, project manager and the project officer and was approved by the technical advisory committee.

TREATMENT FACILITIES

Facilities to provide activated sludge treatment of Snokist Growers processing wastewater were constructed in 1967 and 1968 and were in existance at the start of this study. Effluent polishing facilities were constructed in 1975 to enable the cannery to reclaim water for reuse.

Biological Treatment Facilities

The wastewater treatment facilities at Snokist Growers were described in the report of the 1967-68 R,D&D Grant.[1] These facilities (Table 1) and a laboratory of approximately 800 square feet were valued at approximately $500,000 in 1968. A schematic flow diagram of the wastewater treatment system is shown on Figure 1. Figure 2 is an aerial view of the system and the cannery.

The nutrient deficient but high strength (carbohydrate) wastewaters are screened, and nitrogen and phosphorus are added before entering the aeration basin. The wastewater is mixed with return sludge and is aerated for biological treatment. Detention time in the aeration basin is from three to five days. The contents of the aeration basin are nearly completely mixed. The aeration basin effluent flows to the clarifier where settling removes the activated sludge mixed liquor suspended solids (MLSS) (bacteria), before discharge of the effluent to the Yakima River and/or to the reclamation facilities. The sludge is returned to the aeration basin by pumping, or "wasted".

Wasted sludge is thickened by the flotation sludge thickener and hauled to land disposal.

TABLE 1. EXISTING 1974 SNOKIST GROWERS PROCESS WASTEWATER TREATMENT FACILITIES

Facility	Description
1. Screening	8 mesh/cm (20 mesh/in) vibrating screens.
2. Aeration Basin	22,700 cubic meter (6 million gallon) earthen dike, PVC lined basin with 5 surface aerators having a total of 292 kw (390 horsepower).
3. Clarifier	27.5 meter (90 ft.) diameter, hydraulic sludge removal, 2.4 m (8 ft.) side water depth, center feed.
4. Sludge Recirculation	Two variable speed pumps each with 6,600 liter per minute (1750 gal. per minute) capacity.
5. Sludge Reaeration	5,700 cu. meter (1.5 million gal.) basin with 45 kw (60 horsepower) surface aeration.
6. Sludge Thickener	9.2 meter (30 ft.) diameter pressurized recycle flotation sludge thickener.

Design Capacity of Biological Treatment System
Flow = 6.8 x 10^6 liters/day (1.8 mgd)
COD = 10,000 kg/day (22,000 lb/day)
BOD = 7,300 kg/day (16,000 lb/day)

Reclamation Facilities

In 1975 Snokist Growers added facilities for reclaiming a portion of the biologically treated processing effluent for reuse in the cannery. These facilities, listed on Table 2, provide for multimedia filtration of the biological effluent, disinfection, and pumping to the cannery for reuse. Filtration is through pressure filters and disinfection is by chlorination at a controlled residual. The reclaimed effluent disinfection system consists of a solution feed chlorinator which dissolves gaseous chlorine into plant water for injection into the filtered

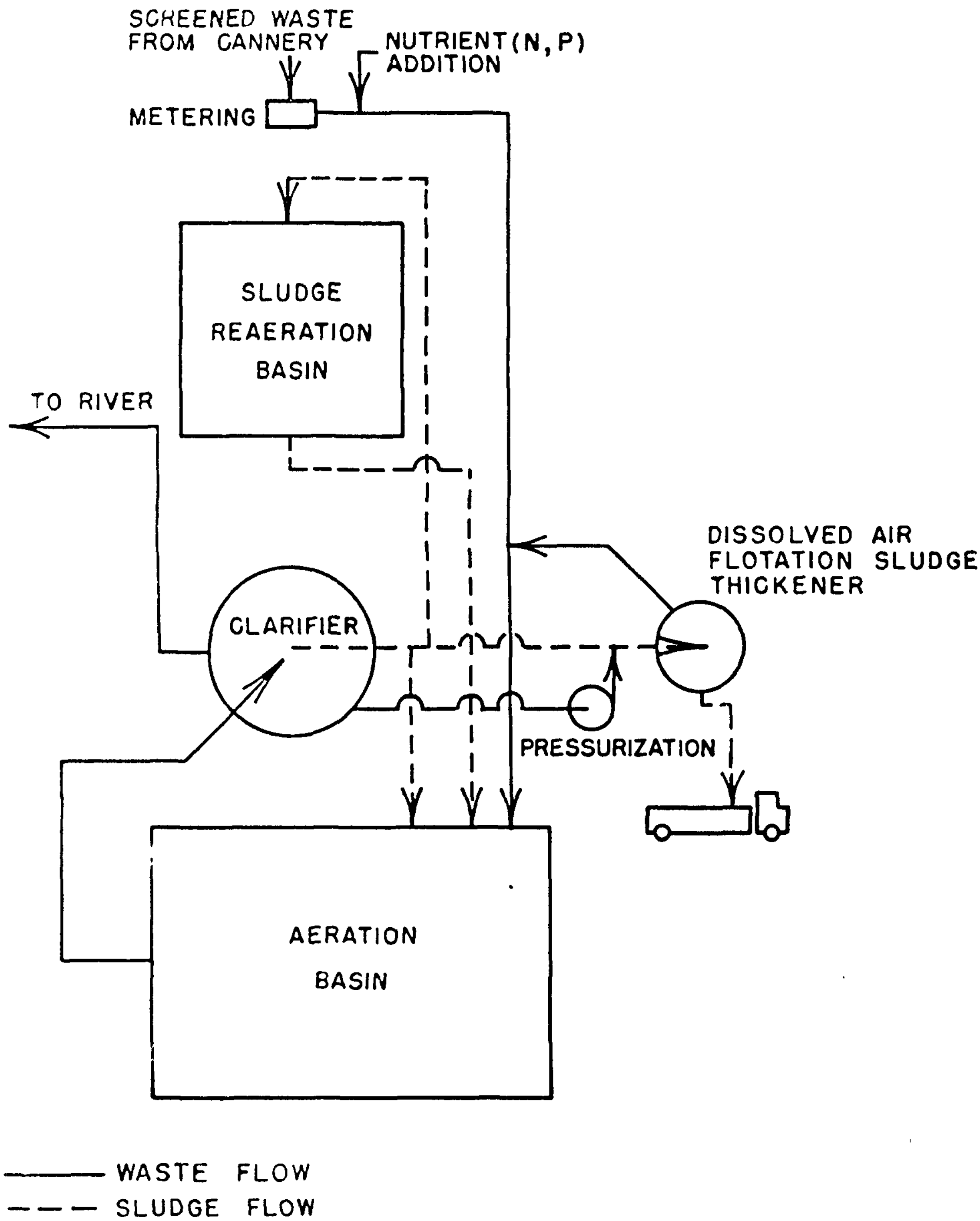

Figure 1. Snokist Growers' wastewater treatment system - schematic flow diagram, 1968 - 1974.

Figure 2. Snokist Growers' cannery and wastewater treatment system - aerial view looking south. Cannery is in the foreground; small aeration basin, clarifier and large aeration basin are at the top; and the sludge thickener, sludge recirculation pumphouse and filter/chlorination building are east of the clarifier.

effluent. The chlorine solution is fed through a perforated pipe diffuser into the filter effluent line ahead of the chlorine contact tank. The chlorine contact tank feed and discharge points are at opposite corners and 6 baffles across the tank prevent short circuiting. The tank volume is approximately 220,000 liters. Bacterial kill is enhanced by plug flow conditions in the chlorine contact facility and the baffles are intended to provide as close an approximation to plug flow as possible.

TABLE 2. WASTEWATER POLISHING FACILITIES CONSTRUCTED IN 1975

Facility	Description
1. Filters	Two 2.4 meter (8 ft.) diameter by 1.8 meter (6 ft.) high pressure filters. Area = 4.7 sq. meters (50 sq.ft.) each. Media = Microfloc MF 177 - 91.5 cm (36 in.) depth: 30% 1.5 sp.gr. anthracite (3 mm); 30% 1.6 sp.gr. anthracite; 30% 2.6 sp.gr. silica sand; 10% 4.0 sp.gr. garnet sand (0.25 mm) supported on 7.6 cm (3 in.) 1-2 mm 4.0 sp.gr. sand and 28 cm (11 in.) graded silica gravel. Max. flow rate = 0.5 cm/sec = 1400 liter/min.ea. Backwash rate = 1.2 cm/sec = 3400 liter/min.ea. Equipped with pipe underdrain, surface wash, pneumatically operated automatic valves, automatic backwash program, flow and headloss meters and automatic flow control.
2. Turbidity Meter	Low range, continuous flow - Hach CR
3. Filter and Backwash Pumps	Two constant speed 3800 liter (1000 gal.) per min @ 20 meter (66 ft.) TDH/2600 liter (700 gal.) per min. @ 23 meter (75 ft.) TDH pumps, interchangeable. 22.5 KW.
4. Chemical Feed Pumps	Liquid alum storage and automatic stroke-adjustable feed pump. Polymer stroke-adjustable feed pump. To be used if needed.
5. Reclaimed Water Pump	Split case 2600 liter (700 gal.) per min. @ 54 meter (177 ft.) TDH pump. 37 KW.

(continued)

TABLE 2. (Continued)

Facility	Description
6. Chlorinator	One 227 kg (500 lb.) per day chlorinator with motorized control valve and motorized vacuum valve for "compound loop" control.
7. Chlorine Residual Analyzers	Two wastewater type amperometric continuous flow analyzers for monitoring and controlling chlorine residual at the filter effluent and for monitoring chlorine residual at the reclaimed water pump inlet.
8. Chlorine Contact Chamber and Backwash Water Storage	Two hundred twenty seven cu. meter (60,000 gal.) baffled chamber - 11.6 meters (38 ft.) x 6.7 meters (22 ft.) x 3 meters (10 ft.) deep with 6 baffles.
9. Controls and Operation	a. Flow to filters automatically maintained according to chlorine contact level up to a preset maximum rate per filter.
	b. Filter backwash initiated by timer, high head loss across filters or manually.
	c. Chlorine residual automatically maintained by flow proportioning and residual monitoring and feed rate adjustment.
	d. Chemical feed of alum and/or polymers, if used, paced to filter flow rate.
	e. Reuse pump automatic shutdown at low contact tank level.
	f. Alarms transmitted to wastewater lab and plant for appropriate action due to the following:
	1) Low or high chlorine residual in reclaimed water. 2) High turbidity in filtered water.

(continued)

TABLE 2. (Continued)

	3) Low contact tank/backwash storage level. 4) Filter system malfunction.

Figure 3 shows a schematic flow diagram of the wastewater treatment facilities including the reclamation facilities. Figures 4, 5 and 6 are photographs of the pressure filters and piping, the chlorine residual and turbidity analyzers, and the pumps used for pumping to the filters and to the cannery.

The cost of construction for the wastewater reclamation facilities was approximately $325,000 as detailed on Table 3. These costs increased Snokist Growers total investment in wastewater treatment and handling facilities to above $800,000.

TABLE 3. COST OF CONSTRUCTION OF WASTEWATER FILTRATION AND DISINFECTION FACILITIES

Facility		Cost
1. Filter Building, including Contact Tank in Basement		$ 76,090
2. Filters, Installed Including Controls		72,140
3. Pumps, Installed		10,800
4. Chlorine Equipment, Installed		15,230
5. Piping & Plumbing in Building		51,020
6. Chemical (Alum) Feed Pump & Storage Installed		5,790
7. Water Line & Reclaimed Water Line to Cannery		12,710
8. Biological Effluent Line to Filter Building		3,060
9. Electrical		20,570
10. Piping Inside of Cannery		36,230
11. Design Engineering		21,930
	Total	$325,570

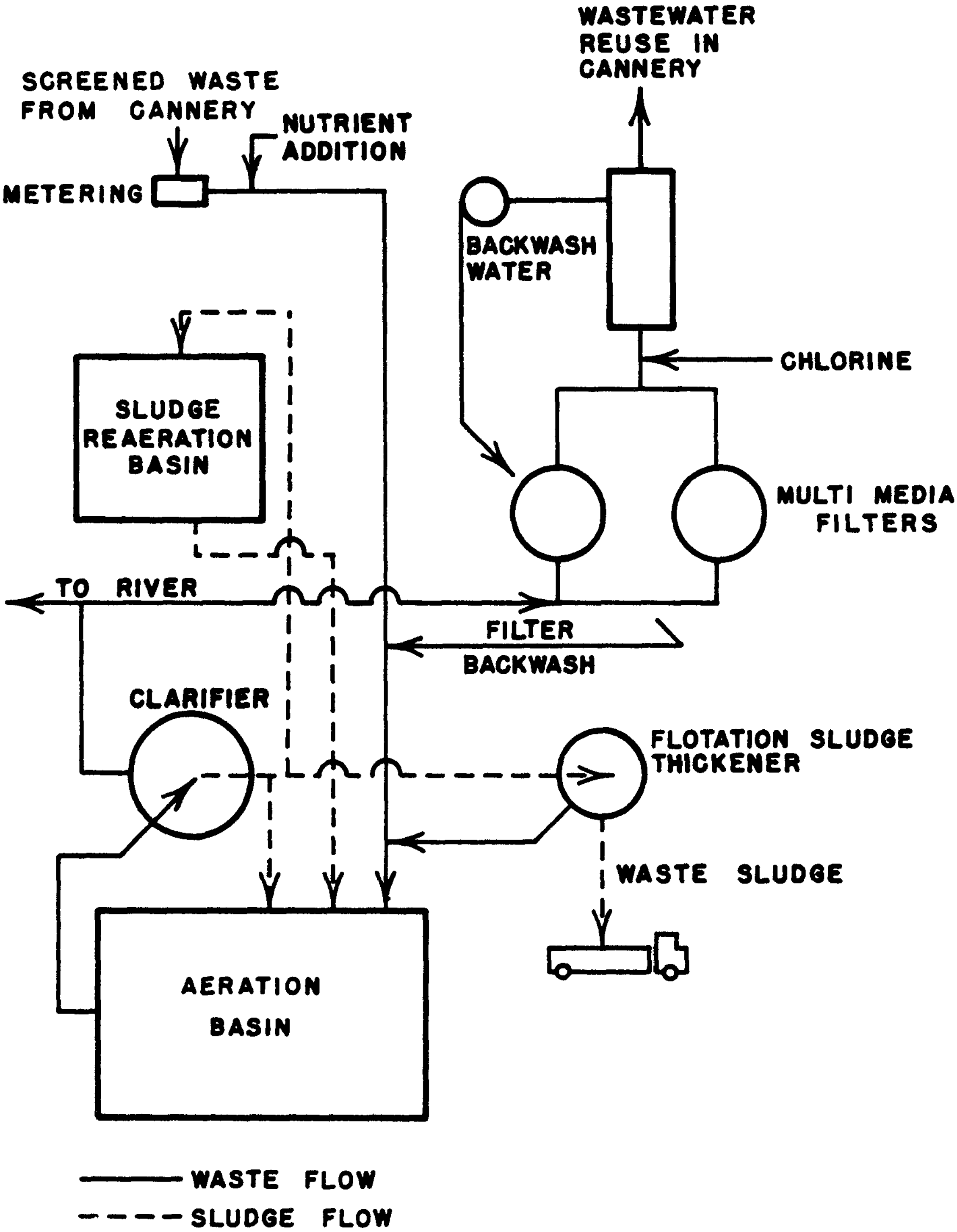

Figure 3. Snokist Growers' wastewater treatment and reclamation system - schematic flow diagram, 1975 and 1976.

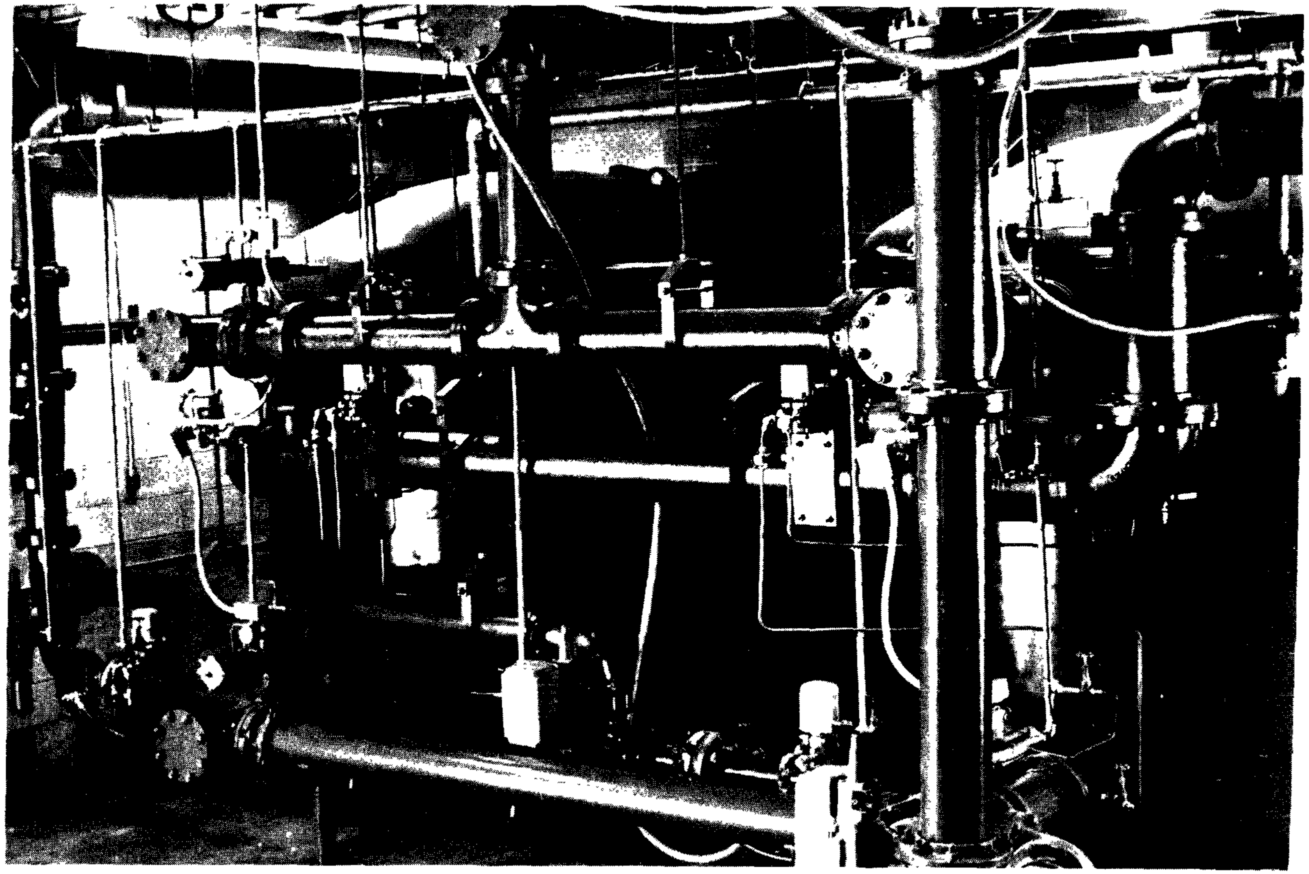

Figure 4. Pressure filter system. Wastewater feed is from the right, filtered water discharges to the left and behind the left (No. 2) filter. Note the filter effluent meters and flow control valves. Chlorine is injected in tee at left margin. Backwash enters through the vertical pipe at right center and discharges through the vertical pipe at the top left center. Backwashing is automatic with pneumatically actuated valves.

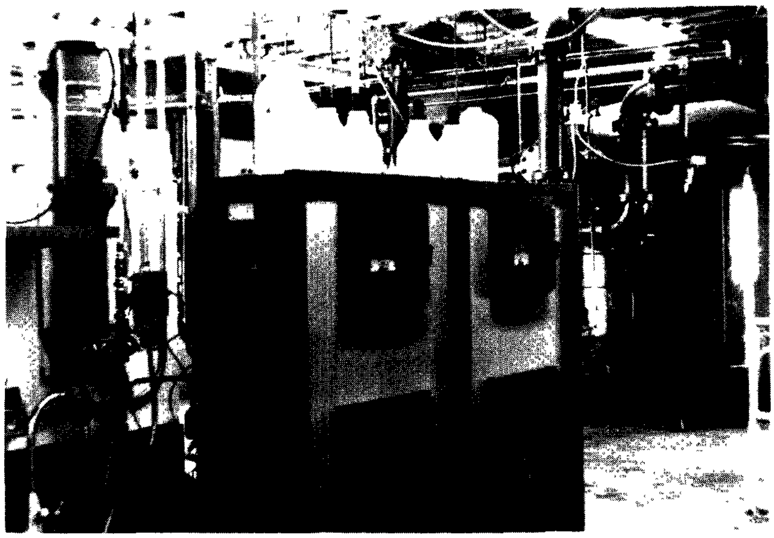

Figure 5. Continuous turbidity and chlorine residual analyzers for reclaimed wastewater. Filters are in the background.

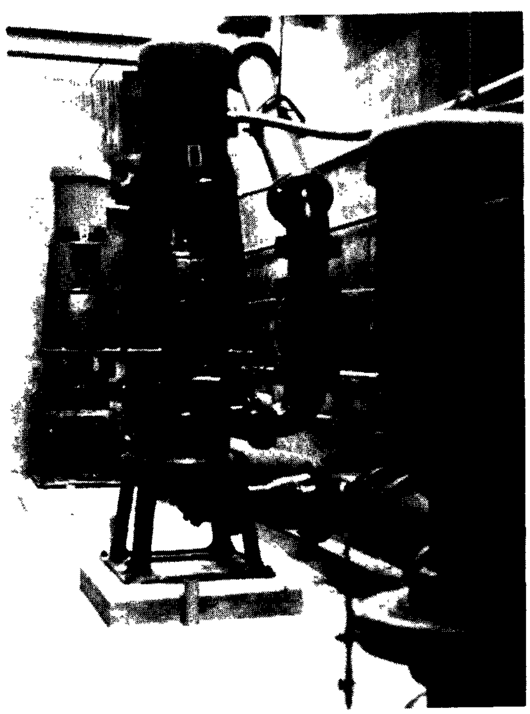

Figure 6. Filter feed and backwash pumps and reclaimed water pump.

TREATMENT SYSTEM OPERATION AND MONITORING

The biological treatment system was monitored during the 1974, 1975 and 1976 processing seasons and the effluent polishing system, constructed in 1975, was operated and monitored during the 1975 and 1976 processing seasons. The performances of the systems were monitored to determine the feasibility for reuse and to document pollutant reduction. Operation and monitoring of the reclamation system was conducted during pear, peach and apple processing from late August into the winter.

Treatment System Operation

Figure 3 shows the schematic flow diagram for the wastewater treatment system. The nutrients nitrogen and phosphorus were added in the form of diammonium phosphate and aqueous ammonia to the screened and metered processing wastewater. The nutrient addition was established initially at ratios of 0.04 to 1 of nitrogen to COD and 0.006 to 1 of phosphorus to COD. After start up and establishment of the biological treatment system, the nutrient feed rate was adjusted according to the concentrations of nitrogen and phosphorus in the supernatent from the mixed liquor. The feed was adjusted to maintain from 0.5 to 1 mg/l of ammonia and/or nitrate nitrogen and the same concentration of phosphate phosphorus. The system was operated to maintain no less than 2 mg/l of dissolved oxygen and sludge recycle was maintained to retain all of the solids in the system. The sludge recycle rate was normally 1.5 to 2 times the wastewater flow rate. After the solids in the basin (mixed liquor suspended solids MLSS) reached approximately 4000 mg/l, sludge wasting was initiated to the flotation thickener. The thickened solids were hauled via tank truck to disposal on farm land in the Yakima area.

The biological treatment system was designed for COD removal rates of approximately 0.20 grams COD per gram mixed liquor volatile suspended solids per day (g COD/g MLVSS day). The clarifier was designed for a surface loading rate not to exceed 16,000 liters per day per square meter (l/sq m-day) and the sludge recirculation capacity was designed for up to two times the maximum influent flow rate. Up to 2,800 liters per minute of secondary effluent can be applied to the pressure filters. The actual flow rate depends on the demand exerted by the reuse pump to the cannery and the need for backwash water for the filters. Filtration rate of the reclaimed wastewater was designed at up to 0.5 centimeters per second(cm/sec) face velocity on the filter media. The filter backwash flow rate was set at approximately 1.2 cm/sec face velocity. Each filter flow rate is controlled by an orifice flow meter and pneumatically operated modulating butterfly valve. Chlorine is injected into the filtered effluent line through a diffuser which extends across the filtered effluent line ahead of the contact tank.

The chlorine residual monitoring points are at the contact tank entrance and effluent. The continuous chlorine residual analyzers record the chlorine residual. The chlorine feed rate is paced to the filter flow rate and adjusted according to the residual at the contact tank entrance, resulting in a compound loop chlorine control system.

Treatment System Monitoring

Snokist Growers wastewater treatment system was routinely monitored through the 1974, 1975 and 1976 processing seasons for several chemical and biological parameters. Points in the system specifically monitored were the processing wastes following screening, the aeration basin, the clarifier effluent, and the return activated sludge. During the 1975 and 1976 seasons, when the reclamation system was in operation, the reclaimed effluent was monitored following filtration and following disinfection. Table 4 shows the routine monitoring program conducted during the study for the treatment system and reclamation systems.

Snokist Growers cannery well water supply was also sampled on a number of days during the 1975 and 1976 processing season. Analyses included COD, total solids, ammonia, organic and nitrate nitrogen, ortho and total phosphorus, calcium, magnesium, alkalinity, chloride, sulfate and color. Trace material analyses were performed on the reclaimed effluent and on the Snokist raw water supply for comparison. Analyses included reactive silicate, detergent (MBAS), polychlorinated biphenyls (PCB), volatile halogenated organics, total halogenated organics, and the heavy metals; arsenic, lead, zinc, tin, copper, cadmium, mercury, iron, sodium, potassium, manganese and aluminum. Heavy metal analyses were also performed on wastewater samples before treatment during the 1976 season for comparison.

Bacteriological analyses on the reclaimed effluent during the 1975 and 1976 seasons included total plate count and total coliform daily; and fecal coliform, staphylococcus and Salmonella weekly. Yeast, mold and total spore forming plate count tests were performed on the reclaimed effluent periodically during the 1976 season.

Analyses were performed according to EPA recommended methods for the most part. However, some of the analyses were not according to the specific method recommended and a number had no EPA recommended method. The analytical methods were agreed upon between the project officer, principal investigator and the project manager prior to initiation of the evaluation. A summary of the methods used is included in the Appendix.

