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Health Effect Potential of Reusing Treated Fruit Processing Wastewater within a Cannery

Esvelt Environmental Engineering, Spokane, WA

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THE HEALTH EFFECT POTENTIAL OF REUSING FRUIT PROCESSING WASTEWATER

The Health Effect Potential of Reusing Treated Fruit Processing Wastewater Within a Cannery

by

Larry A. Esvelt
Esvelt Environmental Engineering
Spokane, Washington 99206

and

Herbert H. Hart
Snokist Growers Cannery
Yakima, Washington 98901

Cooperative Agreement No. CR807441

Project Officer

David A. Brashear
Health Effects Research Laboratory
Cincinnati, Ohio 45268

HEALTH EFFECTS RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

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16. ABSTRACT
Reclamation of fruit processing wastewater by biological treatment, granular media filtration, and disinfection with chlorine, and reuse of the reclaimed wastewater for fruit washing and conveying, and for direct contact container cooling, was investigated over three seasons for its health effect implications. It was concluded that the reclaimed effluent had no adverse effect on product quality. It is recommended that this technology be applied to other processing plants for high acid foods packed in sealed containers, with certain safeguards to protect product quality. It was recommended that application of this technology to plants processing low acid foods be initiated, with additional care and attention to reclaimed water quality.

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FOREWORD

The many benefits of our modern, developing, industrial society are accompanied by certain hazards. Careful assessment of the relative risk of existing and new man-made environmental hazards is necessary for the establishment of sound regulatory policy. These regulations serve to enhance the quality of our environment in order to promote the public health and welfare and the productive capacity of our Nation's population.

The complexities of environmental problems originate in the deep interdependent relationships between the various physical and biological segments of man's natural and social world. Solutions to these environmental problems require an integrated program of research and development using input from a number of disciplines. The Health Effects Research Laboratory, Research Triangle Park, NC and Cincinnati, OH conducts a coordinated environmental health research program in toxicology, epidemiology and clinical studies using human volunteer subjects. Wide ranges of pollutants known or suspected to cause health problems are studied. The research focuses on air pollutants, water pollutants, toxic substances, hazardous wastes, pesticides and nonionizing radiation. The Laboratory participates in the development and revision of air and water quality criteria and health assessment documents on pollutants for which regulatory actions are being considered. Direct support to the regulatory function of the Agency is provided in the form of expert testimony and preparation of affidavits as well as expert advice to the Administrator to assure the adequacy of environmental regulatory decisions involving the protection of the health and welfare of all U.S. inhabitants.

This document reports the results of three years of investigation of the health effect potential of reusing treated and reclaimed processing effluent in the production of canned fruit. The conclusions are applicable to wastewater reclamation and reuse in plants producing high acid processed foods in hermetically sealed containers. The recommended extensions of these findings to production of low acid foods must be approached with suitable precautions to assure full protection of the product against contamination, and to assure its safety.

F. Gordon Heuter, Ph.D., Director
Health Effects Research Laboratory

ABSTRACT

This report presents the results of a three year investigation of the reclamation and reuse of processing wastewater in a fruit cannery. The project, conducted at Snokist Growers cannery, Yakima, Washington, used biologically treated (activated sludge) processing wastewater, containing no sanitary wastes, for reclamation by granular media filtration and chlorination. The reclaimed wastewater was reused for direct contact container cooling, for initial fruit washing and conveying, and for floor and gutter washing. This was the second phase of an earlier study which had recommended more intensive investigation of the potential for constituents being present in the reclaimed water which might affect human health if incorporated into the product (canned fruit), and of the maintenance of product quality when reclaimed water is used. The overall goal of the project was to demonstrate the acceptability of applying properly treated reclaimed processing effluent for critical uses in fruit and vegetable processing.

The project results led to the conclusion that fruit processing wastewater, which has received good biological treatment, filtration and disinfection with chlorine, is suitable for reuse, in a fruit cannery, for critical uses such as direct contact container cooling and initial fruit washing and conveying. The quality of product in containers cooled in the reclaimed wastewater was not adversely affected and the container failure rate was not increased, when compared to cooling in a well water supply. Heavy metals, pesticide residues, and halogenated organic compound concentrations were shown to be acceptable in the reclaimed water. Microbiological quality of the reclaimed wastewater (not containing any sanitary wastes) was acceptable. Reclamation system performance for removing microorganisms measured by total aerobic count, total and fecal coliform tests, total anaerobic count, yeast and mold tests, and aerobic and anaerobic spore tests was determined.

Based on the results of the investigations, recommendation was made that continued use of the reclaimed wastewater at Snokist Growers cannery be approved. Furthermore it was recommended that reclamation and reuse of adequately treated processing wastewater be considered acceptable for all high acid food processing plants, where the product is sealed in containers and given terminal thermal processing. Approved uses would be for container cooling, and fruit and equipment washing, so long as the reclaimed water does not enter the final product.

The trial use of adequately treated reclaimed processing wastewater in low-acid food processing plants was recommended. Special attention to the necessary levels of treatment attainment for removal of anaerobic and spore forming organisms was recommended. The desired amount of documentation regarding halogenated organics in the reclaimed wastewater was not achieved during this program and further documentation of this aspect of reclamation was recommended.

This report was submitted in fulfillment of requirements of EPA Cooperative Agreement CR807441, by Snokist Growers. The report covers the period of September 1980 through December 1982 when investigations were completed.

CONTENTS

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Number	Page

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

This project was conducted at the Snokist Growers Yakima, Washington cannery. The Snokist Growers Board of Directors is acknowledged for its continued support of the concept of wastewater reclamation and reuse as a means for resource conservation and limiting environmental degradation. Mr. R. B. Leavens was general manager during this investigation. Mr. Frank Coleman is currently general manager of Snokist Growers. Mr. Larry Federspiel, assistant to the general manager, provided coordination of activities and communications between the Snokist Growers management and the project. Mr. Bernie Sims, comptroller, established budget control procedures and monitored the project budget and expenditures. Mr. Doug Robberson was cannery manager during 1980 and 1981 processing seasons. Mr. Darwin Finch (deceased), assistant cannery manager during 1980 and 1981 seasons, is acknowledged for his continuing support. Mr. Jim McGee and Mr. Jim Buttes were cannery manager and assistant manager during the 1982 season. Mr. Don Peterson, maintenance superintendent, coordinated and directed equipment modifications to accommodate the wastewater reuse. Mr. Steve Maley, production manager, provided coordination between cannery operations and this project.

Mr. R. D. Kearl, Mr. G. H. Shepard, and Mr. G. D. Peck were USDA Inspectors-in-Charge at the cannery during this project. They are acknowledged for monitoring of water reuse locations within the cannery, observation of relative container failure rates between reclaimed and house water coolers, and assistance in determining causes for container failures.

Mr. Herb Hart, director of pollution control facilities for the cannery, acted as Project Manager. He managed the day to day operation of the wastewater treatment and reclamation system, directed laboratory operations, controlled water reuse within the cannery and assessed container failures for cause. Mrs. Nina Wright, Mrs. Sharon Hill, Miss Steva Ames, and Mrs. Laura Henley performed laboratory testing. Miss Ames performed a major part of the experimental work in assessing the procedures for anaerobic bacteria count tests. Mr. Keith Dusil, Mr. Norman Hart and Mr. Walter Geyer assisted in treatment and reclamation facility operation, sampling, on site testing and calibration of continuous monitoring test equipment.

Dr. Larry Esvelt of Esvelt Environmental Engineering was Principal Investigator for the project. He directed overall project activities, monitored work plan attainment, communicated with outside laboratories, reduced data and prepared reports.

Mr. David Brashear of EPA's Health Effects Research Laboratory was Project Officer. He with Mr. Herbert Pahren, Physical Science Administrator at HERL provided technical and management advice which helped ease the administration of the project.

The National Food Processors Association, Western Research Laboratory, Berkeley, California provided assistance in the form of heavy metals analysis, can failure evaluations and input of ideas to give the project maximum relevance to the rest of the food processing industry. Dr. Henry Chin provided analytical assistance. Mr. Allen Katsuyama reviewed the project and findings from an industry perspective.

The U.S. Department of Agriculture, Agriculture Research Service, Western Regional Laboratory, Albany, California has provided analytical and interpretive assistance for halogenated organic compounds in the reclaimed wastewater. Drs. Charlie Huxsol and Lee Tsai directed these activities.

Battelle Pacific Northwest Laboratories, Richland, Washington provided analytical services for Pesticides, PCBs and for volatile halogenated organics (1981 season only) during this project. Dr. Roger Schirmer and Ms. Barbara Vieux directed and performed the analyses.

Although no formal technical advisory committee was assembled for this project, several persons contributed project review and assisted in the development of conclusions and recommendations. They included:

> Dr. Reginald L. Handwerk, U.S. Department of Agriculture, Science and Education Administration, Beltsville Agricultural Research Center, Beltsville, Maryland.
>
> Dr. Melvin R. Johnston, Division of Food Technology, Food and Drug Administration, Washington, D.C.

Mr. Herbert R. Pahren, Health Effects Research Laboratory, Environmental Protection Agency, Cincinnati, Ohio.

Mr. Kenneth A. Dostal, Industrial Environmental Research Laboratory, Environmental Protection Agency, Cincinnati, Ohio.

Mr. Allen M. Katsuyama, Western Regional Laboratory, National Food Processors Association, Berkeley, California.

Mr. David A. Brashear, Health Effects Research Laboratory, Environmental Protection Agency, Cincinnati, Ohio.

Mr. Herbert H. Hart, Project Manager, Snokist Growers Cannery, Yakima, Washington.

Dr. Larry A. Esvelt, Principal Investigator, Esvelt Environmental Engineering, Spokane, Washington.

SECTION 1

INTRODUCTION

PURPOSE

This study was undertaken to assess the health effect implications of the reuse of reclaimed processing wastewater in a fruit cannery. The technical feasibility of reclaiming biologically treated processing effluent from the cannery had been addressed in an earlier study.[1] This project was to specifically determine the level of constituents in the reclaimed water which may be of health significance if the water is utilized on a continuous basis for direct contact container cooling, initial product washing and conveying, and processing area floor and gutter wash. The constituents of concern include bacteriological indicators of water quality, heavy metal toxicants, pesticides used on the raw fruit to be processed, volatile halogenated organics potentially formed during disinfection processes using chlorine, and other halogenated organics, some of which may be formed during disinfection with chlorine.

The study was performed under a cooperative agreement among the Environmental Protection Agency Health Effects Research Laboratory, the Food and Drug Administration, the U.S. Department of Agriculture, the National Food Processors Association, and Snokist Growers. The work has been performed at the Snokist Growers cannery, Yakima, Washington.

OBJECTIVES

The objective of this project was to demonstrate on a commercial scale whether there are potential health effects related to reclamation and reuse of treated processing effluent in a fruit cannery. Demonstration of the acceptability of the reclaimed effluent for reuse in the critical water use areas of direct contact container cooling and initial fruit washing and conveying would be accomplished by showing the feasibility for the following:

1) production of a consistent, acceptable reclaimed water of adequate bacteriological quality for use in the cannery;

2) production of a water free from contamination with filth; and

3) production of a water with acceptably low levels of toxicants and priority pollutants to prevent development of adverse health effects by the water's reuse.

The ultimate purpose of the project was to determine if a properly treated, reclaimed effluent would be acceptable by regulatory agencies and the fruit and vegetable processing industry for critical uses in food processing.

TECHNICAL REVIEW

The technical review of this project was coordinated by the Project Officer and was conducted by representatives of several agency and industry organizations. The work plan, ongoing project activity reports and this final report have been reviewed by the following individuals, frequently with assistance from members of their staff or organization:

Dr. Melvin R. Johnston, Chief, Plant and Protein Technology Branch, Division of Food Technology, Food and Drug Administration.

Dr. Reginald L. Handwerk, Science and Education Administration Agricultural Research, U. S. Department of Agriculture.

Mr. Allen M. Katsuyama, Head, Sanitation Section, National Food Processors Association, Western Research Laboratory.

Mr. Herbert R. Pahren, Physical Science Administrator, U. S. Environmental Protection Agency Health Effects Research Laboratory.

Mr. Kenneth A. Dostal, U. S. Environmental Protection Agency Industrial Environmental Research Laboratory.

Mr. David A. Brashear, Project Officer, U. S. Environmental Protection Agency Health Effects Research Laboratory.

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

Dr. Larry A. Esvelt, Principal Investigator, Esvelt Environmental Engineering.

BACKGROUND

The fruit and vegetable processing industry (canned, frozen, pickled and dehydrated fruit and vegetables) operates about 1600 plants in the United States and processes about 30 million metric tons (kkg) of raw product per year. The industry uses about 430 million cubic meters (110 billion gallons) of water annually to process this food, and subsequently discharges almost all of the water as wastewater. About 46 % of this wastewater is discharged to publicly owned treatment works (POTWs). About 28 % is treated by the industry and disposed of to surface waters. The remaining 26 % is treated and disposed of on land. Thirty five to forty percent of the industry production occurs in California.

The increasing cost of suitable water and its decreasing availability in some regions will tend to make processing wastewater reclamation and reuse an inviting alternative for supplementing or replacing primary sources of water supply. It is unlikely that wastewaters containing sanitary sewage will ever be seriously considered for reclamation and reuse in food processing.

The degree of treatment already required for discharge of food processing effluents to surface waters makes these plants the most likely candidates for effluent reclamation and reclaimed effluent reuse. If fifty percent of the process wastewater currently discharged to surface waters were reclaimed for reuse it would result in a "new" water supply of 60 million cubic meters (16 billion gallons) per year.

Dischargers to POTWs are facing increasingly higher wastewater treatment charges and, in some instances, limitations on quantities of wastewaters and/or pollutants which can be discharged. These dischargers are faced with expenditures for pretreatment facilities and municipal charges which may make further treatment and reuse economically feasible. If twenty five percent of the process wastewaters discharged to POTWs were reclaimed for reuse it would result in a "new" water supply of 50 million cubic meters (13 billion gallons) per year.

Wastewaters currently treated and discharged on land are probably the least likely to be reclaimed for reuse unless the cost or availability of supply water or land for treatment and disposal would justify the treatment and reclamation system cost.

Up to 110 million cubic meters (29 billion gallons) of fruit and vegetable processing wastewater now being discharged to surface water and POTWs may be feasible for reclamation and reuse if the reclaimed water were satisfactorily demonstrated to be an acceptable water supply.

Processing Wastewater Treatment at Snokist Growers Cannery

Snokist Growers is a fruit 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 and cherries produced by the grower members. The principal annual pack consists of canned pears and canned apple products. During a typical season, the cannery processes about 250 metric tons (kkg) of pears per day for about two months with about 1000 kkg of freestone peaches and about 500 kkg of purple plums processed concurrently. From 100 to 200 kkg per day of apples are processed into slices, sauce and rings for two to four months per year. Cherries and crab apples are processed for limited seasons each year.

For several years prior to 1966, Snokist Growers and its predecessor was subjected 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 teatment 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.[2, 3, 4]

The activated sludge system was effective in reducing biochemical oxygen demand (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). The operating data from studies at Snokist Growers cannery were used in the development of effluent limitation guidelines and new source performance standards for the fruit and vegetable processing industry.[5,6]

Development of Reuse Concept at Snokist

The year 1973 was a low water year in the Northwest which resulted in a declining water table in the vicinity of the plant and in its water supply wells. One of the plant's three wells became unusable and concerns were expressed about the cannery being able to operate with adequate water in the event of mechanical problems in either of the other two. An investigation of the feasibility of a new well, versus reclaiming a portion of the biologically treated process effluent, as a supplementary cannery water supply was initiated.

The wastewater treatment system performed admirably from 1968 through 1973 and consistently produced a highly oxidized and very clear effluent. It was felt that the effluent would provide a suitable supplementary water supply source. The investigation indicated, however, that the lower cost alternative was development of a new well supply source.

Results of the feasibility analysis and the fact that Snokist was considering reclaiming effluent became known to EPA officials interested in reducing food processing wastewater emissions by reclamation and reuse according to goals set forth in Public Law 92-500 for elimination of pollutant discharges.

Research, Development and Demonstration (R, D & D) funds had been appropriated by Congress to evaluate wastewater reuse in industry. The potential availability of these funds to offset the cost differential between the reuse proposal and a new well water supply, prompted Snokist Growers to apply. A grant was awarded in late 1974 for the investigation of reuse of treated fruit processing wastewater within the cannery. The grant allowed for payment of funds to compensate for the well water/water reuse differential and investigation of the reclamation system for a two year period with the principal objective being pollutant emission reduction.

Wastewater Reuse R & D Project

Snokist Growers installed a treated wastewater reclamation system to produce water for reuse in the cannery to supplement the regular well water supply before the start of the 1975 processing season. It should be reiterated that their processing effluent contains no sanitary wastewater. Sanitary wastewater from the plant is discharged to a municipal sewer system. The reclaimed wastewater was put to four trial uses in the cannery during the 1975 and 1976 processing seasons. The uses were as follows:

1) equipment cleaning;

2) product cleaning and conveying;

3) boiler feed to produce steam for cleaning equipment, exhausting product containers, cooking and blanching of product; and

4) direct contact container cooling.

The results were presented in the final report and published in several places.[1,7,8,9] The final report conclusions and recommendations were reviewed and approved by members of a technical advisory committee representing the EPA Industrial Environmental Research Laboratory, the EPA Health Effects Research Laboratory, the Food and Drug Administration (FDA) Division of Food Technology, the USDA Fruit and Vegetable Quality Division, and the National Food Processors Association (NFPA) Western Research Laboratory.

The conclusions from the 1975-1976 project as presented in the final report[1] were as follows:

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 permissible 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.

Recommendations from the reclamation and reuse R & D study were as follows:

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.

<u>Health Effect Potential Study</u>

The project to assess the health effect potential of reusing the reclaimed wastewater in Snokist Growers cannery was initiated in 1980 after partial funding was approved through the EPA Health Effects Research Laboratory. The project was conducted under EPA Cooperative Agreement No. CR807441. It has attempted to address the deficiencies in knowledge identified in the conclusions of the previous R & D project and to follow the recommendations for a "Phase 2" in that project final report, as set forth in the OBJECTIVES.

The Food and Drug Administration, after review of previous documents and the project work plan, concluded that sufficient safeguards were introduced into the final procedure to assure the quality of the resultant processed fruits. They stated that "Based on our continued review of the product, we would agree that the reclaiming water technique would produce a water suitable for the intended use. We would agree that the product would not be deemed unsafe based solely on having been prepared using the reclaimed water. In the absence of other circumstances which would lead to an adulterated product, the prepared foods are considered marketable." (Letter dated August 13, 1980, from Taylor M. Quinn, Associate Director for Compliance, Bureau of Foods, Food and Drug Administration, Public Health Service, Department of Health, Education, and Welfare). The State of Washington concurred with the FDA letter regarding marketability of the product (Letter dated September 8, 1980 from Verne E. Hedlund, Chief, Food Inspection Section, Dairy and Food Division, Washington Department of Agriculture). It was understood that the statements by the FDA and State would be in effect only through the duration of the demonstration project.

SECTION 2

CONCLUSIONS

This three season demonstration of processing wastewater reclamation and reuse has resulted in several conclusions which may be of industry wide significance. In considering the widespread application of wastewater reuse based on the conclusions from this project, it must be remembered that they are applicable to treatment and reclamation of a fruit processing wastewater containing no sanitary wastes. The reclaimed wastewater was used in 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. These conclusions must not be considered applicable to any wastewater containing sanitary wastes.

Since this project is a more intensified version of a previous study of reclaiming food processing wastewater, it should not be surprising that many of the conclusions presented herein are similar to those from the previous work. The conclusions have been reviewed and approved by representatives of the EPA Health Effects Research Laboratory, the EPA Industrial Environmental Research Laboratory, the FDA Division of Food Technology, the USDA Science and Education Administration, and the National Food Processors Association Western Regional Laboratory. Conclusions are as follows:

1. Processing wastewater given good biological treatment, filtration and disinfection with chlorine is suitable for reuse in a fruit cannery, except during periods when the biological treatment system discharges suspended solids in excess quantities.

2. Continuous monitoring of turbidity and chlorine residual with an appropriate alarm system to alert operating personnel of reclaimed water quality deficiencies, is sufficient to protect against using the reclaimed wastewater when quality criteria are not met due to treatment upset or equipment malfunction.

3. The quality of product in containers cooled in the reclaimed wastewater was not adversely affected, and the failure rate of containers cooled in the reclaimed wastewater was not increased in comparison to containers cooled in the cannery well water supply.

4. Heavy metals concentrations in the reclaimed wastewater were within the EPA drinking water standards and were approximately the same as the well water supply.

5. Pesticide residues were not present in the reclaimed wastewater in detectable concentrations.

6. Chloroform was the only volatile halogenated organic compound present in the reclaimed wastewater in detectable concentration. Chloroform concentration in the reclaimed wastewater appeared to be influenced by the free chlorine residual maintained during disinfection. During the limited data collection of this study, concentrations of chloroform reached or exceeded the EPA drinking water level of 0.1 mg/l when free chlorine residual was in the vicinity of 2 mg/l.

7. Turbidity concentrations of 20 NTU or less were attainable. This criterion appeared to protect the quality of product cooled in the reclaimed water. Maintaining this turbidity level did not assure that suspended solids would always be maintained at less than 30 mg/l.

8. Disinfection of the reclaimed wastewater so that coliform organism concentrations were in compliance with drinking water regulations was consistently achieved when turbidity was 20 NTU or less and total suspended solids was 40 mg/l or less.

9. So long as it is assured that no sanitary wastes enter the processing effluent to be reclaimed, it is not necessary to monitor fecal coliform organism concentrations since they will be adequately removed when disinfection reduces total coliforms to acceptable levels.

10. Aerobic total bacterial concentrations can be consistently reduced to 500/ml or less in the reclaimed wastewater and to less than 100/ml a majority of the time with chlorine disinfection. They were present in concentrations of 10^4 to 10^6/ml before disinfection and were reduced by about 3 orders of magnitude by chlorination.

11. Total counts of bacteria which grow under anaerobic conditions were about the same in the wastewater before disinfection as counts for those that grow under aerobic conditions(10^3 to 10^5/ml). They were reduced about 3 orders of magnitude by chlorination.

12. Yeast and mold organisms were present in the reclaimed wastewater before disinfection at concentrations of 100 to 1000/ml and 10 to 100/ml, respectively. They were reduced by chlorination by 2 to 3 and 1 to 2 orders of magnitude, respectively.

13. Both aerobic and anaerobic mesophilic spores were indicated to be present in the reclaimed wastewater (survived boiling for 3 minutes). They were present in concentrations from less than one up to 100/ml before disinfection. Chlorination reduced the counts by about an order of magnitude.

14. The bacteriological quality (total aerobic plate count) of water in can coolers being fed with reclaimed wastewater was equivalent to that of coolers fed with cannery well water.

The Food and Drug Aministration has provided the following conclusion: "As a result of our review, we have concluded that sufficient safeguards were introduced into the final procedure to assure the quality of the resultant reclaimed water for the intended uses and especially cooling of double seamed sanitary metal cans." (Letter dated March 5, 1984, from Mr. Taylor M. Quinn, Associate Director for Compliance, Bureau of Foods, Food and Drug Administration, Department of Health and Human Services).

SECTION 3

RECOMMENDATIONS

The results from this study, the potential health effects of reusing treated fruit processing wastewater in a fruit cannery, have industry wide implications. These recommendations have been reviewed and concurred with by representatives of the EPA Health Effects Research Laboratory, the EPA Industrial Environmental Research Laboratory, the FDA Division of Food Technology, the USDA Science and Education Administration, and the National Food Processors Association. The recommendations are as follows:

1. It is recommended that Snokist Growers continue to reclaim and reuse processing wastewater in the areas of can cooling, initial fruit dumping and conveying and for floor and gutter washing.

2. It is recommended that reclamation and reuse of processing wastewater for container cooling and initial product washing and conveying be considered acceptable for all high-acid food products packaged in hermetically sealed containers and terminally thermal processed.

3. It is recommended that reclaimed processing wastewater be considered acceptable for processing equipment washing in high-acid food processing plants, so long as none of the reclaimed water can enter the final product package and so long as the final product rinse is not accomplished with the reclaimed water.

4. It is recommended that the use of reclaimed processing wastewater be regulated under the same criteria as any other water supply for the processing plant, the Good Manufacturing Practice regulations (GMP's), including 21 CFR 110.35(a) and other applicable parts.

5. It is recommended that the criteria guideline for suitability of a reclaimed processing wastewater for use in direct contact container cooling, initial product conveying and washing, processing equipment cleaning, and floor and gutter washing be as follows:

   1) The reclaimed wastewater should receive good biological treatment to achieve low levels of

biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

2) The reclaimed wastewater should have a low turbidity. At Snokist Growers an objective of 15 NTU or less and a criterion for turbidity not to exceed 20 NTU resulted in consistently adequate disinfection performance. These values are recommended unless specific studies indicate higher values are justified on a case by case basis.