TABLE 4. WASTEWATER TREATMENT SYSTEM TESTING AND MONITORING SCHEDULE

Test	Screened Wastewater	Aeration Basin	Clarifier Effluent	Reclaimed Effluent Following Filters	Reclaimed Effluent Following Contact Tank
Flow Rate or Quantity	D[1]			D	D
Temperature, pH	D.G.[2]	D.G.	D.G.	D.G.	D.G.
Settleable Solids[3]	D.G.	D.G.	D.G.		D.G.
Suspended & Volatile Susp. Solids[3].	D.C.	D.C.	D.C.	D.C.	D.C.
Dissolved Oxygen		D.G.	D.G.		D.G.
Total Solids & Total Volatile Solids	W.C.		W.C.	W.C.	W.C.
Chemical Oxygen Demand (COD)	D.C.	D.C.	D.C.	D.C.	D.C.
Biochemical Oxygen Demand (BOD)	W.C.		W.C.	W.C.	
Ammonia & Organic Nitrogen (NH_3-N,Org.N)	W.C.	W.C.	W.C.	W.C.	
Nitrate Nitrogen (NO_3-N)			W.C.	W.C.	
Total & Orthophosphate Phosphorus (Tot P,PO_4-P)	W.C.	W.C.	W.C.	W.C.	
Calcium (Ca), Magnesium (Mg), Bicarbonate (HCO_3), Sulfate (SO_4), & Chloride (Cl^-)	W.C.		W.C.	W.C.	W.C.

(continued)

TABLE 4. (Continued)

Test	Screened Wastewater	Aeration Basin	Clarifier Effluent	Reclaimed Effluent Following Filters	Reclaimed Effluent Following Contact Tank
Turbidity			D.G.	D.G. & Cont.	D.G.
Color					W.G.
Chlorine Residual				D.G. & Cont.[4]	D.G. & Cont.
Bacteriological					
Total Plate Count			D.G.	D.G.	D.G.
Total Coliform			D.G.	D.G.	D.G.
Fecal Coliform			W.G.	W.G.	W.G.
Staphyloccus			W.G.	W.G.	W.G.
Salmonella			W.G.	W.G.	W.G.

1 Frequency of Monitoring: D = Each Processing Day; W = Weekly; Cont. = Continuous Recorder.

2 Type of Sample: G = Grab Sample; C = Composite Sample; Cont. = Automatic

3 Return Sludge also Monitored - Grab Samples Daily.

4 Following Chlorination but ahead of Contact Tank.

REUSE TESTING OF RECLAIMED WATER

An objective of the study was to determine the feasibility of reusing the treated fruit processing wastewater for:

A. Equipment cleaning;

B. Product cleaning and conveying;

C. Boiler feed to produce steam for:

   1. Cleaning;

   2. Exhausting;

   3. Cooking;

   4. Blanching.

D. *Direct contact container cooling.*

Reclaimed water was used during the 1975 and 1976 processing seasons to conduct pilot experiments in the cannery for each of these uses. Data was collected on using the reclaimed water and on using house water for the same purposes.

Equipment Cleaning

The processing equipment in the cannery is normally cleaned with high pressure chlorinated water mixed with steam from the boiler system. Comparative cleaning experiments were conducted during both the 1975 and the 1976 processing seasons. Peelers and adjacent peeled product belt conveyors (processing lines) were washed down with reclaimed water and house or reclaimed water steam, or the normal steam-water mixture. After wash down, the belts were sampled for total plate count and mold to compare the use of the experimental and the normal wash down water sources. Sampling was done using the swab contact method (see Appendix A) on 2 belts for each processing line studied, a "peeler" belt and a subsequent "shaker" belt.

During the 1975 season, parallel pear processing lines were washed down using reclaimed water and house steam on one line and chlorinated house water and house steam on the other line for several days during the processing season. Following sampling on the lines for bacterial and mold residual, the line washed with the reclaimed water and house steam was rewashed using house water and house steam to assure that no contamination of product could take place. Later during the 1975 season, an apple processing line was washed down using reclaimed water and house steam on several days. It was rewashed with house water and house steam following sampling. The apple line was sampled following wash down under normal procedures with house water and house steam on a like number of days.

During the 1976 processing season, three parallel pear lines were used for equipment cleaning comparison. Line No. 1 was washed down using reclaimed water and steam generated from reclaimed water by a portable steam generator described later. Line No. 2 was washed down using reclaimed water and house steam. Line No. 3 was washed down using house water and house steam. The washed equipment were sampled for total plate count and mold following the wash down procedures which were conducted once each week for six weeks. The processing equipment on the experimental Lines No. 1 and 2 was rewashed with house water and house steam following this sampling.

Figure 7 shows two adjacent "wash down stations" with steam and water pipes joining ahead of the common hose bib for each station. The two wash down stations shown on Figure 7 are adjacent to the experimental wash down area of the No. 1 processing line. Figure 8 shows a typical pear processing line with peelers and the belts used to carry the fruit.

During the 1976 processing season, pear peelings and other solids were recovered prior to entering the gutter system. These solids were transported by a conveyor belt and discharged down a belting covered slide and into bins which were emptied into trucks for hauling to disposal. These slides on Lines 1, 2 and 3 were daily washed with reclaimed water and steam generated from reclaimed water, reclaimed water and house steam, house steam and house water, respectively, for a six week experimental period. They were not rewashed using house water and house steam following sampling. They were sampled twice weekly during this period to determine the long term effect of using reclaimed water for equipment washing. One of these slides is shown on Figure 9.

Product Cleaning and Conveying

During the 1976 processing season, reclaimed water was used in the peach dump tanks which receive peaches from the bins in which they are transported to the cannery. This dump tank system has sodium sulfate added to increase the peach floatability so they can be more easily removed. Reclaimed water was used for a three day period and a comparable three day period using house water was also evaluated. The water in the dump tank; and the peaches prior to dumping, following removal from the dump tank, and following a spray rinse were tested for bacteria count for comparison. The dumping facilities are shown on Figure 10 being utilized for pear dumping. Peach dumping is done in a similar manner.

Following analysis of the results of the peach dumping using

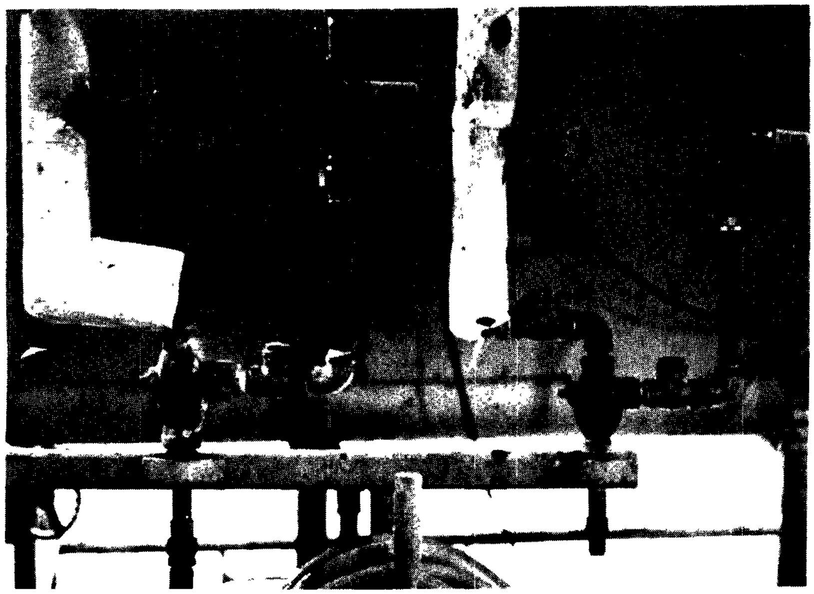

Figure 7. Equipment washdown stations. House steam/house water on the left and reclaimed water steam/reclaimed water on the right for pear line No. 1.

Figure 8. Pear peeler line.

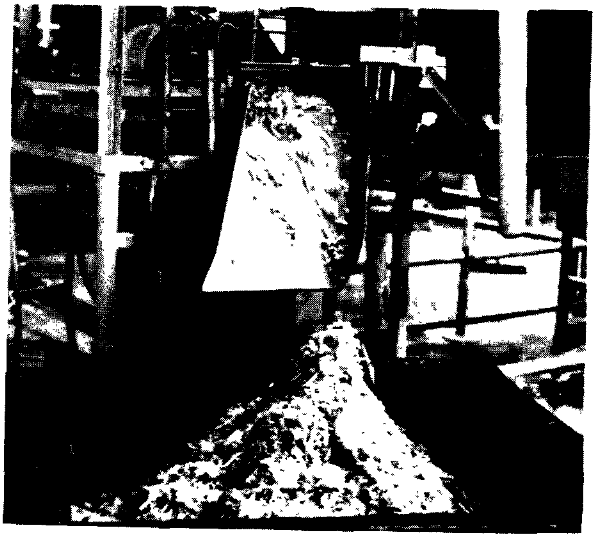

Figure 9. Waste peel and core slide for pear line. Slide was covered with belting.

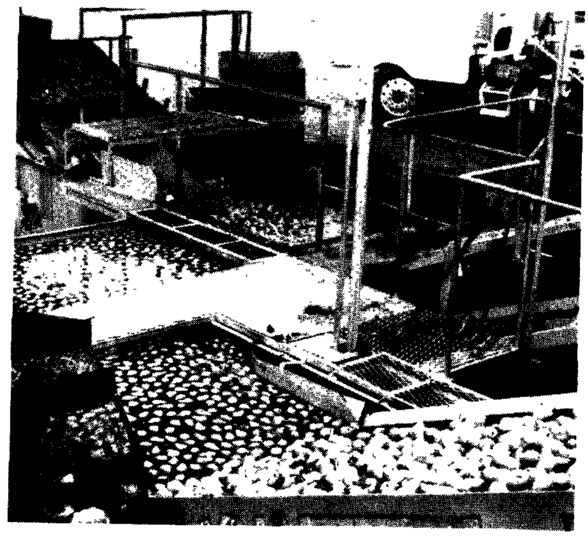

Figure 10. Peach and pear dump and initial conveying area. Fruit in bins entered the dump at top left, floats from the bins at top center and enters the cannery at lower right.

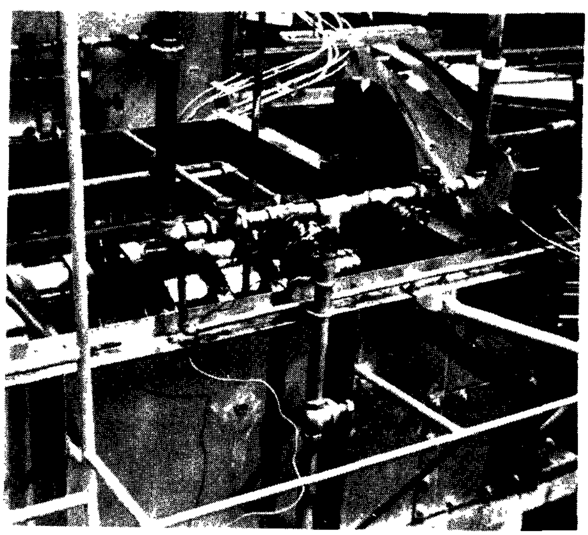

Figure 11. Can cooler. Cooling water enters pipes from top of picture. Left top is house water and right top is reclaimed water.

the reclaimed and house water, and review by the Technical Committee, similar dumping comparisons for apples were conducted for the remainder of the 1976 processing season. The apples prior to dumping and following dumping, and the dump water, were tested for approximately two weeks using reclaimed water, and three weeks using house water.

Using Reclaimed Water for Boiler Feed

During the 1976 processing season, a portable steam generator was rented and installed in the cannery to convert reclaimed water to steam for various pilot uses in the cannery. Pilot tests were conducted over a two month period using the reclaimed water steam for equipment cleaning, exhaust box steam during pear processing, blanching sliced apples and cooking applesauce.

Reclaimed Water Steam for Equipment Cleaning --

The portable steam generator which converted reclaimed water to steam was used over a six week period for comparative cleaning. Testing was described above under Equipment Cleaning. One of the three parallel lines was cleaned with reclaimed water steam and reclaimed water for comparison with the other two lines using house steam and reclaimed water, and house steam and house water. Total plate count and mold analyses were done on samples from the lines following cleaning. After testing for comparative sanitary quality, the equipment and belts which were washed with reclaimed water or reclaimed water steam, were rewashed with house water and house steam in order to prevent inadvertent contamination.

The three peeling and core slides described above were washed with reclaimed water and steam generated from reclaimed water, reclaimed water and house steam, and house water and house steam as discussed earlier.

Exhausting --

Many fruits and vegetables which are sterilized by thermal processing and preserved in sealed cans are "exhausted" before the can lid is seamed into place. This consists of passing the filled can through an "exhaust box" where live steam is applied which preheats the can and its contents to drive out dissolved air before the can lid is applied. During two short pilot runs, steam from the portable steam generator, using reclaimed water, was used to exhaust a batch of canned pears to compare with pears exhausted using the house steam under normal continuous processing procedures. Evaluations were made by grading of the processed fruit and by organoleptic evaluation. The organoleptic evaluation was conducted according to the "triangle test" (Appendix).

Cooking with Reclaimed Water Steam --

Steam generated from the portable boiler was used to batch cook applesauce during two product pilot runs during the 1976 processing season. The commercial applesauce cooker operates on a continuous basis with a scroll auger to move the applesauce through in a certain time period. The experimental operation consisted of batch cooking applesauce with steam generated from reclaimed water. The cooked applesauce was then canned. A similar batch was cooked with steam generated from house water and canned for comparison. Batch cooking consisted of filling the cooker with applesauce and injecting steam to bring the applesauce up to the pre-specified cooking temperature. Containers of applesauce from the normal run (continuously cooked) at the end of the processing day, prior to the batch testing, were retained for comparison with the batch cooked applesauce. Thus three sets of samples from each of the two runs were retained for testing by USDA grading procedures and by organoleptic evaluations.

Blanching with Reclaimed Water Steam --

During the 1976 season, apple slices were blanched using reclaimed water steam from the portable steam generator. Two separate runs of blanching with the reclaimed water steam and with house steam were conducted for comparison. The normal blanching operation, as with the applesauce cooking, is continuous. For experimental blanching, the blancher was filled with apple slices and then steam was injected to bring it up to blanching temperature. The apple slices were canned for preservation. A similar batch of apple slices were blanched under the same conditions with steam generated from house water for comparison. Cans of apple slices from the regular continuous run were retained for comparison with the batch processed products by USDA grading and organoleptic evaluation.

Direct Contact Container Cooling

A major potential use for reclaimed water at the Snokist cannery is direct contact container cooling. This potential use alone could reduce the amount of water supply necessary and the plant discharge by approximately 30 percent. During the 1975 season, slightly over a thousand cans were cooled with reclaimed and with house water under similar conditions in a can cooler that had been brought up to a normal cooling temperature by steam injection (approximately 35°C). One thousand cans from each of the reclaimed and the house water cooling runs were stored at approximately 18°C. They were inspected after six months and after one year for failures. One hundred containers from each of the cooling runs were shipped to the NFPA Laboratory in Berkeley for two months storage at approximately 30°C to simulate long-term storage. Following this storage, they were visually inspected, vacuum was checked and they were opened for product inspection.

During the 1976 season, slightly over three thousand cans (about one pallet) were cooled under continuous flow conditions with each of the reclaimed and house waters. Approximately 100 cans from the control test and 100 from the reclaimed water test, were sent to the NFPA and stored at 35°C for six months. At the end of the storage period, the containers were checked for vacuum and examined for spotting, corrosion and other defects. The remainder of the cans were stored at the cannery at approximately 18°C. They were examined for can failure after one year.

Figure 11 shows the can cooler. The dual piping shown allowed either house water from one of the feed pipes or reclaimed water from the other feed pipe to be used for container cooling.

SECTION 5

RESULTS AND DISCUSSION

The results of monitoring the wastewater, the treatment system and the reuse activities are presented in summarized and analyzed form. Raw data are presented only where necessary to indicate particular aspects of the studies. Monitoring data were contained in two progress reports for 1975[6] and 1976[7] and in a separate EPA report.[8] They are available from the Food and Wood Products Branch of EPA's IERL-Ci if needed.

WASTEWATER CHARACTERISTICS AND BIOLOGICAL TREATMENT

The results obtained during this study are compared with those obtained during the 1967-68 Snokist R&D study[1,2,3] to provide a better knowledge of the wastewater treatability and the biological treatment system characteristics.

Waste Load

During the 1974, 1975 and 1976 seasons, Snokist Growers' cannery processed pears, peaches, apples and plums. Pears were canned as halves or slices as were peaches. Plums were canned whole, and apples were canned as apple rings, apple slices or applesauce. A summary of the cannery emission rates for flow and COD is included on Tables 5, 6 and 7 for the 1974, 1975 and 1976 processing seasons respectively.

The cannery wastewater after screening on the 8 mesh/cm (20 mesh/in) vibrating screen, is very low in suspended solids and the principle loading for the biological treatment system is oxygen demanding soluble organics. These organics are measured as COD and BOD. The COD was monitored on a daily basis, whereas the BOD was only monitored on a weekly basis during the 1975 and 1976 processing seasons, and on a bi-weekly basis during 1974. A BOD to COD ratio was established during this project from 41 samples of screened processing effluent.

BOD:COD ratio = 0.73 mg BOD/mg COD

Standard Deviation = 0.07

This is compared to 0.75 with a standard deviation of 0.10 dur-

TABLE 5. RAW PROCESSING WASTE EMISSION RATE - 1974

Dates	Fruit Processed	Wastewater Flow		COD Emission	
1974	kkg	Thou.cu.m	cu.m/kkg Fruit	Total kkg	Unit kg/kkg Fruit
8/23-24	518 Pr	11.43	22.1	38.8	75
8/26-31	1616 Pr	34.48	21.3	106.4	66
9/3-7	1319 Pr	30.07	22.8	78.1	59
9/9-11	803 Pr	15.92	19.8	49.1	61
9/12-13	502 Pr,55 Pl	12.44	22.3	32.9	59
9/14	66 Pl	4.69	71.1	0.4	6.1
9/16-19	624 Pe,327 Pl	27.39	28.8	45.0	47
9/20	99 Pl	3.51	35.5	1.5	15
9/23-28	1636 Pr,236 A	35.17	18.8	107.1	57
9/30-10/5	1600 Pr,519 A	38.39	18.1	123.7	58
10/7-12	1546 Pr,587 A	42.39	19.9	112.7	53
10/14-19	1588 Pr,595 A	35.00	16.0	93.5	43
10/21-26	1618 Pr,592 A	34.11	15.4	86.1	39
10/29-11/2	1335 Pr,538 A	27.23	14.5	59.2	32
11/4-9	1438 Pr,576 A	30.00	14.9	65.5	33
11/11-15	648 A	14.48	22.3	7.7	12
11/18-22	819A	25.69	31.4	14.7	18
11/25-27	234 A	9.88	42.2	4.9	21
12/2-6	386 A	17.37	45.0	10.6	27
12/9-13	295 A	16.52	56.0	8.7	29

Note: Pears processed were generally of poor quality with excessive soft flesh and higher than usual peeling loss and cull rate.

TABLE 6. RAW PROCESSING WASTE EMISSION RATE - 1975

Dates 1975	Fruit Processed kkg	Wastewater Flow		COD Emission	
		Thou.cu.m	cu.m/kkg Fruit	Total kkg	Unit kg/kkg Fruit
8/26-30	1407 Pr	28.66	20.4	68.3	48.5
9/2-6	1358 Pr	29.19	21.5	65.3	48.1
9/8-13	1664 Pr,46 Pl	38.62	22.6	76.0	44.4
9/15-20	1644 Pr,520 Pl	42.06	19.4	73.3	33.9
9/22-25	928 Pe,280 Pl	22.94	19.0	31.5	26.1
9/26-27	383 Pe	10.68	27.9	16.2	42.2
9/29-10/4	1737 Pr,14 Pl	40.43	23.1	68.0	38.9
10/6-11	1620 Pr,473 A	43.31	20.7	77.4	37.0
10/13-18	1598 Pr,555 A	44.59	20.7	72.5	33.7
10/20-25	1666 Pr,550 A	45.34	20.5	74.1	33.4
10/28-11/1	1334 Pr,498 A	37.94	20.7	61.2	33.4
11/3-8	1730 Pr,570 A	43.20	18.8	74.9	32.6
11/10-15	1670 Pr,682 A	44.95	19.1	73.5	31.3
11/17-19	789 Pr,397 A	21.58	18.2	36.9	31.1
11/20,21,24,25	570 A	10.94	19.2	12.5	22.0
12/1-5	840 A	18.37	21.9	15.3	18.2
12/8-12	881 A	18.14	20.6	13.1	14.8
12/15-18	291 A	7.16	24.6	10.9	37.5

TABLE 7. RAW PROCESSING WASTE EMISSION RATE - 1976

Dates 1976	Fruit Processed[1,2] kkg	Wastewater Flow Thou.cu.m	Wastewater Flow cu.m/kkg Fruit	COD Emission Total kkg	COD Emission Unit kg/kkg Fruit
8/24-28	1529 Pr	31.43	20.6	33.9	22.2
8/30-9/4	1760 Pr	29.44	16.7	36.4	20.7
9/7, 9-11	1209 Pr,178 Pl	23.62	17.0	30.1	21.7
9/8*	311 Pr*	6.36	20.6	13.6	43.6*
9/13-17	1422 Pr,281 Pl	35.36	20.8	34.7	20.4
9/18	86 Pl	7.00	81.4	1.07	12.4
9/20-25, 27	1630 Pe,563 Pl	53.30	24.3	82.0	37.4
9/28-10/2	1490 Pr,168 Pl	27.61	16.7	35.1	21.2
10/4-9	1828 Pr,529 A	40.24	17.1	52.3	22.2
10/11-16	1808 Pr,563 A	36.76	15.5	55.1	23.2
10/18-23	1830 Pr,551 A	37.59	15.8	54.3	22.8
10/25-30	1674 Pr,569 A	34.04	15.2	51.8	23.1
11/1-6	1744 Pr,575 A	31.07	13.4	56.1	24.2
11/8-10	894 Pr,284 A	16.70	14.2	27.9	23.7
11/12-13*	558 Pr*,176 A	12.26	16.7	29.5	40.1*
11/15-19	646 A	14.40	22.3	20.9	32.3
11/22-24	422 A	10.99	26.0	14.1	33.5
11/29-12/3	566 A	21.68	38.3	22.9	40.4
12/6-10	714 A	21.16	29.6	19.8	27.8
12/13-17	728 A	22.64	31.1	21.9	30.1
12/20-22	418 A	13.42	32.1	13.5	32.2
12/27-30	549 A	13.21	24.1	16.2	29.4
1/3-7	678 A	16.69	24.6	26.2	38.6
1/12-14	397 A	9.89	24.9	15.5	39.0
1/17-21	741 A	16.78	22.7	17.7	23.9
1/24-28, 31	958 A	26.02	27.2	22.1	23.0

(continued)

TABLE 7. (Continued).

Dates 1976	Fruit Processed kkg	Wastewater Flow		COD Emission	
		Thou.cu.m	cu.m/kkg Fruit	Total kkg	Unit kg/kkg Fruit
2/23-25	391 A	6.15	15.7	7.9	20.1
2/28-3/4	588 A	8.88	15.1	10.3	17.5
3/7-10	494 A	5.59	11.3	9.7	19.5

Notes: 1. Pear peelings, cores and some juice collected by belt conveyor to water tight bins for separate disposal, except where indicated (*) when all waste went to gutters (for comparison).

2. Apple peel and core dry conveyor system (for recovery and sale to vinegar manufacturer) out of service during much of season due to mechanical problems.

ing the 1967-68 period.

In order to compare waste treatment requirements between various processors and products, it is beneficial to know the unit emission rates for flow and pollutants. The unit emission rate is the quantity of wastewater flow and of pollutants per unit of product or per unit of raw material used in the process. Average emission rates were calculated for peaches and plums by linear regression over the three season period. There were very few days when either of the products were processed separately and even then in the case of plums, the daily waste load reflected extended clean up operations from previous pear or peach processing. The peach and plum emission rates for the study period were as follows based on the quantity of raw fruit processed in metric tons (kkg):

Peach wastewater flow = 16.6 cu.m/kkg

Plum wastewater flow = 44 cu.m/kkg

Peach COD = 36 kg/kkg

Plum COD = 32 kg/kkg

Peach BOD = 26 kg/kkg

Plum BOD = 24 kg/kkg

The BOD emission values were calculated from the BOD/COD ratio and the COD emission rates. The Standard Deviations for these values were about 15 percent of the arithmetic mean. The 1967-1968 period had emission rates of about 30 cu.m wastewater flow/kkg, fruit about 48 kg COD/kkg and about 33 kg BOD/kkg for each product.[1]

Emission rates for pears and apples were calculated for each season when the products were processed separately, and by linear regression for each pear, apple and combined pear-apple season. There were no significant differences between the unit flow rates for apples or pears between the three processing seasons even though the flows varied considerably for the apples, especially within each processing season. Based on linear regression analysis, the wastewater flows for apple and pear processing were as follows:

Pear Wastewater Flow = 17 cu.m/kkg

Apple Wastewater Flow = 22 cu.m/kkg

The Standard Deviation for the wastewater emission rate from pear processing was approximately 10 percent of the mean. For apples, the Standard Deviation was approximately 35 percent of the mean. Apples are processed into several product styles which accounts for the high variation in wastewater flows. These emission rates compare with about 24 cu.m/kkg for pears and 34 cu.m/kkg for apples during the 1967-68 seasons and indicate that in-plant awareness of water usage have resulted in a lowering of the emission flow rate.

The COD emission rates for both pears and apples were significantly different between processing seasons of this study. The linear regression derived unit COD emission rates agreed with measurements taken during separate pear processing. The unit COD emission rates obtained by linear regression for apples, however, were somewhat different from rates found during separate apple processing. The apple processing tonnage was much less than the tonnage of concurrently processed pears and thus the waste load from apples was out weighed by that from pears in the linear regression analysis. Based on the linear regression, the COD and BOD emission rates for pears during the three processing seasons studied were as follows:

Pear 1974 season COD = 61 kg/kkg, BOD = 44 kg/kkg

Pear 1975 season COD = 42 kg/kkg, BOD = 31 kg/kkg

Pear 1976 season COD = 23 kg/kkg, BOD = 17 kg/kkg

There was a significant difference between the COD and BOD unit emission rates for the 1974 and 1975 and 1976 processing season. The differences can be explained as follows: During the 1974 processing season, the pear quality coming into the cannery was poor which resulted in a greater amount of peel and pear flesh lost during processing due to softness. The emission rate was significantly greater than during the 1975 season. It was also greater than during the 1967 and 1968 seasons when a COD unit emission rate of 52 kg/kkg and a BOD emission rate of 39 kg/kkg was experienced. Reduction from the 1967 and 1968 seasons to the "normal" 1975 season was probably due to more efficient handling of the material in the cannery and due to the water saving measures which tended to flush less material into the gutters and thus less sugars were leached into the wastewater. The reduction from the 1975 to the 1976 processing season was due to the improvements in waste material handling. During the 1976 season, the peels and cores from the peeling machines were dropped onto a conveyor belt where they were conveyed to a side chute and deposited into a water tight bin instead of going into the gutters. The collected solid waste material was hauled to separate disposal. This method of handling resulted in nearly a 50 percent reduction in wastewater pollutant load to the treatment system which results in cost savings for power, nutrients and sludge disposal. The Standard Deviation for the unit emission COD values for pear processing was approximately 15 percent of the means.

The organic pollutant emission rates during apple processing for the three seasons was as follows:

Apple 1974 and 1975 seasons COD = 22 kg/kkg, BOD = 16 kg/kkg

Apple 1976 season COD = 27 kg/kkg, BOD = 20 kg/kkg

These values have Standard Deviations of approximately 30 percent of the means. They compare with a COD emission rate of about 35 kg/kkg and a BOD emission rate of 26 kg/kkg during the 1967 and 1968 processing seasons. The reduction in emission rate from 1967 and 1968 to these seasons can be attributed largely to recovery of the peel and cores for vinegar production by a separate plant in the Yakima area. The difference between the 1974 and 1975 seasons and the 1976 season was due to mechanical breakdowns of the core and peel recovery equipment during the 1976 season. This resulted in the cores and peels going to the gutter during a substantial portion of the apple processing season. The exact dates of mechanical failure were not adequately recorded to allow correlation of waste emission rates with the actual breakdown of the equipment. The value of dry recovery of solid waste materials is readily seen from the comparison of the earlier and more current values and between the values during normal and unreliable operation of the solid waste recovery equipment.

Fruit processing wastewater is known to be nutrient deficient for biological treatment. During this study, nutrient analyses were performed on the screened raw wastewater. The nitrogen and phosphorus content of the wastewater as a ratio to the organic content was as follows:

$$\frac{N}{COD} = .004, \text{ std.dev.} = .002$$

$$\frac{N}{BOD} = .006, \text{ std.dev.} = .003$$

$$\frac{P}{COD} = .0016, \text{ std.dev.} = .0013$$

$$\frac{P}{BOD} = .0022, \text{ std.dev.} = .0018$$

Snokist Growers adds both nitrogen and phosphorus to their wastewater for biological treatment.

Biological Treatment of Processing Wastewater

Performance of the biological wastewater treatment system was monitored during the three years of this study. The activated sludge system aeration basin and clarifier are shown on

Figures 12 and 13. The COD, suspended solids, volatile suspended solids, temperature and dissolved oxygen were measured daily in the biological treatment system influent, effluent and aeration basin. The nutrients and BOD were determined on a periodic basis. These test results were analyzed to compare the operation of the biological treatment system with that recorded during the study of 1967 and 1968.[1]

COD and BOD Removal --

The removal rate of organics from the wastewater is defined as the removal of COD or BOD per unit weight of mixed liquor volatile suspended solids (MLVSS) per day. The MLVSS is taken as an indication of the concentration of bacteria in the aeration system. This removal rate is determined by measuring quantity of COD or BOD removed by the biological treatment system on a daily basis and dividing by the quantity of MLVSS. The rate of removal of food by the microorganisms is a function of the concentration of food available. In other words, organisms with a low concentration of organics available will perform at a lower rate. At a higher substrate concentration (BOD, COD) the organisms perform at a higher rate. The removal rates experienced in this study were in the range of .01 to 0.5 g COD removed/g MLVSS-day. It is assumed that a linear relationship describes the removal rate as a function of the availability of the food (COD or BOD). Where f is the COD or BOD removal rate coefficient, COD or BOD removal (g COD or BOD/g MLVSS-day) = f x soluble COD or BOD. The removal rate coefficient (f) is defined as the slope of a line relating the food concentration versus the removal rate. It was shown in the final report on the 1967, 1968 study,[1] that the removal rate coefficient varied with temperature.

During the three seasons of this study, data on substrate (soluble COD or BOD) concentrations available to the microorganisms were gathered and the substrate removal rates were calculated. Separation of the data by temperature range was made for each of the three seasons and the mean ratio of removal rate to soluble effluent COD concentration (removal rate coefficient) was calculated for each group of data. The COD removal rate coefficients by season and by temperature range are given on Table 8. Table 8 also shows a logarithmic regression equation for the information. The COD removal rate temperature relationship was found by least squares regression to be:

$$f_T = 0.019 \times 1.16^{T-20}$$

The mean removal rate coefficient at each temperature was weighted according to the number of data points that went into its calculation. The data points (removal rate coefficient vs. temperature) and the least squares linear regression for the three years of data are shown on Figure 14. There is consider-

Figure 12. Aeration basin.

Figure 13. Clarifier. Aeration basin in background.

TABLE 8. COD REMOVAL RATE COEFFICIENTS

Temperature Range °C	1974 No. of Points	1974 Mean Removal Rate[1] Coefficient	1975 No. of Points	1975 Mean Removal Rate[1] Coefficient	1976 No. of Points	1976 Mean Removal Rate[1] Coefficient
16-19	5	.0057±.0016	15	.0101±.0075	13	.0116±.0129
13-16	15	.0070±.0047	17	.0089±.0063	18	.0060±.0036
10-13	25	.0083±.0061	21	.0098±.0047	13	.0053±.0014
7-10	13	.0015±.0011	13	.0110±.0063	18	.0045±.0022
4-7	5	.0021±.0017	16	.0042±.0035	13	.0024±.0015
0-4	0		0		37	.0047±.0029

[1] Removal Rate Coefficient, f_T for COD defined as removal rate, q, divided by soluble effluent COD. Values given as mean ± one standard deviation.

$$f_T = \frac{q,\ g\ COD\ removed/g\ MLVSS\text{-}day}{COD_s,\ mg/l}$$

f_T = COD removal coefficient at temperature T.

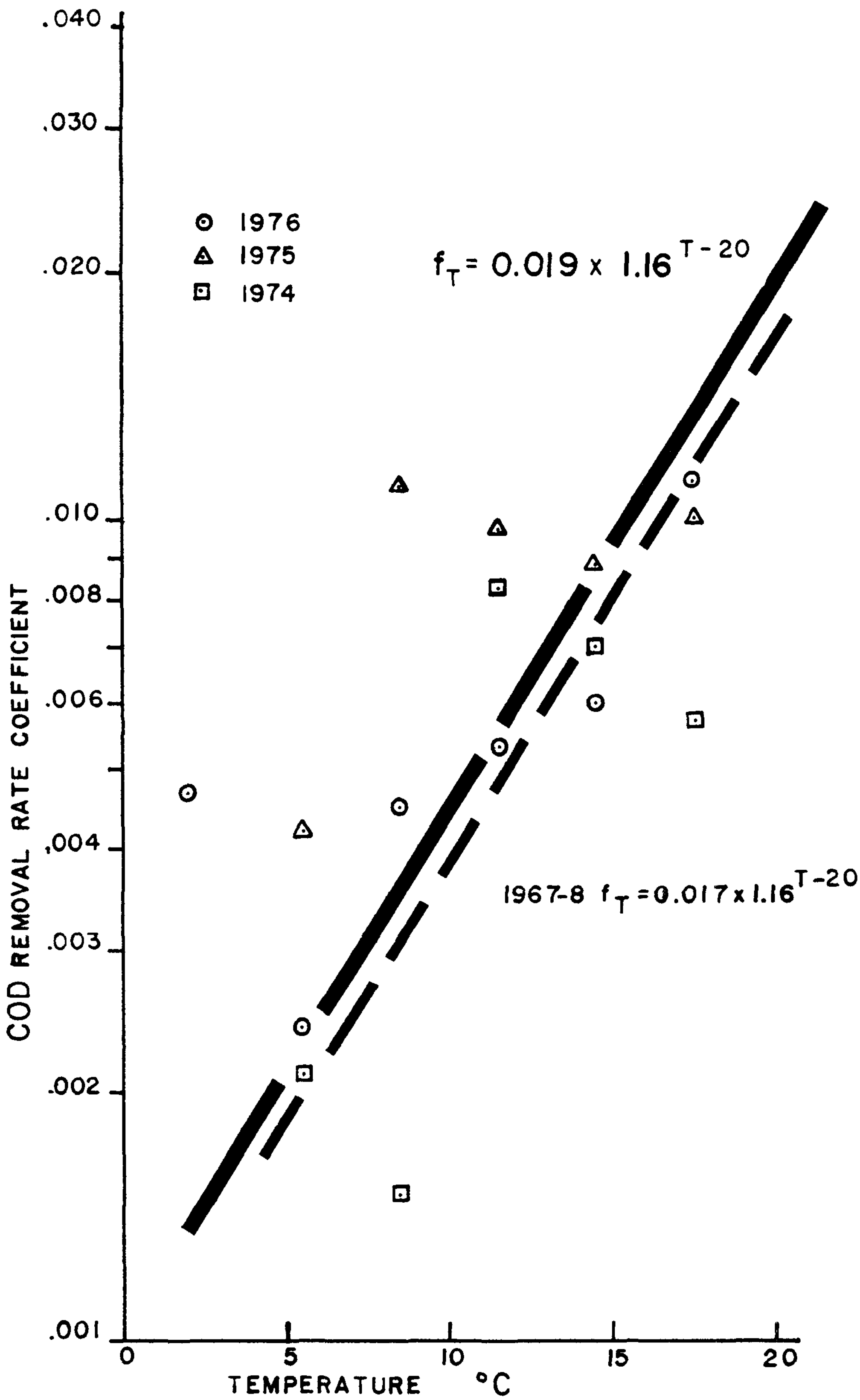

Figure 14. COD removal rate coefficient vs. temperature.

able scatter among the points. The temperature relationship found during the 1967, 1968 study ($f_T = 0.017 \times 1.16^{T-20}$) is also shown on Figure 14 for comparison. The information on Table 8 and Figure 14 show a high correlation between temperature and the COD removal rate coefficient. The coefficient temperature relationship established during this study is very similar to that found during the 1967-1968 season although this study showed a much greater scatter of data than the earlier investigations.

The BOD removal rate coefficient could not be directly determined due to less BOD data being available. Soluble BOD measurement was attempted during the study but the results were erratic. A linear regression was performed using total BOD and volatile suspended solids information for the biological treatment system effluent. The regression indicated that the soluble BOD fraction on an overall average basis, was 4 mg/l. The mean BOD removal rate was 0.089 g BOD removed/g MLVSS per day, and the mean temperature was 9.6°C. Using the average soluble BOD and the average BOD removal rate, a removal rate coefficient at the average temperature was estimated at 0.024 g BOD/g MLVSS-day-mg/l BOD for 9.6°C. By assuming that the temperature relationship for the BOD removal coefficient is the same as for the COD removal rate coefficient, an expression for the BOD removal rate coefficient can be obtained as follows:

$$f_{BOD_T} = 0.11 \times 1.16^{T-20}$$

The 1967 and 1968 study obtained an f_{20} value of 0.068 as compared to 0.11 obtained during this study. Both of these values were derived using the COD removal rate temperature relationship.

Biological Growth --

One aspect of biological waste treatment that strongly influences its cost is the amount of sludge produced by the treatment system. The sludge produced from a highly soluble carbohydrate waste such as from fruit processing, can be correlated to the organic (COD and BOD) removal rate. A constant proportion of the organics removed (defined as the yield coefficient, Y) is converted to sludge by bacterial growth. Endogenous respiration (k_d) by the sludge organisms reduces the net quantity of sludge produced, measured as mixed liquor volatile suspended solids (MLVSS).

$$\text{Net Sludge Production (VSS)} = Y \times \text{COD removed} - k_d \times \text{MLVSS}$$

where the net sludge production includes the sludge wasted, sludge in the effluent and the change in the aeration basin.

During this study, the amount of organics removed from the wastewater was monitored on a dily basis as COD and periodically as BOD. The amount of suspended and volatile suspended solids in the biological system was monitored on a daily basis to determine changes. It was difficult to accurately monitor the solids removed from the system by "sludge wasting" due to metering problems to and from the sludge thickener. Sludge wasting was by flotation thickening and hauling of the flotation thickened sludge by truck to land disposal. The thickener feed rate, overflow solids and sludge volume hauled were not sufficiently recorded to allow an accurate assessment of the amount of sludge wasted in this manner. The amount of solids lost in the effluent was monitored on a daily basis. The net sludge growth was accurately determined only when no sludge wasting was conducted; this eliminated the middle portion of each processing season.

The sludge growth rate and organics (COD, BOD) removal rate data were separated by temperature range. Figures 15, 16, 17 and 18 show the net sludge growth rate in grams of volatile suspended solids increase per gram of mixed liquor volatile suspended solids per day versus the COD removal rate in grams of COD removed per gram of MLVSS per day by temperature range. The slope of the line through the data points is the "yield coefficient" in grams of VSS (sludge) growth converted from each gram of COD removed. The zero removal rate intercept is the apparent endogenous respiration rate (k_d) for the group of data. Four data groupings were possible from the information available for the three processing seasons. Data between 6 and 10°C was insufficient due to sludge wasting to allow confirmation of the yield coefficient or endogenous respiration rate in that temperature range.

A consistent yield rate coefficient adequately describes all of the data on Figures 15, 16, 17 and 18. The yield coefficient found by eye plotting and by linear regression on Figure 15 and 16 during this study was:

Yield Coefficient, Y = 0.50 g VSS/g COD removed.

The yield coefficient for COD can be converted to a yield coefficient for BOD by employing the BOD to COD ratio, 0.73 g BOD/g COD, presented earlier. Thus, the VSS yield coefficient from BOD is:

Yield Coefficient, Y = 0.68 g VSS/g BOD removed.

These yield coefficients compare to 0.49 g VSS/g COD removed and 0.66 g VSS/g BOD removed determined during the 1967-1968 seasons for pear processing.[1]

The endogenous respiration rates determined from Figures 15, 16, 17 and 18 are shown on Figure 19 plotted against temperature.

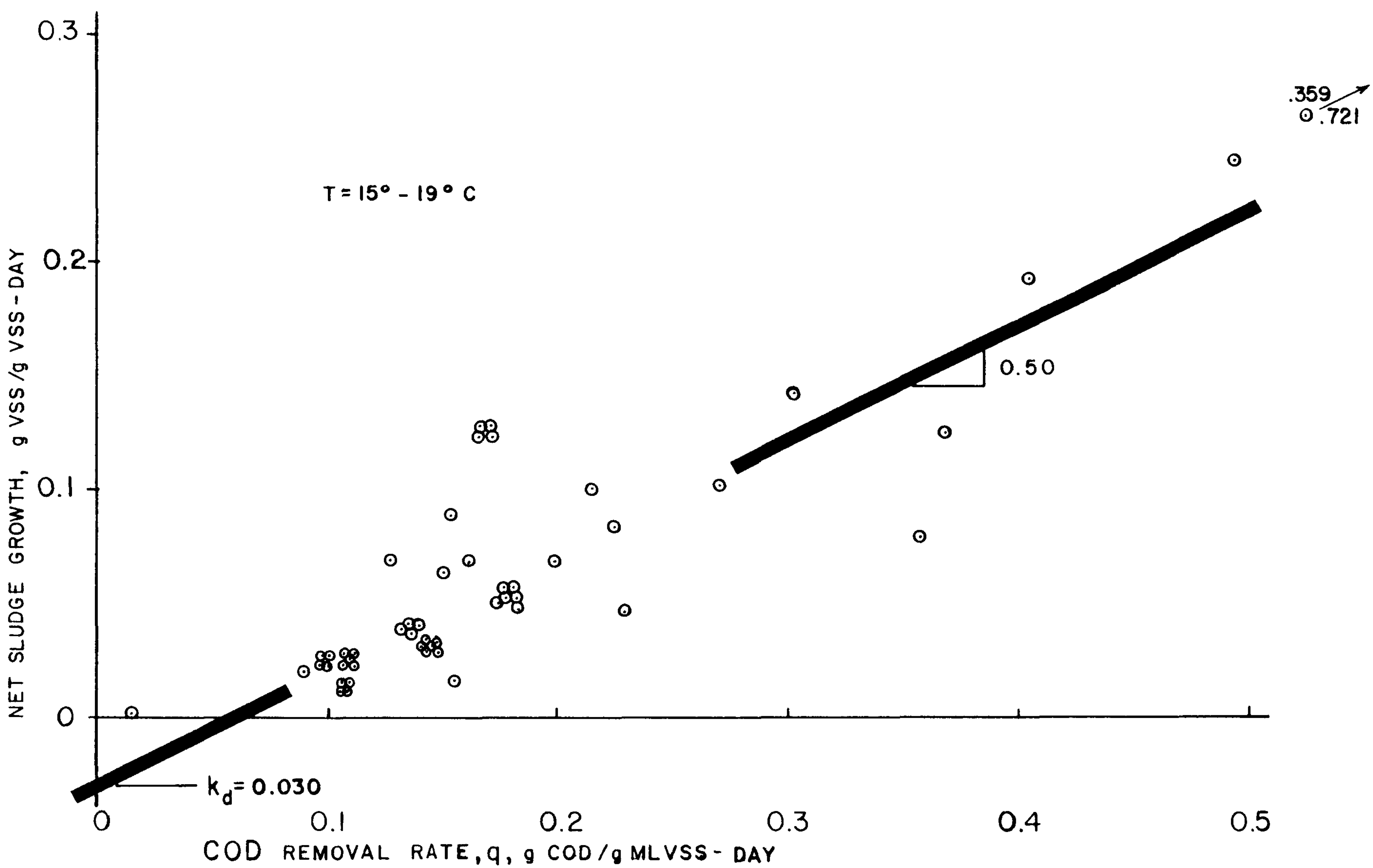

Figure 15. Net sludge growth vs. COD removal rate, 15-19°C.

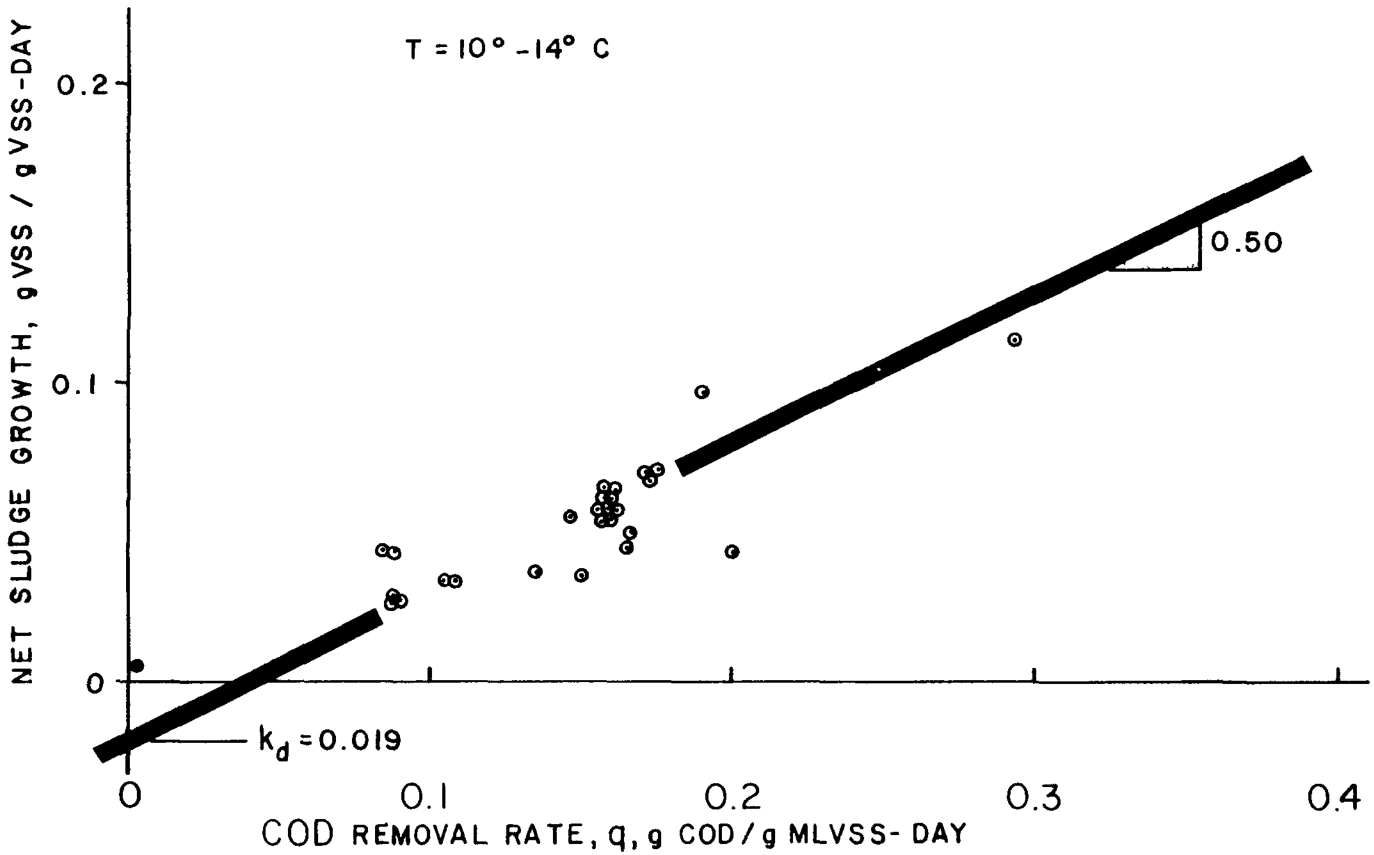

Figure 16. Net sludge growth vs. COD removal rate, 10-14°C.

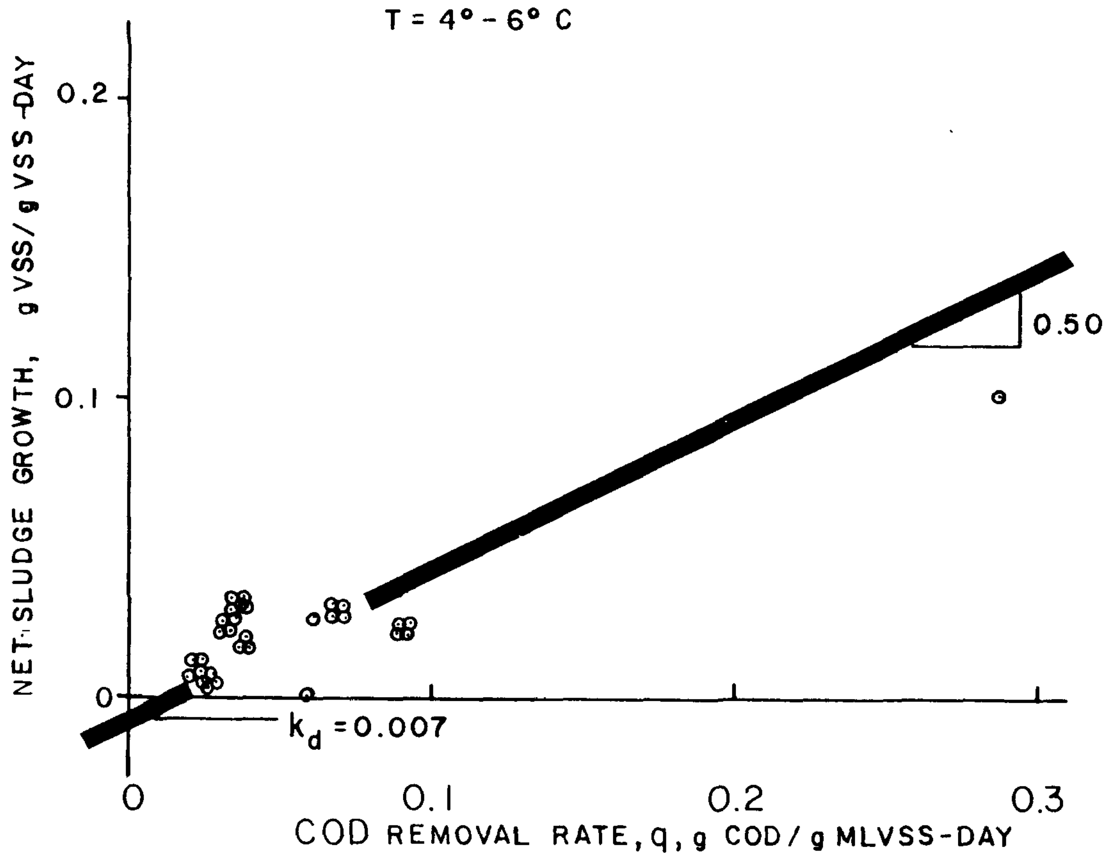

Figure 17. Net sludge growth vs. COD removal rate, 4-6°C.

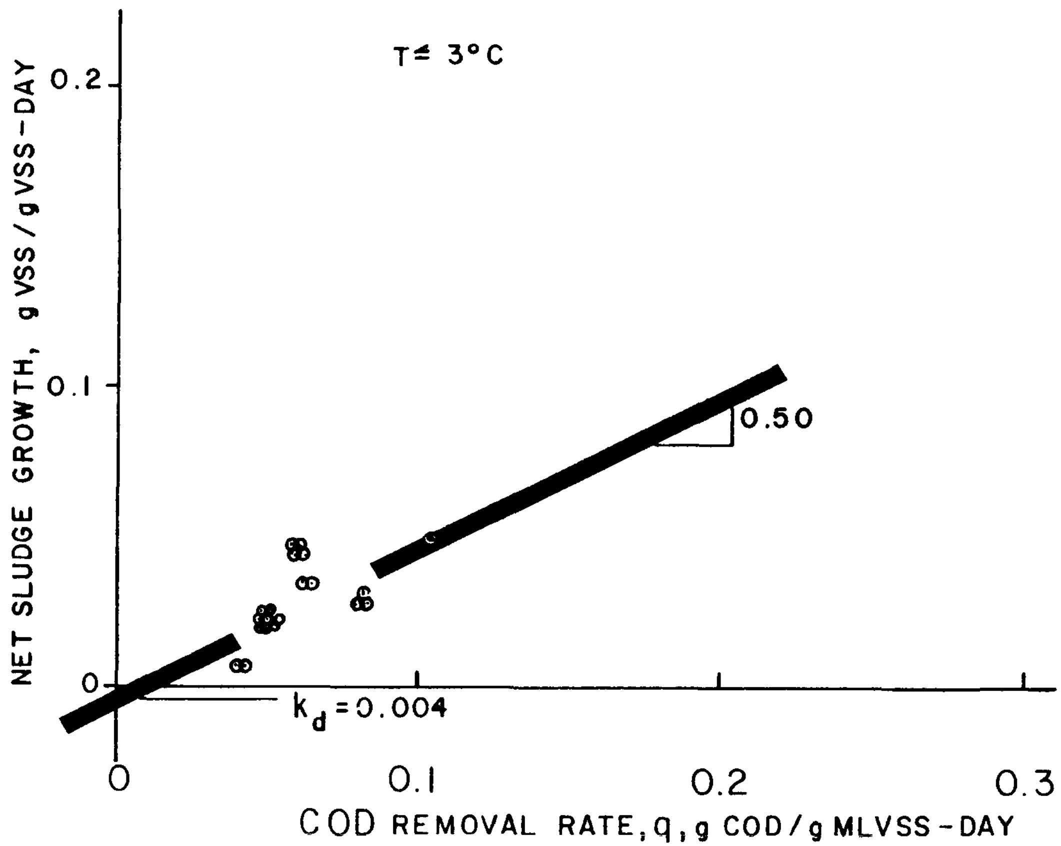

Figure 18. Net sludge growth vs. COD removal rate, 3°C or less.