3) The reclaimed wastewater total suspended solids should be as low as practical. At Snokist Growers an objective of 30 mg/l or less and a maximum concentration criterion of 40 mg/l were compatible with the turbidities given above and resulted in adequate disinfection performance. At other applications permissible suspended solids concentrations may be higher or lower to achieve other water quality objectives.

4) The reclaimed wastewater should be disinfected to comply with drinking water regulations for total coliform organisms.

5) The reclaimed wastewater should be disinfected to reduce the total aerobic bacteriological plate count to 100/ml or less 50% of the time, 500/ml or less 90% of the time, and the total plate count should not exceed 1000/ml.

6) The reclaimed wastewater should be tested periodically for heavy metal toxicants and the heavy metal concentrations should comply with the primary drinking water regulations.

7) Wastewater for reclamation must not receive sanitary sewage discharges, and the processing plant should be periodically surveyed to assure that no sanitary waste enters the processing wastewater system.

8) Reclaimed wastewater should contain a measurable chlorine residual at the point of use.

9) Continuous on line monitors of chlorine residual and turbidity should be included in any wastewater reclamation facility to alert processing plant personnel of deterioration of reclaimed wastewater quality.

6. It is recommended that active consideration be given to trial use of reclaimed processing wastewater in low-acid

food processing plants if they comply with the above recommendations.

7. It is recommended that additional information be developed regarding disinfection needs for anaerobic organisms and spores and the relation to low-acid food processing.

8. Since the full scope of nonvolatile and volatile halogenated organics testing originally anticipated during this study was not accomplished due to a laboratory fire at the USDA Western Regional Research Laboratory, it is recommended that that objective be completed when possible.

The Food and Drug Administration, following review of the results from this project, and these recommendations, states that "The extension of this reclaimed water use to the cooling of low-acid canned foods must be monitored very closely to assure compliance with 21 CFR 113.60(b) 'Cooling Water. Container cooling water shall be chlorinated or otherwise sanitized as necessary for cooling canals and for recirculated supplies. There should be a measurable residual of sanitizer employed at the water discharge point of the container cooler.'" The FDA reiterated the policy developed for this project, for use in implementation of these recommendations: "Based on our continued review of the process, we would agree that the reclaiming water technique would produce a water suitable for the intended use. We would agree that the product would not be deemed unsafe based solely on having been prepared using the reclaimed water. In the absence of other circumstances which may lead to an adulterated product, the prepared foods are considered marketable." (Letter dated March 6, 1984, from Taylor M. Quinn, Associate Director for Compliance, Bureau of Foods, Food and Drug Administration).

SECTION 4

FACILITIES AND CONDUCT OF THE STUDY

This study was conducted at the Snokist Growers cannery, Yakima, Washington. Fruit processing wastewater, containing no sanitary sewage, was treated by screening, aerobic biological treatment, granular media filtration, and disinfection by chlorination for reuse in the cannery during this project. Fruits processed during the reuse of wastewater were pears, peaches, plums and apples. The reclaimed wastewater was reused in the cannery for direct contact container (can) cooling, for initial fruit washing and conveying, and for a floor gutter flush water. Monitoring and testing of the wastewater during and following reclamation and of use within the cannery were according to the detailed work plan attached to the EPA Cooperative Agreement, No. CR807441, and as modified and approved by the Project Officer.

PROCESSING PLANT OPERATIONS

Pears are floated from the bins, sized, peeled by mechanical peelers, rinsed, inspected, placed in cans, syruped, exhausted, capped and seamed, cooked in atmospheric steam cookers, cooled and palleted for warehousing. During this project reclaimed water was used for float water (with sodium sulfate added to increase the specific gravity so the pears would float) and sprays to remove chemical or other residues. It was also used for the direct contact container coolers. During the 1980 season reclaimed water was used in about one-half of the coolers. During the 1981 and 1982 seasons reclaimed water was used in all of the coolers except one.

Peaches are handled similarly to pears except that they are peeled by hot caustic and water sprays. Peaches are processed concurrently with pears using the same equipment following the peeling step.

Plums are not peeled but are washed, inspected, canned, cooked, cooled and warehoused. Reclaimed water was used only for the cooling of the cans.

Apples are dumped from bins into water ahead of peeling. Reclaimed water was used for the dump water. Apple slices are steam blanched, canned, cooked, cooled and warehoused. Reclaimed water was used for cooling. Apple sauce is finished, cooked by direct steam injection, canned, cooled and warehoused. After problems with product loss due to inadequately sterilized containers from the cooked sauce, a short duration atmospheric can cooker using steam was installed between the seamer and cooler before the 1982 season. Reclaimed water was used for cooling during all three seasons. Apple rings are packed in glass containers, pressure retorted and cooled under water sprays. Reclaimed water was used for the sprays.

SOLID AND LIQUID WASTE GENERATION

Solids generated in the processing area are collected on conveyor belts from the peelers and inspection area and transported to a "slurry processing" area. Pear and apple slurry is sold to a juice processor for incorporation into that company's products.

All processing wastewater, product and equipment spray drainage, spillage, washdown water for equipment and floors, water from the bin dumps and all other sources except the cooler overflows, is discharged to the floor gutter drainage system. The floor gutters drain by gravity to a sump in the treatment area where it is pumped to inclined screens and then piped to the treatment system.

Cooler water is discharged to a separate pump sump. From this sump a portion is pumped to the fruit receiving area for use in the bin dumps and for flushing water in the gutters. The remainder is pumped directly to the plant outfall to the Yakima river, bypassing the treatment system.

Wastewater from the cafeteria, restrooms, quality control laboratory and the first aid room is discharged to the Terrace Heights Sewer District sewer system. Wastewater from the wastewater laboratory is disposed of into a separate septic tank and drainfield system.

PROCESSING WASTEWATER TREATMENT AND RECLAMATION FACILITIES

Facilities to provide activated sludge aerobic biological treatment of Snokist Growers cannery processing wastewater to meet effluent requirements were completed in 1968. Effluent polishing and disinfection facilities were constructed in 1975 to enable the cannery to reclaim water for reuse.

Biological Treatment Facilities

The wastewater treatment facilities to provide an effluent quality adequate for discharge to the Yakima river were described in the report of the 1967-68 R & D project.[1] These facilities consisted of the components described in Table 1 along with interconnected piping, controls and auxiliary components. The biological treatment facilities along with a laboratory of approximately 800 square feet were valued at about $500,000 at the time of construction.

TABLE 1. SNOKIST GROWERS BIOLOGICAL TREATMENT FACILITIES - COMPLETED 1968

Facility	Description
1. Screens - 2 ea.	4 ft. wide x .030 in. mesh, sidehill.
2. Aeration Basin	22,700 cubic meter (6 million gallon) earth dike, PVC lined basin with 5 surface aerators - 4 @ 45 KW (60 HP), 1 @ 112.5 KW (150 HP).
3. Clarifier	27.5 meter (90 ft.) diameter, hydraulic sludge removal, 2.4 meter (8 ft.) side water depth, center feed.
4. Wastewater Pumping	Three variable speed pumps each with 6,600 liter per minute (1750 gal. per minute) capacity for clarifier sludge recirculation and pumping from equalization to aeration.
5. Equalization	5,700 cubic meter (1.5 million gallon) basin with 2 - 22.5 KW (30 HP) low speed surface aerators.
6. Sludge Thickener	9.2 meter (30 ft.) diameter pressurized recycle dissolved air flotation thickener.

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

The nutrient deficient but high strength (carbohydrate) wastewaters are screened, nitrogen and phosphorus nutrients are added and they are conveyed to the aeration basin. The wastewater is mixed with return sludge and air is furnished by low speed surface aerators to allow oxidation of the soluble organics. Detention time in the aeration basin is from 3 to 5 days based on the untreated wastewater flow rate.

From the aeration basin the wastewater flows to the clarifier where settling removes the activated sludge mixed liquor suspended solids before the clarified effluent is discharged to the Yakima river or is pumped to the reclamation system. Suspended solids removed in the clarifier (activated sludge) are returned to the aeration basin or wasted. Waste activated sludge is thickened by the flotation thickener and hauled to disposal on agricultural land.

Reclamation Facilities

In 1975 Snokist Growers added facilities for reclaiming a portion of the biologically treated cannery processing effluent for reuse in the cannery. These facilities are described in Table 2.

Wastewater reclamation includes granular media filtration, chlorination, retention for chlorine contact and pumping to a separate water distribution piping system inside of the cannery. A pump feeds the filters by pressure. Chlorine is administered proportional to flow at a ratio automatically adjusted to meet a preset residual. Disinfection is enhanced by injection of the chlorine solution from the gas chlorinator into the discharge pipe from the filters. After a short plug flow contact in the pipe the chlorinated water enters the baffled chlorine contact chamber. The contact chamber also acts as storage and the flow through the reclamation system is automatically adjusted downward from its preset flow rate to keep the basin from overfilling. The reclaimed water pump maintains a nearly constant pressure in the reclaimed water distribution piping system.

Figure 1 shows a schematic diagram of the wastewater treatment and reclamation system.

WASTEWATER RECLAMATION SYSTEM OPERATION AND MONITORING

The wastewater reclamation system at Snokist Growers cannery during the 1980, 1981 and 1982 processing seasons produced water for reuse in can cooling, initial fruit conveying and floor gutter wash. Reclamation system performance was monitored during pear, peach and apple processing each of the seasons from about September through December and occasionally into the winter portion of the apple processing season.

TABLE 2. SNOKIST GROWERS CANNERY WASTEWATER RECLAMATION FACILITIES - CONSTRUCTED 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 = 91.5 cm depth (36 in.): 30% 1.5 sp. gr. anthracite ; 30% 1.6 sp. gr. anthracite; 30% 2.6 sp. gr. silica sand; 10% 4.0 sp. gr. garnet sand. With sand and gravel media support, pipe underdrains, surface wash, automatic backwash program and flow control. Des. flow rate (each) = 0.34 cm/sec (5 gpm/sq. ft.) = 950 l/min (250 gpm). Max. flow rate (each) = 0.48 cm/sec (7 gpm/sq. ft.) = 1400 l/min (350 gpm). Backwash rate = 1.2 cm/sec (18 gpm/sq. ft.).
2. Pumps	Filter and backwash: Two 3800 liter/min. (1000 gpm) @ 20 meter (66 ft.) TDH each. 22.5 KW (30 HP). Reclaimed water: 2600 liter/min. (700 gpm) @ 54 meter (177 ft.) TDH. 37.5 KW (50 HP).
3. Chlorinator	227 kg (500 lb) per day gas-solution chlorinator with motorized control valve and motorized vacuum valve for "compound loop" control.
4. Contact/Storage Tank	227 cu. meter (60,000 gal.) baffled tank - 11.6 m x 6.7 m x 3 m deep (38' x 22' x 10') with 6 transverse baffles.
5. Monitoring Equip.	Turbidity meter - low range, continuous flow, light scattering to read filter effluent, range = 0 to 30 NTU. Chlorine residual analyzers - Two wastewater type amperometric continuous flow analyzers for monitoring chlorine residual at the inlet and outlet to the contact tank.

(Continued)

TABLE 2. (Continued)

Facility	Description
5. (Continued)	Flow meters - orifice meters for total flow, flow from each filter. Head loss - differential pressure across each operating filter. Contact/storage tank level - bubbler with differential pressure sensor.
6. Controls	Flow control - throttling valves on filter discharge to a preset maximum flow or to not exceed a preset contact tank water level. Backwash control - timer, headloss or manual initiation, automatic sequence and timing. Chlorine control - proportional according to filter water flow rate with motorized chlorine gas valve; ratio adjustment by vacuum control in chlorinator to meet preset chlorine residual analyzer value.
7. Alarms	High turbidity - two level for alarm and shutdown. Chlorine residual - high and low alarms on reuse pump discharge. System malfunction or shutdown.

Operation of the Reclamation System

Figure 1 shows the schematic flow diagram of the processing wastewater treatment and reclamation system as it has been operated during this project. The nutrients nitrogen (as ammonia, NH_3-N) and phosphorus (as diammonium phosphate, $(NH_3)_2HPO_4$) were added following screening to allow proper biological growth in the activated sludge system. The equalization basin was used to prevent chlorine residual in the untreated wastewater from plant cleanup from entering the aeration basin.

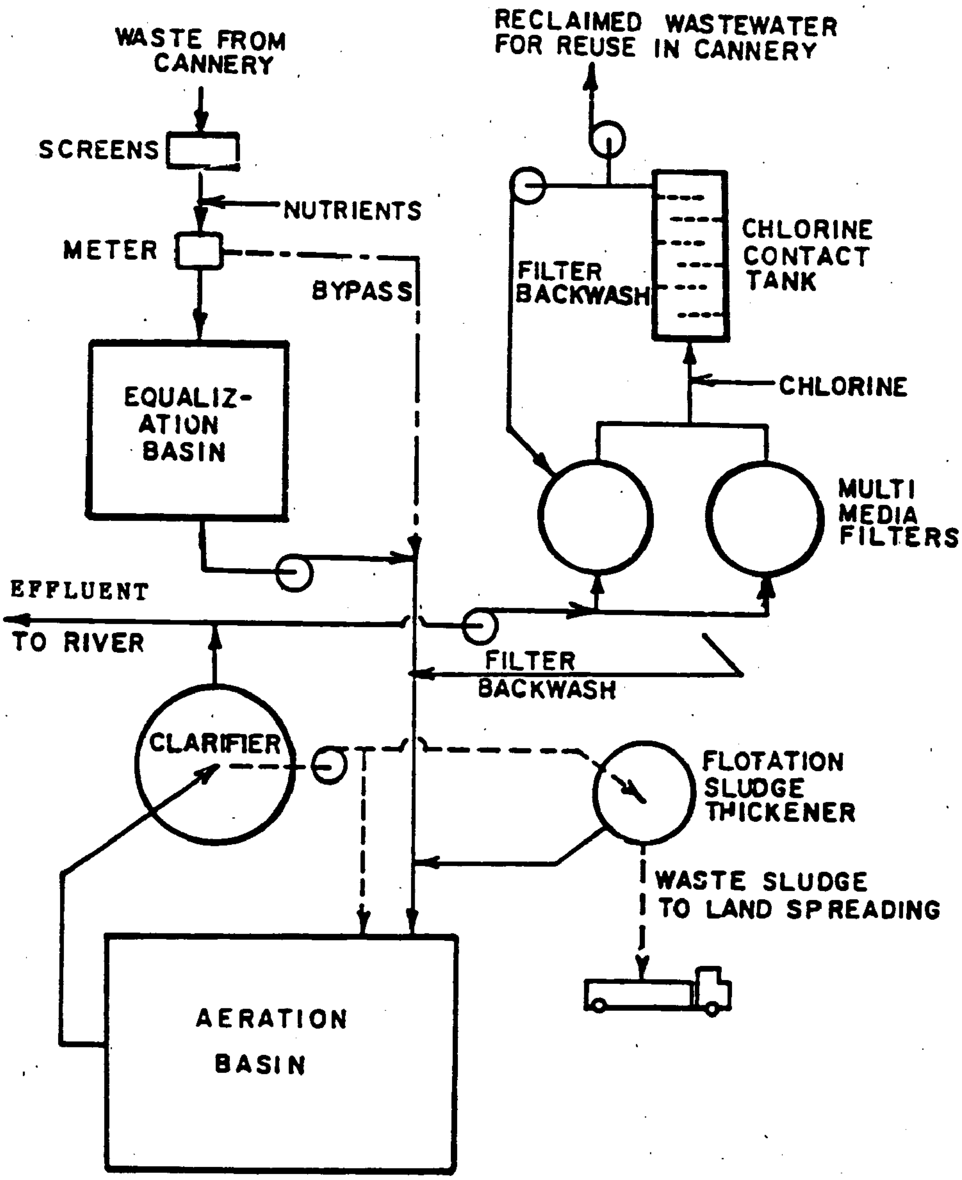

Figure 1. Snokist Growers cannery wastewater treatment and reclamation system - schematic flow diagram.

Viable biological solids are maintained in the activated sludge aeration basin on a year round basis. Periods of cannery inactivity result in no waste being discharged to the system for extended intervals but the treatment performance rapidly reestablishes itself when waste flow begins again. Summer processing of cherries and crab apples provides the system with some feed prior to pear processing but the feed rate is low due to the relatively small amount of these products processed. Pear processing gives the treatment system a sudden heavy load and it normally takes several days of operation to meet discharge requirements, especially for suspended solids content. It takes several more days to achieve effluent suspended solids concentrations low enough to allow initiation of wastewater reclamation.

The aeration basin aerators are operated to maintain a dissolved oxygen concentration of 2 mg/l. Sludge recycle rate for the activated sludge system normally averages 1.5 to 2 times the wastewater flow rate. After the start of the pear processing season in August, the mixed liquor suspended solids level is allowed to build up to about 4000 mg/l before sludge wasting is initiated. Thickened sludge is disposed to farm land.

Treated wastewater reclamation was initiated on September 10 during the 1980 and 1981 processing seasons and on August 31 during 1982. Each pressure filter flow rate limit was set at 950 l/m (250 gpm) with the system set to throttle the flow as the contact/storage tank reached its top 30 cm (1 ft) of capacity. The chlorine dose rate was maintained to get a 3 to 4 mg/l total residual during the 1980 and 1981 seasons and about 5 mg/l during 1982.

The pollution control supervisor (project manager) had control over the operation of the reclamation system. He established the points of use of the reclaimed water and initiated the reclamation and reuse at the start of each day's processing. During the day shift if the reclaimed water turbidity or chlorine residual monitors indicated noncompliance with quality criteria (alarm actuation), or if the reclamation system malfunctioned, the project manager immediately initiated a remedy of the problem or terminated reuse for can cooling, according to the problem. During other shifts any alarm condition was responded to by the cannery process supervisor by terminating reuse in the coolers (and fruit receiving area) until the following day shift, when the project manager could rectify the problem and again initiate reuse.

Reclamation System and Reclaimed Water Monitoring

The wastewater treatment and reclamation system was monitored for proper operation during all periods of reuse. The wastewater at various points in the system was monitored according to the project work plan during each of the processing seasons. The specific points of wastewater monitoring were as follows:

1. Screened Wastewater - wastewater following the screening station at the weir for metering.

2. Aeration Basin - effluent from the aeration basin to the clarifier.

3. Clarifier Effluent - effluent from the clarifier which is discharged to the river or reclaimed for reuse.

4. Filtered Effluent - effluent from the granular media filters, prior to chlorination for all parameters except chlorine residual and turbidity monitoring, which were following the chlorine injection point and about 5 m (16 ft.) of 20 cm (8 in.) pipe.

5. Reclaimed Effluent - effluent at the discharge from the chlorine contact tank where it is withdrawn for pumping to the cannery for reuse.

6. Well Water - the cannery normal water supply, at a tap from the water supply system within the cannery.

The monitoring and testing schedule for wastewaters is shown in Table 3. All routine testing was performed at the Snokist Growers cannery wastewater laboratory. These tests included normal wastewater parameters and bacteriological analyses. Testing for heavy metals was performed by the National Food Processors Association, Western Research Laboratory, Berkeley, California during the 1980 and 1981 seasons. Testing for pesticides and polychlorinated biphenyls (PCBs) (1980 and 1981) and for volatile halogenated organic compounds (1981 season only) was performed by Battelle Pacific Northwest Laboratories, Richland, Washington. The U. S. Dept. of Agriculture (USDA) Western Regional Lagoratory, Albany, California was scheduled to test for halogenated organics (volatile and nonvolatile) during the 1980 and 1981 processing seasons, but a lab fire prevented completion of this task.

Automatic monitoring equipment was calibrated daily in the early morning. Additional checks were made in the afternoon and the calibration was adjusted if needed.

Analyses were performed according to EPA recommended methods for the most part although several tests had no recommended procedures. A list of the procedures used is included in Appendix A.

TABLE 3. RECLAIMED WASTEWATER TESTING AND MONITORING SCHEDULE

Test	Sample Frequency[1] and Type[2] by Location					
	Screened Waste	Aeration Effluent	Clarifier Effluent	Filter Effluent	Reclaimed Water	Well Water
Flow Rate or Quantity	D[3]			D[3]	D[3]	
Temperature & pH	D,G[3]	D,G[3]	D,G[3]	D,G	D,G	
Total Suspended & Volatile Suspended Solids (TSS & VSS)	D,C[3]	D,C[3]	D,C[3]	D,C[3]	D,C[3]	
Settleable Solids	D,G[3]	D,G[3]	D,G[3]			
Dissolved Oxygen (DO)		D,G[3]	D,G[3]			
Total, Total Volatile & Total Dissolved Solids (TS, TVS & TDS)	W,C		W,C[3]	W,C	W,C[3]	W,C
Chemical Oxygen Demand (COD)	D,C[3]	D,C	D,C[3]	D,C	D,C[3]	W,G
Biochemical Oxygen Dem. (BOD)	W,C[3]		W,C[3]	W,C		
Ammonia & Organic Nitrogen (NH_3-N & Org. N)	W,C	W,C[3]	W,C[3]	W,C		
Nitrate Nitrogen (NO_3-N)			W,C[3]	W,C		
Total & Orthophosphate Phosphorus (Tot. P & PO_4-P)	W,C	W,C[3]	W,C[3]	W,C		
Total & Calcium Hardness	W,C		W,C	W,C	W,C	W,C
Alkalinity, Sulfates, & Chlorides (Alk., SO_4 & Cl^-)	W,C		W,C	W,C	W,C	W,C
Detergents & Silica (MBAS & SiO_2)			M,C		M,C	M,C

(Continued)

TABLE 3. (Continued)

Test	Sample Frequency[1] and Type[2] by Location					
	Screened Waste	Aeration Effluent	Clarifier Effluent	Filter Effluent	Reclaimed Water	Well Water
Turbidity			D,G	D,G[3]	D,G[3] & CONT.[3,4]	W,G
Color					M,G	M,G
Conductivity	W,C		W,C	W,C	W,C	W,C
Total Chlorine Residual (T Cl_2)				D,G[3,4] & CONT.[3,4]	D,G[3] & CONT.[3]	
Free Chlorine Residual (F Cl_2)				D,G[3,4]	D,G[3]	
Microbiological Testing						
Total Plate Count			W,G[3]	W,G[4]	D,G[3]	
Total Coliform			W,G[3]	W,G[4]	D,G[3]	
Fecal Coliform			W,G	W,G[4]	W,G	
Mold			W,G	W,G[4]	W,G	
Yeast			W,G	W,G[4]	W,G	
Aerobic Spores			W,G	W,G[4]	W,G	
Total Anaerobe Count[5]			W,G[3]	W,G[4]	W,G[3]	
Anaerobic Spores[5]			W,G	W,G[4]	W,G	
Outside Testing						
Heavy Metals[6]	4		4	4	12	4
Halogenated Organics[7]	4		4	4	12	4
Pesticides & PCBs[8]	4		4	4	12	4

(Continued)

TABLE 3. (Continued)

Notes:

1. Sampling Frequency: D = Each Processing Day; W = Weekly; M = Monthly; CONT. = Continuous Monitor and Recorder.

2. Type of Sample: G = Grab Sample; C = Composite Sample; CONT. = Continuous.

3. Testing followed same schedule in 1982 processing season. Basic schedule is for processing seasons 1980 and 1981. No note reference indicates test was not performed during the 1982 season.

4. Turbidity (continuous), and residual chlorine samples taken after chlorination but ahead of chlorine contact tank. Microbiological testing was both before and after chlorine addition.

5. Anaerobic bacteria testing was initiated during the 1981 season after communication between the various parties to the Cooperative Agreement.

6. Number of samples per season. Heavy metals samples sent to National Food Processors Association Western Research Laboratory, Berkeley, California for analysis.

7. Number of samples per season. Halogenated Organics samples sent to USDA Western Regional Laboratory, Albany, California for analysis of volatile and total halogenated organics. During the 1981 season duplicate samples were sent to Battelle Pacific Northwest Laboratories, Richland, Washington for volatile halogenated organics analysis.

8. Number of samples per season. Samples for Pesticide and PCB testing were sent to Battelle Pacific Northwest Laboratories, Richland, Washington for analysis.

USE OF RECLAIMED WASTEWATER

During the previous study of wastewater reclamation and reuse at Snokist Growers cannery, several trial areas of reuse were evaluated. Final deliberations among the technical advisory committee resulted in the recommendation that during a further study of the health effect potential of the reclaimed wastewater, full scale reuse be applied to direct contact can cooling, initial fruit washing and conveying and floor and gutter wash. No uses where the reclaimed water could contact the peeled fruit or become otherwise incorporated in the finished product were considered acceptable during this project.

Direct Contact Container Cooling

One of the major water use areas within the Snokist Growers Cannery is container (can) cooling. The cans following cooking in atmospheric pressure steam retorts are conveyed into coolers where a combination of submersion and water sprays cool them sufficiently to stop the cooking process. The cans are mechanically conveyed through the coolers with the can retention time in the cooler preset by the mechanical drive speed. The exit temperature of the can is a function of its retention time in the cooler, its entrance temperature, and the cooler temperature. The entrance temperature is constant from the cooker retort, retention time is preset by the cooler mechanical drive speed and the cooker temperature is maintained by an automatic temperature control valve.