Regression analysis of the points on Figure 19 indicate that the endogenous respiration rate as a function of temperature is:

$$\text{Endogenous Respiration Rate, } k_d = 0.050 \times 1.15^{(T-20)}$$

The endogenous respiration rate expression found from data collected during the 1967 and 1968 seasons was $k_d = 0.115 \times 1.14^{(T-20)}$.[1] The data collected during this study indicates a much lower endogenous respiration rate constant but approximately the same temperature relationship.

The endogenous respiration rate constant found during this study was approximately half of that found during the 1967-1968 seasons. The possible explanation for this is the much lower organics removal rate ranges for which data were collected during this study as opposed to 1967-1968, when removal rates ranged to much higher values. At higher removal rates, the activity of the biological solids is probably higher and the endogenous respiration rate could then be higher. The implication of the lower endogenous respiration rate found during this study is that a greater amount of suspended solids must be intentionally wasted to maintain a set solids level in the biological treatment system.

Biological Sludge Characteristics --

The biological sludge in the aeration basin was monitored during each of the three study seasons for suspended solids level, volatile suspended solids, COD, nitrogen and phosphorus content. The ratio of volatile suspended solids to the suspended solids; and the ratios of COD, organic nitrogen and organic phosphorus to the volatile suspended solids were calculated for each of the three seasons and on an overall basis. The results of these calculations are shown on Table 9. Also shown on Table 9 is the BOD to volatile suspended solids ratio for the biological sludge. This value was obtained from a linear regression analysis at the same time that the average soluble BOD in the effluent was determined.

It can be noted from Table 9 that there were slight differences between the means for various years in these ratios. Even though the differences are slight, they were significant at the 95 percent level between the 1974 and 1975 seasons, and the 1976 season. Differences between the means for the 1974 and 1975 seasons were not significant. The volatile fraction of the sludge, the nitrogen and phosphorus content and the COD of the biological sludge, were all slightly lower during the 1976 season. This may be due to the use of alum for filtering the biological effluent and the return of alum sludge from the filter backwash to the aeration basin. It is impossible though, to estimate the fraction of alum sludge which was present in the aeration basin at any particular time. For comparison,

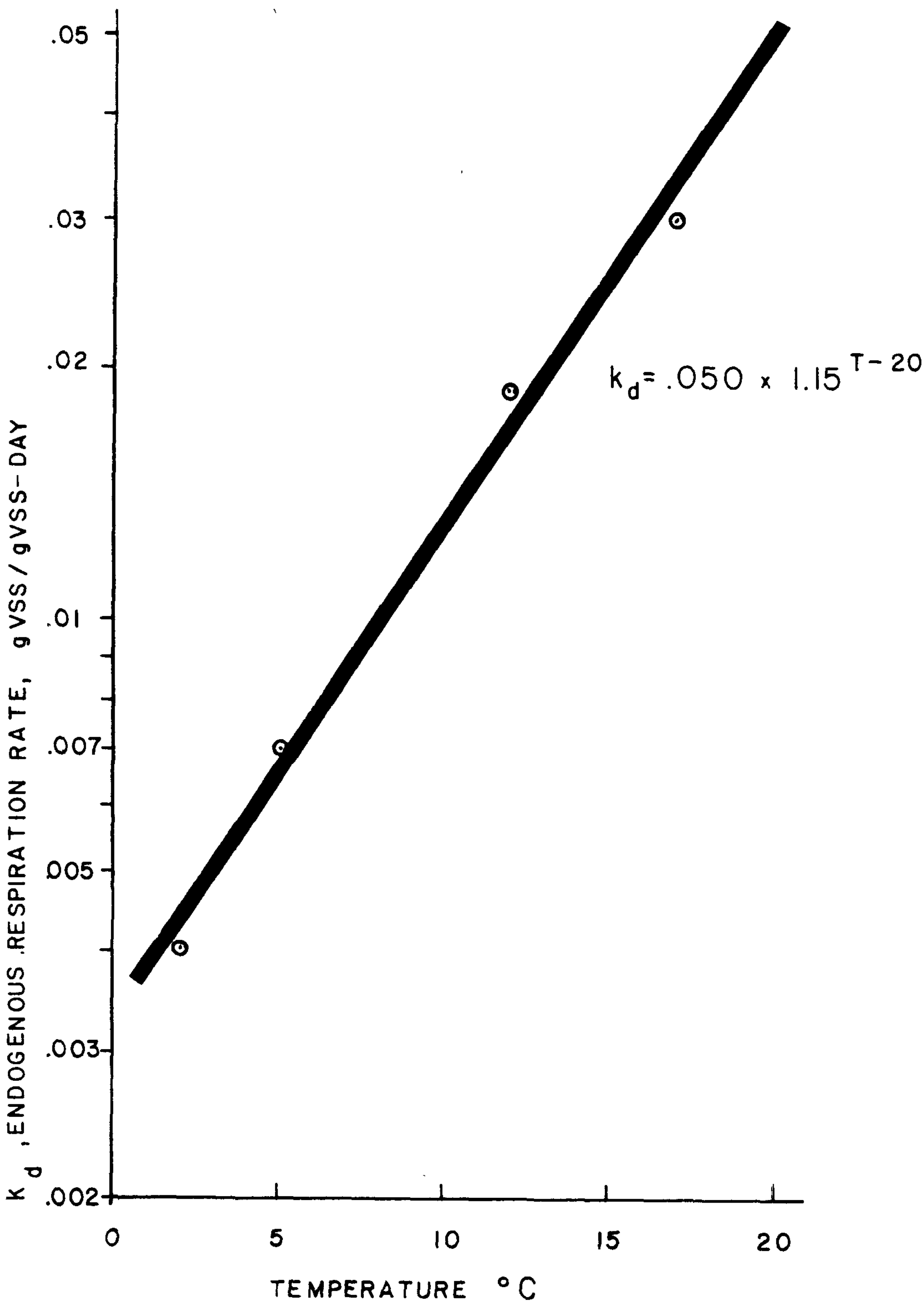

Figure 19. Endogenous respiration rate vs. temperature.

during the 1967 and 1968 processing seasons, the COD to VSS ratio was 1.39; the N to VSS ratio was 0.087; and the P to VSS ratio was 0.016. Only the nitrogen content of the biological sludge seems to be significantly different than the values obtained during this study. During the 1967-1968 study, the BOD content of the mixed liquor volatile suspended solids was approximately 0.33 at a BOD removal rate of 0.1 g BOD/g MLVSS day. The .25 value found during this study was about 25 percent less than that found during 1967 and 1968.

TABLE 9. CHARACTERISTICS OF BIOLOGICAL SLUDGE

Ratio	Processing Season			
	Overall	1974	1975	1976
MLVSS / MLSS	0.890±0.021*	0.895±0.012	0.895±0.026	0.883±0.020
COD / MLVSS	1.38±0.12	1.39±0.03	1.39±0.03	1.36±0.03
N / MLVSS	0.074±0.009	0.076±0.004	0.078±0.012	0.070±0.007
P / MLVSS	0.016±0.003	0.017±0.001	0.017±0.004	0.015±0.002
BOD / MLVSS	0.25			

* Mean ± Standard Deviation

Biological Effluent Quality --

Effluent water quality from the biological treatment system clarifier is summarized on Table 10. The summary is broken down by product processed and by water quality ranges which are significantly different at the 95 percent level.

During the 1974 season, the effluent quality was initially poor apparently due to nutrient deficiency in the aeration system following start up. Then the effluent quality improved and was fairly consistent through pear and peach processing. The quality deteriorated slightly when pears and apples were processed, possibly due to lower temperatures in the aeration basin in this later part of the season, although chlorine use in the cannery may have affected the treatment system. Apple processing beginning in November saw a further deterioration of effluent quality with more suspended solids in the effluent during the colder operating conditions. Chlorine use again could have been causative in lowering the effluent quality. The effluent BOD and soluble COD concentrations declined during apples, apparently due to the lower organic loading on the aeration system.

TABLE 10. BIOLOGICAL EFFLUENT QUALITY

Product By Season & Dates	Mean mg/l ± Std. Dev. (No. of Samples)		
	COD	BOD	Susp. Sol.
1974			
Pears (8/23-31)	133±75(8)	142(1)	54±28(8)
Pears, Peaches (9/3-20)	32±10(17)	12±7(3)	8±3(17)
Pears & Apples (9/23-11/9)	42±16(36)	8.6±2.5(5)	16±7(36)
Apples (11/11-12/13 except 12/5)	52±39(21)	6.0±7.11(7)	20±12(21)
(12/5)	850(1)		680(1)
1975			
Pears, Peaches (8/26-10/4)	58±23(34)	9.7±5.3(6)	25±8(34)
Pears & Apples (10/6-10/23)	139±47(16)	20±10(3)	98±45(16)
Pears & Apples (10/24-11/19)	45±14(22)	6.3±3.2(4)	19±7(22)
Apples (11/20-12/18)	101±37(18)	29±12(3)	51±29(18)
1976			
Pears, Peaches (8/24-9/7, 9/13-10/2)	32±8(30)	4.8±2.1(5)	9±4(30)
Pears (9/8-11 Upset)	247±170(4)	47(1)	66±22(4)
Pears & Apples (10/4-11/13)	40±11(35	4.5±2.3(8)	14±5(35)
Apples (11/15-24)	49±4(7)	6.0±1.4(2)	16±5(7)
Apples (11/29-12/2)	85±14(4)	15 (1)	56±6(4)
Apples (12/3-1/6)	52±18(19)	10±3(3)	32±12(21)
Apples 1/7-19)	Aeration Basin Frozen Over		
Apples (1/20-31, 2/23-3/10)	113±35(20)	20±9(3)	77±31(20)

Effluent quality during the 1975 season was not as good as during the 1974 season and not as good as expected. It was concluded that inadequate management of chlorination in the cannery during cleanup operations resulted in the effluent quality being lower than anticipated during this entire season. The 1976 season showed an effluent quality improvement overall from the 1975 season and return to an effluent quality comparable to that experienced in 1974, with some exceptions. The first exception was during the week following Labor Day when an apparent toxic discharge, possibly chlorine, from the cannery, resulted in a biological upset. Microscopic examination of the floc before and after the upset showed that the motile life forms in existence before the upset had all been immobilized. Management of the wastewater treatment system and in-plant efforts to control future toxic discharges, resulted in a rapid recovery of the biological system so that good effluent quality was experienced through remainder of the pear processing seasons. Relatively good effluent quality continued on through apple processing until about the first of December although periodically measurable residual chlorine levels were detected in the discharge to the biological treatment system. Effluent quality began to deteriorate rather severely about December 1st, when prolonged cold conditions resulted in aeration basin temperatures at less than $2^{\circ}C$. On January 7th, the aeration basin finally froze over resulting in shut-down of the system. On January 20th, the aeration basin thawed and the treatment system was put back in operation. Effluent quality for the remainder of January and during a short processing period in late February and early March was fairly consistent but not particularly good as high suspended solids in the effluent resulted in the high COD and BOD readings. One exception to the generally good water quality during apple processing, prior to the first part of December, was in the few days following the Thanksgiving shut-down when quality deteriorated. This deterioration may have been due to clean up operations in the cannery.

It is evident from this that careful control of the biological treatment system and the feed to the system is necessary to maintain consistently good effluent quality. The toxicants which apparently entered the system during much of 1975 processing season and at least a couple of times in 1976, resulted in upset of the system. The toxic discharges, assuming they were chlorine, can be controlled through diligent in-plant efforts, combined with equalization ahead of the biological treatment system.

BIOLOGICAL EFFLUENT POLISHING FOR REUSE

The biologically treated effluent was polished by the mixed media pressure filter system and disinfected by chlorination to produce a reclaimed water for reuse in the cannery. During this study several equipment malfunctions and difficulties in start up occurred. During the 1975 seasons, the backwash system for the filters malfunctioned several times due to problems with automatic control valves. These problems caused some periods of improper operation of the system. Also the chlorine residual control equipment functioned poorly during much of the 1975 season. The relatively low chlorine demand allowed the chlorination system to be operated, however, in a flow-pace mode to obtain satisfactory results. Better results were obtained during the 1976 season when the equipment functioned relatively well during most of the season.

Mixed Media Filter Performance

The mixed media filters used for polishing the biological effluent were pressure filters fed by pumps as described earlier. The filter media consisted of two densities of anthracite, silica sand and a layer of garnet sand. Liquid alum was fed to the wastewater stream ahead of the pumps to the filters during portions of the 1975 operation season and much of the 1976 season. The alum feed was varied from 15 to 60 mg/l to determine the effect of alum feed concentration. A cationic polymer was tried during the 1976 season and laboratory investigations of anionic and non-ionic polymer addition with the alum feed was tried during the 1976 season.

The filter effectiveness is indicated on Figure 20 where the frequency distribution of suspended solids levels in the biological effluent and in the filtered effluent are shown. As discussed above, the biological effluent quality was better in 1976 than in 1975 with 1974 being similar to 1976. The biological and filtered effluent data for 1975 and 1976 covered comparable time periods.

Table 11 shows the suspended solids removal effectiveness of the filter system for the 1975 and 1976 seasons. The suspended solids level in the biological effluent and in the filter effluent are shown, as is the amount removed and the percent removal for various time periods. Each of the time periods had significantly different suspended solids levels or removal performance than adjacent time periods.

Effect of Chemical Addition --

The wastewater reclamation facilities had provisions incorporated for addition of chemicals. Liquid alum, paced according to flow, could be added ahead of the pumps to the filters. There were also the capability incorporated for addition of polymers. Alum was added during a portion of the 1975 processing season and during the majority of the 1976 processing season. Specific trials when alum dosage was varied and the turbidity monitored after stabilization of the filters, were conducted in 1976. The results of these trials on several dates are shown on Figure 21. There appeared to be little beneficial effect of the alum with increases in dosages or in comparison to filtration without alum addition.

Periods of comparable effluent feed to the filters with and without alum addition, were statistically analyzed. The period from October 24, 1975 through November 24 had a relatively consistent filter feed quality (see Table 11). During this period, alum was added at a rate of approximately 30 mg/l for 10 days and no alum was administered on 14 of the days of operation. Statistically there was no difference, at the 95

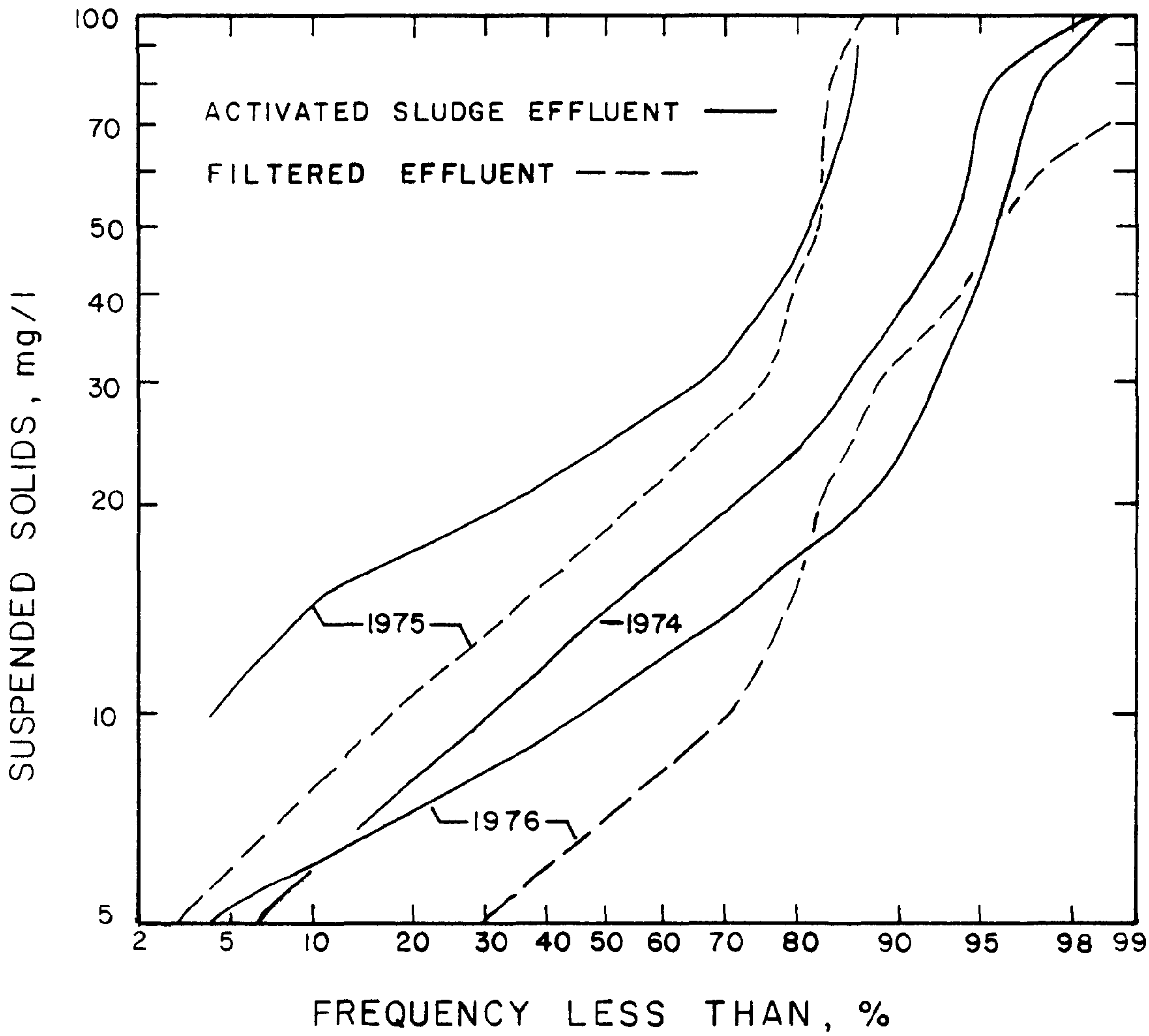

Figure 20. Suspended solids in biological effluent and filter effluent.

TABLE 11. MIXED MEDIA FILTER SUSPENDED SOLIDS REMOVAL

Processing Season & Dates	No. of* Test Days	Suspended Solids Mean mg/l ± Std.Dev. Biological Effluent	Suspended Solids Mean mg/l ± Std.Dev. Filter Effluent	Suspended Solids Removal Mean ± Standard Deviation mg/l	Suspended Solids Removal Mean ± Standard Deviation %
1975					
8/12-10/4	29	25 ± 8	17 ± 8	8 ± 4	33 ± 18
10/6-10/23	14	92 ± 46	85 ± 42	7 ± 11	8 ± 10
10/24-11/19	21	19 ± 7	15 ± 6	4 ± 3	20 ± 16
11/20-11/24	3	14 ± 7	9 ± 1	5 ± 7	22 ± 35
12/1-12/9	7	80 ± 14	70 ± 11	9 ± 7	11 ± 7
12/10-12/18	7	42 ± 12	34 ± 10	8 ± 5	18 ± 9
1976					
8/24-9/4, 9/13-10/2	28	8.2 ± 2.6	5.6 ± 2.4	2.6 ± 3.2	26 ± 44
9/7-9/11	5	56 ± 28	42 ± 22	14 ± 8	27 ± 15
10/4-11/4	27	13 ± 4	9 ± 4	4.0 ± 2.2	31 ± 14
11/5-11/13	7	18 ± 4	29 ± 5	-11 ± 8	-70 ± 62
11/15-11/23	7	16 ± 5	30 ± 13	-14 ± 10	-85 ± 53
11/29-12/3	5	52 ± 9	121 ± 36	-69 ± 32	-134 ± 65
12/6-1/7	21	32 ± 12	23 ± 15	9 ± 6	33 ± 21
1/19-1/31	9	78 ± 19	56 ± 18	22 ± 11	29 ± 11
2/23-3/10	12	79 ± 40	77 ± 38	2 ± 8	3 ± 10

* Alum added

Season	Dates	mg/l	Season	Dates	mg/l
1975	10/8-15, 11/5-8	Approx. 15	1976	11/10-12/1	22
	11/11-14, 17-20	30		12/2-4	45
	12/2-5, 8-12, 15-19	30		12/6-1/19	30
1976	10/1-7, 15-19	15		1/20	45
	10/7-14, 20-11/9	20		1/21-3/10	15

* Filter rate - maximum set at 1400 liter/min. ea. (0.5 cm/sec.)

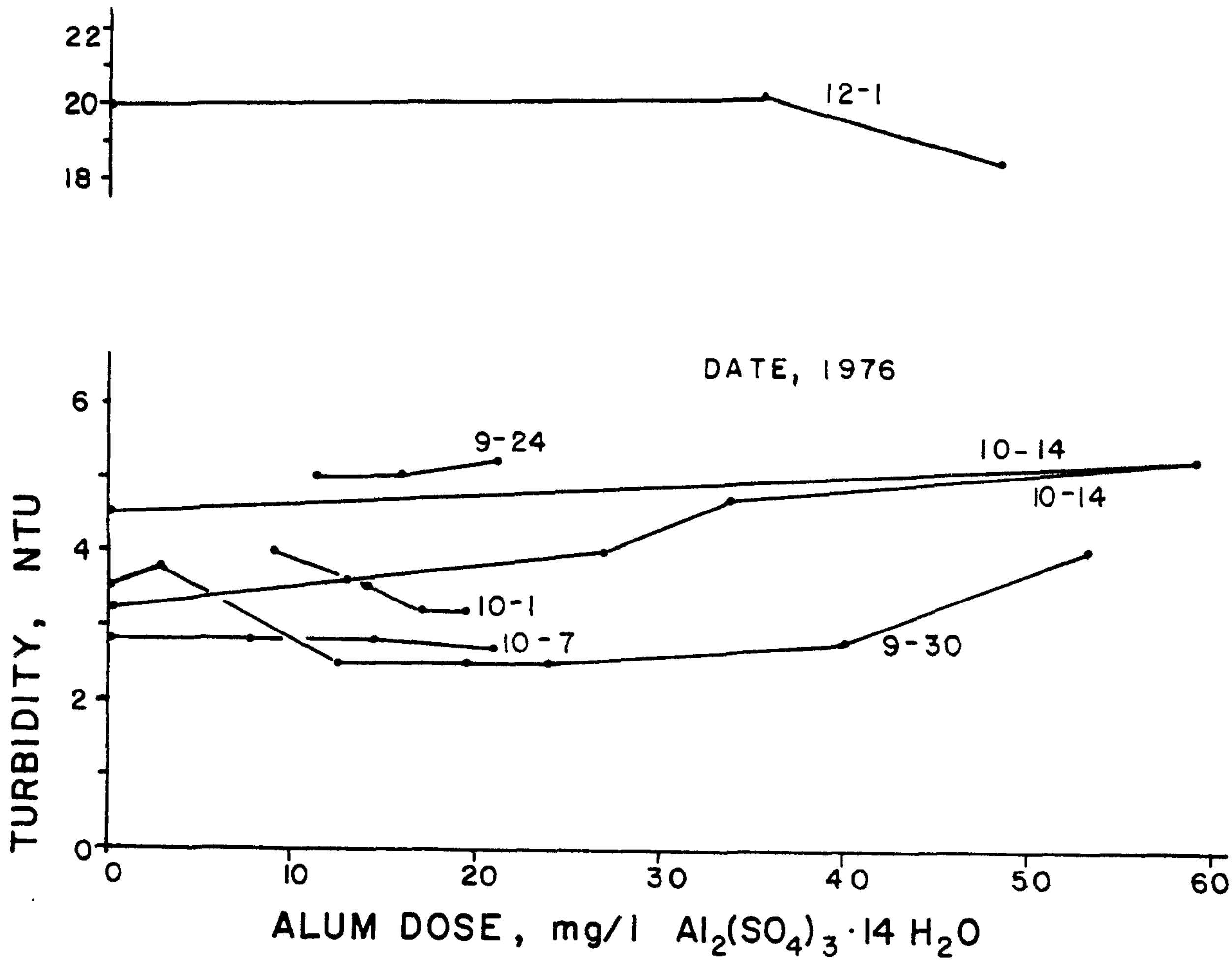

Figure 21. Effect of Alum dose on turbidity in filter effluent.

percent significance level, between the filter feed or the filter effluent suspended solids concentrations between periods when alum was added and the periods when no alum was being applied. The suspended solids removal in mg/l and in percent reduction were also statistically similar. The automatic backwash valve malfunctioned about 6 days during the period, three each during alum addition and no alum addition. These days were included in the comparison.

From August 24 through November 4, 1976, with the exception of September 7 through 11, the biological effluent quality was good. During this period, the first twenty-four days were operated without alum addition. Subsequently, from October 1 through November 4, there were nine days of operation with alum fed at about 15 mg/l (as $Al_2(SO_4)_3 \cdot 14\ H_2O$) and 20 days when alum was fed at about 20 mg/l. Comparison of the data between the two alum dosage rates showed there to be no difference, at a significance level of even 80 percent, between the suspended solids in the biological effluent, in the filter effluent and in the suspended solids removed. Comparison of the entire 32 days of operation when alum was added with the 24 days when alum was not added, showed that the suspended solids concentration in the biological effluent fed to the filters, and in the filter effluent, were significantly higher (at the 95 percent level) during alum addition. The removal of suspended solids was not significantly different either as mg/l removed or percent reduction between the two time periods.

During the 1976 processing season, alum was added from approximately the 1st of October through the end of the processing season at various levels. Referring to Table 11, it can be seen that suspended solids actually increased from the biological to the filter effluent from about November 5 through December 3. This increase was probably attributable to the alum addition as no other source of suspended solids production would be available. The filters were backwashed by headloss limit switch from 3 to 6 times per day during this time period.

Alum addition from December 6 through January 7 was at a dosage rate of 30 mg/l and from January 19 through the end of processing at a rate of 15 mg/l. Even though there were significant differences between the suspended solids in the filter feed and filter effluents, there was no significant difference in the reduction of suspended solids measured as mg/l between the two periods.

Anionic and non-ionic polymers (magnifloc 844A and 990N) were tested on a bench filter to determine whether suspended solids removal could be enhanced. Both polymers achieved slightly over 20 percent improvement in suspended solids reduction at a 4 mg/l dosage with alum dosage at 15 mg/l. The tests took place during a period when suspended solids feed to the filters of about 40 mg/l was being reduced to about 36 mg/l with only the alum feed.

Cationic polymer (DOW C31) was added to the filter feed on a trial basis one day during 1976 when the inlet suspended solids was approximately 40 mg/l. The polymer, added at 2 mg/l (with no alum), resulted in a decrease in the capture of the suspended solids. The turbidity of the filter effluent with no chemical addition was at 4.7 NTU and increased after polymer addition to 6.2 to 8.0 NTU.

Based on these studies, there appears to be little if any benefit of aluminum sulfate addition, at the dosages used, ahead of the filters for removing suspended solids from the biological effluent. There was also little indication of benefit due to polymer addition. Alum dosage up to 120 mg/l was tried for a short period at the maximum filter rate (1400 l/min.) but the filter run was shortened to about 30 min., an impractical duration.

Disinfection

Disinfection is a function of initial mixing of the chlorine solution with the filtered water (diffuser across a 20 cm pipe) and contact time. The contact should be under plug flow conditions. Figure 22 shows the results of tests for chlorine residual on the contact basin influent and effluent when the chlorine feed was turned off for approximately one-half of a detention time. The resulting chlorine residual at the tank discharge indicates that the tank provided a reasonably good approximation of plug flow at the 1500 l/min. feed rate during the test (detention time, $\bar{t}$, of 2.4 hr).

Disinfection efficiency is a function of consistency of maintaining a chlorine residual as well as the initial mixing and chlorine contact. The facilities at Snokist Growers had some difficulties during start up and through the 1975 season due to the chlorine residual analyzer unit partially clogging with solids and causing the chlorine residual to fluctuate. The chlorine residual measured in the reclaimed wastewater at Snokist was as total residual chlorine. Since the ammonia content of the biological effluent was always near zero, the residual was probably as "free chlorine" however.

Wastewater Bacteriological Quality --

The processing wastewater, biological treatment effluent and filtered effluent bacteriological quality are shown on Table 12. Also included is the bacteriological quality of the house water supply for the cannery, an on-site well. The cannery water supply was of excellent bacteriological quality.

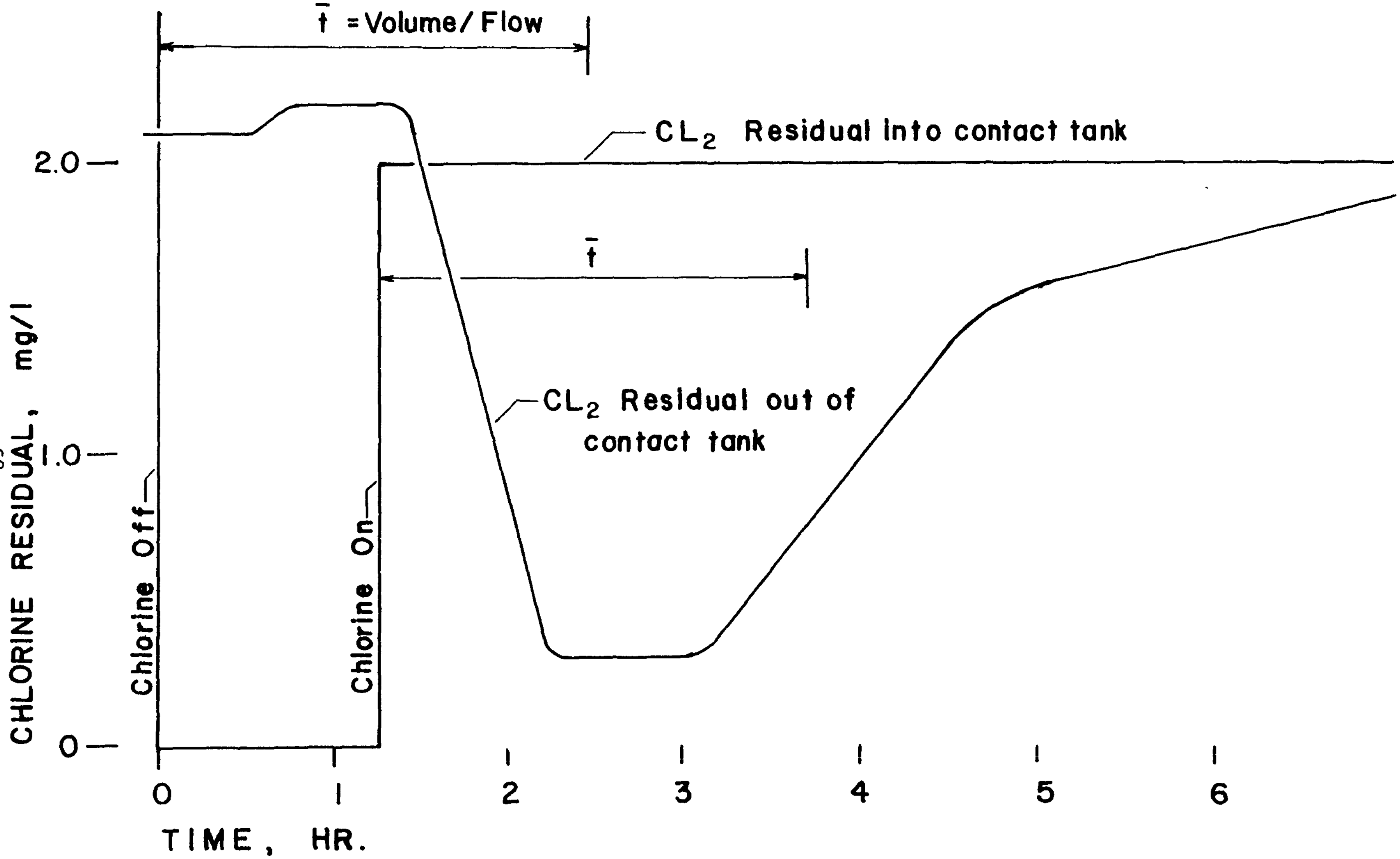

Figure 22. Chlorine contact tank flow-through characteristics.

TABLE 12. WASTEWATER AND WATER SUPPLY BACTERIOLOGICAL QUALITY

Sample	Season (No. Samples)	Test Units	Log Mean	95% Confidence Interval (Log Mean ± 2 Log Std.Dev.)
Raw Water Supply (Unchlorinated)	1975(17)	Total Coliform/100 ml	<1	No Positive Results
	1976(5)		<1	No Positive Results
	1975(11)	Total Plate Count/ml	0.8	0.001 to 600
	1976(3)		14	1.3 to 160
Processing Wastewater*	1975(18)	Total Coliform/100 ml	1.3×10^5	90 to 1.8×10^8
	1976(20)		1.1×10^6	71,000 to 1.8×10^7
	1975(10)	Fecal Coliform/100 ml	53	0.1 to 26,000
	1976(24)		4,000	120 to 1.3×10^5
	1975(11)	Total Plate Count/ml	83,000	6,200 to 1.1×10^6
	1976(20)		70,000	11,000 to 4.7×10^5
Biological Effluent	1975(75)	Total Coliform/100 ml	3.2×10^5	6,700 to 1.6×10^7
	1976(120)		4.7×10^5	34,000 to 6.4×10^6
	1975(17)	Fecal Coliform/100 ml	120	1.7 to 9,200
	1976(24)		660	14 to 31,000
	1975(78)	Total Plate Count/ml	38,000	3,300 to 4.5×10^5
	1976(80)		29,000	500 to 1.6×10^6
Filter Effluent (Unchlorinated)	1975(75)	Total Coliform/100 ml	1.6×10^5	1,500 to 1.8×10^7
	1976(120)		3.9×10^5	27,000 to 5.5×10^6
	1975(15)	Fecal Coliform/100 ml	33	0.3 to 4,300
	1976(24)		430	8.6 to 22,000
	1975(74)	Total Plate Count/ml	29,000	1,500 to 5.4×10^5
	1976(80)		21,000	260 to 1.6×10^6

*No sanitary wastes can enter the processing wastewater

The untreated process wastewater had a high bacterial content. The total coliform count present in the wastewater undoubtedly resulted from soil washed from the fruit during processing. There is also bacteria which indicated positively in the fecal coliform test, although their low numbers confirmed that sanitary waste was not being discharged into the wastewater. Some fecal coliform indicator organisms may be washed from the fruit or from the floor. Organisms which positively react to the fecal coliform test may be maintained and incubated in wet warm areas of the cannery waste system.

Table 12 shows that there is very little difference in the bacteriological quality of the processing wastewater and the biological effluent. There is a very small reduction in bacterial count through the filtration system. The removal of bacteria by the filters was significant during some periods of operation but not during others. The data from periods when alum was used on the filter was compared with information gathered when there was no alum used. Data from 1975 indicated that alum was beneficial in the removal of coliform and total plate count bacteria but the information gathered during 1976 did not confirm this.

Chlorination Disinfection Effectiveness --

Disinfection effectiveness on sanitary wastewaters in municipal treatment has been related to the reduction in coliform as a function of contact time and chlorine residual. The greater variation in input organism level to the disinfection system at Snokist Growers' cannery made organism reduction correlation unfeasible. The most consistent method for assessing the disinfection performance seemed to be the relation of effluent quality to the chlorine residual maintained in the contact tank. It was shown earlier that the contact tank had relatively good plug flow characteristics.

Total Coliform Removal--Probably the most appropriate measurements of sanitary water quality from a public health standpoint are the coliform and fecal coliform organisms. Their reduction in the reclaimed water was felt to be of critical importance. Disinfected effluent quality during the 1976 and 1975 processing seasons, measured as coliform count per hundred ml, as a function of chlorine residual in the contact tank, is shown on Figures 23 and 24. The chlorine residual was the average of the inlet and outlet concentration as measured with the amperometric titrator. Figures 23 and 24 indicate that 3 mg/l chlorine residual was adequate to assure a very low level of coliform bacteria in the reclaimed water. No positive results were obtained on the coliform test when chlorine residuals of greater than 3 mg/l were maintained. Figure 24 shows three erratic points during the 1975 processing season. These can probably be attributed to the chlorine

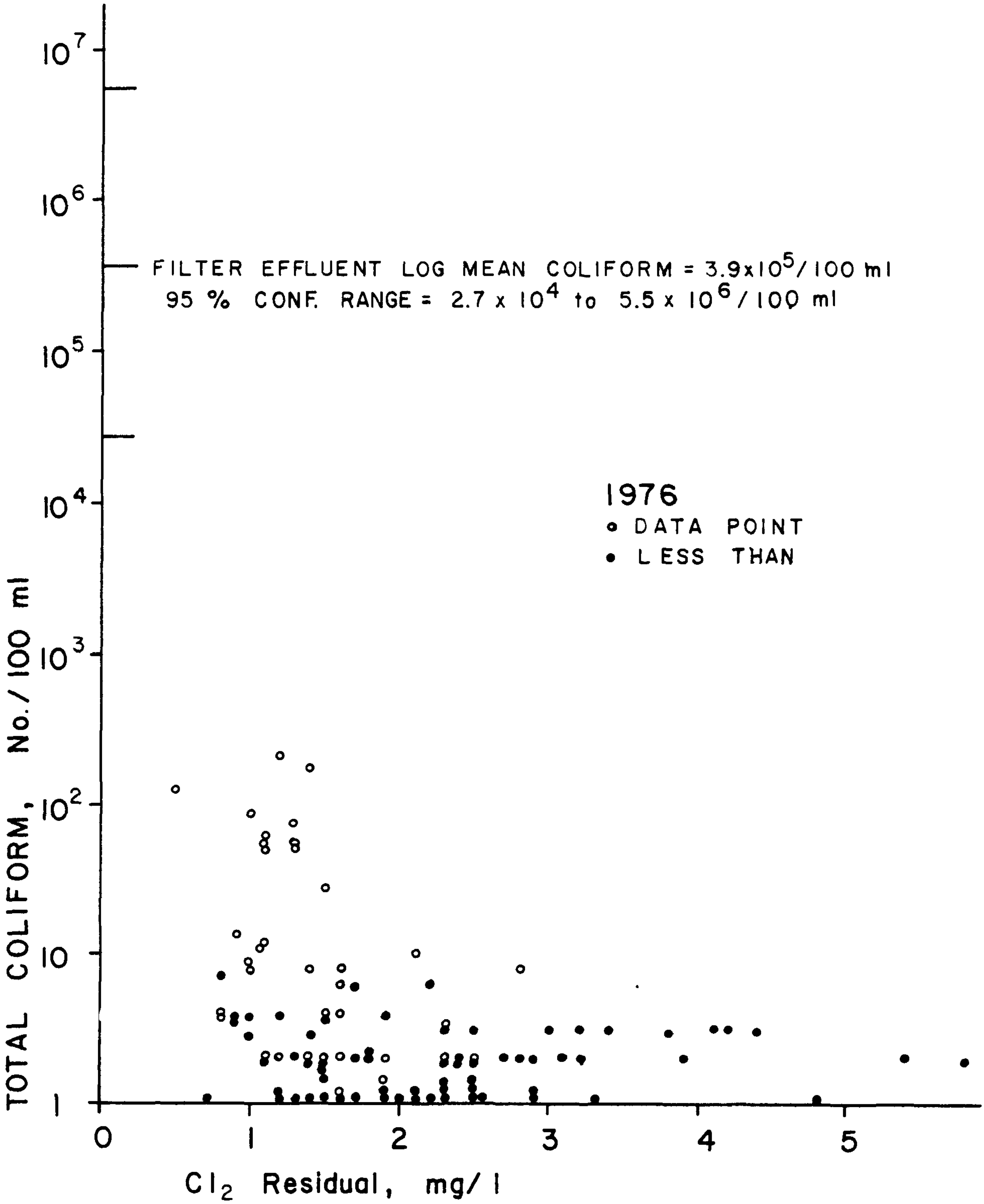

Figure 23. Reclaimed effluent coliform count vs. contact chlorine residual, 1976.

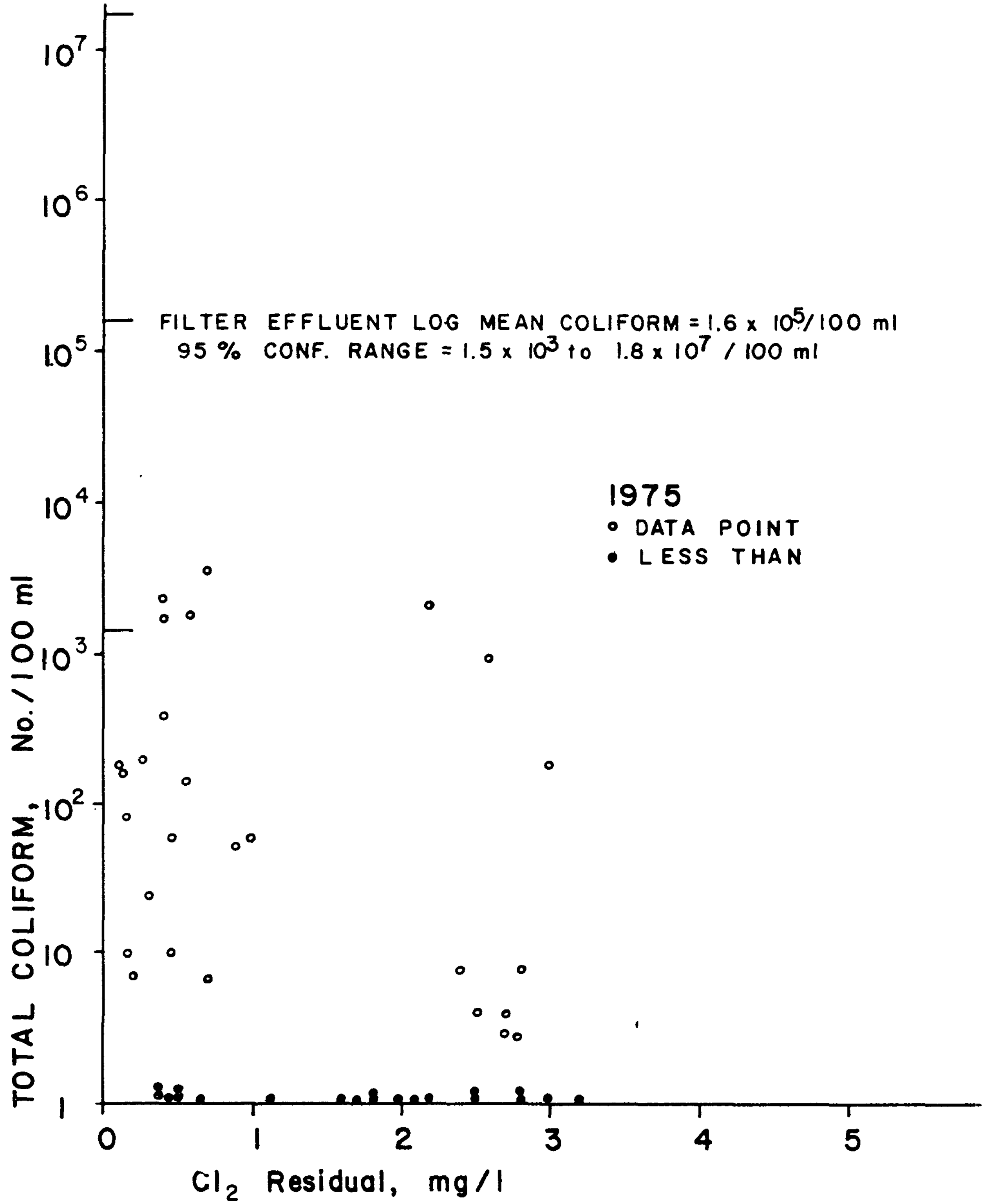

Figure 24. Reclaimed effluent coliform count vs. contact chlorine residual, 1975.

residual control problems prevalent during that season. Occasionally, chlorine residual oscillated during the processing day due to instability in the feedback control system. The control system maintained a more consistent chlorine residual during 1976.

Fecal Coliform Removal--The relatively low level of fecal coliform organisms in the wastewater was due to the absence of any sanitary waste entering the system. However, dirt sources and animal contamination by water fowl and turtles in the aeration basin and clarifier resulted in some fecal coliform bacteria in the filtered wastewater. These levels were shown on Table 12. Weekly testing during both the 1975 and the 1976 processing seasons showed no positive fecal coliform counts in the reclaimed water if chlorine residual was present.

Total Bacteria Reduction--The level of total bacterial content in the wastewater was assessed by use of the total plate count. The total plate count vs. chlorine residual in the reclaimed effluent is shown on Figures 25 and 26 for the 1976 and 1975 processing seasons respectively. Marked improvement with chlorination is readily evident from Figures 25 and 26. The reclaimed effluent consistently contained fewer than 500 organisms/ml when the chlorine residual was maintained at 3 mg/l or above.

Reclaimed Water Biological Quality --

Total coliform, fecal coliform and total plate count bacterial water quality was discussed in the previous section. Quality was found to be dependent on the reclamation system disinfection efficiency. Additional reclaimed water testing was done for Salmonella and Staphyloccus bacteria, for the presence of yeast and mold organisms, and for mesophilic spores.

No positive Staphyloccus organism reactions were obtained during testing. Non-lactose fermenting colonies isolated during the concentration step were selected for innoculation into enterotubes to determine the presence of Salmonella organisms. The enterotube reactions were read and interpreted and no Salmonella typical reactions were found. Staphyloccus and Salmonella isolation analyses were conducted on the reclaimed water weekly through the two seasons, 1975 and 1976.

Yeast and mold organism analyses were conducted on the reclaimed water during the 1976 processing season. The results are shown on Figure 27 plotted against chlorine residual. The analyses indicated low concentrations of these organisms but there was no clear cut evidence on Figure 27 that they are eliminated at the levels of chlorination used during the testing.

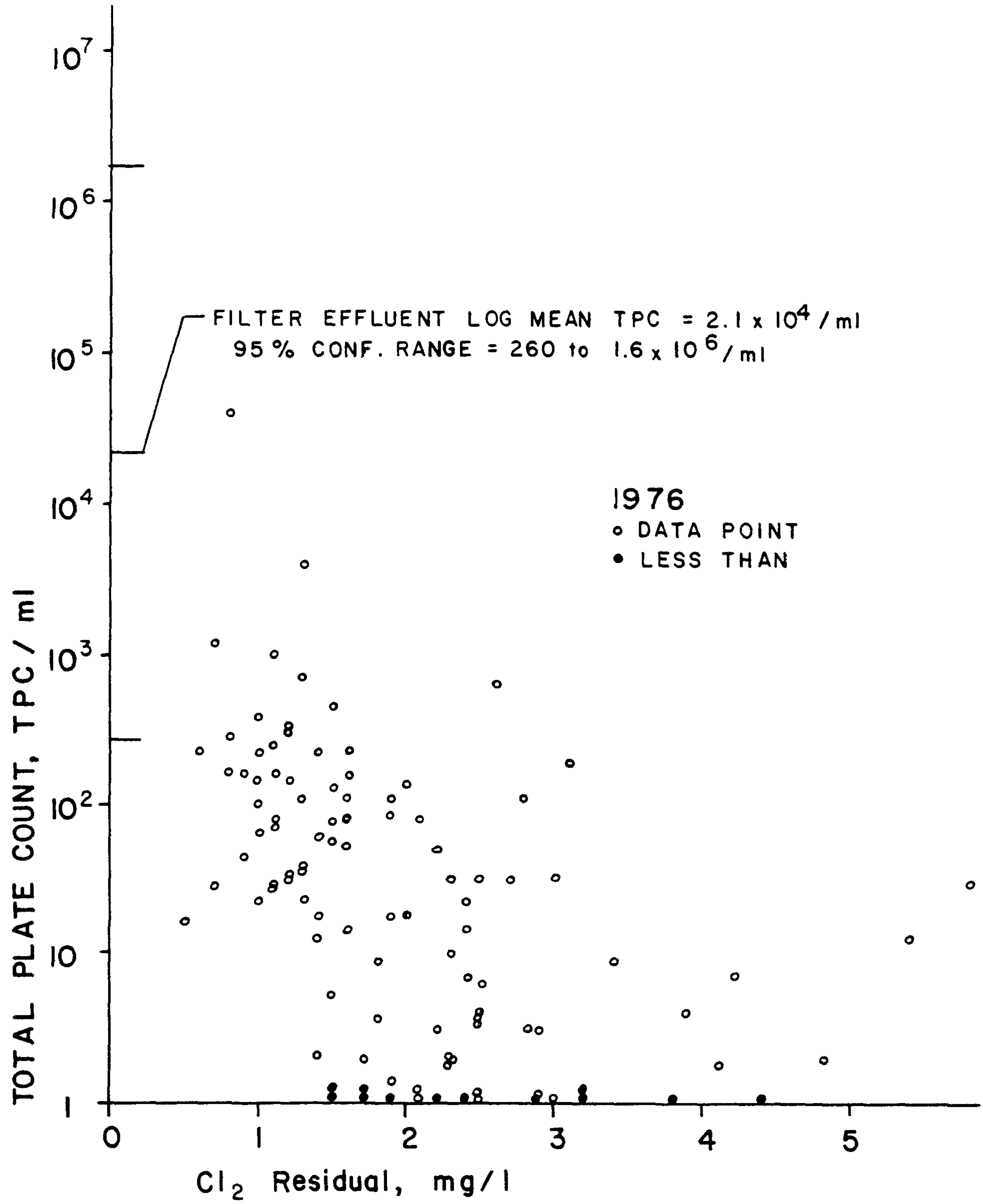

Figure 25. Reclaimed effluent total plate count vs. contact chlorine residual, 1976.

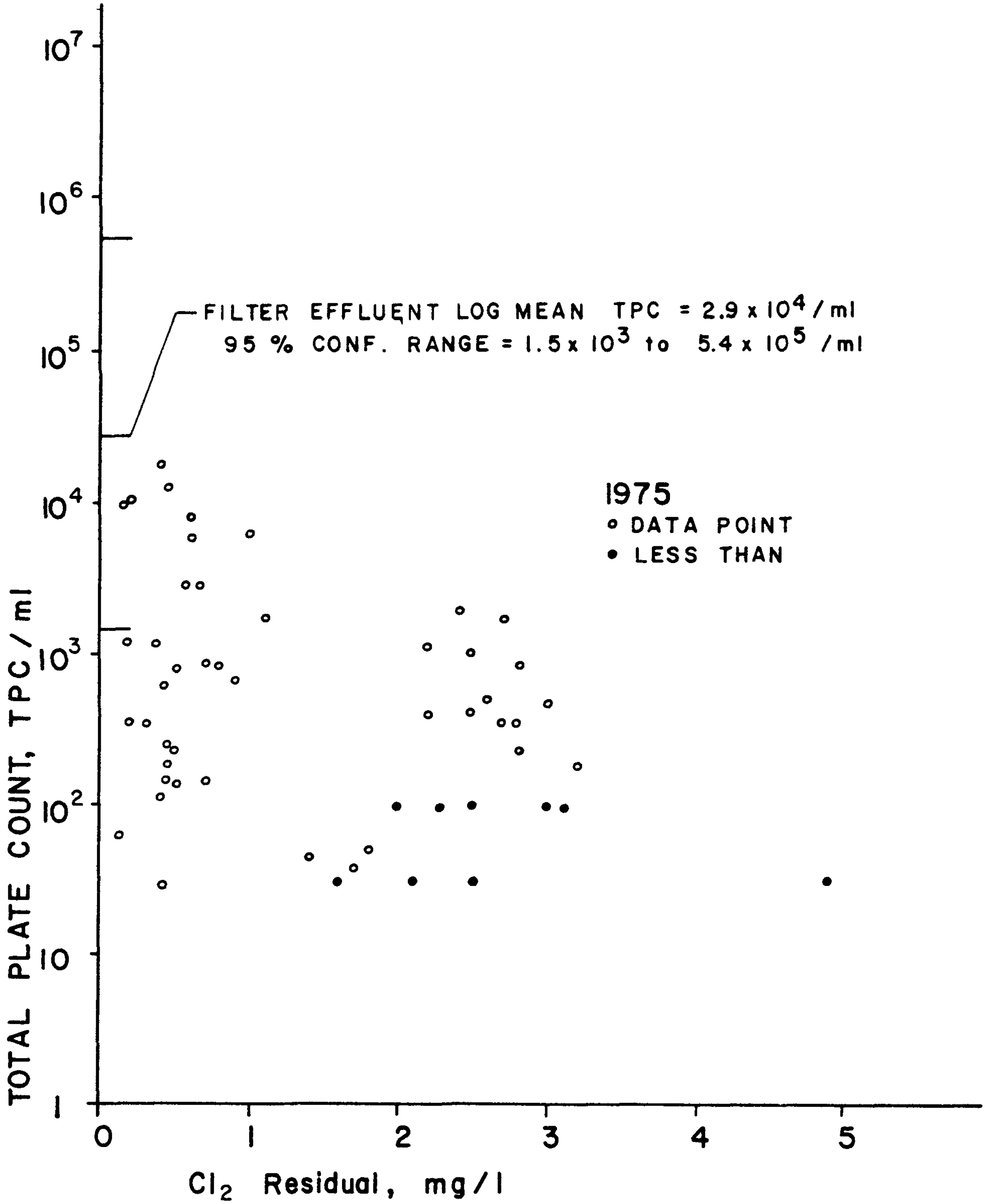

Figure 26. Reclaimed effluent total plate count vs. contact chlorine residual, 1975.