The temperature control valve admits enough new cooling water to maintain the temperature of the cooler at its preset value. The coolers are preheated at the beginning of the processing day to the desired operating temperature by direct steam injection. A constant controlled temperature is important to assure that the cans are cooled sufficiently to arrest all cooking of the product, but remain warm enough to dry in the air to prevent external corrosion.

During the 1980 processing season for pears, peaches and apples, following the initiation of reclaimed water use, about one-half of the finished product was cooled using reclaimed water in the can coolers. After the season was over it was discovered that documentation of the fate of the containers from the two cooling waters was insufficient to statistically compare the rate of container failure from the two lots. This was due to container size and handling differences and product mix differences. Observations by the USDA inspectors, who were constantly aware of the reclaimed water use, and by the persons performing market follow-up, did however provide a qualitative comparison.

During the 1981 processing season the reclaimed wastewater was used, as quality permitted, in all of the can coolers except one. That cooler used the regular cannery well water supply only and was for comparison with two coolers using reclaimed wastewater. The three coolers were of the same configuration and received essentially the same product in the same size of can (#2 1/2 cans, 4 1/6 x 11/16 in.). An attempt to track the product from these comparative systems was made in order to establish a statistical comparison of the failure rate of containers cooled in the well water supply versus the reclaimed processing wastewater.

The rate of failure of the cans cooled in the two waters during the 1981 season was determined by retaining all cans rejected during labeling from the coolers under comparison. Rejection could result from low can vacuum (inadequate depression of can ends), dents, swells, leakage, other damage, corrosion or any other appearance of nonuniformity. Each of the rejected cans was inspected and those with physical damage were eliminated from consideration as having failed due to the cooling water quality. Of the cans receiving no outwardly apparent physical damage, inspection included a teardown to determine if there was some other physical reason for loss of vacuum (which was the predominant cause of rejection after apparent physical damage), or failure. Seams and welds, as well as other container characteristics, were examined. Evidence of actual product spoilage was also sought to determine if microbiological contamination had occurred.

Since there was a higher than expected rate of rejection of undamaged cans which were apparently low in vacuum from both waters, the National Food Processors Association was asked to help determine the cause. Cans were shipped to the NFPA laboratory in Berkeley, California for examination and testing of the containers and contents.

The retention of one cooler on well water for comparison with cooler product using reclaimed water was maintained through the 1982 pear and peach processing season. Results from this testing are in qualitative form, as observations by the cannery personnel in charge of labeling and shipping of product. There was not an excessive overall failure rate, as had occurred during the 1981 season, and no apparent differences in failure rate between product cooled in reclaimed water and that cooled in house water.

Initial Fruit Washing and Conveying

Water from the can coolers was collected and reused again in the area of initial fruit washing and conveying. The water was used to fill the fruit bin dumping vats and used in the sprays for washing the residue from the dumping vat from the pears. The fruit and dumping water using reclaimed water versus well water was compared during the 1975 and 1976 processing season reuse trials and was reported earlier[1]. There was no difference in the bacteriological content of the dump water from the two sources during that study and no difference in the bacteriological concentration on the fruit. No monitoring of this use was done during this project.

Floor and Gutter Wash

Reclaimed water was used for all of the cannery needs for flushing floor gutters during this study period. No washdown of floors or equipment with the reclaimed water was performed in areas where splash could reach equipment handling peeled fruit. Since this use was not of a critical nature, there was no monitoring of the use. Reclaimed water for gutter flushing was obtained either from the can cooler reuse line or directly from the reclaimed water line from the treatment area.

SECTION 5

RESULTS AND DISCUSSION

Reclamation and reuse of processing wastewater at Snokist Growers cannery was conducted and monitored for three processing seasons. Initiation of reclamation and reuse followed the start of pear processing by a sufficient time each season to assure that the wastewater treatment and reclamation processes had stabilized. The biological treatment system characteristically takes a short acclimation period in order to adjust to the large organic waste load accompanying the start of pear processing. When functioning well the biological treatment system produces an effluent sufficiently clear for reclamation. Dates of start of pear processing and of wastewater reclamation for the three seasons were as follows:

Processing Season	Pear Processing Start	Wastewater Reclamation Start
1980 - 81	August 22, 1980	September 10, 1980
1981 - 82	August 24, 1981	September 10, 1981
1982	August 24, 1982	September 1, 1982

The 1982 season startup delay is most representative of the acclimation period expected under normal circumstances. The delay in 1980 was largely predicated on finalization of the work program, and administrative details surrounding this study. Reclamation facilities could have been started on about September 1, 1981, but the filter system control air compressor failed and took another week to fix. The clarifier was clogged with blowing weeds and debris from a wind storm and required cleaning at about the same time.

Reclamation and reuse of the treated processing wastewater (sanitary sewage from lavatories, cafeteria and laboratories is discharged to the Terrace Heights Sewer District) continued through apple processing and ended the 1980-81 processing season on April 15, 1981. Reclamation and reuse of wastewater terminated on February 18, 1982 during apple processing in the 1981-82 season. The collection of data for this project concluded on November 8, 1982 at the end of pear canning in the 1982-83 processing season.

WASTEWATER REUSE

The reuse of reclaimed processing wastewater in the Snokist Growers cannery was continuous except for reclamation system mechanical failure when the water could only be used for waste gutter flushing. Reuse of the reclaimed wastewater was less continuous for the critical use areas of direct contact container (can) cooling and initial fruit dumping and conveying. These uses depended not only on the ability of the equipment to supply the water, but also on the quality of the reclaimed water produced.

Criteria for use of the reclaimed water in "critical areas" were set at the initiation of this project and were understood by all parties to the Cooperative Agreement to comply with the criteria recommended in the final project report from the wastewater reuse study conducted at Snokist Growers cannery during the 1974 through 1976 processing seasons.[1] Those recommended criteria were as follows:

Parameter	Criteria
Coliform bacteria	National Interim Primary Drinking Water Regulations[10] (monthly mean $\leq$ 1 /100 ml; and $\leq$ 5 % of samples with $\geq$ 4 /100 ml).
Fecal coliforms	Same as for coliforms.
Total aerobic bacteria (Total Plate Count, TPC)	Average $\leq$ 500/ml. Maximum $\leq$ 1000/ml.
Turbidity	$\leq$ 20 NTU.
Total Suspended Solids (TSS)	$\leq$ 30 mg/l.
Chlorine residual	Measurable at the point of use.

During day to day operation of the wastewater reclamation system, the decision to use reclaimed water in critical areas, was based on attainment of the turbidity criteria, and maintenance of a chlorine residual, known by experience to indicate compliance with the bacteriological criteria. This procedure was followed since testing for TSS and bacteriological parameters takes one to two days to obtain results, and an immediate method of determining compliance is necessary.

The turbidity was continuously, automatically monitored at the reclamation system with an alarm set point at 15 NTU and an automatic shutdown set point at 20 NTU. The shut down mode could be overridden, but the project manager had the responsibility of assuring that reuse in the critical areas was terminated if the override was actuated. On one or more occasions, water of high turbidity was introduced to the coolers, but the product was retained for observation and determined to be of ordinary quality on these occasions before it was released.

Chlorine residual was monitored at two points, ahead of the chlorine contact tank, and at the intake to the pump which supplied reclaimed wastewater to the cannery reclaimed water distribution system. The first monitoring unit supplied a signal to the chlorination equipment to keep the residual within a preset range. The second chlorine residual monitor contained alarm setpoints to be actuated if the chlorine residual dropped below a preset minimum. The wastewater manager, or an alternate person, was designated to shutdown reclaimed water use in critical areas if the alarm was actuated.

As it turned out, and as will be shown below, TSS violations can, and did occasionally, occur even though the turbidity was within the allowable range. Bacteriological noncompliance was only observed when turbidity and/or chlorine residual were outside their preset ranges.

<u>1980 - 81 Processing Season</u>

After startup of the reclamation system on September 10, 1980 the system was operated an additional ten days to assure that the reclaimed water quality met the study criteria before using in the coolers or fruit dumping area. The reclaimed water was introduced into the can coolers on September 24. During the period from September 10 through the end of pear processing monitoring indicated that the reclaimed wastewater was suitable for use on 32 of 42 days. On the 10 days when wastewater could not be reused, 9 were due to clarifier mechanical failure. The other day of unsuitable quality was due to an apparent slug of chlorinated water being discharged to the biological treatment system, causing it to upset and cause loss of solids over the clarifier weir.

During the apple processing portion of the 1980-1981 season, the reclamation system was operated for 89 processing days. The reclaimed wastewater was suitable for use in the critical areas (can coolers) on only 79 of those days. It was unsuitable on the first day following the long Christmas holiday shutdown due to high turbidity, and for 9 consecutive days in mid-February when turbidity was high. The weather was quite cold at the time which could explain the loss of solids over the clarifier weir. Other activated sludge plants have been observed to upset during extended cold periods.

A summary of the reuse during periods when the reclamation system was mechanically operable during the 1980-1981 season is as follows:

	Pear Processing	Apple Processing	Full Season
Water quality suitable for use	32 days	79 days	111 days
Unsuitable for use	1 day	10 days	11 days
Total	33 days	89 days	122 days
Days suitable	97 %	89 %	91 %
Wastewater during suitable days	46.6 MG	53.7 MG	100.3 MG
Reclaimed on suitable days	15.0 MG 32 %	20.3 MG 38 %	35.3 MG 35 %
Wastewater flow	1.46±0.19mgd	0.68±0.21mgd	0.90±0.41mgd
Reclaimed flow	0.47±0.10mgd	0.26±0.15mgd	0.32±0.17mgd

Note: MG = million gallons; mgd = million gallons per day; MG x 3.785 = thousand cubic meters; mgd x 3.785 = thousand cubic meters per day.

1981 - 1982 Processing Season

The 1981 - 1982 fruit processing season began with a filter system control air compressor breakdown which delayed startup of the reclamation system. Then a pipe feeding the filter system broke which shut it down for 6 processing days (8 days total). This was followed by a breakdown in the delivery system for nutrient chemicals (nitrogen and phosphorus) which are necessary for efficient biological treatment. The biological solids became nutrient deficient and suspended solids soon began to appear in the clarifier effluent in concentrations too high for the filters to remove effectively on a consistent basis. The nutrient deficient biological solids in the wastewater treatment system were the apparent source of turbidity and TSS problems which occurred in the biological effluent a number of times from mid-October into December. Periods of high turbidity and TSS were accompanied by inadequate disinfection. On some occasions, the solids were sufficiently high to make shutdown of the filter system necessary and reclaimed water could not even be used for gutter flushing.

During the pear processing season, the reclamation system produced water of suitable quality on only 34 days out of a possible 59. Breakdowns prevented reclamation on 14 days, and the water quality was unsuitable for use on another 11 days. Of 46 processing days during apple processing reclaimed water was suitable for use on only 17. Thus during this season reclaimed water was available for pear processing only 58 % of the time, and only 49 % of the time overall.

A summary of wastewater reuse during the 1981-82 season when the reclamation system was mechanically operable is as follows:

	Pear Processing	Apple Processing	Full Season
Water quality suitable for use	34 days	17 days	51 days
Unsuitable for use	11 days	29 days	40 days
Total	45 days	46 days	91 days
Days suitable	76 %	37 %	56 %
Wastewater during suitable days	37.9 MG	16.9 MG	54.8 MG
Reclaimed on suitable days	14.8 MG 39 %	4.7 MG 28 %	19.5 MG 36 %
Wastewater flow	1.11±0.18mgd	0.99±0.27mgd	1.07±0.22mgd
Reclaimed flow	0.44±0.19mgd	0.27±0.11mgd	0.38±0.18mgd

All but two coolers used reclaimed wastewater when it was of suitable quality for reuse during this season. On one processing day, water of high turbidity was inadvertently piped to the cooler for applesauce gallon cans. The USDA on-site inspector placed a hold on all of that product for 30 days, until it was determined that no container contamination had taken place. On several days, when the turbidity was within the range of the criteria for this project, the total suspended solids were above 30 mg/l. In spite of this, the total bacterial aerobic plate count remained below 1000 /ml, and no incidence of can failures was experienced.

Water overflowing the coolers was piped to a pump sump and equipment was installed so it could be recycled for use in the fruit dump and initial wash area and for use in gutter flushing.

Equipment was also installed which permitted bypassing of waste cooling water around the treatment system to the plant outfall to the river. This reduced the total wastewater flow to the treatment system. It also resulted in the percentage of wastewater reclaimed being not directly comparable to the 1980-81 season. A portion of the waste cooling water still went to the wastewater treatment system however, since the bypass pumps were inadequate to handle it all.

The combination of additional coolers using reclaimed water, and a portion of the cooler overflow being pumped directly to the river outfall, resulted in the reclaimed percentage of total wastewater flow being higher than in 1980, even though the poorer water quality resulted in a lower percentage of days when the water could be reused.

1982 Fall Processing Season

The reclaimed wastewater was suitable for use based on the turbidity and bacteriological criteria established for this study, for a full 53 days after initiation of reclamation on September 1. Although the turbidity did not exceed 11 NTU, the TSS exceeded 30 mg/l on 8 days (maximum was 42 mg/l). The reclaimed wastewater was used for can cooling on all days. The maximum TPC was 200 /ml and only exceeded 50 /ml on 7 days. A summary of wastewater reclamation and reuse during the 1982 season (pears only) is as follows:

Pear Processing

Reclaimed wastewater suitable for use	53 days 100 %	
Total wastewater	54.3 MG	1.02 ± 0.16 mgd
Reclaimed wastewater	28.9 MG 53.3 %	0.55 ± 0.14 mgd

During this season an improvement was made in the capability for bypassing waste cooling water to the plant outfall. This resulted in a lower flow of total wastewater to the treatment system which, along with a slight increase in the reclaimed wastewater flow, made the percentage of processing flow reclaimed higher than in 1980 or 1981.

The 1982 season is illustrative of the potential for reclamation and reuse of processing wastewater. Even during this season a slight nutrient deficiency occurred for a short period of time just preceding and probably accounting for those days when suspended solids were slightly higher than the project objective.

RECLAIMED WATER QUALITY

Quality parameters of the well water supply, processing wastewater, and treated and reclaimed wastewater were monitored through the three seasons of operation of this project. The principal objective of this monitoring was to determine if substances might be present, or introduced during use or treatment, that could cause detrimental effect on the health of consumers of canned fruit that had been produced using the reclaimed water. The operating characteristics of the treatment system were not a primary concern of this project since they had been studied and reported earlier.[1,2]

Chemical Quality

The chemical quality of the reclaimed water and of the well water supply was tested at the Snokist Growers cannery laboratory. Table 4 contains a summary of the results of this testing.

TABLE 4. WELL WATER AND RECLAIMED WASTEWATER QUALITY

Parameter	Units	Well Water Mean	Well Water Std. Dev.	Recl. Wastewater Mean	Recl. Wastewater Std. Dev.
Conductivity	umho/cm	85	5	251	105
Tot. Dis. Solids	mg/l	85	5	296	109
pH	units	8.1	0.2	7.0	0.5
Hardness	mg $CaCO_3$/l	40	10	22	10
Ca Hardness	mg $CaCO_3$/l	34	6	20	6
Alkalinity	mg $CaCO_3$/l	71	11	73	45
Chloride	mg/l	3.7	2.2	66	34
Sulfate	mg/l	4.2	2.3	24	20
Silica	mg SiO_2/l	44	7	49	8
Color	units	3.9	1.1	10.4	7.8
Detergents	mg LAS/l	0.005	0.008	0.03	0.02
COD	mg/l	8.4	6.0	26	16
BOD	mg/l	#		7.8	10.8
Organic Nitrogen	mg N/l	#		3.0	3.7
Ammonia Nitrogen	mg N/l	#		0.1	0.7
Nitrate Nitrogen	mg N/l	#		1.7	4.1
Total Phosphorus	mg P/l	#		11.6	11.7
Sodium*	mg/l	18	6	93	44
Potassium*	mg/l	2.7	0.4	12.2	5.1
Calcium*	mg/l	10	2	5.4	2.0
Magnesium*	mg/l	1.7	0.3	0.9	0.4

Analytical results near zero.
* Analyses performed at National Food Processors Association laboratory, Berkeley, California.

As seen on Table 4 there are substantial differences between the chemical quality of the water supply and the reclaimed wastewater. Most evident is the increase in the dissolved salt content as illustrated by the conductivity, chlorides and sulfates. This is a result of salt being used on the cannery floor to reduce slickness, salt solutions used to prevent discoloration of fruit and the use of sodium sulfate to increase the specific gravity of water for pear flotation from the bins. The pH averages lower in the reclaimed water even though the alkalinity averages about the same as for the water supply, probably due to the increase in carbonic acid (CO_2) from biological treatment of the wastewater. The hardness and calcium are lower in the reclaimed wastewater on the average, possibly due to precipitation in the biological treatment system with alkalinity from caustic added for peach peeling, and occasional caustic addition to keep the treatment system pH in the optimum range for biological treatment.

Temperature--

The temperature of the reclaimed wastewater is of interest to Snokist Growers, since they plan to use it for can cooling. As during the earlier study, the reclaimed water temperature decreased as the processing season progressed. The following is a summary of temperatures recorded during this project:

	Mean, °C	Std. Dev.
Well water supply	14.5	0.5
Reclaimed wastewater		
September 1 - 15	17.6	1.7
September 16 - 30	16.6	2.3
October 1 - 15	14.4	2.7
October 16 - 31	12.4	2.1
November 1 - 15	11.1	2.6
Nov. 16 - Dec. 31	7.8	2.4
January & February	6.9	2.5
March & April	10.6	1.8

From about October 1, the reclaimed water offers an advantage over the well water for cooling cans due to its lower temperature.

Total Suspended Solids and Turbidity--

The total suspended solids (TSS) content of the biological treatment effluent, the filter effluent and the reclaimed wastewater (filter effluent after chlorination and retention for contact) had considerable variation during this project. Figures 2, 3 and 4 show the TSS concentration frequency for the 1980, 1981 and 1982 processing seasons. Turbidity readings obtained from the continuous nephelometric turbidity monitor are also plotted on these figures. Readings above 30 NTU were off scale.

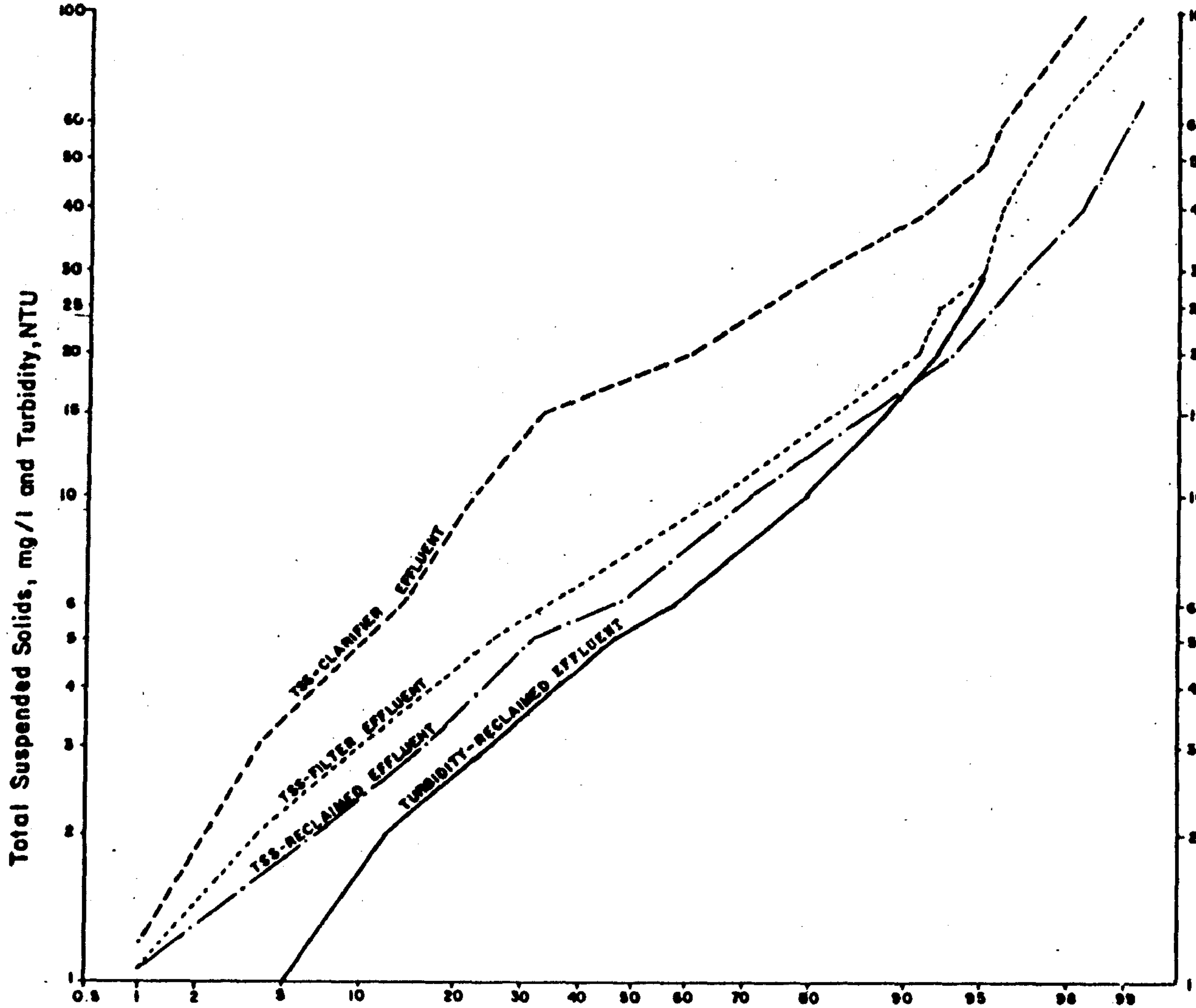

Figure 2. Total suspended solids and turbidity frequency distribution - 1980.

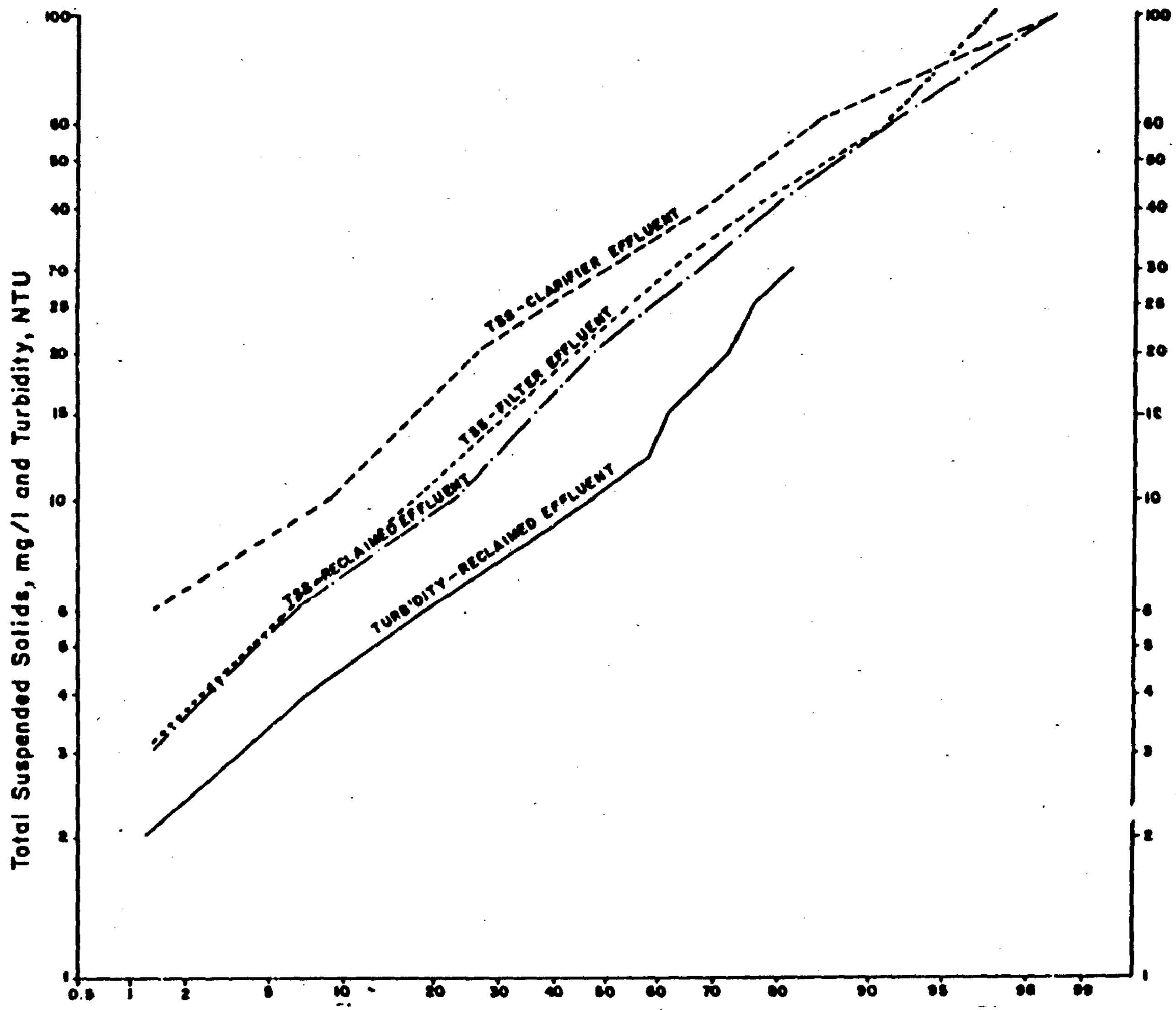

Figure 3. Total suspended solids and turbidity frequency distribution - 1981.