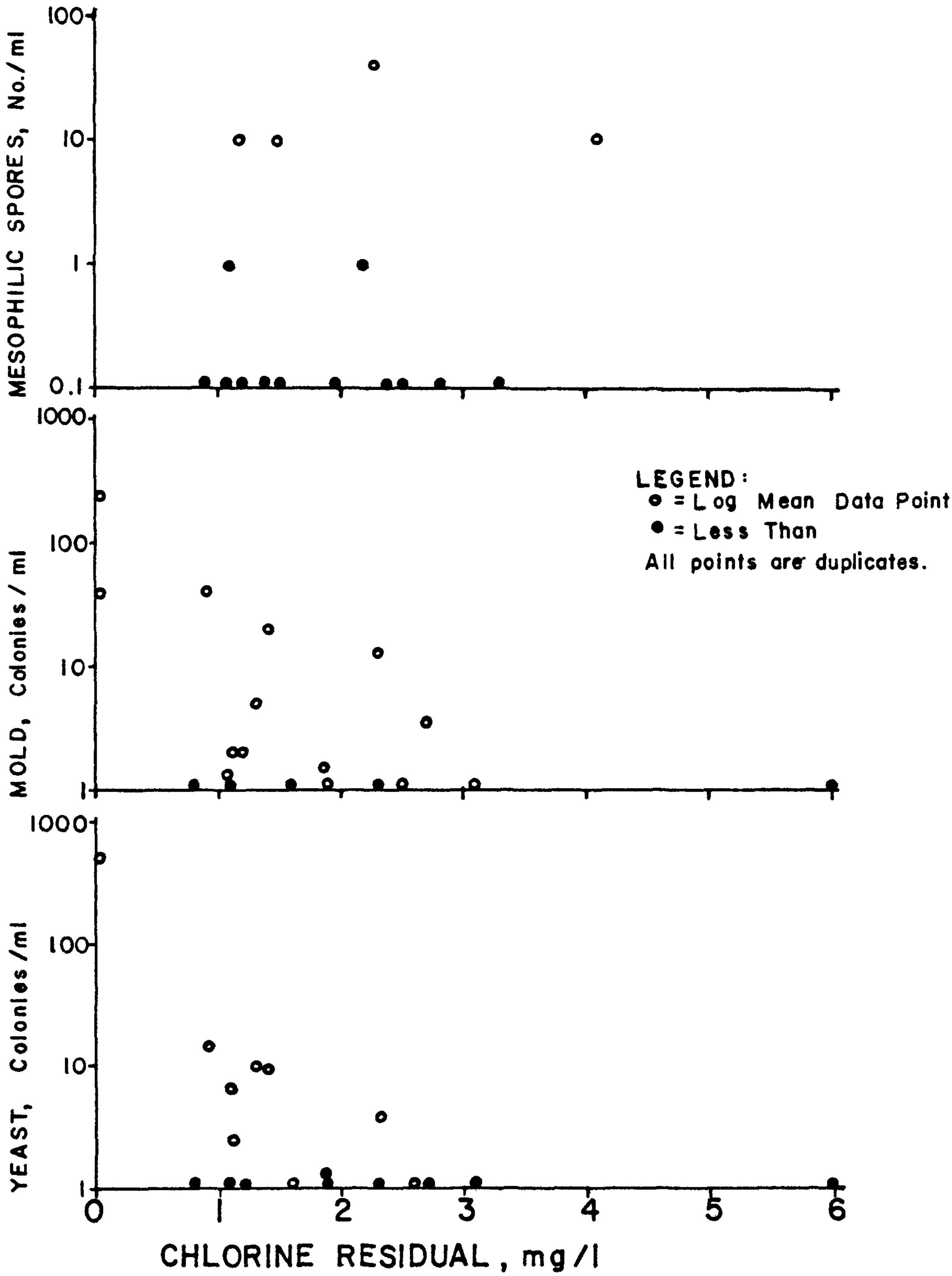

Figure 27. Yeast, mold and mesophilic spore content in reclaimed water vs. chlorine residual, 1976.

PHYSICAL AND CHEMICAL QUALITY OF THE RECLAIMED WATER

The physical and chemical characteristics of the reclaimed water are important in evaluation of its uses.

Temperature

The temperature of the reclaimed water was very close to that in the aeration basin although slight heating occurred through the pumping energy input and ground heating in the chlorine contact tank. During the first four weeks of 1975 processing, the reclaimed water temperature averaged 17.2°C. During the first two weeks of processing in 1976, the temperature averaged 17.8°C. This compared to a house water normal temperature of 15°C, and indicated that during the early part of each processing season, if reclaimed water were used for can cooling, it would take more of the reclaimed water than house water. At a water temperature of 18°C, it would take 18 percent more reclaimed water for cooling than house water, or approximately an additional 200,000 liters per day. However, as soon as the temperature of the reclaimed water decreased to below 15°C, about 4 weeks into the season during 1975 and 2 weeks into the season during 1976, the demand for cooling water from the reclaimed water source would be less than that from the house water. By the end of pear processing, the reclaimed effluent temperature was approximately 12°C or less indicating a saving of cooling water of at least 13 percent or approximately 150,000 liters per day. During the entire pear processing season of 1975, there would have been no difference in water use between the house water and reclaimed water. During the 1976 season, however, an average of 80,000 liters of cooling water could have been saved per day, based on the comparative temperatures of house and reclaimed water.

pH

The pH of the wastewater discharged to the treatment system was fairly constant throughout the season except during peach processing. The peaches were lye peeled which resulted in a high pH discharge. During 1975, excepting peaches, the average pH of the discharge was 7.1 with a standard deviation of 0.3 with no significant differences between various products. During 1975 peach processing, the pH averaged 11.4 with a standard deviation of 0.3. During the 1976 processing season, except peach processing, the average pH of the processing effluent was again 7.1 with a standard deviation of 0.3. The pH averaged 11.5 with a standard deviation of .1 during peach processing.

The high pH discharge during peaches resulted in some fluctuation in the pH of the reclaimed effluent. The pH of the reclaimed effluent during each the 1975 and 1976 seasons, prior to peach processing, averaged 7.0 with a standard deviation of approximately 0.5, except during the one week of 1976 when chlorine caused an upset of the biological treatment. During that week the pH average dropped to below 6. This pH depression during upset is characteristic of biological treatment systems receiving strong waste during upsets. Reclaimed water pH during the 1975 week of peach processing, increased to an average of 8.1 and then decreased during the subsequent two weeks to average 7.9 and 7.5. The next three week average was 7.4 with no significant difference between the weeks and the average for the remainder of the season was 7.2. During the 1976 week of peach processing, the pH raised to an average of 7.5 and during the subsequent three weeks, increased to an average of 7.8, then decreased to 7.5 and 7.3. The remaining season average was 7.0 and there were no significant differences between processing weeks.

Total Dissolved Solids

Total dissolved solids analyses were conducted on a weekly basis throughout the two processing seasons. Total dissolved solids levels in the reclaimed water averaged 290 mg/l with a standard deviation of 99 mg/l. There was no significant difference in the values between the 1975 and the 1976 seasons. The total dissolved solids in the house tap water averaged 120 mg/l.

Turbidity

Turbidity was measured in biological, filtered and chlorinated effluent grab samples once or twice daily with a forward scatter turbidimeter* during the 1975 and 1976 processing seasons. During the 1976 season, a continuous flow turbidimeter* was placed in operation to record turbidity in the filter effluent. This unit measured turbidity as side (90°) scatter light. Also during 1976, a side scatter bench unit* was used for about a month to measure turbidity in grab samples in parallel with the forward scatter unit. The standard method for low level turbidity measurement is with a "nephelometer" containing a light source and one or more photoelectric detectors and a readout device to indicate the intensity of light scattered at 90 degrees to the path of the incident light. Forward-scattering turbidimeters are excessively sensitive to the presence of larger particles in comparison to the side

* The bench model forward-scatter turbidimeter used throughout the study was a Monitek Model 150.
The continuous side-scatter turbidimeter placed in operation for the 1976 season was a Hach CR low range Model 1720 (range 0-30 NTU).
The bench model side scatter turbidimeter used for one month during the 1976 season was an HF Instruments Model DRT-100.

scattering units. The continuous flow turbidimeter and the side scattering bench unit used during the 1976 season comply with standard methods while the forward scattering unit does not.

The side scatter turbidity meters always yielded lower results than the forward scatter (non-standard) turbidimeter. The log mean ratio of the continuous reading turbidity values (in NTU) to the readings obtained from the bench forward scatter turbidimeter was 0.35, (95% confidence range 0.20 to 0.60). There was no significant (95%) difference between the log mean ratios from one portion of the processing season to another including when alum feed was on or off. All continuous flow meter readings were on the filter effluent.

From December 3, 1976, to January 6, 1977, the bench model side scatter turbidimeter was used to analyze grab samples in parallel with the forward scatter machine. On filtered effluent the log mean ratio of side scatter to forward scatter readings was 0.26 (95% confidence range 0.14 to 0.50). The log mean ratio on unfiltered biological effluent was 0.21 (95% confidence range 0.15 to 0.30). This ratio is significantly different at the 95% level from the ratio obtained for filtered effluent. Alum feed was on during the entire period.

The turbidity of the reclaimed wastewater is shown on Table 13. The turbidity data is in NTU (nephelometric turbidity units) as derived from the continuous flow turbidity meter, or as calculated from the values obtained on grab samples from the forward scatter unit (x0.35). Table 13 shows that the reclaimed effluent turbidity was very low during the 1976 season through November 23 except for the one week upset following Labor Day. A short run in May also produced a low turbidity reclaimed water. Reclaimed water turbidity from November 29 through January 7 was marginal with 13 of 23 days at 15 NTU or less, and after the January freeze through March 10, was high with only 4 of 18 days having 15 NTU or less. The 1975 processing season did not result in particularly good reclaimed water turbidity either, although from start up through October 4 the reclaimed effluent was consistently below 20 NTU.

The maintenance of a consistent low turbidity reclaimed water must, apparently, yet be demonstrated after cold weather and product changes occur late in the processing season. The 1976 data indicate that consistency was maintained during the main portion of the season. The primary drinking water standards[9] call for turbidity of 5 NTU or less plus demonstration of adequate disinfection. Disinfection consistency was demonstrated as documented above. The reclaimed effluent is not to be used for final product contact, inclusion with the final product or for human consumption. The reclaimed effluent

TABLE 13. RECLAIMED EFFLUENT TURBIDITY

Dates	Nephelometric Turbidity[1,2] Mean ± Std.Dev.,NTU	Proportion of Readings Equal or Less Than[1] 5 NTU	10 NTU	15 NTU	20 NTU	30 NTU
8/27-10/4/75	8.8 ± 4.5	0.20	0.67	0.83	1.00	1.00
10/6-10/23/75	——	0	0	0.06	0.18	0.30
10/24-12/18/75	——	0.28	0.48	0.68	0.75	0.88
8/24-9/4 and 9/18-11/4/76	3.4 ± 1.5	0.86	1.00	1.00	1.00	1.00
9/7-11/76	——	0	0.20	0.20	0.40	0.40
11/5-11/23/76	5.3 ± 2.6	0.46	0.96	1.00	1.00	1.00
11/29/76-1/7/77	——	0.19	0.47	0.58	0.77	0.84
1/19-31/77	——	0	0.18	0.18	0.36	0.64
2/23-3/10/77	——	0	0.05	0.20	0.30	0.50
5/3-17/77	5.2 ± 2.3	0.65	0.95	1.00	1.00	1.00

1 From continuous readinq side-scatter turbidimeter or calculated from forward scatter turbidimeter data. Maximum scale = 30 NTU.

2 Arithmetic means were not calculated for periods when a portion of the readings exceeded 30 NTU.

at turbidities less than 20 NTU appears to be attainable and adequate for reuse in the cannery.

Dissolved Oxygen

Dissolved oxygen in the reclaimed effluent during the two processing seasons was above 8.0 mg/l with the exception of three days each season. During 1975, the lowest dissolved oxygen recorded was 6.7. The other two readings below 8.0 were 7.6 and 7.9 mg/l. During the 1976 season, a 7.7 mg/l reading was obtained and two readings of 7.9 mg/l were recorded.

Alkalinity

The alkalinity of the reclaimed effluent varied considerably as would be expected due to the lye peeling of peaches during a portion of each processing season. The range of alkalinity was approximately the same during each of the seasons from about 40 to approximately 290 with a median of from 60 to 70 mg/l as $CaCO_3$. The mean alkalinity was not significantly different between the two seasons and the overall average was 86 mg/l as $CaCO_3$. For comparison, the well water supply had an average alkalinity of 61 mg/l as $CaCO_3$.

Hardness

Hardness was measured as total hardness and as calcium hardness during each of the two processing seasons, each measured as $CaCO_3$. The hardness stayed relatively constant with a total hardness range over the two seasons of 17 to 57 mg/l as $CaCO_3$ and the calcium hardness range from 11 to 35 mg/l as $CaCO_3$. The mean values for the two seasons (there was no significant difference between seasons) were 30 mg/l as $CaCO_3$ for total hardness and 20 mg/l as $CaCO_3$ for calcium hardness. The well water supply total hardness averaged 41 mg/l as $CaCO_3$ and calcium hardness averaged 30 mg/l as $CaCO_3$. Thus both total and calcium hardness reduction were approximately 10 mg/l as $CaCO_3$ through the biological treatment and effluent polishing. The reduction was probably due to calcium carbonate precipitation, principally during and following peach processing when the alkalinity was high as a result of lye peeling.

Chlorides and Sulfates

The chloride content in the reclaimed effluent reflected the variations in chlorides in the effluent to the biological treatment system. The chlorides in the cannery effluent were largely a function of the amount of salt used on the floor to prevent the wet floors from becoming slick and hazardous to foot traffic. Chlorides ranged from near 0 to 112 mg/l. There was no significant difference between the average chloride concentration between the two seasons. The overall mean was

49 mg/l and the standard deviation 32 mg/l. Chlorides in the well water supply were less than 1 mg/l.

Sulfates in the reclaimed effluent were variable with a range from 5 to 60 mg/l. There was no significant difference between the means obtained in 1975 and 1976 and the overall average was 21 mg/l with a standard deviation of 12 mg/l. The well water supply sulfate level was 5 mg/l.

Reactive Silicate, Detergents and Color

Reactive silicates were measured in the reclaimed effluent and in the house water supply. There was no significant difference between the mean concentrations determined during the two seasons. The average in the reclaimed effluent was 2.5 mg/l with a standard deviation of 0.9 mg/l. The house water supply had an average reactive silicate level of 2.4 mg/l.

Detergent concentration was measured by the methylene blue active substance (MBAS) test, as LAS, in the house water supply and in the reclaimed effluent. The house water supply showed less than 0.01 mg/l of MBAS as LAS and the reclaimed effluent showed less than 0.1 mg/l MBAS as LAS on all tests.

Color was estimated in the reclaimed effluent by color comparater on a weekly basis over the two seasons. There was no significant difference between the two seasons. The range was from 5 to 90 color units with a median color reading of 25 color units.

Heavy Metals

Heavy metals analyses were performed by National Food Processors Association Laboratories in Berkeley, California, by atomic absorption. The results of the heavy metal analyses on the reclaimed water, the untreated wastewater, the biological effluent and on the tap water are shown on Tables 14 and 15 for the 1975 and 1976 seasons respectively. The detectable limits for the various heavy metals were different for different analysis days. This resulted from sensitivity of the atomic absorption apparatus varying between dates of analysis. The values reported as "less than", reflected the sensitivity at the time of running that particular set of analyses. The sensitivity was checked during calibration on each day that analyses were conducted.

The aluminum content in the reclaimed wastewater was of measurable concentration only when alum was being fed ahead of the filters. The remainder of the time, it was below detectable limits. Heavy metals for which primary drinking water standards[9] have been promulgated are lead, arsenic, cadmium and mercury. The lead (Pb) concentration limit of

TABLE 14. HEAVY METALS ANALYSIS RESULTS, 1975

Date	11/4/75	11/4	11/18/75	12/16/75	12/16	12/16	12/16
Sample	Reclaimed Water	Reclaimed Water	Reclaimed Water	Waste-water	Clarifier Effluent	Reclaimed Water	Tap Water
Pb	0.05k*	0.05k	0.05k	0.05k	0.05k	0.05k	0.05k
As	0.05k	0.05k	0.05k	Not done	Not done	Not done	Not done
Zn	0.50	0.50	0.02	Not done	Not done	0.15	Not Done
Sn	Not done	Not done	Not done	3.0k	3.0k	3.0k	3.0k
Cu	0.05k	0.05k	0.05k	0.05k	0.05k	0.05k	0.05k
Cd	0.03k	0.03k	0.03k	0.03k	0.03k	0.03k	0.03k
Hg	0.0002k	0.0002k	0.0003	0.0004	0.0008	0.0009	0.001
Ca	6.0	7.0	6.0	11.6	11.0	11.0	12.5
Mg	0.5	0.5	1.0	1.8	1.3	1.3	1.8
Fe	0.1k	0.1k	0.1k	0.9	0.2k	0.2k	0.2k
Na	60	60	60	17	24	22	15
K	17	16	15	16	7.0	7.0	3.0
Mn	0.05k	0.05k	0.05k	0.05k	0.05k	0.05k	0.05k
Al	0.10k	0.10k	0.10k	0.50	0.2k	2.2	0.2k

* k = 'less than', results are in mg/l.

TABLE 15. HEAVY METALS ANALYSIS RESULTS, 1976

		Heavy Metals, mg/l						
Date	Sample Point	Fe	As	Cd	Sn	Cu	Pb	Mn
9/21/76	Tap	.25 k*	.01 k	.02 k	1.0 k	.012 k	.01 k	.025 k
	Reclaimed	.25 k	.01 k	.02 k	1.0 k	.012 k	.01 k	.025 k
10/12/76	Tap	.15 k	.01 k	.01 k	1.0 k	.018 k	.01 k	.01 k
	Reclaimed	.15 k	.01 k	.01 k	1.0 k	.018 k	.01	.01 k
10/14/76	Untreated	1.37	.01 k	.01 k	1.0 k	.018 k	.02	.01 k
	"	1.30	.01 k	.01 k	1.0 k	.018 k	.06	.01 k
	"	1.22	.01 k	.01 k	1.0 k	.018 k	.05	.01 k
	Clarifier	.15 k	.01 k	.01 k	1.0 k	.018 k	.01 k	.01 k
	"	.15 k	.01 k	.01 k	1.0 k	.018 k	.03	.01 k
	"	.15 k	.01 k	.01 k	1.0 k	.018 k	.01 k	.01 k
11/16/76	Tap	.15 k	.01 k	.01 k	1.0 k	.018 k	.01 k	.01 k
	Reclaimed	.15 k	.01 k	.01 k	1.0 k	.018 k	.02	.01 k
12/14/76	Tap	.15 k	.01 k	.02 k	1.0 k	.015 k	.01 k	.01 k
	Reclaimed	.20	.01 k	.02 k	1.0 k	.015 k	.01	.01 k
3/8/77	Tap	.15 k		.02 k	.70 k	.01 k	.01 k	.01 k
	Reclaimed	.15 k		.02 k	.70 k	.01 k	.01 k	.01 k

*k=less than.

(continued)

TABLE 15. (continued).

Date	Sample Point	Heavy Metals, mg/l						
		Hg	Zn	Ca	Mg	K	Na	Al
9/21/76	Tap	.0017	.01 k*	9.80	1.48	3.00	14.6	
	Reclaimed	.0026	.22	7.52	1.30	14.8	112.5	
10/12/76	Tap	.0003	.015	11.7	1.60	2.70	12.25	0.1
	Reclaimed	.0008	.625	6.60	1.15	14.4	84.0	1.6
10/14/76	Untreated	.0005	.092	9.60	1.84	18.24	72.0	0.2
	"	.0005	.085	9.80	1.94	22.50	78.0	0.4
	"		.085	-	2.00	19.08	79.2	0.3
	Clarifier	.0083 k	.022	5.56	1.13	13.8	69.0	0.1
	"	.0004	.022	5.56	1.15	12.3	70.8	0.1 k
	"	.0005	.022	6.16	1.13	11.52	72.0	0.1
11/16/76	Tap	.0003 k	.015	11.7	1.67	2.72	13.5	0.1 k
	Reclaimed	.0003 k	.182	5.24	0.94	14.88	49.08	1.7
12/14/76	Tap	.0003	.015	12.44	1.80	3.00	14.0	
	Reclaimed	.0004	.33	6.70	1.39	8.90	35.25	
3/8/77	Tap	.0003 k	.02	11.80	1.60	2.90	14.0	
	Reclaimed	.0003 k	.28	10.40	1.60	10.20	24.6	

* k=less than.

0.05 mg/l was not exceeded in any of the reclaimed or tap water samples analyzed but was approached in the sample of processing effluent analyzed in 1976. The arsenic (As) limit of 0.05 mg/l was not approached in any of the samples analyzed. The limit for cadmium (Cd), 0.01 mg/l was not exceeded in any of the samples. The mercury (Hg) limit, 0.002 mg/l, was exceeded in the reclaimed effluent on September 21, 1976. Results for mercury analysis on that date were higher than observed at any other time for both tap water and reclaimed water samples however, indicating that there could have been problems in the analysis on that particular day. The higher results were not indicated at any other time in the tap water even though the well water source was consistent throughout the project.

Pesticides

Pesticide analyses were conducted by the EPA Region X laboratory in Seattle, Washington, and by Columbia Laboratories in Corbett, Oregon, during this study. The Region X laboratory conducted analyses during both the 1975 and the 1976 seasons for a wide variety of pesticides. They are shown on Table 16 with the detectable limit, the samples analyzed, and the occurrence of positive results. The analyses (primarily herbicides) performed by Columbia Laboratories are also shown on Table 16. Pesticides listed on Table 16 for which there are primary drinking water standards limitations are: Endrin = 0.2 μg/l; Toxaphene = 5 μg/l; Lindane 4 μg/l; Methoxychlor 100 μg/l; 2,4-D 100 μg/l; and Silvex = 10 μg/l. Since 2,4-D was not known to have been applied (it would kill fruit trees) it was not run on the samples.

The positive pesticide results obtained during this study and indicated on Table 16 were not particularly consistent in that they were not shown to persist in the case of BHC or lindane. The PCB 1248/1254 results were somewhat more consistent, although their occurrence was principly in the tap water and even then was not particularly consistent in quantity or in its detection. The significance of this polychlorinated biphenyl is not documented but its presence was detected in the house water supply and could be of concern if it were found to be of public health significance. The inconsistency of its detection could mean that there is a problem with the analysis for this constituent. Its concentration was too low to confirm by mass spectrograph.

The Diphenylamine detected in the two samples for which herbicides were analyzed could have occurred from its application to stored apples, which were subsequently brought out of storage and processed in the cannery. There were no analyses performed earlier in the season, before the start of processing of stored apples. There was also some uncertainty as to the results at this low level due to difficulty with clearing

TABLE 16. PESTICIDE RESULTS

Pesticide	Detectable Limit µg/l	Samples Analyzed[1]	Results[2]
Aldrin	0.001	a	0
BHC	0.001	a	w
Chlordane	0.005	a	0
DDD	0.001	a	0
DDE	0.001	a	0
DDT	0.003	a	0
Dieldrin	0.001	a	0
Endrin	0.003	a	0
Toxaphene	0.060	a	0
Heptachlor	0.001	a	0
Heptachlor Epoxide	0.001	a	0
Lindane	0.001	a	x
PCB's	0.015	b	0
PCB 1242	0.010	c	0
PCB 1248/1254	0.010	c	y
PCB 1260	0.030	c	0
Organo Phosphates as Parathion	0.010	a	0
Perthane	0.010	c	0
Endosulfan	0.005	c	0
Silvex	1.0	d	0
Sevin	10	d	0
Benomyl	20	d	0
Diphenylamine	1	d	z
Plictran	10	d	0
Karathane	4	d	0
Omite	2	d	0
Maneb	0.2	d	0
Methoxychlor	0.01	a	0

[1] a. Reclaimed and house tap water tested by EPA Region X Lab, Seattle, WA. 11-4, 11-17 & 12-16-75; 9-21, 10-12 (dup),11-16 & 12-14-76, & 3-8-77.
b. Same as a. but 1975 samples only.
c. Same as a. but 1976-77 samples only.
d. Recl. water tested by Columbia Labs, Corbett, OR. 12-14-76 & 3-8-77.

[2] 0 = less than detectable limits.
w. BHC: 11-4-75 - Recl. water = 0.008 µg/l.
9-21-76 - House water = 0.021 µg/l, Recl. water = 0.028 µg/l.
x. Lindane: 11-4-75 - Recl. water = 0.016 µg/l.
y. PCB 1248/1254: 9-21-76 - Recl. water = 0.015 µg/l. 10-12-76 - House = 0.028 (dup.=0). 11-16-76 - House = 0.013. 12-14-76 - House = 0.023 (dup.=0.065). 3-8-77 - House = 0.051, Recl. = 0.143 µg/l.
z. Diphenylamine: 12-14-76 - Recl. = 1-2 µg/l. 3-8-77 - Recl. = 2-4 µg/l. There is uncertainty in the diphenylamine results due to difficulty in elimination of the blank from the analyzer. A source of diphenylamine was identified as an application to apples brought from storage to processing.

the Diphenylamine blank from the analytical appartus.

Organohalides

During the 1975 season, three sets of samples from the reclaimed effluent and from the house tap water were submitted to the Seattle EPA laboratory for organohalides analysis. The samples were taken November 4, November 17 and December 16. Analysis by the EPA laboratory yielded results on total volatile chlorinated organics as chloroform. The analysis on the first set of samples was somewhat insensitive and only indicated that organohalides in both the reused and tap water were less than 1 mg/l. On November 17 and December 16, the reclaimed water results indicated less than 3 μg/l, while on November 17, the tap water analysis showed 20 μg/l and on December 16, less than 3 μg/l. The 20 μg/l reading was confirmed by gas chromatagraph/mass spectrograph. The reading presents somewhat of an anomoly since the tap water was not chlorinated.

Organohalides were run by Foremost laboratories in Dublin, California and by Dohrmann Laboratory in Santa Clara, California, during the 1976 season. Table 17 contains the results of these analyses and shows that the reclaimed water is definitely higher in concentration of volatile organic halides than the house tap water. It appears that the volatile organic halides are predominately as chloroform. For reference the chlorine residual on the days that these samples were collected in the reclaimed water was approximately 2.9 mg/l on September 21, 1976, approximately 1.2 mg/l on October 12, approximately 3.3 mg/l on November 16, 1.6 mg/l on December 14 and 1.5 mg/l on March 8, 1977. It appears that a correlation between chloroform level and the residual chlorine may exist, although it is not well established. The total organic chlorides and total organic halides results, based on the solvent (hexane and ether) extraction procedures suggested by Food and Drug Administration chemists to Dohrmann and by Dohrmann's own procedures, were inconclusive.

The volatile organic halides in the tap or reclaimed water were not high enough in any of the samples to cause alarm when compared with values observed in drinking water samples at other locations[10] where values up to 300 μg/l chloroform were observed in some municipal water systems.