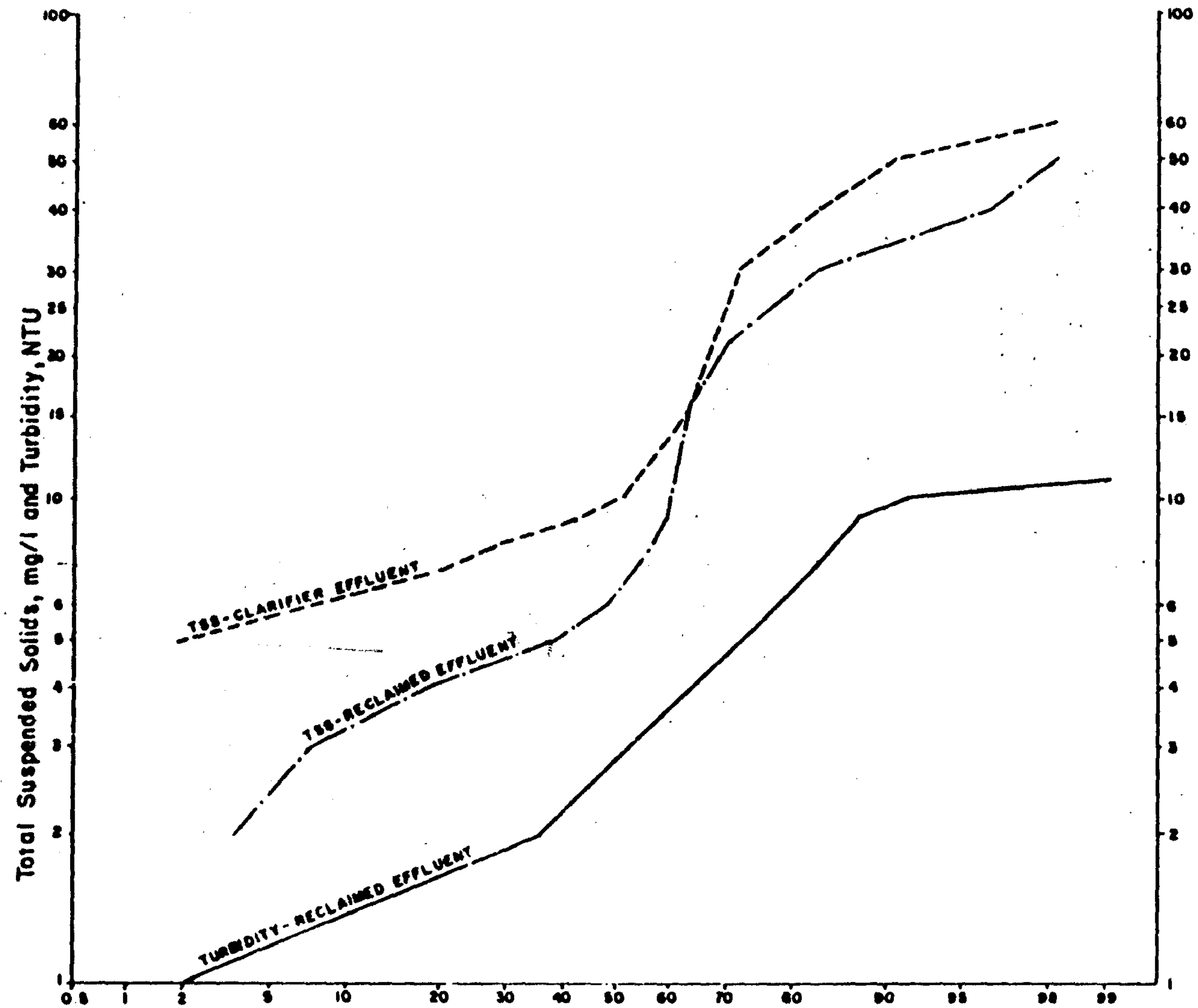

Figure 4. Total suspended solids and turbidity frequency distribution - 1982.

A comparison among the three years is difficult without placing the plots on top of each other but the following comparative values at the 50 and 90 percentile values for suspended solids are helpful in confirming that the reclaimed water quality was better during the 1980 and 1982 seasons than during 1981.

Effluent Sampling point	Year	TSS less than or equal, mg/l 50 % of time	90 % of time
Clarifier	1980	18	37
	1981	29	67
	1982	10	48
Filters	1980	7.5	19
	1981	22	56
Reclaimed	1980	6.2	17
	1981	21	55
	1982	6.2	33

It was noted following the study conducted in 1975-76 that the reclaimed effluent quality was highly dependent on the biological treatment system producing an effluent low in suspended solids. The TSS concentrations shown on Figures 2, 3, and 4 show how closely the reclaimed water quality corresponded to the biological (clarifier) effluent during this investigation.

Figure 5 shows the reclaimed effluent turbidity frequency plots from 1980, 1981 and 1982 all on the same graph for comparison. Once again it is clearly evident that the 1980 and 1982 seasons enjoyed much better reclaimed water quality than 1981. The 50 and 90 percentile intercepts are as follows:

Year	50 %	90 %
1980	5.2	16.4
1981	10.3	>30
1982	2.8	9.5

Another use for the information on the figures is a comparison of the percentages of the readings within the criteria established for reusing the reclaimed water in critical areas. The values are as follows:

	1980	1981	1982
Turbidity < 20 NTU	92 %	73 %	100 %
TSS < 30 mg/l	97 %	68 %	83 %

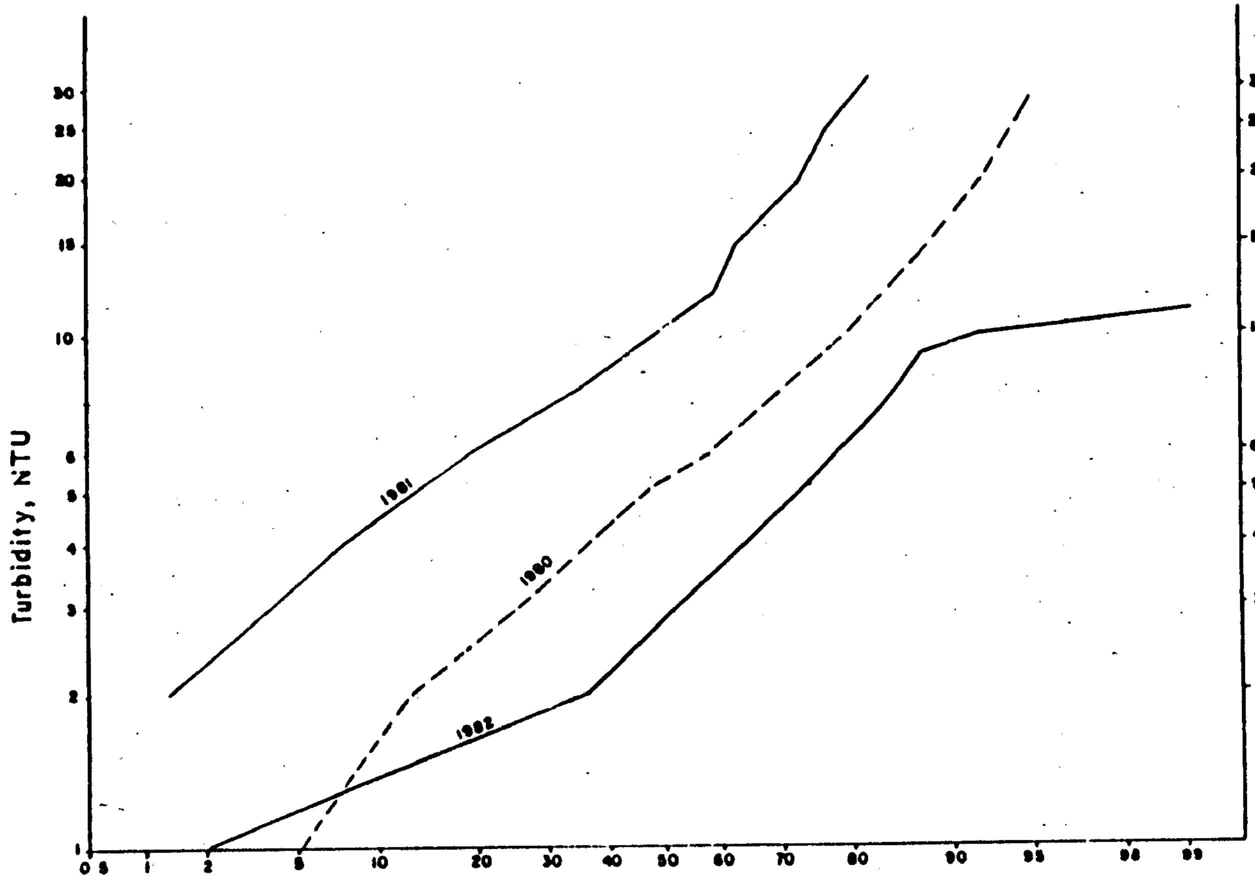

Figure 5. Reclaimed effluent turbidity frequency distributions - 1980, 1981, 1982.

The turbidity and TSS data illustrate that the 1981 processing season produced less desirable reclaimed water for reuse, probably due to the mechanical breakdowns and nutrient feed deficiencies which made the biological solids more difficult to remove by clarification.

Microbiological Water Quality

Daily monitoring of the reclaimed wastewater for total coliform organisms and total aerobic plate count was performed to assure that the reclaimed water complied with the preestablished project criteria and would be suitable for critical uses in the cannery. Additional, less frequent monitoring evaluated the reclaimed water for the presence of yeast and mold organisms, organisms which will grow under anaerobic conditions, and organisms which will survive high stress and grow under aerobic or anaerobic conditions.

Coliform Organisms--

Figures 6, 7 and 8 show the coliform and fecal coliform concentration frequencies in the clarifier, filter and reclaimed effluents during the three processing seasons. Coliforms are consistently reduced by 30 to 50 percent by the filter system as shown on Figures 6 and 7. The percentile concentrations from these figures are as follows:

Sample point	Year	50 %	90 %
Total Coliform Organisms/100 ml			
Clarifier effluent	1980	30,000	590,000
	1981	300,000	3,400,000
	1982	260,000	560,000
Filter effluent	1980	20,000	200,000
	1981	170,000	2,500,000
Reclaimed effluent	1980	< 1	1
	1981	< 1	1
	1982	< 1	< 2
Fecal Coliform Organisms/100 ml			
Clarifier effluent	1980	80	540
	1981	700	2,800
Filter effluent	1980	50	350
	1981	430	2,800
Reclaimed effluent	1980	< 1	1
	1981	< 1	< 1

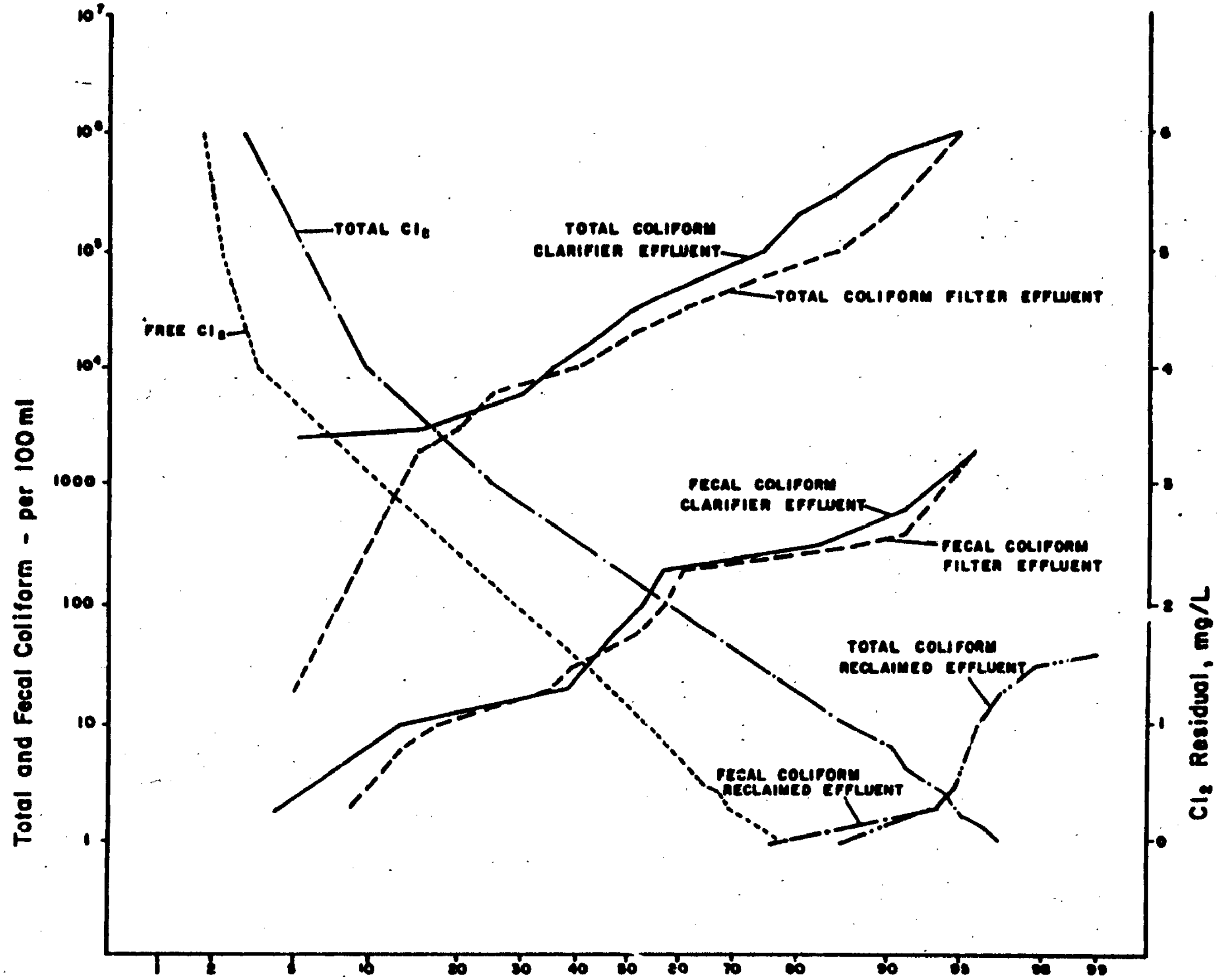

Figure 6. Total and fecal coliform frequency distribution - 1980.

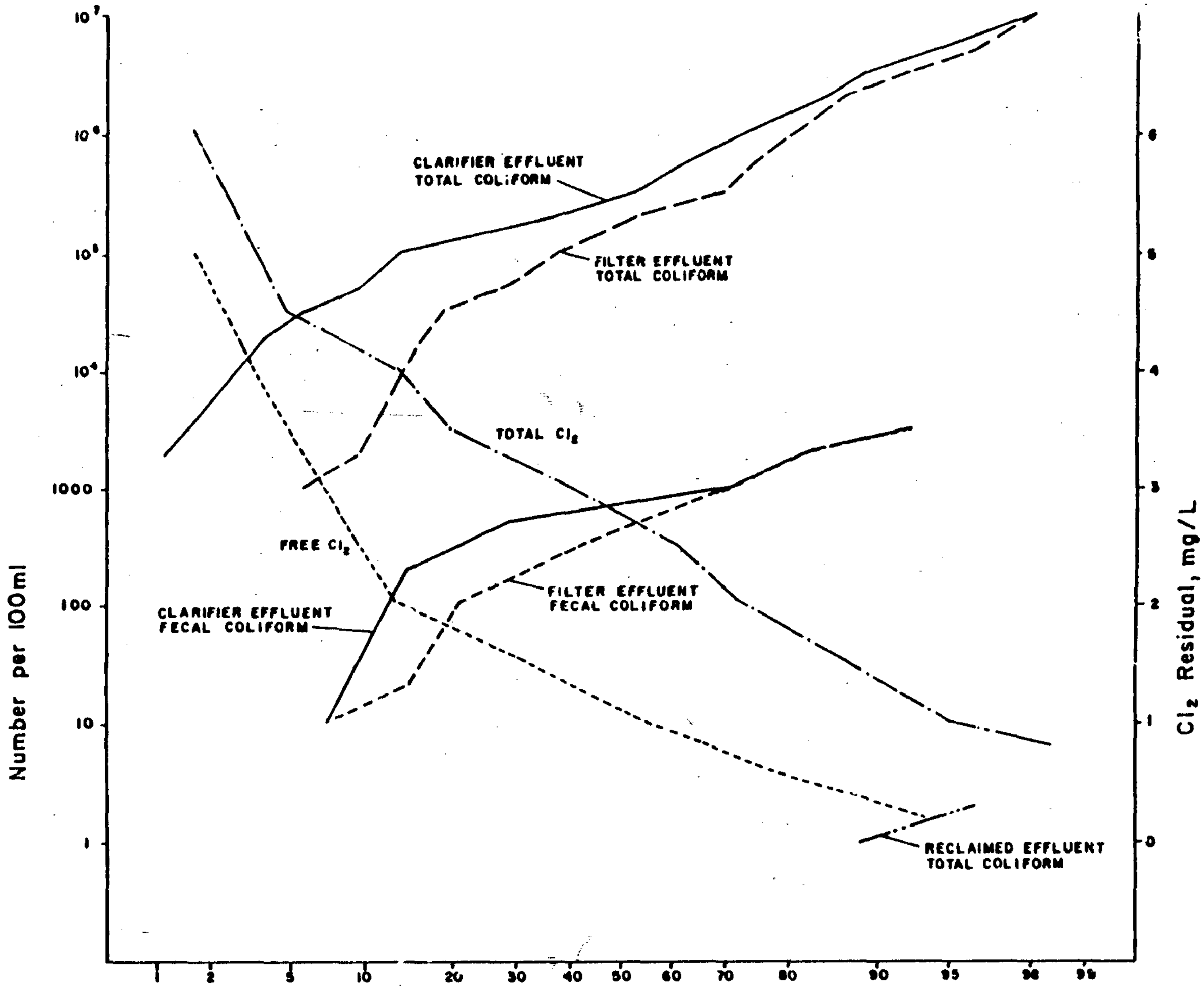

Figure 7. Total and fecal coliform frequency distribution - 1981.

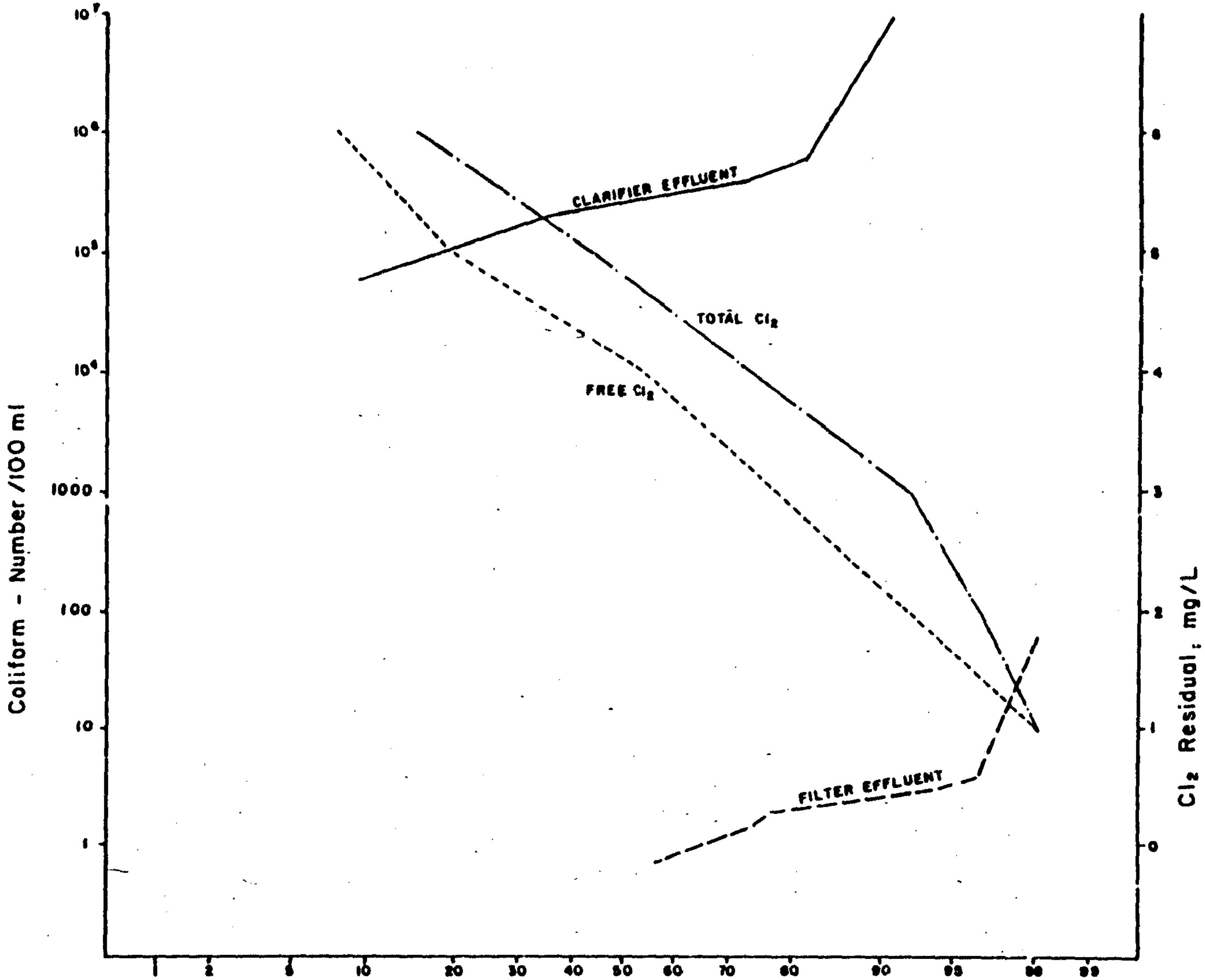

Figure 8. Total coliform frequency distribution - 1982 processing season.

These figures and values show that the disinfection system is very effective in reducing the total and fecal coliform organism counts to within the limits established by the Interim Drinking Water Standards[10] and established as criteria for wastewater reuse in critical areas during this project.

Total Aerobic Plate Count--

Total aerobic bacterial count (TPC) frequencies for the clarifier, filter and reclaimed effluents are plotted on Figures 9, 10 and 11 for the years 1980, 1981 and 1982. Concentrations in the clarifier effluents are similar between 1980 and 1982 with 1981 concentrations higher. Reduction through the filters is about 30 to 50 %, similar to the reduction for coliform organisms. The 50 and 90 percentile TPC values are as follows for comparison:

Total Plate Count / ml

Sample point	Year	50 %	90 %
Clarifier effluent	1980	19,000	50,000
	1981	52,000	170,000
	1982	12,000	36,000
Filter effluent	1980	13,000	47,000
	1981	28,000	120,000
Reclaimed effluent	1980	4	60
	1981	35	300
	1982	9	120

The percentage of time that the TPC in the reclaimed effluent met the criteria for reclaimed water use in critical areas and other levels of quality are as follows:

Year	<50/ml	<100/ml	<500/ml	<1000/ml
1980	89 %	91 %	97.5 %	100 %
1981	65 %	75 %	96.5 %	100 %
1982	86 %	87 %	100 %	100 %

The disinfection system is very effective at reducing TPC to the criteria level for reuse in critical areas as stipulated for this project. The TPC before disinfection was clearly higher in the 1981 season, which indicates poorer effluent quality. This corresponds with observations made from suspended solids and turbidity data. The 1982 season showed that when the turbidity and chlorine residual remain within proper ranges, the TPA will be consistently within the preset criteria.