POLLUTANT REDUCTION BY WASTEWATER REUSE

The emission rates for COD, BOD and suspended solids for Snokist Growers' cannery through the three processing seasons; 1974, 1975 and 1976, on a weekly average basis, are shown on Tables 18, 19 and 20, respectively. The EPA effluent limitation guidelines for the products processed at Snokist Growers'

TABLE 17. ORGANOHALIDES IN RECLAIMED AND HOUSE WATER, 1976

FOREMOST RESULTS - (Micrograms per liter, µg/l)

Date	Sample	Chloroform	1,2-Dichloroethane	Carbon tetrachloride	Bromodichloromethane	Chlorodibromomethane	Bromoform
9/21/76	House Tap	1 k	1 k	N.D.	1 k	1 k	N.D.
	Reclaimed	8.2	N.D.	1 k	1	2	N.D.
10/12/76	House Tap	2 k	N.D.	N.D.	1 k	1 k	1 k
	Reclaimed	5.8±0.6	N.D.	1 k	1 k	1 k	1 k
11/16/76	House Tap	1 k	N.D.	1 k	1 k	1 k	N.D.
	Reclaimed	24.8±2.3	N.D.	1 k	1 k	1 k	N.D.
12/14/76	House Tap	1 k	N.D.	N.D.	N.D.	1 k	N.D.
	Reclaimed*	1.5±0.2	N.D.	N.D.	N.D.	1-3	N.D.
	Reclaimed*	1.6±0.2	N.D.	N.D.	N.D.	1-3	N.D.
3/8/77	House Tap	1 k	N.D.	1 k	N.D.	N.D.	1 k
	Reclaimed	13.4±2	N.D.	1 k	1 k	1 k	1 k

DOHRMANN RESULTS

Date	Sample	Total Organic Chlorides (Solvent Extraction), µg/l		Total Volatile Organic Halides (Dohrmann DE-200)µg/l	Total Organic Halides - (Dohrmann MCTS-20 System)mg/l
		Hexane	Ether		
12/14/76	House Tap	11±2	44±2	3.2	0.1±0.3
	Reclaimed*	6±1	30±2	12.8	4.7±2.2
	Reclaimed	10±1	85±2	12.8	0.3±0.2
3/8/77	House Tap	54±5	30±15	6.8±1.0	0.1 k
	Reclaimed	14.6±1.3	9.8±0.7	12.7±1.0	0.1 k

k = less than the value given, compound detected but quantitation impossible.
N.D. = Not Detected. Limit of Detectability 300-500 parts per trillion.
* = Duplicate

TABLE 18. 1974 POLLUTANT EMISSIONS

Week	Fruit Processed* kkg	COD Emission Total kg	COD Emission kg/kkg Fruit	BOD** Emission kg/kkg	Suspended Solids Emission Total kg	Suspended Solids Emission kg/kkg
8/23-24	518 Pr	1590	3.07	-	1050	2.03
8/26-31	1616 Pr	4520	2.80	3.00	1430	0.88
9/3-7	1319 Pr	1030/4 da	0.98	0.06	189/4 da	0.18
9/9-14	1305 Pr,121 Pl	1025	0.72	0.06	229	0.16
9/16-20	624 Pe,426 Pl	810	0.77	-	230	0.22
9/23-28	1636 Pr,236 A	1000	0.53	0.07	450	0.24
9/30-10/5	1600Pr,519A,20Pl	765/5 da	0.43	--	309/5 da	0.17
10/7-12	1546 Pr,587 A	1830	0.86	-	785	0.37
10/14-19	1588 Pr,595 A	1750	0.80	0.20	486	0.22
10/21-26	1618 Pr,592 A	1930	0.87	0.15	825	0.37
10/29-11/2	1335 Pr, 538 A	770/3 da	0.69	0.13	473	0.25
11/4-9	1438 Pr, 576 A	1095	0.54	0.09	428	0.21
11/11-15	648 A	1260	1.94	0.64	474	0.73
11/18-22	819 A	770/4 da	1.18	0.09	140/4 da	0.21
11/25-27	234 A	255	1.09	0.14	136	0.58
12/2-6	386 A	4440***	11.5	0.19	3530***	8.63
12/9-13	295 A	540	1.83	0.16	310	1.05

* Pr = Pears, Pe = Peaches, Pl = Plums, A = Apples
** 1 day or 2 days during week only
***1 day high results skewed results

Total Wastewater Flow 8/23 - 12/13/1974 = 460,600 cu.m.
Total Fruit Processed 8/23 - 12/13/1974 = 22,800 kkg
Wastewater Discharge Rate = 20.2 cu.m./kkg (4770 gal/ton)

TABLE 19. 1975 POLLUTANT EMISSIONS

Week	Fruit Processed* kkg	COD Emission Total kg	COD Emission kg/kkg Fruit	BOD** Emission kg/kkg	Suspended Solids Emission Total kg	Suspended Solids Emission kg/kkg
8/26-30	1407 Pr	1300	0.92	0.16	592	0.42
9/2-6	1358 Pr	880	0.65	0.076	346	0.25
9/8-13	1664 Pr, 46 Pl	1940	1.13	0.22	817	0.48
9/15-20	1644 Pr, 520 Pl	1700	0.79	0.12	625	0.29
9/22-27	1311 Pe, 280 Pl	1330	0.84	0.105	630	0.40
9/29-10/4	1734 Pr, 14 Pl	1230	0.70	0.070	627	0.36
10/6-11	1620 Pr, 473 A	4240	2.03	0.31	3290	1.57
10/13-18	1598 Pr, 555 A	3320	1.54	0.27	2230	1.04
10/20-25	1666 Pr, 550 A	2590	1.17	0.14	1590	0.72
10/28-11/1	1334 Pr, 498 A	1190	0.65	0.054	482	0.26
11/3-8	1730 Pr, 570 A	1990	0.87	0.13	829	0.36
11/10-15	1670 Pr, 682 A	1130	0.48	0.115	505	0.21
11/17-19	789 Pr, 397 A	350	0.30	0.033	88	0.074
11/20,21,24,25	570 A	362	0.64	--	125	0.22
12/1-5	840 A	1540	1.83	0.39	1035	1.23
12/8-12	881A	1070	1.21	0.25	585	0.66
12/15-18	291 A	455	1.56	0.26	161	0.55

*Pr = Pears = Pe = Peaches, Pl = Plums, A = Apples
**1 day per week only

Total Wastewater Flow 8/26-12/19/75 = 557,500 cu.m.
Total Wastewater Reused = 180,100 cu.m.
Total Effluent to River = 377,400 cu.m.
Total Fruit Processed 8/26-12/19/75 = 27,000 kkg
Wastewater Flow Rate = 20.6 cu.m./kkg (4950 gal/ton)
Effluent Flow Rate = 14.0 cu.m./kkg (3350 gal/ton)

TABLE 20. 1976 SEASON POLLUTANT EMISSIONS

Week	Fruit Processed* kkg	COD Emission Total kg	COD Emission Unit kg/kkg	BOD** Emission kg/kkg	Susp. Solids Total kg	Susp. Solids Unit kg/kkg
8/24-8/28	1529 Pr	449	.326	.078	172	.112
8/30-9/4	1760 Pr	514	.292	.027	118	.067
9/7-9/11	1520 Pr, 178 Pl	3854	2.27	.454	1022	.602
			(max. da. = 5.2)		(max. da. = 1.09)	
9/13-9/18	1422 Pr, 376 Pl	742	.415	.046	196	.110
9/20-9/25	1601 Pe, 470 Pl	1020	.493	.120	309	.149
9/27-10/2	1490 Pr, 29 Pe, 261 Pl	610	.343	.026	147	.083
10/4-10/9	1828 Pr, 529 A	694	.294	.027	211	.090
10/11-10/16	1808 Pr, 563 A	772	.326	.030	232	.098
10/18-10/23	1830 Pr, 551 A	845	.355	.053	362	.152
10/25-10/30	1674 Pr, 569 A	1001	.446	.041	295	.132
11/1-11/6	1744 Pr, 575 A	957	.413	.044	403	.174
11/8-11/13	1452 Pr, 459 A	1146	.600	.099	364	.190
11/15-11/20	646 A	584	.904	.066	155	.240
11/22-11/24	422 A	408	.967	.137	178	.423
11/29-12/3	566 A	1127	1.99	.336	751	1.33
12/6-12/10	714 A	867	1.21	.245	606	.849
12/13-12/17	728 A	602	.827	.165	366	.503
12/20-12/22	418 A	470	1.13	--	266	.636
12/27-12/30	549 A	315	.574	--	149	.271
1/3-1/7***	678 A	573	.845	.111	488	.720
1/12-1/14***	397 A	2797	7.05	--	686	1.73
1/17-1/21***	741 A	4460	6.02	--	1627	2.20
1/24-1/28 & 1/31	958 A	1938	2.02	.57	1277	1.33
2/23-2/25	391 A	570	1.46	--	439	1.12
2/28-3/4	588 A	709	1.21	.238	449	.764
3/7-3/10	494 A	238	.482	.047	140	.283

	8/24/76-11/13/76	11/15/76-3/10/77
Total Wastewater Flow	422,720 cu m	209,750 cu m
Total Wastewater Reused	159,660 cu m, 38%	60,340 cu m, 29%
Total Effluent to River	263,060 cu m	149,410 cu m
Total Fruit Processed	24,209 kkg	8,290 kkg
Wastewater Flow Rate	17,500 l/kkg	25,300 l/kkg
	4,190 gal/ton	6,080 gal/ton
Effluent Flow Rate	10,900 l/kkg	18,000 l/kkg
	2,610 gal/ton	4,330 gal/ton

Overall Reuse = 34.8%
Overall Effluent Flow Rate = 12,700 l/kkg, 3,050 gal/ton

* Pr = Pears, Pe = Peaches, Pl = Plums, A = Apples.
** One or two days per week for BOD data.
*** Aeration Basin partially or completely frozen over, aerators inopperable.

cannery during these seasons, is shown on Table 21. The emissions during the 1975 and 1976 processing seasons reflect the actual emission rate to the Yakima River and therefore take into acocunt the wastewater reclamation and reuse in the cannery. Tables 18, 19 and 20, show that the emission rate of pollutants increased between the 1974 and 1975 season even though the unit wastewater flow decreased due to the effluent reuse. The increase in emission rates was due to the poorer quality biological effluent in 1975. The effluent degradation is thought to have occurred primarily due to uncontrolled chlorination practices in the cannery which affected the biological treatment system. During 1976 pear processing, the emission rates improved over both the 1974 and 1975 processing seasons. The pollutant emission rates during apple processing, on a unit basis, increased over pear and apple processing combined, during all three of the seasons. This was due to the relatively high water useage during apple processing and the wastewater treatment system being sized for the greater organic waste load that accompanies peach and pear processing. The effluent quality during pear processing carried over to apple processing and affected unit emission rates to some extent. Also, the colder weather during the latter portion of pear processing season and then the extremely cold weather during apple processing, especially in 1976, undoubtedly resulted in increased suspended solids and BOD unit emission rates. This can be seen especially during January 1977 when the aeration basin froze over for about a week. The use of dry chlorine in the plant following cleanup may also have affected the biological treatment system during apple processing.

Comparison of the unit emission rates on Tables 18, 19 and 20 with the effluent limitation guidelines on Table 21, shows that the best available technology guidelines, 30-day maximum average, were met by weekly averages during a majority of each of the three seasons for suspended solids and BOD through the end of pear processing. The exceptions were the 1974 season, during startup, and the 1975 season, during pear and apple processing. During the 1976 season, the 1-day and the 30-day limitations were exceeded by the average emission during the week following the upset which occurred over the Labor Day weekend.

The weekly average unit emission rates during apple processing exceeded the 30-day effluent limitations guidelines for best practicable technology during most of all three seasons when apples were processed alone.

Based on the comparison of the unit emission rates and the effluent limitations guidelines, it appears that Snokist Growers with the wastewater reclamation reuse system, will be able to meet best available technology effluent limitations during their peach and pear processing seasons. During their apple process-

TABLE 21. EPA EFFLUENT LIMITATIONS GUIDELINES

Category	BPCTCA[1]		BATEA[2]	
	BOD	TSS	BOD	TSS
Apple Products				
Max 30 Day Ave.	0.55	0.70	0.10	0.10
Max 1 Day	1.10	1.40	0.20	0.20
Peaches				
Max Annual Ave.	0.67	1.26	0.324	0.324
Max 30 Day Ave.	0.93	1.93	0.583	0.583
Max 1 Day	1.51	2.72	0.766	0.766
Pears				
Max Annual Ave.	0.83	1.55	0.397	0.397
Max 30 Day Ave.	1.12	2.32	0.664	0.664
Max 1 Day	1.77	3.21	0.855	0.855
Plums				
Max Annual Ave.	0.29	0.54	0.095	0.095
Max 30 Day Ave.	0.42	0.87	0.204	0.204
Max 1 Day	0.69	1.24	0.283	0.283

1 BPCTCA = Best practicable control technology currently achievable. To be implemented by July 1, 1977.

2 BATEA = Best available technology economically achievable. To be implemented by July 1, 1983. Peach, pears and plum limitations shown are for large processors.

3 Limitations are in kg of pollutant per kkg of raw product processed.

ing seasons. During their apple processing season, it does not appear that they will be able to meet these effluent limitations. It is evident that the apple limitations are somewhat more stringent than those for peaches and pears and therefore may be unrealistic for Snokist Growers to achieve even with the capability for wastewater reclamation and reuse.

It was evident during both 1975 and 1976 processing seasons that substantial water reduction was achieved through the reclamation and reuse of treated wastewater. The overall reduction in water use per ton of processed product from the 1974 to the 1975 and 1976 seasons, was 31 percent and 37 percent respectively. The proportion of the wastewater reclaimed and reused during the 1975 and 1976 seasons was 32 percent and 35 percent respectively.

Potential Additional Waste Load Reduction

Based on the assumed suitability of the reclaimed effluent for use as direct contact container cooling water, the wastewater flow could be reduced still further than during 1975 or 1976. The reclaimed water could be used for cooling with subsequent use for floor and gutter wash. The additional cooling use would reduce the overall flow rate during pear and apple processing by about 1,100 l/min. or about 1,000 cu.m/day. This would result in the effluent flow rate being reduced from approximately 6,800 cu.m/day to approximately 5,800 cu.m/day. With the existing effluent reclamation system capacity of about 2,500 cu.m./day in use, the final effluent quantity would be reduced to the river to approximately 3,300 cu.m/day. The unit discharge rate during apple and pear processing, would be about 8.5 cu.m/kkg with this type operation or over a 50 percent reduction from the levels existing prior to wastewater reclamation and reuse. Assuming that the biological effluent quality would be equal to that experienced without the effluent reclamation and reuse, the BOD and total suspended solids emission rates would also be decreased by 50 percent.

A large proportion of the apple processing wastewater flow results from water spray glass container cooling. Separation of this flow from the effluent and use of reclaimed water for its makeup could result in a substantial emission reduction during apple processing.

Cost of Wastewater Reclamation

The cost of wastewater reclamation for reuse includes the additional operating costs for the wastewater reclamation facilities and the amortized first cost of the facilities on an annual basis. The unit costs would vary according to the quantity of water reclaimed per season. Table 22 shows the estimated operating costs for the wastewater reclamation facilities on an annual and per unit of reclaimed water basis. Also included on Table 22 is the annual capital cost based on amortization over 15 years at 8 percent interest with no credit taken for investment tax credits, early write off or other potential savings (see Table 3 for capital cost of facilities). Snokist Growers is a non-profit corporation so such credits are not applicable. The cost of power and chemicals for reclaiming the effluent is approximately the same as the operating costs for providing the same amount of raw water supply. Because of the high capital cost wastewater reclamation for reuse at Snokist Growers' cannery could not be economically justified on a water supply savings basis alone. The same amount of water provided each year, assuming a new well costing $150,000, would be required, would cost approximately .085 dollars per cubic meter (.32 dollars/1,000 gal.).

TABLE 22. COST OF WASTEWATER RECLAMATION FOR REUSE

Item	Cost	
O & M Cost (for 220,000 cu.m/yr)		
Power	$ 900	
Chlorine	400	
Coagulant	500	
Extra Technician	4,200	
Total O & M	$ 6,000/yr,	$0.027/cu.m ($0.103/1000 gal)
Capital Cost Amortization $325,000 @ 8%, 15 yrs	38,000/yr	
Total Annual Cost	$44,000/yr,	$0.20/cu.m ($0.76/1000 gal)

Reclamation and reuse may be justified in order to achieve EPA best available technology for reducing waste loads in the effluent. The reclamation system will apparently achieve this through the peach and pear processing season. These standards could probably not be achieved on a consistent basis without effluent reclamation and reuse.

RECLAIMED WATER USE

The reclaimed water was put to use during the 1975 and 1976 processing seasons in pilot cannery areas. During the 1975 season, uses were limited to equipment washing and cleaning, and direct contact container cooling. Uses in 1976 included: equipment washdown; initial product cleaning and conveying; direct contact container cooling; and boiler feed for steam generation for cleaning, exhausting, cooking and blanching.

Equipment Cleaning

During the 1975 processing season, comparative cleaning of belts on the peeler line was done on six occasions with reclaimed water and house steam and with house water and house steam. Swab tests for total plate count were conducted on the belt receiving peeled product (peeler belt) and the belt which transports fruit from the peeler belt to shaker screens (shaker belt), following cleaning. There were four seperate samples, each analyzed in duplicate from each belt washed with either the house or reclaimed water and steam.

Table 23 contains the log mean swab total plate count and one standard deviation range each side of the mean for the six 1975 washing trials on the peeler and shaker belts. The trials were conducted between September 19 and December 20, 1975.

TABLE 23. SWAB TESTS ON PROCESSING BELTS AND EQUIPMENT CLEANED WITH RECLAIMED AND HOUSE WATER, 1975 PROCESSING SEASON

Item	House Water House Steam	Reclaimed Water House Steam
Peeler Belt - Swab Water Count	n = 6	n = 6
Log Mean Plate Count/100 ml	1.24×10^5	3.26×10^5
Log Mean - 1 Std.Deviation	1.10×10^4	3.64×10^4
Log Mean + 1 Std.Deviation	1.40×10^6	2.92×10^6
Shaker Belt - Swab Water Count	n = 6	n = 6
Log Mean Plate Count/100 ml	1.34×10^5	1.03×10^6
Log Mean - 1 Std.Deviation	6.74×10^3	1.09×10^5
Log Mean + 1 Std.Deviation	2.76×10^6	9.86×10^6
Peeler & Shaker Belts	n = 12	n = 12
Log Mean Plate Count/100 ml	1.29×10^5	5.75×10^5
Log Mean - 1 Std.Deviation	9.55×10^3	6.31×10^4
Log Mean + 1 Std.Deviation	1.74×10^6	5.25×10^6
Chlorine Residual in Water		
Mean, mg/l	4.1	0.3
Std. Deviation	0.4	0.4

There was no significant difference between results from the peeler belt and shaker belt utilizing either wash water. The log swab total plate count and one standard deviation range for the peeler and shaker belts combined also are shown. There is a slight difference between the results using the house and reclaimed waters for washing equipment, although it is not statistically significantly different at the 90 percent level. The minor difference that exists can probably be explained by the differences in chlorine residual in the two waters used for washing. The mean chlorine residual in the house water during the cleanup periods was 4.1 mg/l while in the reclaimed water, the average chlorine residual was only 0.3 mg/l.

During the 1976 processing season, three parallel pear processing lines were separately washed using: reclaimed water and steam generated from reclaimed water on line 1; reclaimed water with house steam on line 2; and house water with house steam on line 3. During the 1976 equipment washing trials, the chlorine residual in the house water was controlled so the mean residual chlorine in the two waters used for washdown were equal and averaged 0.9 mg/l. The results are shown on Table 24.

The waste slide results shown on Table 24 resulted from bi-weekly monitoring of the waste peel and core slide described in Section 4 which was washed with the indicated treatments over the entire six weeks of study without intervening wash-downs with any other treatment. There was no trend in the results over the six week period and no buildup or changes on any of the belts other than an apparently random distribution of total plate count values. There is no significant difference between the three waste slides on the lines 1, 2 or 3 at the 70 percent level.

The peeler and shaker belt information shown on Table 24 was collected during weekly parallel washdown procedures using the treatments indicated on the three parallel lines. Following washdown with the particular treatments, the lines washed with reclaimed water were rewashed with house water to avoid the potential for residual contamination. The peeler belt information and shaker belt information were separately analyzed for each of the lines and then jointly analyzed as indicated on the Table. There is no significant difference between the washdown results using reclaimed water and reclaimed steam, reclaimed water and house steam. or house water and house steam at the 90 percent level of significance. The equipment cleaning during the 1976 season was conducted between October 1 and November 15.

Product Cleaning and Conveying

Use of the reclaimed water for initial conveying and

TABLE 24. SWAB TESTS ON WASTE & PRODUCT BELTS CLEANED WITH RECLAIMED AND HOUSE WATER AND STEAM, 1976 PROCESSING SEASON

Item	Line 1 Reclaimed Water Reclaimed Steam	Line 2 Reclaimed Water House Steam	Line 3 House Water House Steam
Waste Slide - Swab Water Count	n=20	n=22	n=22
Log Mean Plate Count/100 ml	1.30×10^5	2.08×10^5	1.45×10^5
Log Mean - 1 std. Deviation	3.23×10^4	4.05×10^4	5.35×10^4
Log Mean + 1 std. Deviation	5.20×10^5	1.06×10^6	3.92×10^5
Peeler Belt - Swab Water Count	n=10	n=10	n=10
Log Mean Plate Count/100 ml	8.03×10^5	3.09×10^5	1.43×10^5
Log Mean - 1 std. Deviation	2.14×10^5	2.70×10^4	2.83×10^4
Log Mean + 1 std. Deviation	3.01×10^6	3.54×10^6	7.23×10^5
Shaker Belt - Swab Water Count	n=10	n=10	n=10
Log Mean Plate Count/100 ml	3.68×10^4	8.01×10^4	2.58×10^4
Log Mean - 1 std. Deviation	1.36×10^4	7.33×10^3	2.86×10^3
Log Mean + 1 std. Deviation	9.97×10^4	8.74×10^5	2.33×10^5
Peeler & Shaker Belts	n=20	n=20	n=20
Log Mean Plate Count/100 ml	1.72×10^5	1.57×10^5	6.08×10^4
Log Mean - 1 std. Deviation	2.45×10^4	1.36×10^4	7.63×10^3
Log Mean + 1 std. Deviation	1.21×10^6	1.82×10^6	4.85×10^5
Chlorine Residual, mg/l	Reclaimed Water		House Water
Mean	0.9		0.9
Std. Deviation	0.5		0.6

cleaning of fruit was conducted during the 1976 processing season. The water was initially used during a portion of the peach processing season and compared with house water used during the other portion of the peach processing. The results of the total plate count analyses are shown on Figure 28. The peach dump tank water, after filling and after chemicals were added, was not changed for the 3 days of operation with either water. Minimal make up water was added. The peach dump operations were performed on the week of September 20 through 25, 1976.

House water and reclaimed water were alternately used in the apple dump and conveying area for about a five week period. The results of total plate count analyses on the fruit during these dumping operations are shown on Figure 29. The apple dump operations were performed using the reclaimed water through December, part of January and into March. The reclaimed water chlorine residual averaged 2.9 mg/l and ranged from 0.8 mg/l to 5.2 mg/l in the chlorine contact tank. It was not checked at the point of use. The house water was not chlorinated. The dump tank was refilled each day and water flowed through it continuously at a rate to replace the contents each shift.

There was no significant difference between the total plate count on the fruit or in the dump tank whether reclaimed or house water was used for the initial fruit dumping and conveying for these two products.

Steam Generation

The suitability of the reclaimed effluent for steam generation in the cannery was compared with the house tap water and with the maximum recommended concentrations for low pressure boiler feed water of various constituents in Table 25. There doesn't appear to be any significant difference between the suitability of the house tap water and the reclaimed water for boiler feed according to the concentration of silica, aluminum, iron, manganese, copper, pH, or MBAS. The dissolved oxygen in the reclaimed water exceeded the recommended concentration. The dissolved solids of the reclaimed water are significantly higher than in the house tap water although both were less than the maximum recommended concentration. The alkalinity of the reclaimed water was higher than that of the tap water and exceeded the recommended level a portion of the time. The period when the alkalinity exceeded that recommended, occurred during and for approximately two weeks following peach processing when the lye peel residuals raise the alkalinity significantly. During the 1975 and 1976 processing seasons, the maximum alkalinity was from 270 to 300 mg/l. The alkalinity exceeded 200 mg/l for two weeks during each of the seasons and otherwise did not exceed the 140 mg/l recommended limitation.

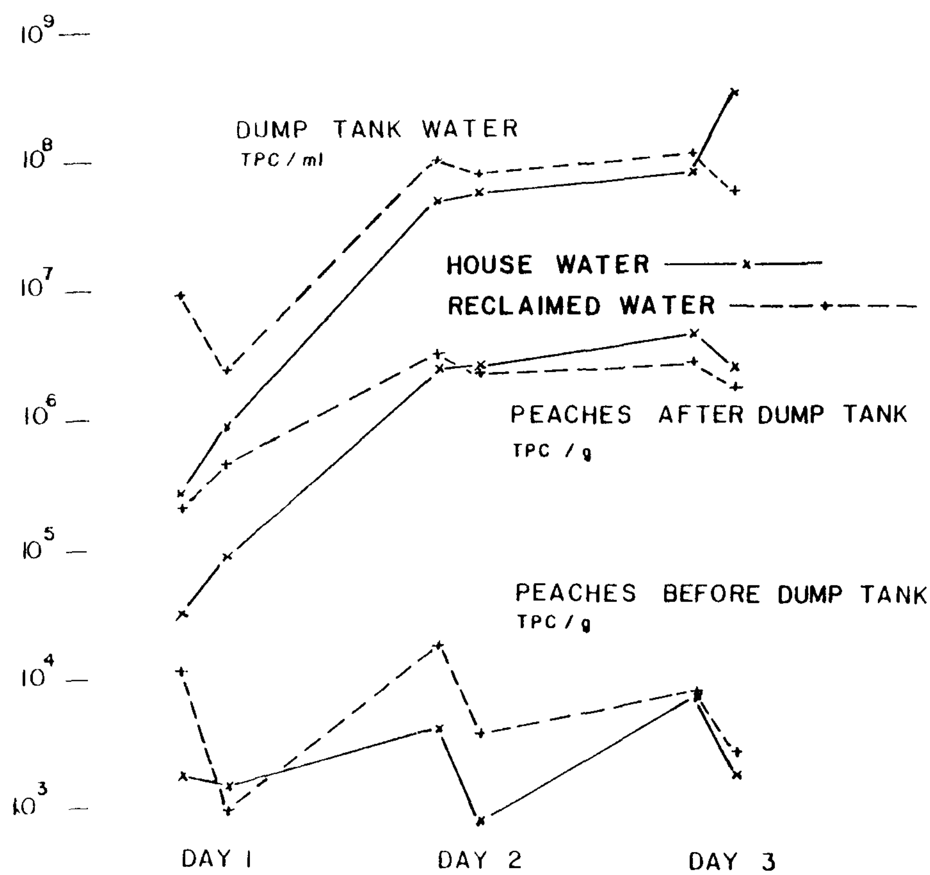

Figure 28. Bacterial count on fruit and in dump tank using reclaimed water and house water for peach dumping and initial conveying.

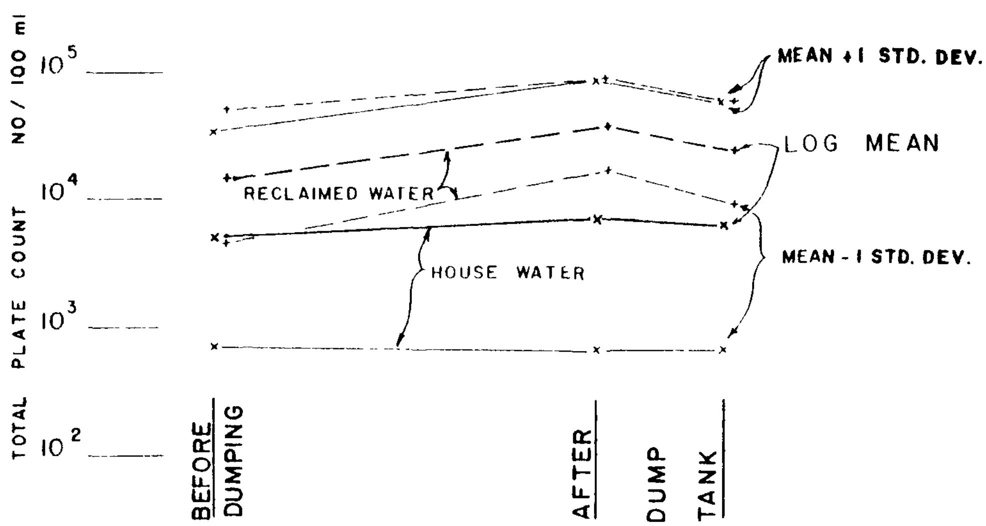

Figure 29. Bacterial count recovered from fruit using reclaimed water and house water for apple dumping and conveying.

TABLE 25. BOILER FEED SUITABILITY

Constituent	Max. Concentration[1]	House Tap Water[2]	Reclaimed Water[2]
Silica (SiO_2), mg/l	30	2.4 ± 0.3	2.5 ± 0.9
Aluminum (Al), mg/l	5	<0.1 - 0.1	<0.1 - 2.2[3]
Iron (Fe), mg/l	1	<0.2	<0.2
Manganese (Mn), mg/l	0.3	<0.01	<0.01
Copper (Cu), mg/l	0.5	<0.02	<0.02
Dissolved Solids, mg/l	700	120 ± 11	290 ± 99
Alkalinity ($CaCO_3$), mg/l	140	61 ± 3	86 ± 62
Hardness ($CaCO_3$), mg/l	20	41 ± 6	30 ± 10
pH, units	8-10	8.1 - 8.3	7.15 ± 0.45
MBAS, mg/l	1	<0.01	<0.1
COD, mg/l	5	5-10	<40,80% of 1976 Pear
Dissolved Oxygen, mg/l	2.5	2.5 - 3.5	7-12
Suspended Solids, mg/l	10	<1	<10,70% of 1976

[1] Maximum recommended concentration before adding substances used for internal conditioning. From Water Quality Criteria, FWPCA, 1968, Table V-5, for low Pressure Boiler Feed Water (0 to 150 psig).

[2] These columns contain the Mean ± Standard Deviation, or the Range of values observed.

[3] Al in Reclaimed Effluent <0.1 - 0.1 if Alum not used, 1.6 - 2.2 if Alum being used.

The hardness of the reclaimed water was less than for the house water. Each of the hardness concentrations exceeded the 20 mg/l maximum concentration recommended but Snokist Growers normally uses an ion exchange system to reduce hardness in the cannery boiler feed water. The reclaimed water would not exhaust the ion exchange system as rapidly as the tap water and therefore would provide a more economical boiler feed from the hardness standpoint.

The chemical oxygen demand (COD) of the house tap water was at the minimum concentration measurable. The reclaimed water COD exceeded the recommended 5 mg/l virtually all of the time. During the 1976 pear processing season, when the reclaimed effluent was of the most consistent and best level of quality, the COD was less than 40 mg/l 80 percent of the time. The period when the COD exceeded 40 mg/l was principally during the week following the Labor Day biological treatment system upset. Suspended solids in the reclaimed effluent were much greater than those in the house tap water. However, the suspended solids in the reclaimed water were within the recommended 10 mg/l maximum concentration 70 percent of the 1976 processing season and for a greater proportion of the time during the pear processing portion of the season.

Reclaimed water was used during six weeks of the 1976 processing season for feed to a portable steam generator to produce steam for pilot uses inside the cannery. During the period from October 4 through the week of November 12, steam generated from the reclaimed water was used with reclaimed water to clean a waste peel and core slide on a daily basis and to clean equipment belts weekly. Parallel equipment was cleaned using reclaimed water and house steam, and house water and house steam. The results are reported under <u>Equipment Cleaning</u> above.

Steam generated from the reclaimed water was also used for exhausting canned pears prior to sealing, for cooking applesauce, and for blanching sliced apples.

Exhausting --

On October 15 and October 23, 1976, batches of processed pears in cans were exhausted in the steam exhaust box using steam from reclaimed water. The canned pears were then capped, cooked and cooled and retained for comparison with pears exhausted under normal conditions using house steam. The control products were run on a continuous basis, whereas the test products were run on a semi-batch basis where the canned pears were transported into the exhaust box, then the exhaust box brought up to temperature with the steam generated from the reclaimed water and then transported to the remainder of processing.

Comparison of the pears exhausted using reclaimed water steam, were made with the pears from the normal run by organoleptic evaluation at National Food Processors Association's laboratory at Berkeley, California. The "triangle test" evaluation by 17 in-house panelists at NFPA resulted in 15 correct responses out of 34 for the October 23 set which is not significantly different from random response at the 95 percent significance level. The October 15 samples obtained 20 correct responses initially which is significant at the 99 percent level but upon retesting, only obtained 11 correct responses. The combined results were nearly significant at the 95 percent level. The NFPA specialists conducting the tests, concluded that taking into account all of the results, there was no difference in sensory attributes between control and test samples. This was in spite of the differences in processing between the test and control products.

The reclaimed water quality on October 15 and October 23 was consistently good with coliform counts less than 1/100 ml, total plate counts from less than 1 to 3/ml, turbidity in the range from 3 to 4 NTU on the continuous analyzer. Suspended solids were 8 and 13 mg/l on the two dates respectively and COD was 39 and 28 mg/l.

Applesauce Cooking --

Applesauce cooking trials with steam generated from the reclaimed water were conducted on November 29 and 30, 1976. Applesauce cooking is normally done by live steam injection on a continuous basis. However, in order to conserve the amount of product loss, the trial run was made on a batch basis in the commercial cooker. For comparison, applesauce was also cooked using house steam on a batch basis on each of the two days. Product from each of the runs was graded according to the standard scoring procedures for the cannery. Samples from each of the runs were also sent to NFPA laboratory for organoleptic evaluation. The three comparative treatments, house steam continuous cooking control, house steam batch cooking and reclaimed steam batch cooking, resulted in grading scores of 96, 89 and 90 respectively. The control was different from the house steam and reclaimed steam scores at the 99.9 percent significance level. The house steam and reclaimed steam scores were not significantly different at the 95 percent level. The catagories in which the control was most different from the house steam and reclaimed steam treated samples were in color and flavor.

The organoleptic evaluation on the triangle difference test was conducted using 18 NFPA employees. Each employee conducted two triangle difference tests, one between the control and the house steam treated sample, and one between the house steam and reclaimed steam treated samples, for each of the trial days. In every case, the correct responses were significantly different than would have been randomly generated at the 99.9 percent level. The organoleptic evaluations did not indicate which treatment was preferable, only that the panel was able to distinguish the difference between the samples.

Comments from the tests between the control and house steam samples indicated that the house steam treated applesauce was darker. Between the house steam and reclaimed steam samples, notes indicated that the house steam treated samples were darker in each case. The panelists were forced to wear dark glasses during the testing so the difference in taste was their principle means for detecting difference.

The NFPA specialist who conducted the test indicated that the difference in color and the difference in taste may have related to caramelization. This probably originated not from the source of the steam but from the method in which the applesauce was cooked and the lack of careful and close control over the temperature in the cooking vessel during the trial batch runs. They noted that the finish or texture varied between the samples also. This also could have been influenced by the cooking procedure.

As nearly as could be determined from the tests, there were no differences in the product which related to the origin of the water used in generating the steam. However, it would be impossible to state that the steam generated from the reclaimed or the house water are equivalent since the test differences due to handling methods influenced the product greater than did the steam source.

Reclaimed water quality during the applesauce cooking trials with steam generated from the reclaimed water was as follows on the two days respectively: pH = 7.1 and 7.2; suspended solids = 52 and 44 mg/l; chlorine residual = 2.2 and 1.5 mg/l; total coliform = less than 2/100 ml; total plate count = 190 and 30/ml.

Sliced Apple Blanching --

Trials with reclaimed steam for sliced apple blanching were conducted on November 22 and 23, 1976. On each day, control samples were drawn from the end of the continuous processed blanched sliced apple run. Batch blanched sliced apples using house steam and using steam from reclaimed water were retained. The samples of canned fruit were graded according to Snokist Growers normal grading procedures. Additional samples of the canned fruit were sent to the NFPA laboratory for organoleptic evaluation.

The mean grading scores for the control processed fruit, the fruit blanched with house steam on a batch basis, and fruit blanched with reclaimed water steam on a batch basis were 79, 84, and 79, respectively. The house steam batch processed fruit score was significantly different from the control and the reclaimed steam processed fruit at the 95 percent level. There was no significant difference between the control and the reclaimed steam processed fruit grading scores. The uniformity of the control fruit was distinguishably less than either of the batch processed fruit and the character of the reclaimed steam processed fruit was graded lower than either of the others.

The organoleptic evaluation by 18 NFPA employees using the triangle test, each employee running two tests, resulted in significant differences between the control fruit and that processed on a batch basis with house steam and between the fruit processed on a batch basis with house steam and reclaimed steam. The specialist at NFPA who conducted the test again attributed the differences to texture and degree of caramelization which was felt to be unrelated to the origin of the steam. The principle differences were judged to be influenced by batch to batch variability in the fruit processed and the processing variables such as holding time and temperature.

The reclaimed effluent quality used for generating steam for sliced apple blanching was as follows for the two respective days: pH 7.1 and 7.2; suspended solids 17 and 18 mg/l; chlorine residual 0.6 and 1.0 mg/l; total coliform less than 1 and 28/100 ml; total plate count 30 and 460/ml.

As with the use of the reclaimed steam for applesauce cooking, its use for sliced apple blanching could not be finally judged based on these tests. Apparently the differences in processing variables unrelated to steam source had greater effect on the product quality than the source of water for steam generation.

Direct Contact Container Cooling

On October 24, 1975 and on September 15, 1976, contact container cooling with reclaimed water was performed on a trial basis. The trials were conducted in one of the coolers regularly used for cooling the canned product. In each of the trials, approximately the same number of containers cooled in house water in the normal fashion was retained for control as were cooled in the reclaimed water.

The 1975 direct contact container cooling trial produced 1,150 cans of pears cooled in each of the two waters. One hundred twenty cans from each of the treatments were sent to NFPA's laboratory where they were incubated at 30°C for 2 months to simulate longer termed storage. The remainder of the cans were retained in Snokist Growers' warehouse basement at approximately 18°C.

The 1976 cooling trial produced about 3,000 cans from the process trial run and about 3,000 cans of control were retained for comparison. One hundred eight cans from each of the waters were sent to National Food Processors Association for accelerated storage trial at 35°C for 6 months and the remainder stored in Snokist Growers' warehouse basement at approximately 18°C.

NFPA incubated the 1975 trial cooled pears and controls for 60 days at 30°C. At the end of that period, they checked the vacuum and pH of each can and examined approximately one third of the cans microscopically for biological contamination. The average vacuum for the cans cooled in house and reclaimed water was 7.2 inches and 8.7 inches Hg, respectively. The ranges were 0-11 inches and 5-14 inches. The low vacuums, less than 3 inches, from the house water group occurred in dented cans. The pH averages for the house and reclaimed water cooled cans, respectively, were 3.93 and 3.96, with a range of 3.85 to 4.10, and 3.85 to 4.05. The microscopic examination results were nagative for all cans checked and the NFPA personnel judged all cans to be commercially sterile.

NFPA incubated 96 reclaimed water cooled cans and 115 house water cooled cans for 6 months at 35°C from the 1976 cooling water trial. Once again, all of the cans were checked for vacuum and pH and the containers were examined for spotting and corrosion. No swollen or leaking containers were detected and all samples were stable with the product having normal color and texture. All of the containers were free of spotting and corrosion both externally and internally. The vacuum in the reclaimed water and house water cooled cans averaged 8.8 and 9.4 inches Hg, respectively. The range was 3.0 to 13.5 and 2.5 to 17.0 for the reclaimed and house water cooled containers, respectively. The pH averaged 3.8 and 3.9 with the ranges 3.6 to 4.9 in both cases.

The 1,000 cans cooled in reclaimed water and the 1,000 cans cooled in house water for control were retained from the 1975 processing season cooling water trial for one year. Examination of all of the cans for failures reveled that there were no swelled or leaking cans at the end of that period of storage.

Approximately 3,000 experimental and control cans for the 1976 cooling water trials were stored at the cannery for one year and the entire lot examined for failures. No leaking or swelled cans were observed at the end of this period.

Quality of the reclaimed water during the 1975 cooling water trial was as follows: pH = 7.5; suspended solids = 18 mg/l; chlorine residual = 0.6 mg/l; total coliform = 1900/100 ml;

total plate count = 5,900/ml. Reclaimed water quality during the 1976 contact container cooling trial was as follows: pH = 7.1; suspended solids = 5 mg/l; chlorine residual = 0.7 mg/l; total coliform = 80/100 ml; total plate count = 140/ml. The chlorine residual was maintained at 1 mg/l in the cooling vessel during the cooling trials by chlorine solution addition.

The contact container cooling trials were conducted on each of the two years during a period of time when the bacteriological quality of the reclaimed effluent was not as good as was experienced at other periods during the years. Since there were no failures of the containers during the contact container cooling trial runs, it can be concluded that with an even better bacteriological quality of the reclaimed effluent that direct contact container cooling can be conducted safely with the reclaimed water.

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APPENDIX

This appendix contains three tables, A1, A2, and A3, which outline the analytical methods used during this study.

TABLE A1. SAMPLE HANDLING AND ANALYTICAL METHODS

Parameter	Sample Preservation	Analytical Procedure
Alkalinity (Total)	Refrigeration at 4°C	Standard Methods[1]: Pg. 52, Method 102
Biochemical Oxygen Demand (BOD	Refrigeration at 4°C	Standard Methods[1]: Pg. 489, Method 219
Chemical Oxygen Demand (COD)	Refrigeration at 4°C	Standard Methods[1]: Pg. 495, Method 220; except proportion of sample and dichromate solution reversed for strong samples
Chlorine Residual (Total)	N.A.	Amperometric Titration Back titration of excess .00564 N PAO with .00564 N Iodine at pH4-Standard Methods Pg. 160
Color	Refrigeration at 4°C	Standard Methods[1]: Pg. 160, Method 118
Dissolved Oxygen (DO)	N.A.	EPA[2]: Pg. 56, Probe Method
Hardness (a) Total (EDTA) (b) Calcium (Ca)	N.A.	Standard Methods[1]: (a) Pg.179, Method 122B (b) Pg.84, Method 110C
Ions (a) Chloride (b) Sulfate	None	Standard Methods[1]: (a) Pg.97, Method 112A (b) Pg.334, Method 156C
Metals 1. Total (a) Aluminum (b) Arsenic (c) Cadmium (d) Tin (e) Copper	25 ml HNO_3 per liter	EPA[2]: (a)-(j) Pg.78-155 Atomic Absorption Methods, Performed by National Canners Association, Western Regional Lab.,Berkeley, Calif.

See Footnotes at end of Table.

TABLE A1. SAMPLE HANDLING AND ANALYTICAL METHODS (Continued)

Parameter	Sample Preservation	Analytical Procedure
(f) Iron (g) Lead (h) Manganese (i) Mercury (j) Zinc		
2. Total (a) Calcium (b) Magnesium (c) Potassium (d) Sodium	None Required	EPA[2]: (a)-(d) Pg.78-155, Atomic Absorption Methods
Methylene Blue-Active Substances (MBAS as LAS, detergents)	Refrigeration at 4°C	Standard Methods[1]: Pg. 339, Method 159A
Microbiological (a) Coliforms (1) Fecal (2) Total		(a) Standard Methods[1]: (1) Pg.684, Method 408B (2) Pg.679, Method 408A
(b) Mold		(b) Swab-count method for machinery mold-see attached procedure - Table A2
(c) Mold (viable)		(c) Recommended Methods[3]: Pg.101 &use acidified potato dextrose agar plate water directly)
(d) Salmonella		(d) Methods of Analysis[8]: Pg.905, Salmonella
(e) Spores		(e) Recommended Methods[3]: Pg.68, Spore Forming Bacteria
(f) Staphlococcus		(f) Recommended Methods[3]: Pg.149, Staphlococcus
(g) Total Plate Count		(g) Liquid - Standard Methods[3]: Pg.660, Method 406; Surface-Standard Methods[4]: Pg.190, Swab Contact Method; on Raw Fruit-See Table A3

See Footnotes at end of Table.

TABLE A1. SAMPLE HANDLING AND ANALYTICAL METHODS (Continued)

Parameter	Sample Preservation	Analytical Procedure
(h) Yeast (viable)		(h) Recommended Methods[3]: Pg.101 (use acidified potato dextrose agar, plate water directly)
Nitrogen (a) Ammonia (NH_3-N)	Refrigeration at 4°C	(a) EPA[2]: Pg. 159 Distillation Procedure
(b) Nitrate (NO_3+NO_2-N)		(b) Standard Methods[1]: Pg.461, Method 213C (Brucine)
(c) Organic (Org-N)		(c) EPA[2]: Pg.175, Total Kjeldahl (Org-N=Tot. Kjeld-NH_3-N)
Organoleptic Evaluation		Triangle Test[9]
Pesticides (a) Organo-Chlorine (b) Organo-Phosphorus (c) Other specific pesticides	Store in brown glass bottles & refrigerate at 4°C	FDA[5]: Performed by Region X EPA Laboratory and by Columbia Laboratories, Inc.
pH	N.A.	Standard Methods[1]: Pg.276, Method 144A (Electrometric)
Phosphorus (a) Ortho (Ortho-P) (b) Total (Tot-P)	400 mq $HgCl_2$ per liter or Refrigeration at 4°C	EPA[2] (a) Pg.249, Single Reagent Method (b) Pg.249, Single Reagent Method following alkaline ashing of evaporated sample[8]
Polychlorinated-biphenols (PCB)	Store in cool dark place	EPA approved method[6]. Performed by Region X EPA Laboratory

See Footnotes at end of Table.

TABLE A1. SAMPLE HANDLING AND ANALYTICAL METHODS (Continued)

Parameter	Sample Preservation	Analytical Procedure
Reactive Silicate	40 mg/l $HgCl_2$ or Refrigeration at 4°C	Manual of Sea Water Analysis[7]: Pg.67
Suspended Solids (SS)	Refrigeration at 4°C	Standard Methods[1]: Pg.537, Method 224C (Membrane Glass Filter Method)
Temperature (T)	N.A.	Standard Methods[1]: Pg.348, Method 162
Total Dissolved Solids (TDS)	Refrigeration at 4°C	Standard Methods[1]: Pg.539, Method 224E
Total Halogenated Organics		Performed by Dohrmann Laboratories
Total Solids (TS)	Refrigeration at 4°C	Standard Methods[1]: Pg.536, Method 224A
Total Volatile Solids (TVS)	Refrigeration at 4°C	Standard Methods[1]: Pg.536, Method 224A
Turbidity (Turb)	N.A.	EPA[2]: Pg.295 (electrometric) continuous with nephelometric apparatus
Volatile Halogenated Organics (chloroform, bromodichloromethane, dibromochloromethane, bromoform, carbon tetrachloride, and 1, 2 dichloroethane)		GC-MS. Performed by EPA Laboratory in 1975. Performed by Foremost Laboratories in 1976 season.
Volatile Suspended Solids (VSS)	Refrigeration at 4°C	Standard Methods[1]: Pg.538, Method 224D

[1] APHA, 1971. Standard Methods for the Examination of Water and Wastewater. 13th ed. New York, NY.

[2] USEPA, 1974. Methods for Chemical Analysis of Water and Wastes. EPA-625/5-74-003.

TABLE A1. SAMPLE HANDLING AND ANALYTICAL METHODS (Continued)

[3] APHA, 1966. Recommended Methods for the Microbiological Examination of Foods. 2nd ed. New York, NY.

[4] APHA, 1967. Standard Methods for the Examination of Dairy Products. 12th ed. New York, NY.

[5] USFDA, 1972. rev. Pesticide Analytical Manual. Vol. I & II. Washington, DC.

[6] Armour, J.A. and J.A. Burke. Method for Separating Polychlorinated-biphenols from DDT and Its Analogs. Jour. AOAC, Vol.53, No.4, pg. 761-768. 1970

[7] FRBC, 1965. re. A Manual of Sea Water Analysis. Bulletin No. 125, 2nd ed. Ottawa.

[8] AOAC, 1975. Official Methods of Analysis of the Association of Official Analytical Chemists. 12th ed. Washington, DC.

[9] Amerine, M.A., R.M. Pangborn, and E.B. Roessler. Principles of Sensory Evaluation of Food, Pg. 335-342. Academic Press, NY, 1965

TABLE A2. SWAB-COUNT METHOD FOR MACHINERY MOLD

This method has been suggested for a rapid semi-quantitative check on the presence of mold in or on equipment, with the source identified.

Laboratory Equipment and Materials:

Disposable, plastic swab tubes: unbreakable test-tube with a swab attached to the cap, available from scientific supply firms.

30-Power stereoscopic microscope with diffused light from below the stage.[1]

[1] Use a dissecting microscope, commonly referred to as an "insect fragment counting scope". Provide a sub-stage light source, using a light diffuser (parchment paper works well).

TABLE A2. SWAB-COUNT METHOD FOR MACHINERY MOLD (Continued)

Plate glass counting plate, about 9 cm x 10 cm, with three spacers made of layers of scotchtape,[2] and cover glass about 8 cm x 9 cm, with ruled parallel lines. One - milliliter pipette with tapered end cut off.

Thickener such as pectin solution or Certo (filter the solution if it contains mold fragments).

Gentian violet solution, about 10% crystal violet in alcohol.

Add three milliliters of a mixture of tap water and a little thickener solution to each swab-tube. Swab a suspected surface, standardizing approximately the area swabbed and the pressure applied. Shake the swab in the tube; squeeze the swab against the side of the tube and discard the swab; add a drop of gentian violet. Count by microscope all of the identifiable pieces of mold in a 0.5 ml sub-sample.[3] Repeat samplings in each plant will show what counts to expect, the effects of clean-up and so on.

Also suggested is a system of line samples of the product, as opposed to the equipment. At different steps in preparation, take amounts of the product equivalent to the quantity in a No. 303 can (which has net weight close to 500 grams, the AOAC sample size for Geotrichum). Soak the product sample in water and follow approximately the AOAC Geotrichum method. using No. 16 and No. 230 screens. (Rinse the product sample with a stream from a wash bottle while it is on the screen.)

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[2] Spacers should be located at two corners and at the middle of the opposite side of the slide. The thickness should be adjusted by trial-and-error such that when the cover glass is placed on the 0.5 ml. sample, the drop will spread to a diameter of about 6 cm.

[3] Use AOAC Geotrichum method criteria for identifying machinery mold.

TABLE A3. DETERMINING BACTERIAL AND SOIL LOADS ON RAW COMMODITIES

Equipment

Plastic bags with labels
Scale or balance

Cylinder, preferably plastic or metal*
Wire basket with handle and wire top**
Containers, 1 liter capacity
Whirl-Pak bags
Ice chest
Apparatus for total and fixed suspended solids
Apparatus for total plate counts.

Procedure

1. Randomly collect from each sampling point approximately five pounds of raw commodity. (Use one plastic bag per sample and identify with a suitable code.)

2. Weigh each sample; place the raw commodity in the wire basket and secure the wire top.

3. Weigh a volume of water equivalent to twice the weight of commodity. Use a portion of the water to rinse the plastic bag; combine with remaining volume in the cylinder. Discard the plastic bag.

4. Rinse the commodity for 1 minute by briskly raising and lowering the basket within the cylinder. The commodity should remain submerged during this period.

5. Withdraw the commodity from the water and allow the adhering water to drain into the cylinder for 30 seconds. Discard the raw commodity.

6. Vigorously mix the contents of the cylinder.

7. Fill one Whirl-Pak bag and one container with aliquots from the cylinder. Discard the excess volume.

8. Seal the Whirl-Pak bag and the container, identify with suitable code (use indelible or waterproof ink), and immediately ice these samples.

9. Use the contents of the Whirl-Pak bag for bacteriological analyses.

10. Use the contents of the container for solids and other chemical determinations.

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* Fabricate a cylinder by fusing a 61 cm length of 20 cm (8 in.) x .6 cm (1/4 in.) wall thickness Plexiglass tubing to a 25 cm x 25 cm x 0.6 cm Plexiglass base; or fabricate

a metal cylinder of comparable dimensions from galvanized sheetmetal.

** Fashion a 56 cm x 15 cm cylinder from .6 cm (1/4 in.) screen (hardware cloth). Attach a bottom by soldering a 15 cm diameter circle of the screen to the cylinder. Use a second 15 cm diameter circle, attached by wire, as a lid.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-78-203	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Reuse of Treated Fruit Processing Wastewater in a Cannery		5. REPORT DATE September 1978 issuing date 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Larry A. Esvelt		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Esvelt Environmental Engineering for Snokist Growers Yakima, Washington 98901		10. PROGRAM ELEMENT NO. 1BB610 11. CONTRACT/GRANT NO. S-803280
12. SPONSORING AGENCY NAME AND ADDRESS Industrial Environmental Research Lab. - Cinn, OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final Report 10/74 - 5/77 14. SPONSORING AGENCY CODE EPA/600/12

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Reclamation of the biologically treated effluent by filtration through mixed media pressure filters and disinfection with chlorine was investigated for two processing seasons. The reclaimed water was put to several trial uses: (a) initial product conveying, (b) equipment, floor and gutter wash, (c) direct container cooling, and (d) boiler feed. Steam generated from the reclaimed water was used on a trial basis for equipment cleaning, exhausting, cooking and blanching. No degradation of the product was produced as a result of reclaimed water use during these trial runs.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Cannery, Waste water, Apples, Peaches, Pears	Fruit Cannery Processing Wastes Reclamation and Reuse, Activated Sludge Fruit Processing, Biological Treatment	68D

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 126
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

☆ U.S. GOVERNMENT PRINTING OFFICE 1978— 657-060/1508