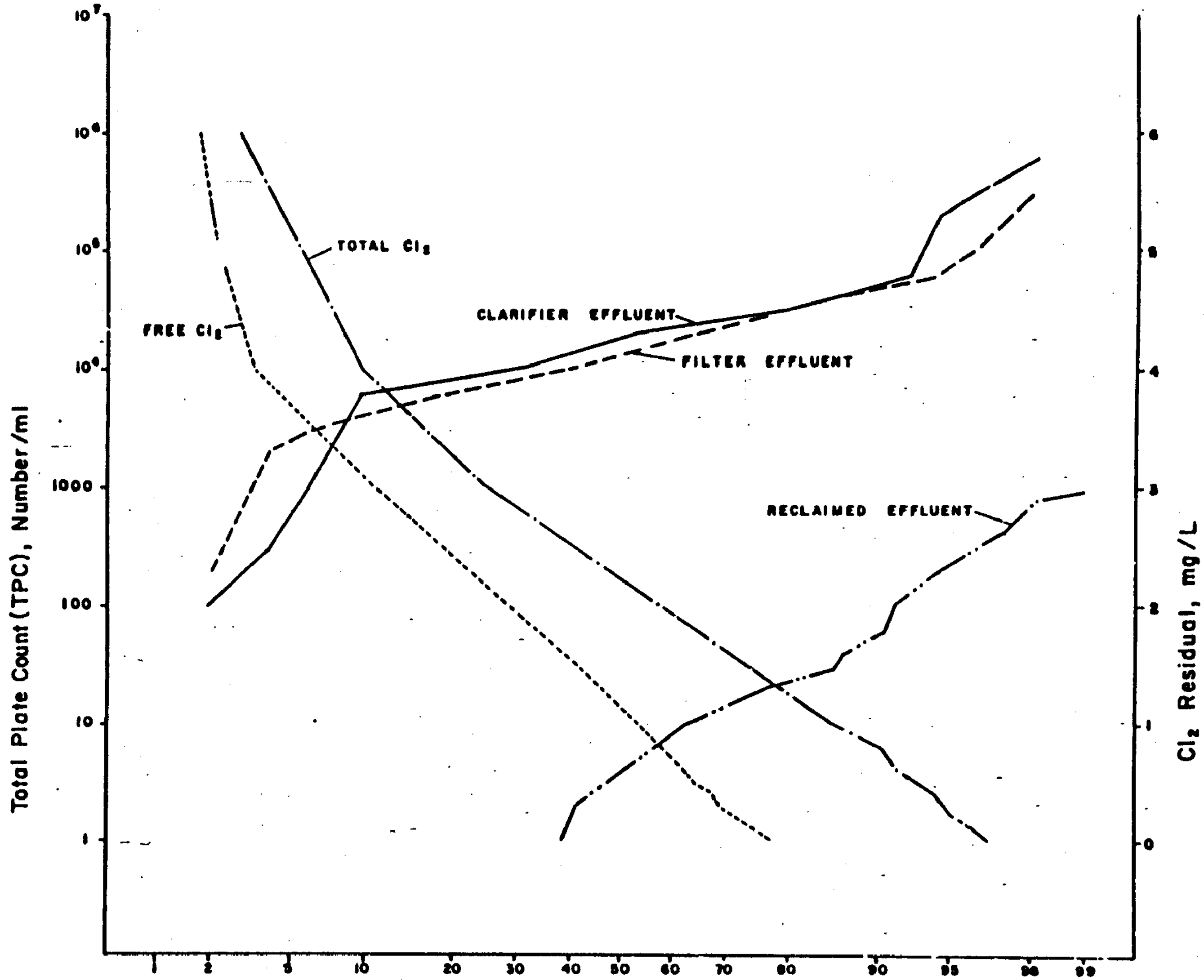

Figure 9. Aerobic total plate count frequency distribution - 1980.

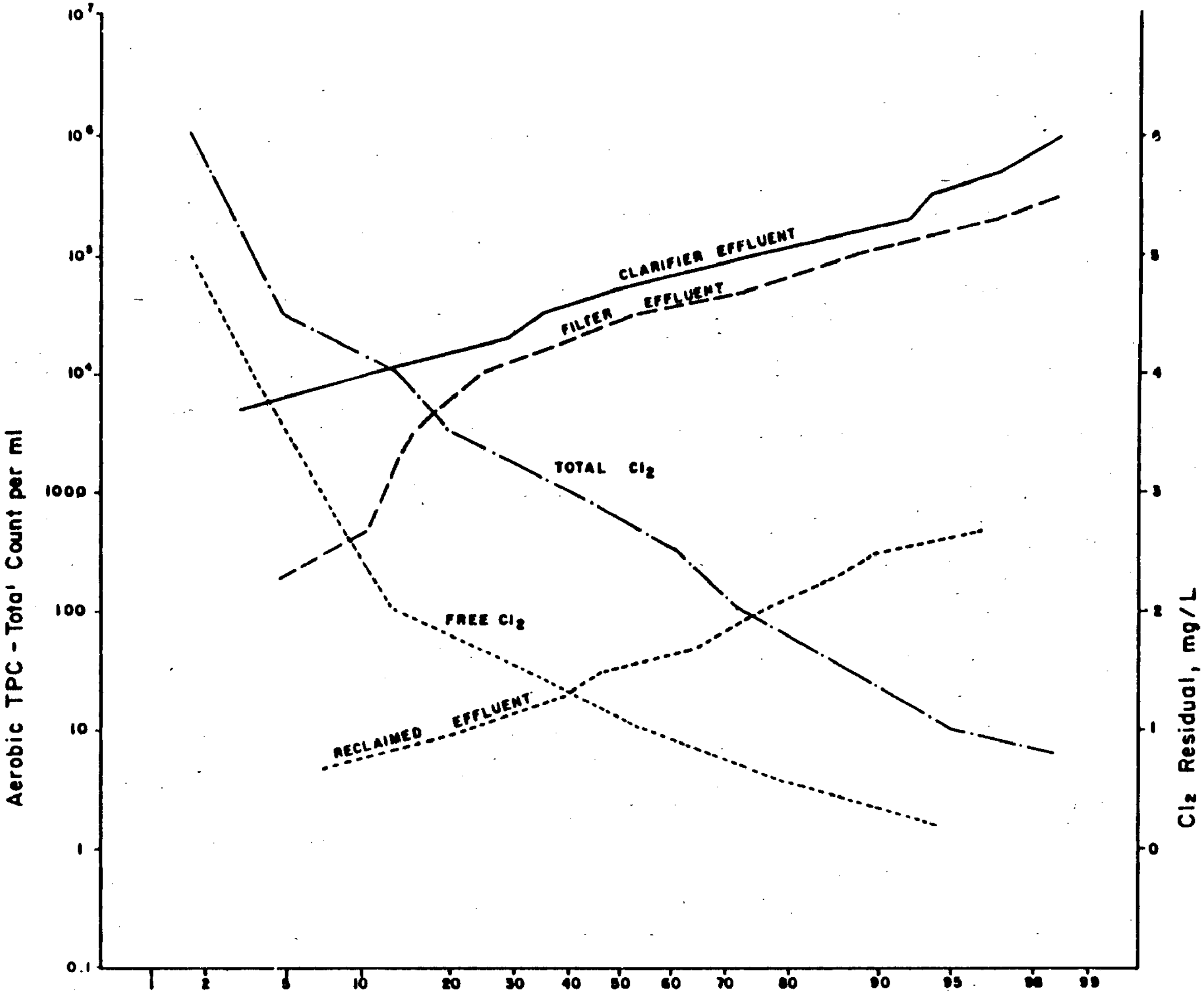

Figure 10. Aerobic total plate count frequency distribution - 1981.

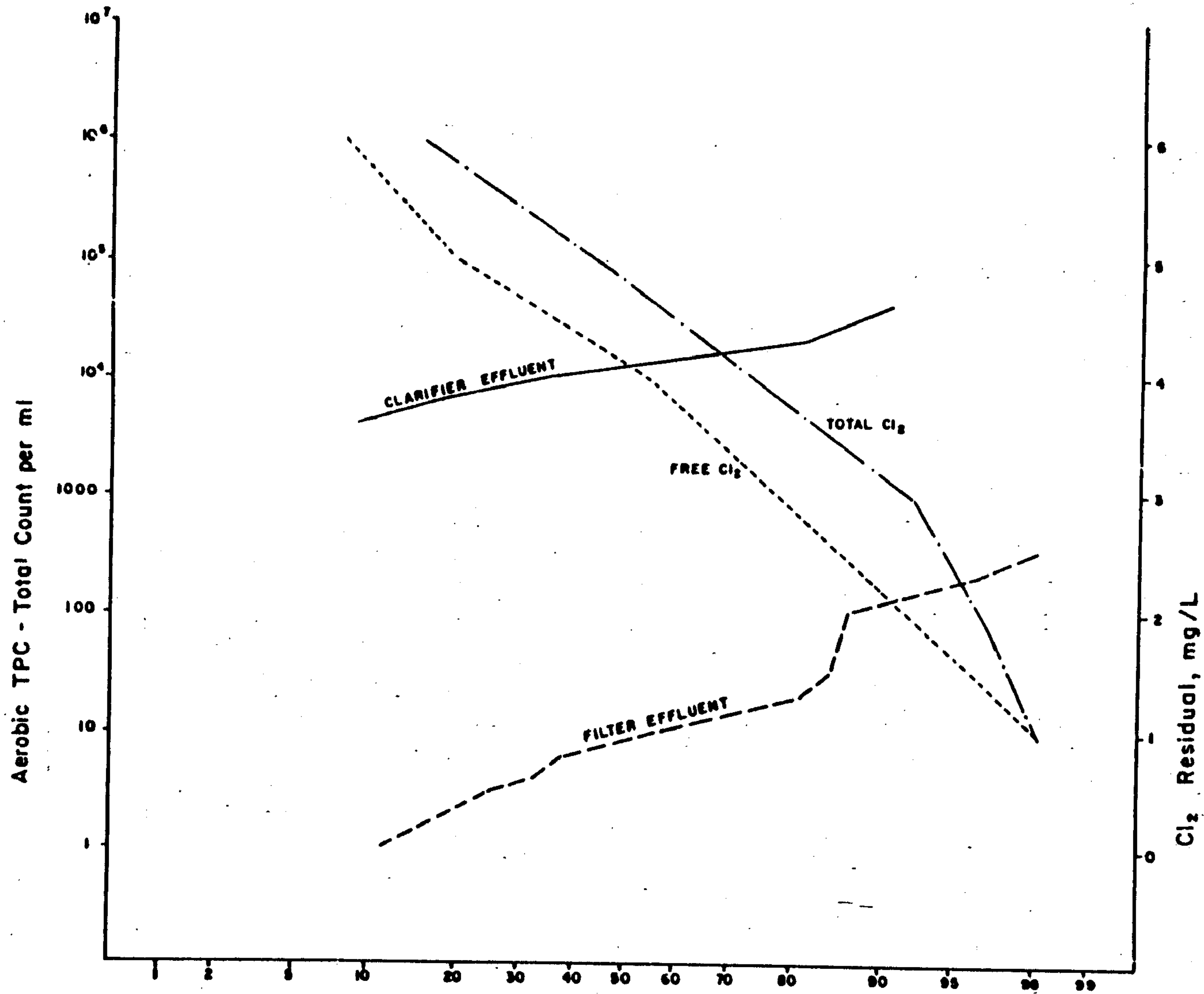

Figure 11. Aerobic total plate count frequency distribution - 1982.

Yeast and Mold--

Frequency graphs for yeast and mold organism concentration in the clarifier, filter, and reclaimed effluent for the 1980 and 1981 seasons are shown on Figures 12, 13, 14 and 15. The 50 and 90 percentile intercepts on these graphs are as follows:

Sample point	Year	Yeast / ml 50 %	Yeast / ml 90 %	Mold / ml 50 %	Mold / ml 90 %
Clarifier effluent	1980	170	>3000	25	70
	1981	340	1000	54	160
Filter effluent	1980	120	470	18	60
	1981	260	520	33	250
Reclaimed effluent	1980	< 1	20	< 1	20
	1981	< 0.5	1	0.4	6

Yeast and mold organisms are of interest in reclaimed wastewater because of the potential for vegetative yeast organisms to invade cans and cause spoilage, especially in high acid foods. Mold organisms may seed equipment cleaned with the reclaimed water and cause growth of mold, which could then contaminate the product coming in contact with the equipment. The filters appear to reduce the organism count by 30 to 50 %. The disinfection system appears to be effective at killing the yeast and mold organisms, although no criteria are available to indicate desirable levels of achievement.

Total Anaerobic Plate Count--

Organisms which grew on BBL Anaerobic Agar (TM of Becton, Dickenson & Co.) under anaerobic conditions were enumerated during the 1981 and 1982 seasons. Figures 16 and 17 show frequency plots of the results for the two years. No standard method exists for this test and the technique for its performance was new to the technicians and to the project manager, so variability in the results was expected. A different technician did the testing in 1982 than in 1981. The percentile intercepts from the frequency plots are:

Anaerobic Total Plate Count / ml

Sample point	Year	50 %	90 %
Clarifier effluent	1981	1,700	9,000
	1982	6,000	300,000
Filter effluent	1981	1,800	18,000
Reclaimed effluent	1981	3	10
	1982	3	50

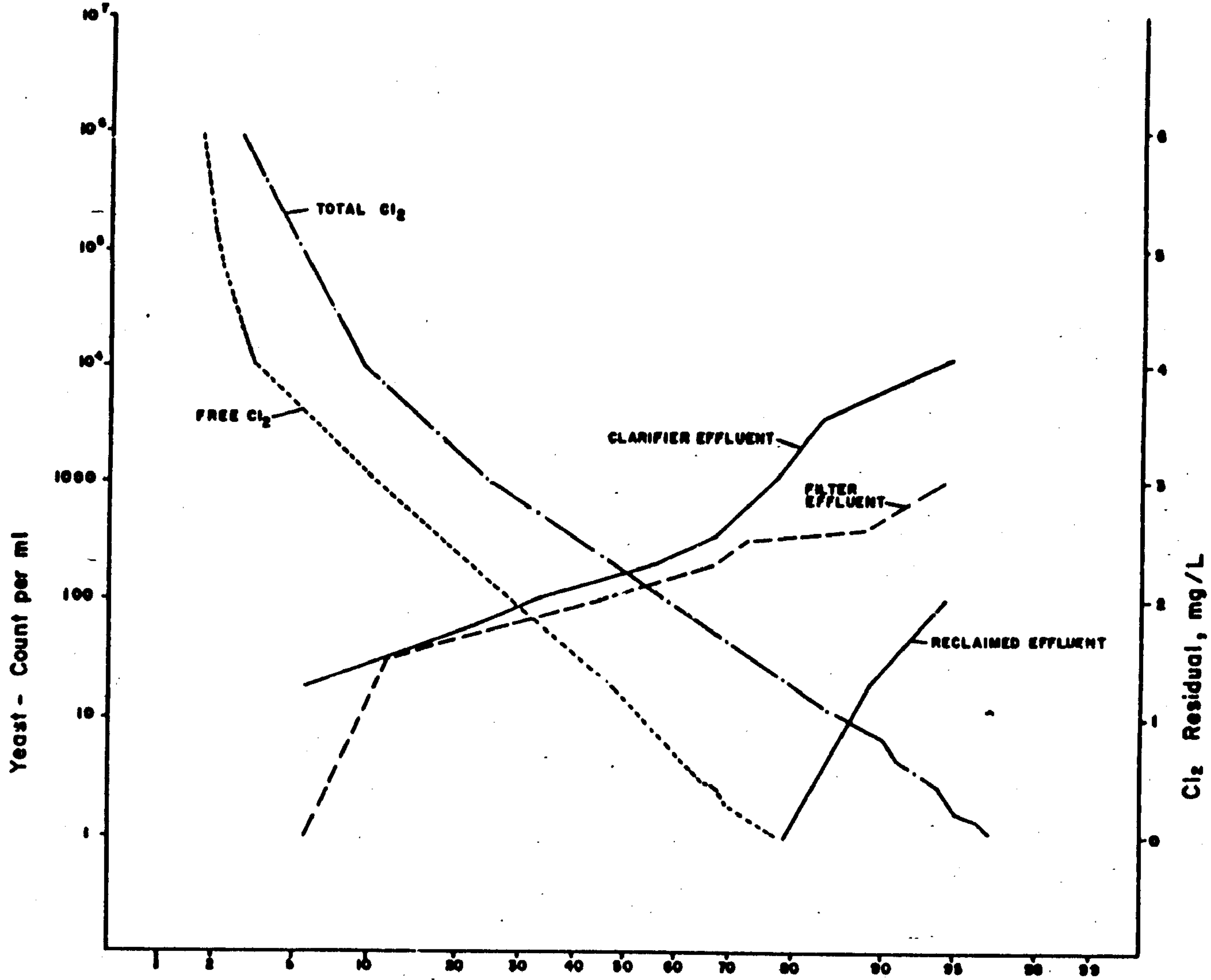

Figure 12. Yeast count frequency distribution - 1980.

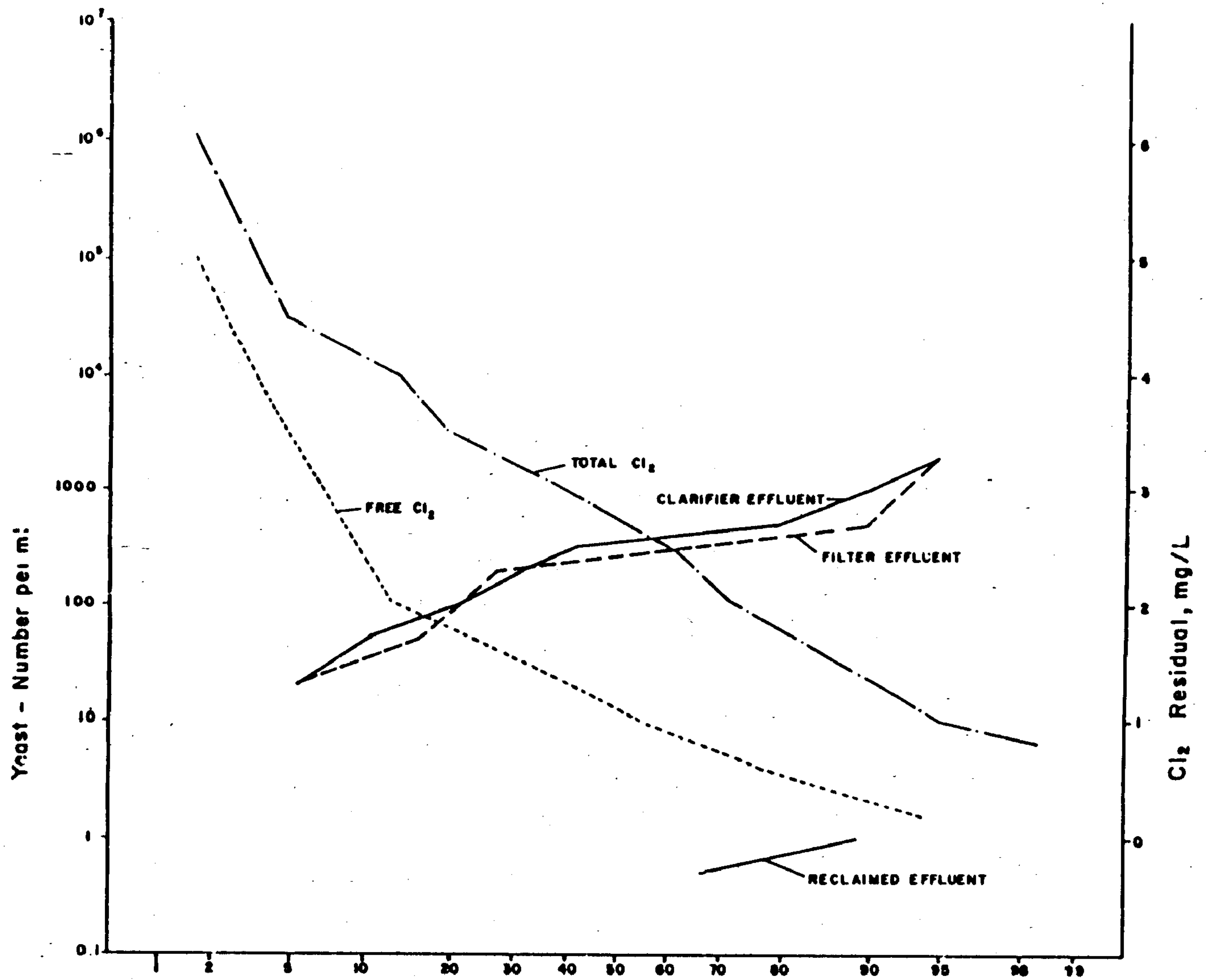

Figure 13. Yeast count frequency distribution - 1981.

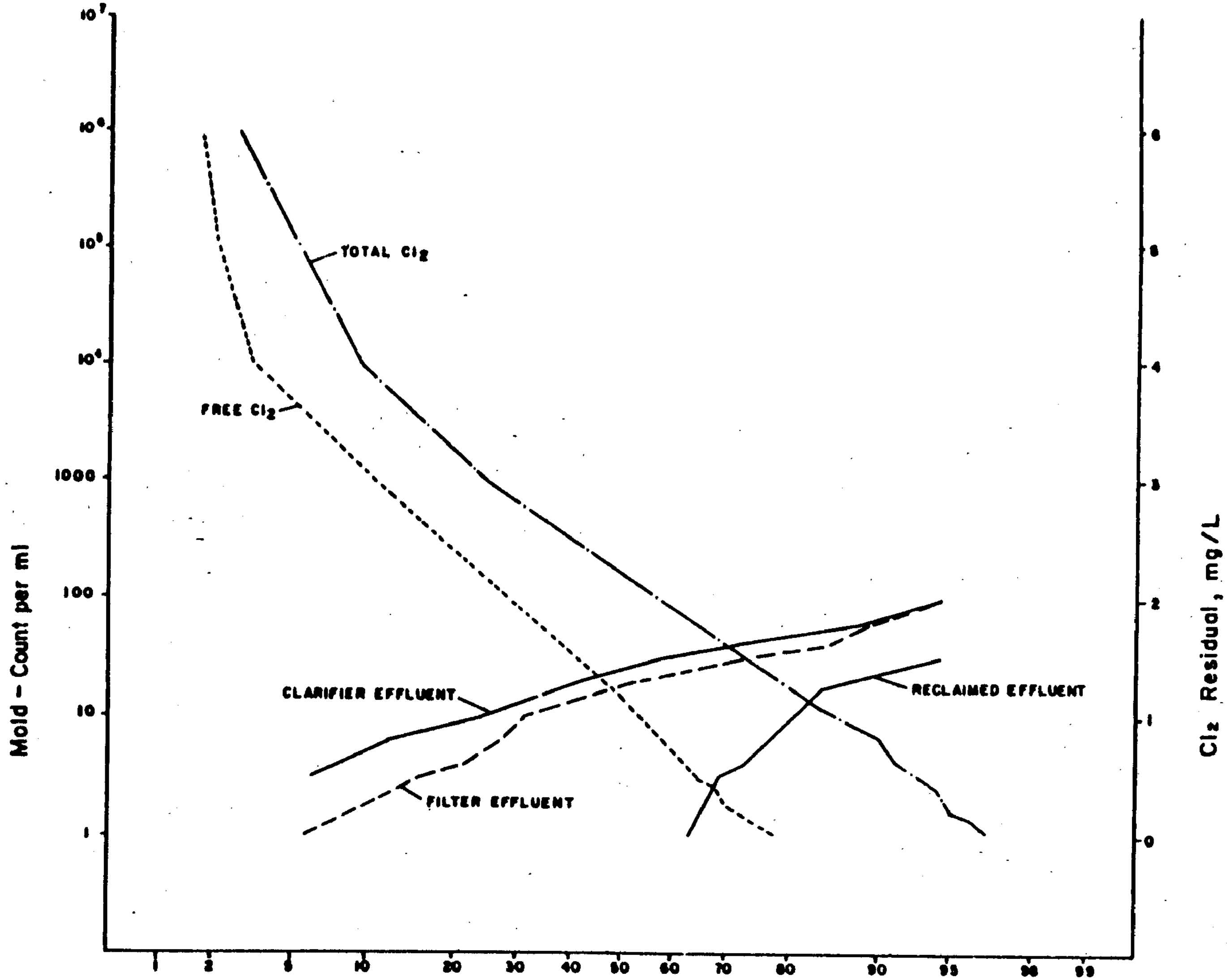

Figure 14. Mold count frequency distribution - 1980.

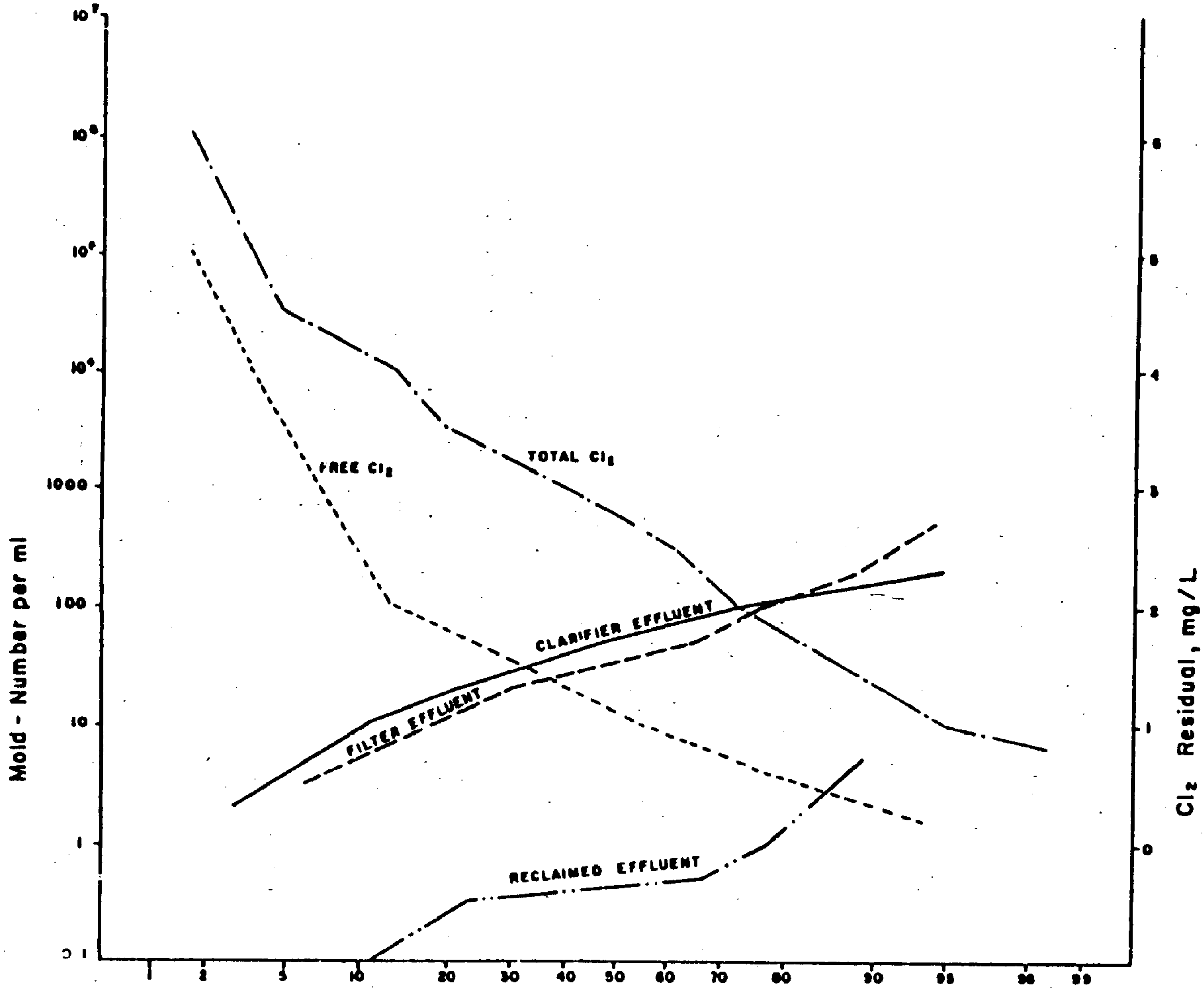

Figure 15. Mold count frequency distribution - 1981.

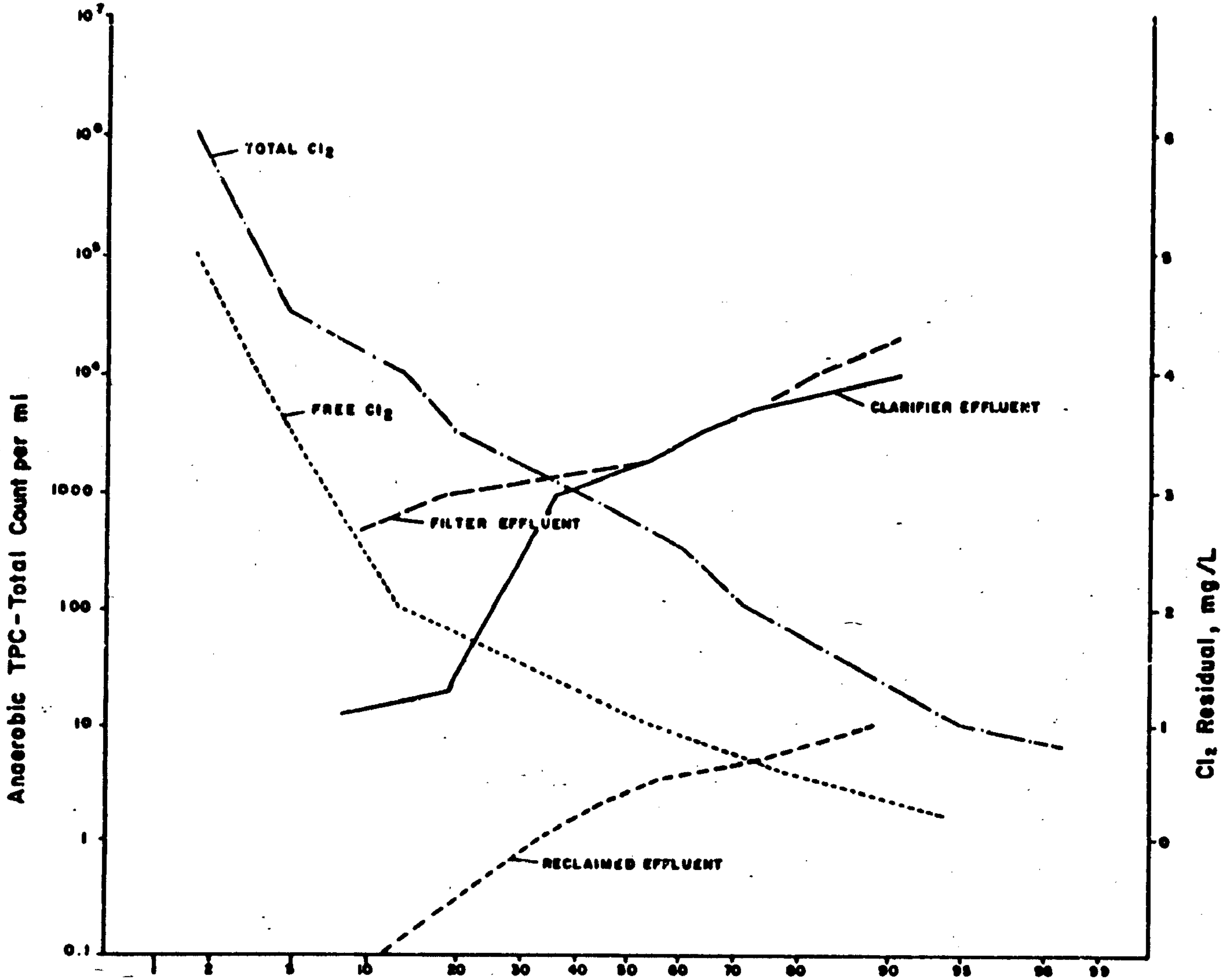

Figure 16. Anaerobic total plate count frequency distribution - 1981.

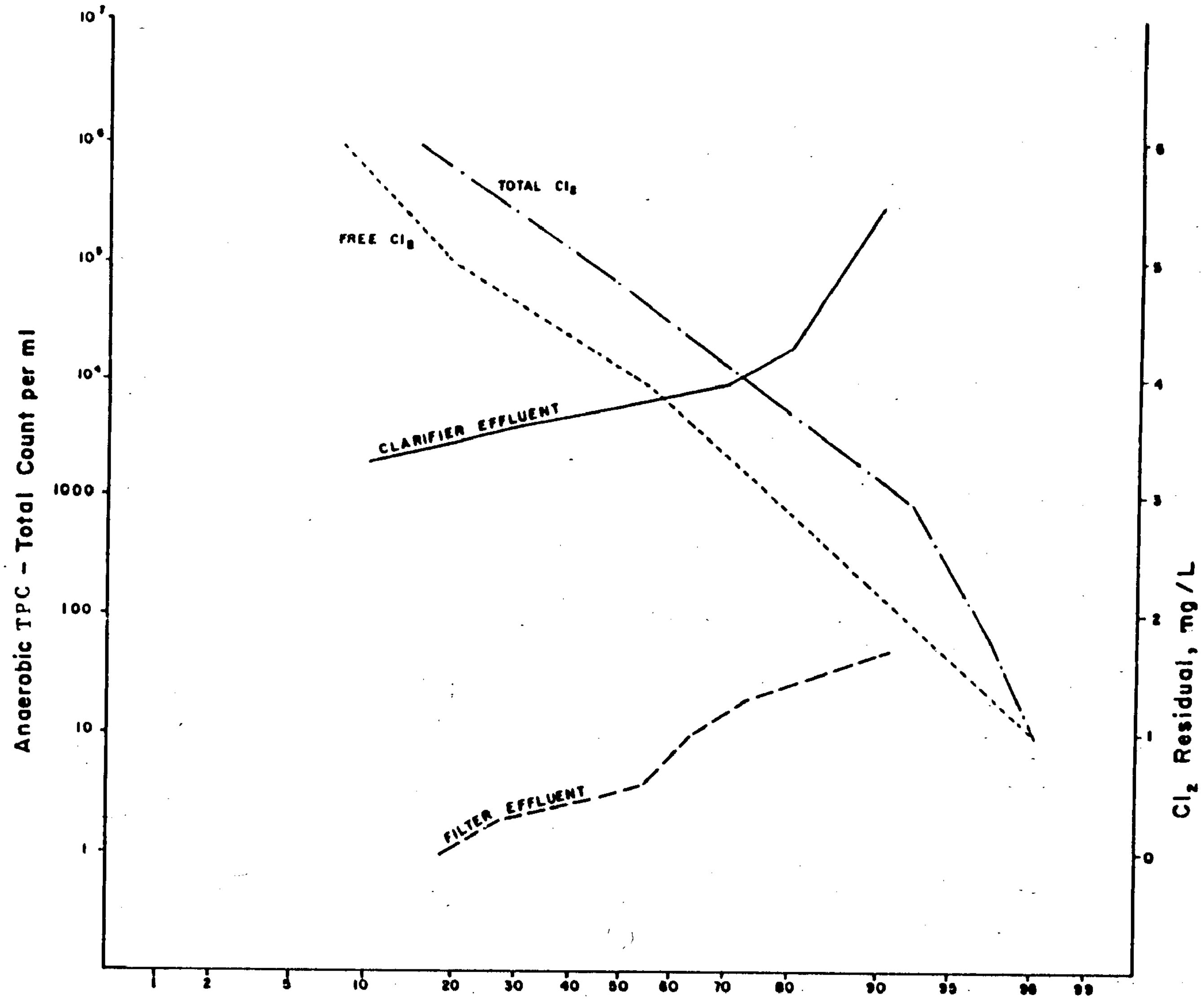

Figure 17. Anaerobic total plate count frequency distribution - 1982.

The results from 1981 indicated that the Anaerobic TPC of the clarifier and filter effluents was one-fifth to one-tenth the values for the aerobic TPC. The 1982 results indicated them to be nearly equivalent however. The effect of disinfection seemed to be about the same as for the aerobic TPC.

There are no criteria for anaerobic TPC. Anaerobes could be significant in cooling water, where these organisms may enter the container, and especially where a low acid environment inside the container would allow the organisms to grow. Some organisms which would grow under an anaerobic environment, can produce toxins inside low-acid food containers.

Spore Forming Organisms--

Tests were run during the 1981 processing season for organisms that formed spores resistant to boiling for 3 minutes. The samples after boiling were tested for both aerobic total plate count (TPC) and for anaerobic TPC with incubation at mesophilic temperatures. Frequency plots of the results are shown on Figures 18 and 19. Percentile intercepts from the plots are as follows expressed as spores/ml:

		Aerobic Spores		Anaerobic Spores	
Sample point	Year	50 %	90 %	50 %	90 %
Clarifier effluent	1981	<0.5	2.5	2.5	300
Filter effluent		<0.5	3	3	20
Reclaimed effluent		0.4	<1	0.1	<10

Due to the low numbers of these organisms, the infrequency of the testing, and inexperience of the technicians it is difficult to draw any significant conclusions from this data. It does appear that the disinfection system causes a reduction in concentrations.

69

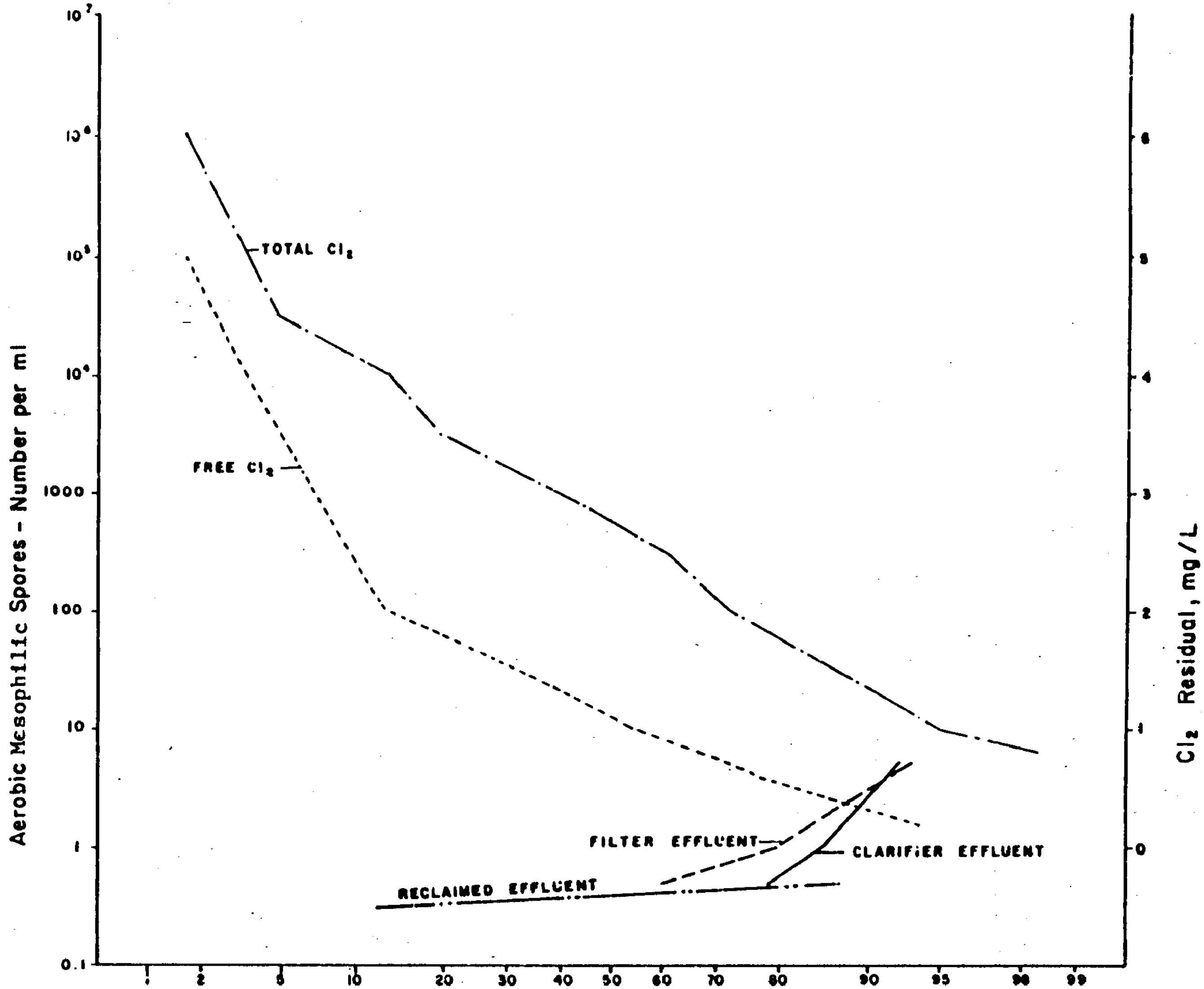

Figure 18. Aerobic spore count frequency distribution - 1981.

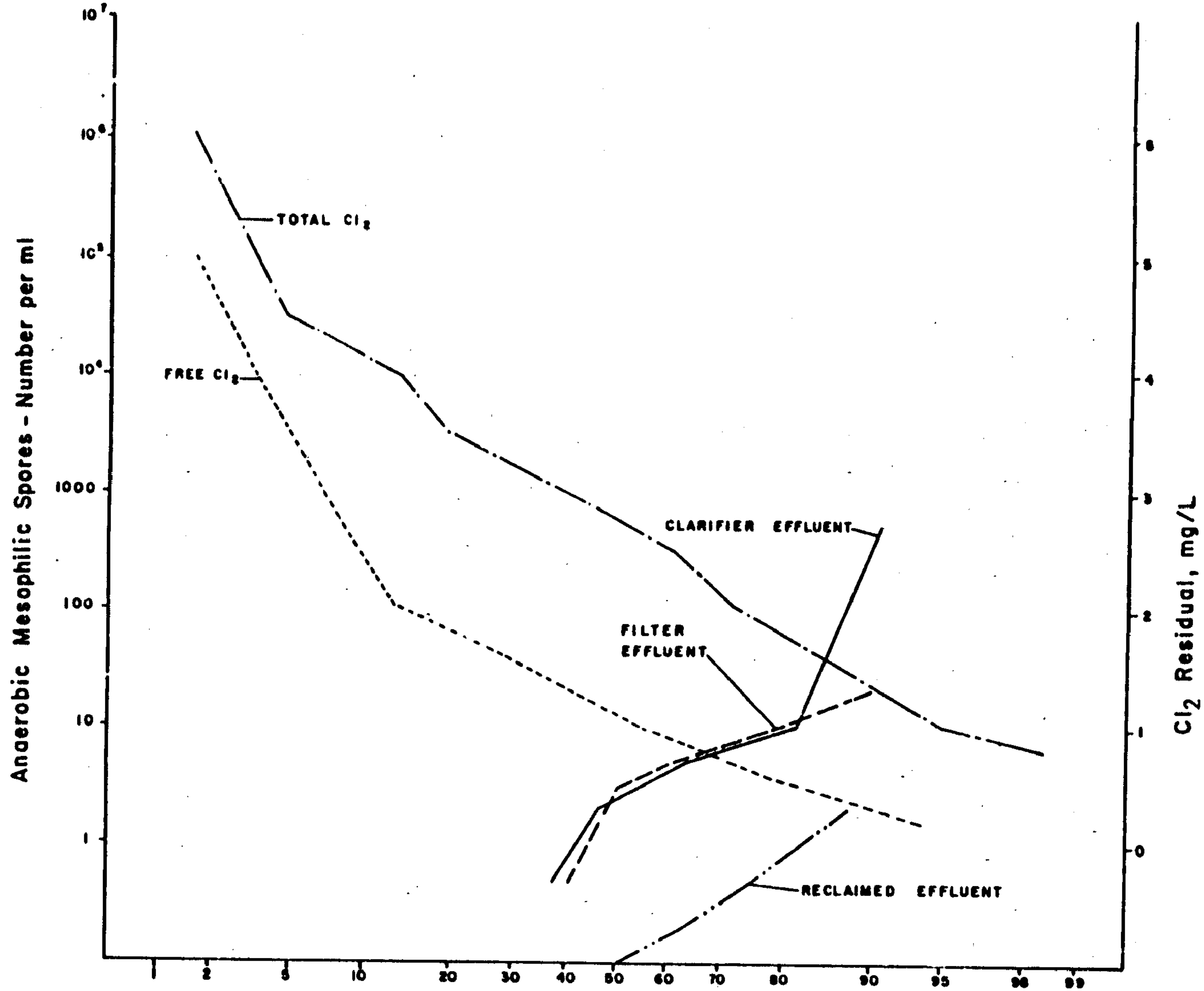

Figure 19. Anaerobic spore count frequency distribution - 1981.

Heavy Metals

Heavy metals analyses were performed on samples from the 1980 and 1981 seasons by the National Food Processors Association Western Research Laboratory, Berkeley, California. Samples were shipped to the laboratory by air after preservation with acid (see Appendix A). A portion of the samples were spiked for quality control (see Appendix B). Table 5 contains a summary of the results on well water samples, cannery effluent (before treatment), and the reclaimed wastewater. Also included is a summary of results from analyses of reclaimed wastewater during the 1975-1976 project for comparison. The primary and secondary EPA drinking water standard maximum contaminant level concentrations are included for reference.

TABLE 5. HEAVY METALS TEST RESULTS

Heavy Metal (MCL1)	Sample Point	Number Samples	Concentration, mg/l Median	Concentration, mg/l Maximum
Arsenic (.05)	Well water	3	.006	.009
	Cannery effluent	3	.007	.008
	Reclaimed water	7	.008	.014
	75-76 Reclaimed2	7		<.05
Barium (1.0)	Well water	7	<.5	<.5
	Cannery effluent	7	<.5	<.5
	Reclaimed water	19	<.5	<.5
Cadmium (.01)	Well water	7	<.005	.01
	Cannery effluent	8	<.005	<.005
	Reclaimed water	19	<.005	.01
	75-76 Reclaimed	9	<.03	<.03
Chromium (.05)	Well water	6	.01	.04
	Cannery effluent	7	<.01	.03
	Reclaimed water	18	.01	.073
Lead (.05)	Well water	7	.004	.01
	Cannery effluent	8	.005	.03
	Reclaimed water	19	<.004	.01
	75-76 Reclaimed	9	<.05	<.05
Mercury (.002)	Well water	7	.0006	.0008
	Cannery effluent	8	.0007	.0008
	Reclaimed water	19	.0006	.0008
	75-76 Reclaimed	9	.0003	.00264

(Continued)

TABLE 5. (Continued)

Metal (MCL)	Sample Point	Number Samples	Concentration,mg/l Median	Maximum
Aluminum	Well water	7	<.2	.2
	Cannery effluent	8	.3	.9
	Reclaimed water	19	.1	.8
	75-76 Reclaimed	6	.8	2.2
Copper (1.0)[5]	Well water	7	<.007	.04
	Cannery effluent	8	.04	.06
	Reclaimed water	19	.01	.03
	75-76 Reclaimed	9	<.05	<.05
Iron (0.3)[5]	Well water	7	.11	1.98
	Cannery effluent	8	1.57	2.15
	Reclaimed water	19	.15	.41
	75-76 Reclaimed	9	<.15	.2
Manganese (0.05)[5]	Well water	7	<.01	.02
	Cannery effluent	8	.02	.03
	Reclaimed water	19	<.01	.02
	75-76 Reclaimed	9	<.05	<.05
Tin	Well water	7	<.3	<.3
	Cannery effluent	8	<.3	.3
	Reclaimed water	19	<.3	<.3
	75-76 Reclaimed	6	<3	<3
Zinc (5.0)[5]	Well water	7	.03	.05
	Cannery effluent	8	.13	.24
	Reclaimed water	18	.05	.37
	75-76 Reclaimed	9	.25	.63

Notes:

1. MCL in mg/l is EPA maximum contaminant level[10].
2. 75-76 is results from 1975-1976 study[1].
3. Second highest sample result was .03 mg/l.
4. Second highest sample in 75-76 was .0009 mg/l.
5. MCLs for copper, iron, manganese and zinc are "Secondary" MCLs which are for esthetic control of water quality and not for health protection.

Only one value for any of the heavy metals exceeded the primary drinking water standard values. The second highest chromium value recorded was well within the standards indicating that the high value was transient in nature or a product of sampling or analytical mishap.

Pesticide Results

Samples of the well water, cannery effluent, biological treatment effluent (clarifier effluent), and the reclaimed wastewater were sampled into brown glass bottles and shipped on ice to Battelle Pacific Northwest Laboratories, Richland, Washington for pesticide analysis. Four samples of the well water, five samples of each the cannery and clarifier effluents and seven samples of the reclaimed wastewater were tested during the 1980-81 processing season. Four well water and clarifier effluent samples, five cannery effluent and 12 reclaimed wastewater samples were tested during the 1981-82 season. Table 6 contains a list of the pesticides which were included in the analyses.

TABLE 6. PESTICIDES ANALYZED BY BATTELLE NORTHWEST LABORATORIES

Chlorinated Hydrocarbons	Organophosphorus, Organosulfur, and Organonitrogen compounds
Aldrin	Smiazine (Princep®)
a, b and g BHC	Guthion®
Captan	Imidan®
Casuron® (Dichlobenil)	Parathion
Chlordane	Ethion
2,4-D	Malathion
DDD, DDE and DDT	Phosphamidan
Diazinon	De-Fend®
Dichlone	Omite®
Dieldrin	Ziram
Endosulfan I	Elgetol® (4,6-Dinitro-o-cresol)
Endosulfan Sulfate	Rootone®
Endrin	Amid Thin W® (Amid)
Heptachlor	Ethephon
Heptachlor Epoxide	Plictran® (Cyhexatin)
Kelthane	Systox®
Methoxychlor	Sinbar® (Terbacil)
PCB 1016, 1254, and 1260	SOPP (sodium o-phenylphenol)
Perthane	Nabam (Dithane®)
Pydrin®	Zineb (Dithane®)
Silvex	Maneb (Dithane®)
Toxaphene	Karathane® (Dinocap)
Aniline-d_5	Morestan® (Mesurol®)
Nitrobenzene-d_5	BAAM®
2-fluorophenol	

Analysis of all of the samples was by gas chromatography/mass spectrometry by EPA Method 625 with internal standards following extraction. Battelle reported that none of the target pesticides or herbicides were detected in any of the water samples. Detection limits varied, but were appropriate to the MCL's for pesticides with drinking water limitations, and were normally 10 ug/l or less for all others. Earlier analyses, without the mass spectrometry, gave false positive indications that some of the compounds were present. Complete results of these analyses were contained in Annual Data Reports No. 1 and No. 2 for this project.

Volatile Halogenated Organic Compounds

During the 1981 processing season, Battelle Northwest Laboratories analyzed 15 samples for volatile organic compounds in addition to the pesticides and herbicides. Twelve were of the reclaimed wastewater and one each from the well water, cannery effluent and clarifier effluent. The samples were analyzed by EPA method 624 (see appendix A) for "Purgeables". Table 7 contains a list of the purgeable organic compounds and detection limits for the analyses.

TABLE 7. DETECTION LIMITS FOR PURGEABLE ORGANIC COMPOUNDS

Compound	Detectable Limits, ug/l
Bromoform	14
Bromodichloromethane	10
Carbon tetrachloride	11
Chlorobenzene	1
Chloroform	8
Dibromochloromethane	8
Dibromomethane (methylene bromide)	8
trans - 1,2-dichloroethane	5
1,2-dichloropropane	2
1,1,1-trichloroethane	8
1,1,2-trichloroethane	26
Trichloroethene	15
Tetrachloroethene	10

The only volatile halogenated organic compounds found during the initial analyses were chloroform and dibromomethane. After an extensive search for the source of the dibromomethane and no result, it was decided to reanalyze the samples (fortunately duplicates had been collected along with most of the original samples and kept refrigerated in sealed containers). The reanalysis determined that dibromomethane was not present in the duplicate samples, and therefore its earlier presence was concluded to be laboratory contamination.

The only confirmed halogenated organic compound in the reclaimed effluent was chloroform. The chloroform findings are shown on Table 8. The drinking water MCL for total trihalomethanes, including chloroform, is 100 ug/110.

TABLE 8. CHLOROFORM RESULTS

Sample Point	Date	Chloroform, ug/l
Reclaimed effluent	09/09/81	94
	09/15/81	62
	09/22/81	127
	09/29/81	37
	10/14/81	29
	10/22/81	107
Well water	11/03/81	2
Cannery Effluent		3
Clarifier effluent		<1
Reclaimed effluent		7
	11/10/81	21
	12/01/81	13
	12/08/81	43
	01/07/82	62
	01/19/82	19

Many literature sources have indicated that chloroform is generated as a byproduct of water chlorination, due to reaction of chlorine and organic materials in the water. Chloroform concentration in the reclaimed wastewater is plotted on Figure 20, against free chlorine residual on the day that the samples were collected for halogenated organics analysis. From this figure it appears that the amount of chloroform in the reclaimed water is correlated to the free chlorine residual, although the limited amount of data precluded elimination of other potential constituents to which it could have been correlated (i.e., COD, TSS, turbidity). Since chlorination is essential for attaining the low levels of microorganisms necessary to make the reclaimed wastewater safe for critical uses, it appears that chloroform is a necessary undesirable companion. Since it is unlikely that reclaimed water will be used for actual filling of containers or be intentionally incorporated into the processed food the presence of chloroform at these low concentrations would not appear to be detrimental. The quantity that could be expected to enter the processed product would be practically nil.

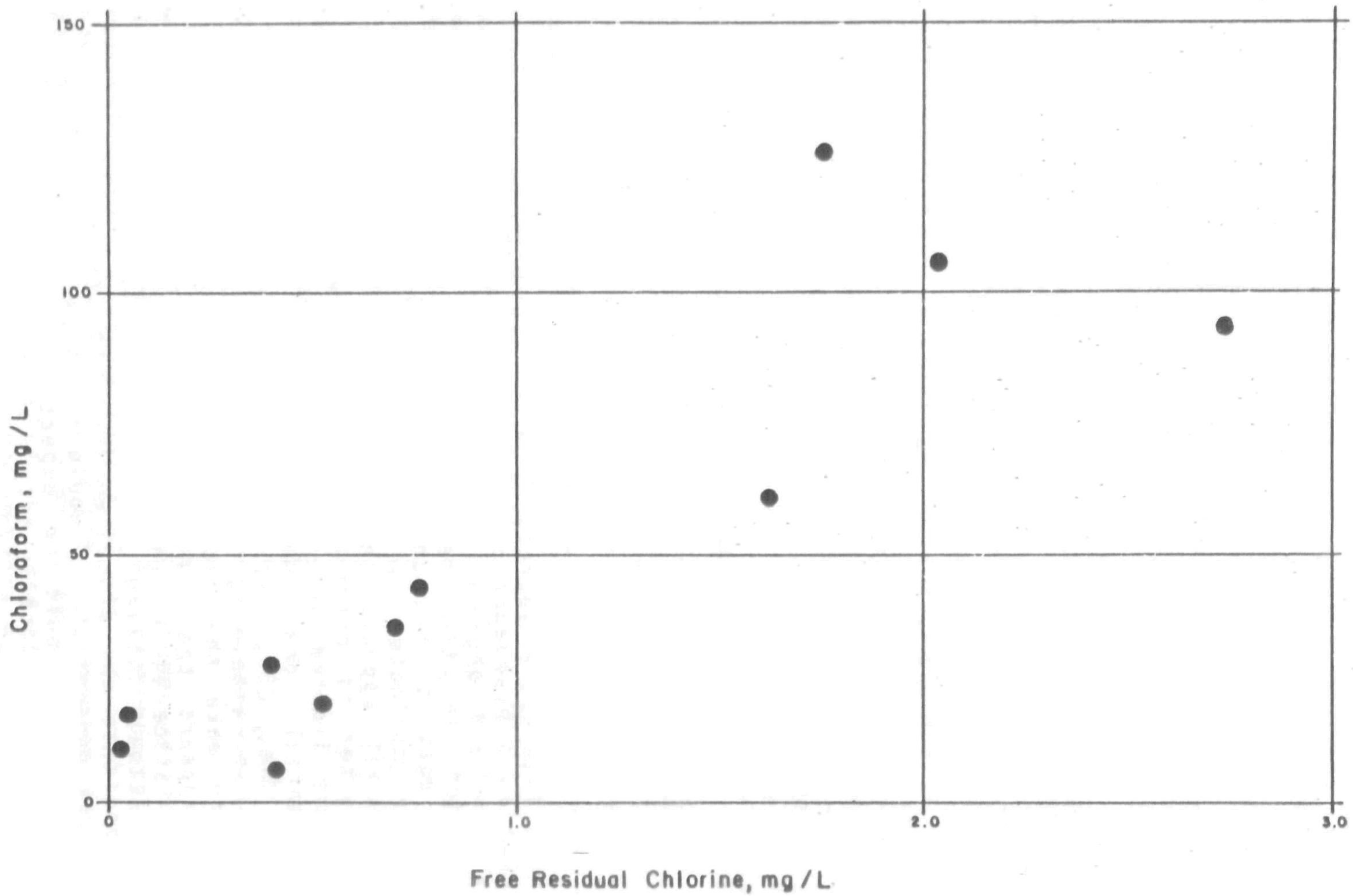

Figure 20. Chloroform in reclaimed wastewater vs. free chlorine residual.

WASTEWATER REUSE IN COOLERS

During the three processing seasons of this project reclaimed wastewater was used in can coolers on a demonstration scale basis. Following is a summary of estimated quantity of product cooled in reclaimed wastewater during the three processing seasons encompassed in this project:

Product	Process Season	Total cases cooled in Reclaimed Water	Portion of total pack
Canned Pears	1980	180,000	18 %
Apple products		210,000	35 %
Canned Pears	1981	510,000	46 %
Apple products		180,000	28 %
Canned Pears	1982	800,000	78 %

Note: One case represents 24 cans, 2 1/2 size.

During all three of the seasons, the USDA in-plant inspectors and the project manager monitored the use of the reclaimed wastewater and observed the product quality on a routine basis, per their regular schedule and duties. The USDA inspectors "were asked to report any abnormality in regard to product quality which might have resulted from the use of recycled cooling water." "The inspectors reported that they observed no significant changes in product quality as a result of the use of recycled water." (Letter dated January 23, 1984, from Mr. R.D. Kearl, Inspector-in-Charge, USDA, Agricultural Marketing Service, Yakima, WA.)

In one instance when a substantial number of cans of applesauce were subjected to reclaimed water of substandard quality (high tubidity and suspended solids), the entire lot of product was retained an extra 30 days under close scrutiny to assure that no deterioration of product had occurred before it was released for distribution.

Container Rejection Rates Using Reclaimed and House Water

In order to estimate the comparative can rejection rate due to failures after cooling in reclaimed water vs. well water, comparable coolers were operated in parallel on pear processing lines during the 1981 and 1982 processing seasons. The cans were coded for future identification.

1981 Processing Season -

All cans coming from those coolers that were rejected for any reason, during labeling of the 1981 product, were closely examined. Cans without physical damage (dents, punctures, etc.) were subjected to teardown (opened) for inspection of the contents and can interior. Of the total number of cans rejected during labeling, 3,728 cans were without physical damage. None of these cans showed any evidence of microbiological contamination (gas swells, leakage due to internal pressure, fruit spoilage). All cans had been held in storage for from 2 months to one year prior to labeling, at which time the rejects were pulled out.

There was no apparent difference between the failure rate among cans cooled using reclaimed water compared to those cooled with the well water supply. The total pack of this size container during that season was 214,000 cases (24 cans per case), of which about half were cooled in each of the two waters.

All of the 1981 season undamaged rejects were a result of inadequate lid depression, an evidence of low vacuum. Some of the low vacuum cans (less than 5 %) were due to subtle damage to the seal surface (skip seam). The entire remainder, had an indeterminant cause but nearly all showed signs of container corrosion, either as head space pitting, or as body pitting.

A representative number of cans were sent to the National Food Processors Association laboratory in Berkeley, California for inspection and determination of the cause of low vacuum. The laboratory responded that the lack of vacuum resulted from "the formation of hydrogen gas as a result of product-container interaction. Examination of the steel, after removal of tincoating, showed the presence of moderate amounts of pitting primarily at the body beads. The occurrence of pitting is strongly suggestive that the phenomenon known as rapid canned pear corrosion is operative in these containers." (Letter dated December 14, 1982, from Mr. Henry B. Chin, Ph.D., Director, Chemistry Division, National Food Processors Association, Berkeley, CA.)

Discussion with representatives of NFPA indicated that several canneries had experienced product loss due to container internal corrosion, and that the industry is attempting to determine the reason for this problem. It is abundantly clear, however, that the failures experienced in this study were not related to the use of reclaimed wastewater.

1982 Processing Season -

During the 1982 season a similar number of total 2 1/2 cans were cooled in the parallel cooling lines, using reclaimed water for approximately one-half and house (well) water for the other half. Observation by the USDA inspectors, the project manager, and by the cannery managers in charge of labeling and distribution, indicated there were no abnormal numbers of rejects, and that there was no apparent difference between lots cooled in the two waters.

Cooler Water Quality

Water quality in the can coolers was monitored during the 1980-81 and 1981-82 processing seasons in order to compare the microbiological quality of those using reclaimed wastewater to those using the cannery house water (well water). The frequency distribution of total aerobic bacterial plate counts of samples taken from the coolers is shown on Figures 21 and 22 for the 1980 and 1981 seasons. Total chlorine residual for the coolers is shown on Figures 23 and 24.

There doesn't appear to be any significant difference in cooling water bacterial counts during the two seasons, between the coolers receiving reclaimed water and those receiving well water. The coolers receiving reclaimed water generally had a slightly higher chlorine residual as a result of the chlorine residual in the reclaimed water feed. Chlorine solution was added to all coolers by a manually adjusted feed system from a separate chlorinator. Based on the bacteriological quality of water in the coolers, spoilage rates of containers cooled by waters from the two sources would not be expected to differ.

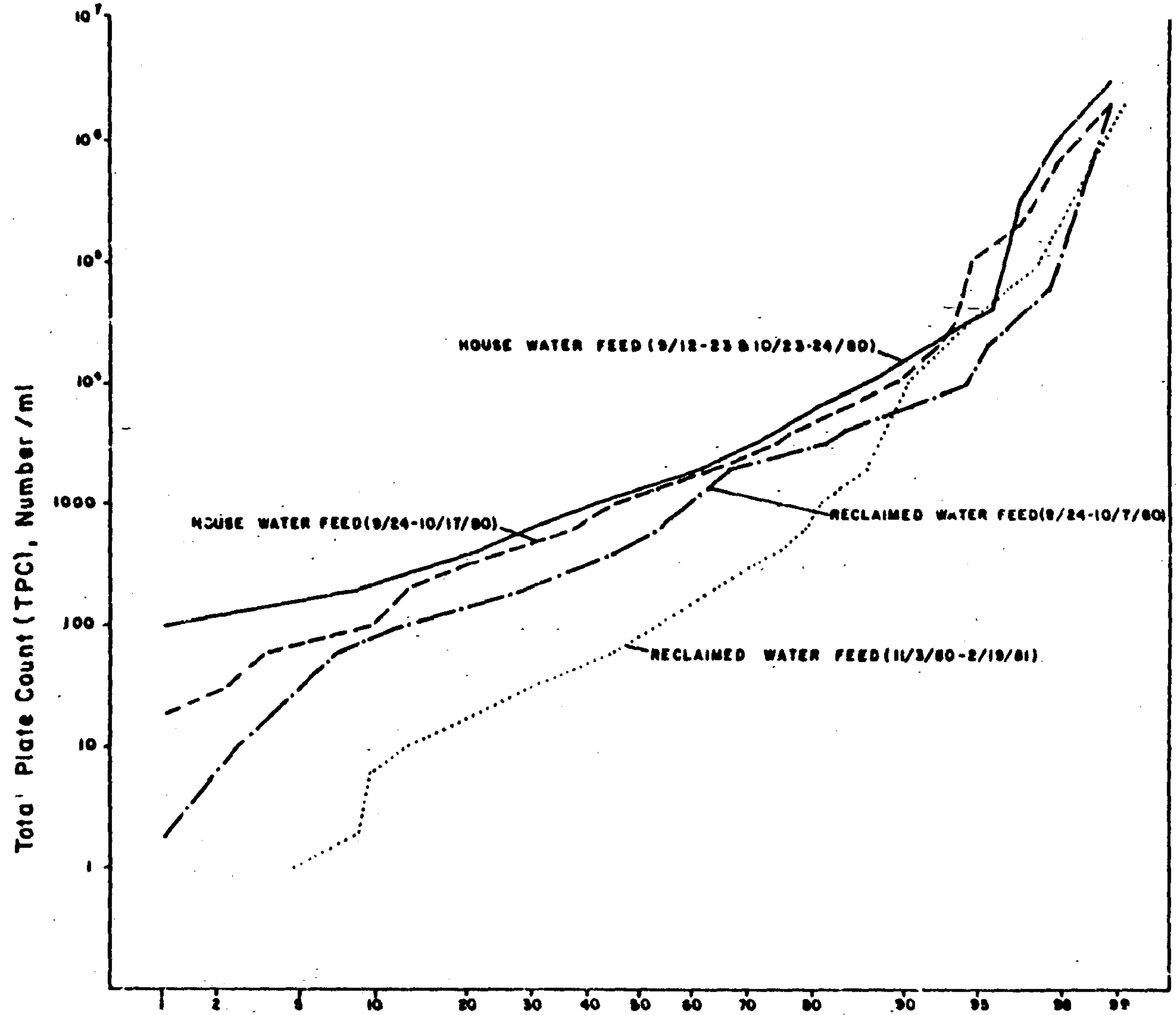

Figure 21. Can cooler aerobic total plate count frequency - 1980.

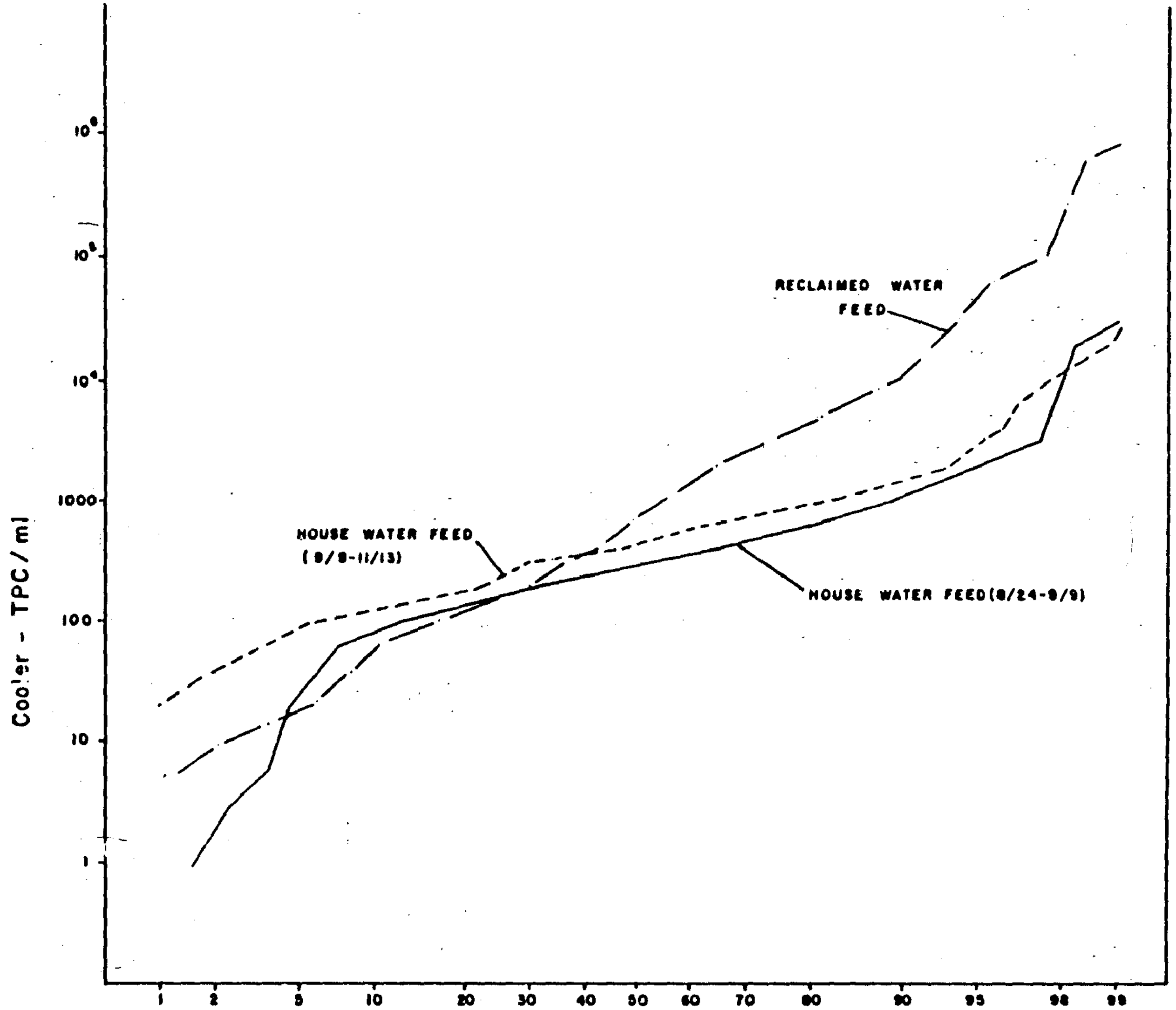

Figure 22. Can cooler aerobic total plate count frequency - 1981.

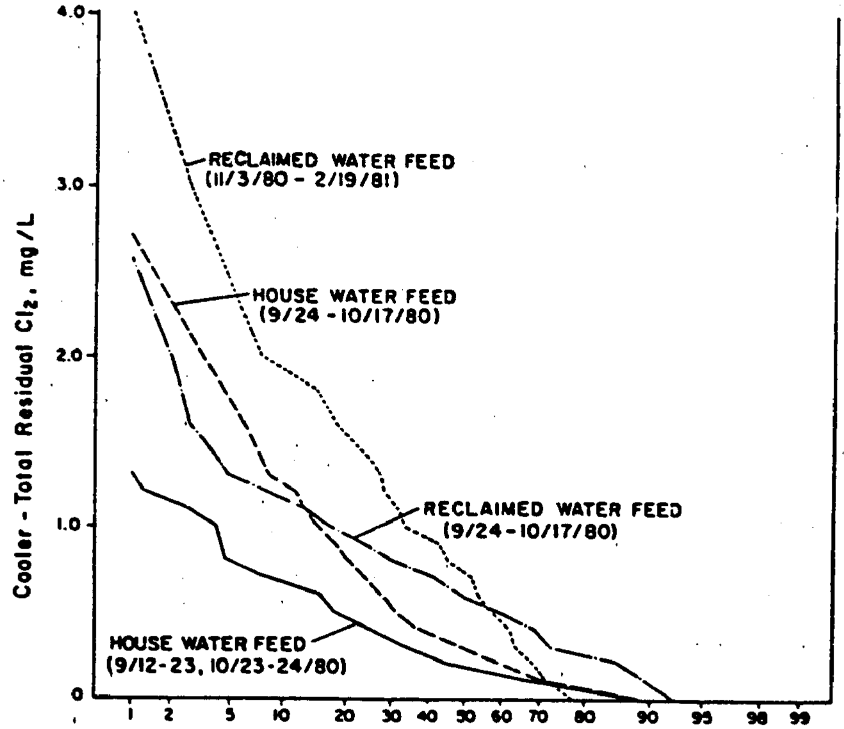

Figure 23. Can cooler chlorine residual frequency - 1980.

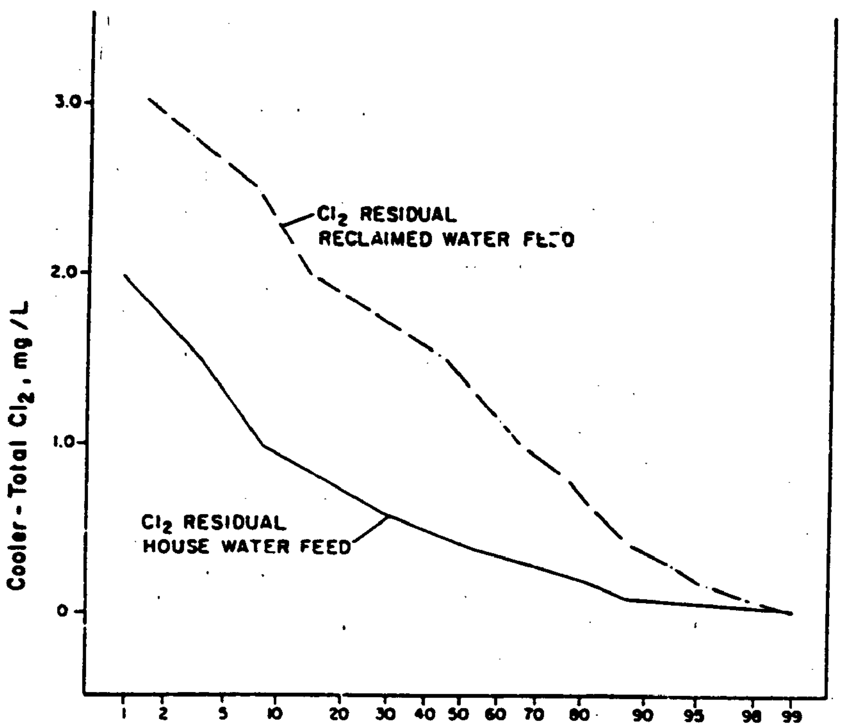

Figure 24. Can cooler chlorine residual frequency - 1981.

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3. Esvelt, L.A., "Aerobic Treatment of Liquid Fruit Processing Waste," Proceedings First National Symposium on Food Processing Wastes, Federal Water Quality Administration, April, 1970.

4. Esvelt, L.A. and H.H. Hart, "Treatment of Fruit Processing Wastes by Aeration," Journal Water Pollution Control Federation, 42, 1305, July, 1970.

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8. Esvelt, Larry A., "Food Processing Water Reuse - Case History", Proceedings, Industrial Water Reuse Conference, Oct. 31 and Nov. 1, 1978, Culver City, California (California Office of Water Recycling).

9. Thompson, H.W. and L.A. Esvelt, "Reclamation and Reuse of Fruit Processing Wastewater", Paper presented at the 1978 Summer Meeting of the American Society of Agricultural Engineers, Logan, Utah.

10. "National Interim Primary Drinking Water Regulations", Federal Register, Vol. 40, No. 248, page 59566, December 24, 1975.

SEE ALSO (Available for review from EPA HERL, Cincinnati, Ohio)

Annual Data Report No. 1, The Health Effect Potential of Reusing Treated Fruit Processing Wastewater Within A Cannery. Snokist Growers Cannery, July 27, 1981.

Annual Data Report No. 2, The Health Effect Potential of Reusing Treated Fruit Processing Wastewater Within A Cannery. Snokist Growers Cannery, February 28, 1983.

APPENDIX A

ANALYTICAL METHODS

This appendix contains a summary of the procedures used during this investigation for collecting, preserving and analyzing samples. The sample handling and analytical methods are summarized in Table A-1 for chemical tests run at the Snokist Growers cannery laboratory, tests run by National Food Processors Western Research Laboratory, Berkeley, California and for continuous monitoring of the reclaimed wastewater. Table A-2 summarizes the procedures for analyzing samples for pesticides and volatile halogenated organics used by Battelle Pacific Northwest Laboratories, Richland, Washington and procedures used by the USDA Western Regional Laboratory, Albany, California for volatile and nonvolatile halogenated organic compounds.

Sampling for all testing was done by the Snokist laboratory staff. All sampling was representative of the water being tested and according to best practices. Composite samples were normally the result of six or more grab samples from the sample point, taken over an 8 hour period per day, combined in equal volumes, except that an automatic sampler was used to take a 24 hour time composite on the wastewater entering the treatment system.

TABLE A-1. SAMPLE HANDLING AND ANALYTICAL METHODS

Parameter	Preservation Holding time	Analytical Procedure
Alkalinity (Total) as $CaCO_3$	Cool - 4°C 24 hr.	Standard Methods[1] p 278 Titrate to pH 4.5
Biochemical Oxygen Demand (BOD)	Cool - 4°C 24 hr	Standard Methods[1] p 543 Acclim. seed, Winkler
Chemical Oxygen Demand (COD)	Cool - 4°C 24 hr.	Standard Methods[1] p 550 Dichromate Reflux
Chlorine Residual (free & total) (continuous)	none none	Standard Methods[1] p 318 Amperometric titration Amperometric potential
Chloride	Cool - 4°C 7 day	Standard Methods[1] p 304 Mercuric Nitrate
Dissolved Oxygen	none	Probe
Hardness (total & calcium) as $CaCO_3$	Cool - 4°C 7 day	Standard Methods[1] p 202 & p 189; EDTA titration
Hydrogen ion (pH)	none	Standard Methods[1] p 460 Electrometric probe
Methylene blue active substances (detergents)	Cool - 4°C 24 hr	Standard Methods[1] p 600 Extraction, color
Metals[3] (aluminum, arsenic, barium, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, potassium, sodium, tin, zinc).	25 ml conc. HNO_3 per liter 6 months	1974 EPA Methods[2] p 92, 95, 97, 101, 103, 105, 108, 110, 112, 114, 116, 118, 143, 147, 150[4], 155

Continued

TABLE A-1. (Continued)

Parameter	Preservation Holding time	Analytical Procedure
Nitrogen, ammonia	Cool - 4°C	Standard Methods[1] p 410
organic	24 hr	Distillation, p 437 Kjeldahl minus ammonia
nitrate		p 427, Brucine
Phosphorus, ortho	Cool - 4°C 24 hr	EPA Methods[2] p 249 Single Reagent method
total		Alkaline ashing and EPA Methods[2] p 249
Reactive Silicate (silica)	Cool - 4°C 24 hr	Manual of Sea Water Analysis[5] p 67, color
Settleable Solids	none	Standard Methods[1] p 95
Suspended Solids (total & volatile)	Cool - 4°C 24 hr	Standard Methods[1] p 94 & p 96, glass fiter filtration, dry @ 105°C ignition @ 550°C
Solids (total, volatile & dissolved)	Cool - 4°C 24 hr	Standard Methods[1] p 91, 95 & 93, dry @ 105°C ignition @ 550°C
Sulfate	Cool - 4°C	Standard Methods[1] Turbidimetric
Turbidity (grab samples) (continuous)	none	Standard Methods[1] p 132 Forward scatter Nephelometric
Temperature	none	Standard Methods[1] p 125 Glass thermometer
Microbiological	Cool - 4°C 24 hr	
Coliforms (total) (fecal)		Standard Methods[1] p 928 p 937, membrane filter
Total aerobic		Standard Methods[1] p 908, Std. plate count

Continued

TABLE A-1. (Continued)

Parameter	Preservation Holding time	Analytical Procedure
Microbiological (continued)		
Total anaerobic		Standard plate count, or membrane filter on BBL Anaerobic Agar[7], Incubated in anaerobic Environmental Paks[8].
Spores		Boil for 3 minutes:
aerobic		see total aerobic above
anaerobic		see total anaerobic
Mold (viable)		Recommended Methods[6] p 101, acidified potato dextrose agar
Yeast (viable)		Recommended Methods[6] p 101, acidified potato dextrose agar

Notes:

1. APHA, 1975. Standard Methods for the Examination of Water and Wastewater. 14th ed. Washington, D.C.
2. USEPA, 1974. Methods for Chemical Analysis of Water and Wastes. EPA-625/5-74-003.
3. Metals analyses were performed by National Food Processors Association laboratory at Berkeley, California.
4. Tin analysis preparation used a mixture of H_2SO_4 and HNO_3 to enhance recovery.
5. FRBC, 1965. A Manual of Sea Water Analysis. Bulletin No. 125, 2nd ed., Ottawa.
6. APHA, 1966. Recommended Methods for the Microbiological Examination of Foods. 2nd ed. New York.
7. Trade Mark of Becton, Dickinson & Co.
8. Trade Mark of Marion Scientific Corp.

TABLE A-2. HALOGENATED ORGANICS ANALYSES

Parameter	Preservation Holding time	Analytical Procedure
Pesticides & other extractable organic compounds[2]	Cool - 4°C Glass bottles with Teflon caps.	EPA Method 625[1] Extraction and GC/MS
Volatile halogenated organics[3]	Cool - 4°C Glass bottles, Teflon caps, no air space.	EPA Method 624[1] Purge and trap, GC/MS
Volatile & nonvolatile halogenated organics[4]	Glass bottles, Teflon caps, freeze and hold @ -34°C	EPA Method[1] Extraction, GC/FID &/or GC/EC with GC/MS for identification

Notes:

1. Federal Register, Vol. 44, No. 233, December 3, 1979, p. 69464.

2. Pesticide analyses were performed by Battelle Pacific Northwest Laboratories, Richland, Washington.

3. Volatile halogenated organic compound analyses were performed by Battelle Pacific Northwest Laboratories, Richland, Washington for the 1981 season only.

4. Samples for volatile and nonvolatile halogenated organic compound analyses were collected during the 1980 and 1981 processing seasons for analysis by the USDA Agriculture Research Service Western Regional Laboratory, Albany, California. Unfortunately results and unfinished samples were destroyed by a fire at that facility.

APPENDIX B

ANALYTICAL QUALITY CONTROL

Throughout this project laboratory procedures were monitored by the project manager for consistency and accuracy. Replicate chemical tests were performed on five per cent of the samples included in the work plan test program for the Snokist Growers canner. laboratory. In addition, samples were obtained from the EPA laboratory in Cincinnati, Ohio, for check testing of samples with known concentrations.

Table B-1 contains the results of testing the known samples from EPA in the Snokist Growers cannery laboratory. Four samples were analyzed over the project period, two during 1981 and two during 1982, for all tests except chlorine, which was run only in 1982. An average and standard deviation of differences between the EPA published results and the results obtained by Snokist Growers are included. Overall results obtained by the laboratory at Snokist Growers cannery were satisfactory although consistency of analyses for total dissolved solids, total hardness, chlorides, sulfates, ammonia nitrogen and ortho phosphate could have been better.

Table B-2 contains an analysis of the results of chemical analytical tests run on replicates of the same samples in the Snokist Growers laboratory. The data is divided into groups at various concentration levels. Mean and standard deviation of the concentration, mean and standard deviation of the difference between replicates, and the mean and standard deviation of the difference divided by the mean concentration are included for each data group. Generally the analyses on replicate samples show that the techniques employed yielded consistent results. The difference between results divided by their mean averaged 10 % or less, except for total volatile solids (23 %) at low concentrations (<200 mg/l) and total and volatile suspended solids at low concentrations (13 and 12 % at <40 mg/l).

Table B-3 shows an analysis of the results obtained from microbiological testing on wastewater samples. Microbiological testing was usually performed by inoculating or filtering varying volumes or dilutions of sample for growth on the selected media. The counts obtained with each volume or dilution was recorded. Table B-3 contains an analysis of the consistency of results by comparing the count obtained from a particular dilution or sample volume with the count obtained from 10x the dilution or 1/10 the volume. The data in Table B-3 is grouped by counts obtained from the greater volume or lesser dilution (greatest number of counts between the two results compared). The results of tests on replicate samples are also included. The data indicates good consistency of results. The mean of the differences divided by the averages is less that 20 % for all tests, except for mold at very low counts (<10 per plate).

Table B-4 contains the results of testing spiked (fortified) samples for heavy metals at the NFPA laboratory. A known amount of the heavy metals was added to a replicate sample of reclaimed water for comparative testing to determine accuracy and recovery. The amount of fortification, the number of fortified samples tested and compared with the unfortified reclaimed water, and the recovery are shown. The recovery is shown as the mean difference between the test results from the fortified and the unfortified samples, divided by the fortified amount. Overall results indicate good recovery and consistency. Mean recovery ranged 76 % for tin to 135 % for mercury. Arsenic and zinc, at 88 %, were the only other metals which did not average within 8 % of ideal (100 %) recovery.

Tables B-5 and B-6 contain the results of testing samples for recovery of pesticides and volatile (purgeable) halogenated organic compounds by Battelle Pacific Northwest Laboratories. Data is as provided by Battelle accompanying their report on the analytical results. The full reports containing all analytical results and quality control results are contained in Data Reports No. 1 and 2 for this project.

Of the extractable organic compounds (Table B-5) only methoxychlor was analyzed as a field spiked sample (methoxychlor was added to a replicate sample of reclaimed water), as shown. All other quality control was based on obtaining purchased standards and running four replicate laboratory spiked samples. Some constituents were tested in 1980 and some in 1981 for recovery determination and quality assurance. Spiking levels for the 1981 recovery testing are included. Spiking levels for many of the 1980 tests are unavailable, but were in the same range. These results indicate that recoveries were good and confirm that if these constituents were present in the reclaimed wastewater they would have been detected. A list of recoveries for these compounds as found in readily available literature is included for comparison.

The purgeable organics recovery data in Table B-6 shows good consistent recovery, indicating that the results of analyses can be relied upon. Standards were analyzed with each daily run to verify proper calibration. The recovery data in Table B-6 are for four replicate laboratory spiked samples.

TABLE B-1. RESULTS OF TESTS ON EPA CHECK SAMPLES[1]

Analysis	Date[2]	Results #1	Results #2	EPA Value #1	EPA Value #2	% Difference[3] Mean	% Difference[3] Std.Dev.
pH, units	4/81	8.5	7.4	8.6	7.7		
	4/82	7.6	8.5	7.4	8.6	0.9	2.7
Conductivity,	4/81	546	106	572	113		
u mho/cm	4/82	125	496	125	479	1.8	4.4
Total Dis. Solids	4/81	446	77	338	54		
mg/l	4/82	30	236	66	277	-9.3	43.8
Total Hardness,	4/81	140	14.4	136	20.7		
mg/l as $CaCO_3$	4/82	30	60	26.6	109	14.9	27.3
Calcium Hardness,	4/81	110.6	14.0	101.5	13.3		
mg/l as $CaCO_3$	4/82	18.0	81.8	16.8	80.0	-6.1	2.9
Alkalinity,	4/81	76.6	21.8	74.7	21.7		
mg/l as $CaCO_3$	4/82	15.0	69.1	16.0	73.7	2.3	4.6
Chloride, mg/l	4/81	66.0	14.0	87.9	18.4		
	4/82	21.9	76.1	20.5	70.2	8.4	18.5
Sulfate, mg/l	4/81	92.8	6.8	93.6	7.2		
	4/82	6.7	52.0	12.0	75.0	20.3	20.6
Chemical Oxygen	4/81	18.5	224.4	15.4	233.3		
Demand, mg/l	9/82	9.8	188.1	10.4	192.7	-2.0	12.1
Biochemical Oxygen	4/81	2.9	108.5	2.4	100.6		
Demand, mg/l	9/82	3.0	94.2	3.2	83.9	-8.7	11.3
Ammonia, NH_3-N	8/81	0.30	1.26	0.19	1.3		
mg/l	4/82	0.10	1.05	0.19	1.3	3.0	44.5
Nitrate, NO_3-N	8/81	0.27	1.47	0.31	1.59		
mg/l	4/82	0.29	1.38	0.31	1.59	10.0	3.5
Orthophosphate,	8/81	0.023	0.134	0.031	0.154		
PO_4-P, mg/l	4/82	0.015	0.136	0.031	0.154	25.5	18.5
Total Kjeldahl	8/81	0.50	4.10	0.52	4.12		
Nitrogen, mg/l	4/82	0.58	4.03	0.52	4.12	-1.3	7.0
Total Phosphorus,	8/81	0.15	0.97	0.14	0.93		
mg/l	4/82	0.15	1.02	0.14	0.93	-7.1	2.2
Chlorine, mg/l	4/82	0.41	1.40	0.55	1.61	19.3	8.8

Notes:

1. Samples received from U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.
2. Month samples were analyzed.
3. Percent (%) difference = $\frac{\text{EPA result - Snokist result}}{\text{EPA result}} \times 100$

   Means and standard deviations are for all four samples analyzed (two for Chlorine).

TABLE B-2. CHEMICAL ANALYSES ON REPLICATE SAMPLES

Test	Number[1] of Replicates	Concentration[2] Mean	Concentration[2] Std. Dev.	Difference[3] Mean	Difference[3] Std. Dev.	Diff./Mean Conc.[4] Mean	Diff./Mean Conc.[4] Std. Dev.
Total Suspended Solids, mg/l	39	18.2	16.0	1.6	1.5	.132	.126
	19	153	153	13	22	.075	.082
	25	4800	1520	54	75	.012	.017
Volatile Suspended Solids, mg/l	39	17.2	14.6	1.5	1.8	.124	.129
	19	144	142	8.2	11.3	.051	.069
	25	4110	1250	52	66	.013	.017
Chemical Oxygen Demand (COD), mg/l	39	35.5	29.6	2.2	2.2	.086	.099
	14	1630	900	14	16	.008	.008
	12	4980	1170	57	51	.011	.008
Total Solids, mg/l	8	122	17	12	15	.090	.098
	25	294	118	19	16	.070	.068
	8	1290	500	9	16	.006	.009
Total Volatile Solids, mg/l	34	103	45	22	18	.233	.171
	8	1040	440	5.6	6.1	.005	.005
Ammonia, mg/l N	28	0.91	1.96	0.05	0.20		
Total Kjeldahl Nitrogen, mg/l	21	5.8	6.2	0.10	0.08	.038	.042
	8	264	60	2.5	1.6	.010	.007
Nitrate, mg/l N	17	0.22	0.26	0.008	0.011	.025	.046
Total Phosphorus, mg/l	22	3.4	4.6	0.13	0.17	.068	.089
	8	81	23	2.9	2.5	.035	.027
Orthophosphate, mg/l P	6	0.57	0.46	0.03	0.03	.087	.107
	18	3.3	3.7	0.07	0.14	.018	.022
Conductivity, micro mhos/cm	9	86.4	4.7	0.11	0.33	.001	.004
	36	255	117	0.36	1.07	.002	.008

(Continued)

TABLE B-2. (Continued)

Test	Number[1] of Replicates	Concentration[2] Mean	Concentration[2] Std. Dev.	Difference[3] Mean	Difference[3] Std. Dev.	Diff./Mean Conc.[4] Mean	Diff./Mean Conc.[4] Std. Dev.
Total Hardness,	27	16.7	8.7	1.17	1.24	.102	.122
mg/l as $CaCO_3$	18	54.1	28.8	2.06	2.50	.038	.048
Calcium Hardness,	27	18.5	5.8	0.80	0.90	.047	.065
mg/l as $CaCO_3$	18	38.1	5.9	1.01	0.69	.026	.018
Chloride, mg/l	8	4.3	2.9	0.49	0.66	.102	.112
	24	66	37	1.7	2.4	.040	.051
	8	100	67	2.0	3.3	.020	.022
Alkalinity	16	65	33	0.32	0.28	.005	.004
mg/l as $CaCO_3$	25	101	82	0.84	1.44	.009	.021
Sulfate, mg/l	8	4.1	1.7	0.10	0.05	.026	.019
	24	22.9	14.2	1.7	3.0	.050	.036
	8	37.2	25.4	1.7	2.6	.031	.028
MBAS, mg/l LAS	9	0.012	0.013	0.002	0.003		
Silica, mg/l SiO_2	9	44.3	13.6	1.3	1.6	.030	.034
Color, units	14	7	8	0	0		

Notes:

1. Number of tests performed on pairs of replicate samples. Data is separated into ranges of concentration for better definition of precision.
2. Mean of the average concentration from the test pairs.
3. Difference in concentration between the two tests on replicate samples.
4. Ratio of the difference between the test results and their average. No mean and standard deviation indicates that both test results were zero one or more times causing an undefined ratio.

TABLE B-3. COMPARISON OF MICROBIOLOGICAL TEST RESULTS[1]

Test	Count Range[2]	Number Tests[3]	Concentration[4] Mean	Concentration[4] Std.Dev.	Difference[5] Mean	Difference[5] Std.Dev.	Diff./Conc.[6] Mean	Diff./Conc.[6] Std.Dev.
Total Plate Count	>300	32	498	215	35	38	.073	.078
	100-300	59	204	58	30	49	.135	.166
	<100	66	54	36	11	18	.181	.181
Total Coliform	Reps.	90	9.1	22.2	0.78	2.10		
	>100	9	140	30	16	15	.114	.095
	40-100	25	61	21	6.4	6.3	.101	.088
	<40	57	18.8	8.7	2.9	3.8	.157	.175
Fecal Coliform	Reps.	19	1.03	1.80	0.26	0.45		
		25	70.7	46.6	3.64	4.77	.063	.099
Yeast	>300	10	420	123	24	37	.047	.051
	101-300	21	187	66	15.6	20.3	.088	.123
	11-100	34	41.4	22.4	4.77	6.92	.120	.128
	0-10	13	1.15	2.23	0.39	0.51		
Mold	>100	5	131	11.0	7.2	2.4	.055	.018
	11-100	36	29.3	19.5	4.4	4.2	.144	.105
	0-10	35	3.53	2.45	1.17	1.38	.537	.677
Aerobic Mesophilic Spores	0-3	52	0.24	0.52	0.21	0.50		
Anaerobic Total Count		9	630	1810	170	500	.074	.091
Anaerobic Spores		13	9.3	17.0	1.16	3.28	.080	.132

(Continued)

Notes:

1. A comparison between the test results from different dilutions or sample sizes of replicate samples, or between replicate test results from the same dilution or volume of a sample.

2. Range of numbers of colonies on plate or filter with highest count. Test results were separated into ranges to assess differences in precision according to quantity of result. "Reps." indicates that entire test procedure was performed with the same dilutions or volumes on replicate samples.

3. Number of pairs of tests included in comparison.

4. Average number of colonies on plate or filter with highest count. For all comparisons except when replicate tests were used, sample volumes, or dilutions, were different. The count resulting from the smaller volume, or greatest dilution, was adjusted by the ratio of the volumes, or ratio of the dilutions, to obtain the concentration presented, and to obtain the difference. "Reps." means that the comparison was among pairs of samples of the same volume or dilution.

5. Difference in number of colonies between the tests of replicate samples, or between the tests, after the number of colonies from the smaller volume, or greater dilution, was adjusted to reflect the difference in volumes or dilutions.

6. Ratio of the difference between the numbers of colonies, as adjusted, and the average. No mean and standard deviation indicates that average was zero one or more times.

TABLE B-4. HEAVY METAL FORTIFICATION RECOVERY

Test[1]	MDL[2] mg/l	Fortified[3] mg/l	Number	Prop. Recovered[4] Mean	Std.Dev.
Aluminum (Al)	0.1	0.1, 0.5	12	0.97	0.19
Arsenic (As)	0.006	0.01	4	0.88	0.38
Barium (Ba)	0.5	0.1	12	na[5]	
Cadmium (Cd)	0.002	0.1	12	0.996	0.15
Calcium (Ca)	0.03	5.0, 10.1	12	1.02	0.24
Copper (Cu)	0.007	0.1	12	1.06	0.12
Chromium (Cr)	0.007	0.1	11	1.06	0.17
Iron (Fe)	0.01	0.5	12	1.05	0.27
Potassium (K)	0.02	10.0	12	1.04	0.16
Lead (Pb)	0.01	0.1	10	0.96	0.04
Magnesium (Mg)	0.005	1.0	12	1.08	0.26
Manganese (Mn)	0.01	0.1	12	0.96	0.12
Mercury (Hg)	0.0002	0.0005	11	1.35	0.89
Sodium (Na)	0.01	20	12	0.94	0.42
Tin (Sn)	0.3	5.0	8	0.76	0.13
Zinc (Zn)	0.01	0.2	12	0.88	0.11

Notes:

1. Heavy Metals analyses were performed by the National Food Processors Association, Western Research Laboratory, Berkeley, California.
2. MDL = Minimum Detection Limit, based on instrument response and sample concentration factors.
3. One of a pair of replicate samples of reclaimed effluent was fortified in the field, with the concentrations shown on the number of occasions shown. Two numbers indicate that samples one year were fortified with one concentration, and during the other year, the other concentration.
4. Proportion recovered is the test result from the fortified sample, minus the result from the unfortified sample, divided by the amount of fortification.
5. All barium samples were below the MDL.

TABLE B-5. RECOVERY OF EXTRACTABLE ORGANIC COMPOUNDS[1]

Compound	Conc'n, ug/l	Recovery from Lab Spiked Samples[2], % 1980	1981	Std.Dev.	Literature
Aldrin	94		163	19	
BHC (alpha)	122		171	23	
BHC (beta)	95		64	21	
BHC (gamma)	105		100	65	
Captan	103	80			100
Casuron®(Dichlobenil)	102	77	166	35	
Chlordane	49		120		
2,4-D	102		55	29	
DDD	111		122	18	
DDE	103	99	115	20	96
DDT	104		110	19	
De-Fend®		45			
Diazinon	101	93	154	23	108
Dichlone	123	39	6	32	85
Dieldrin	136	99	126	21	
Diphenylamine		88			
Endosulfan	49	87	122	17	91
Endrin	98		48	25	
Ethion		69			100
Guthion®		101			
Heptachlor		94			90
Heptachlor Epoxide	83	95	61	59	90
Imidan®		45			82
Kelthane	129		76	27	
Methoxychlor	102	97	132	29	97
PCB 1254	94		76		
Parathion		81			
Penncap M®		104			
Perthane®	103	112			89
Phosphamidan		69			43
Pydrin	84	88			
Sevin®		38			
Silvex	88		74	18	
Smiazine		136			71
Toxaphene	92	indefinite results			
Analine	121		26	27	
Nitrobenzene-d5	115		26	27	
2-fluorophenol	119		44	2	

Methoxychlor (18 Field spiked samples @ 100 ug/l) - Recovery = 127 $\pm$ 35 %

Notes: 1. Data from Battelle Pacific Northwest Laboratories.
2. Blanks indicate missing data.

TABLE B-6. PURGEABLE ORGANICS RECOVERY DATA[1]

Compound	Batch I			Batch II		
	ug/l	Recovery[2]	Std.Dev.	ug/l	Recovery[2]	Std.Dev.
Bromoform	27.2	97	8	70.5	109	16
Bromodichloromethane	24.6	98	3	51.9	99	7
Carbon tetrachloride	22.6	96	15	60.6	79	23
Chlorobenzene	18.1	94	5	66.9	94	13
Chloroform	17.2	97	4	53.6	119	22
Dibromochloromethane	24.0	77	8	60.0	92	16
1,2-Dichloroethane	25.6	ND[3]		56.6	79	23
1,2-Dichloropropane	37.6	108	28	61.5	78	35
1,1,1-Trichloroethane	33.0	98	2	50.0	89	24
1,1,2-Trichloroethane	24.8	107	25	48.5	103	12
Trichloroethene	44.3	98	29	55.0	79	19
Tetrachloroethene	23.8	91	9	82.6	88	12
Dibromomethane (methylene bromide)	45.7	98	8	66.3	92	18
Surrogate Standards[4]						
Fluorobenzene	12.6	72	28	39.6	74	10
4-Bromofluorobenzene	12.5	102	15	42.5	94	24
Pentafluorobenzene	12.3	103	15	56.7	78	21
Internal Standards[4]						
Bromochloromethane	13.0	84	55	51.1	102	5
1-Bromo-3-chloropropane	12.4	88	30	60.0	110	16
1,4 Dichlorobutane	12.4	97	22	60.5	95	15

Notes:

1. Analyses performed at Battelle Pacific Northwest Laboratories, Richland, Washington. Complete results contained in Data Report No. 2 for this project.
2. Recovery and standard deviations in percent based on four data points obtained on replicate standards, except for 4-bromofluorobenzene in Batch II, which had only three data points.
3. Below detectable limits.
4. Surrogate and Internal Standards were used for machine calibration of the quantitative peak volumes from the compounds of interest.

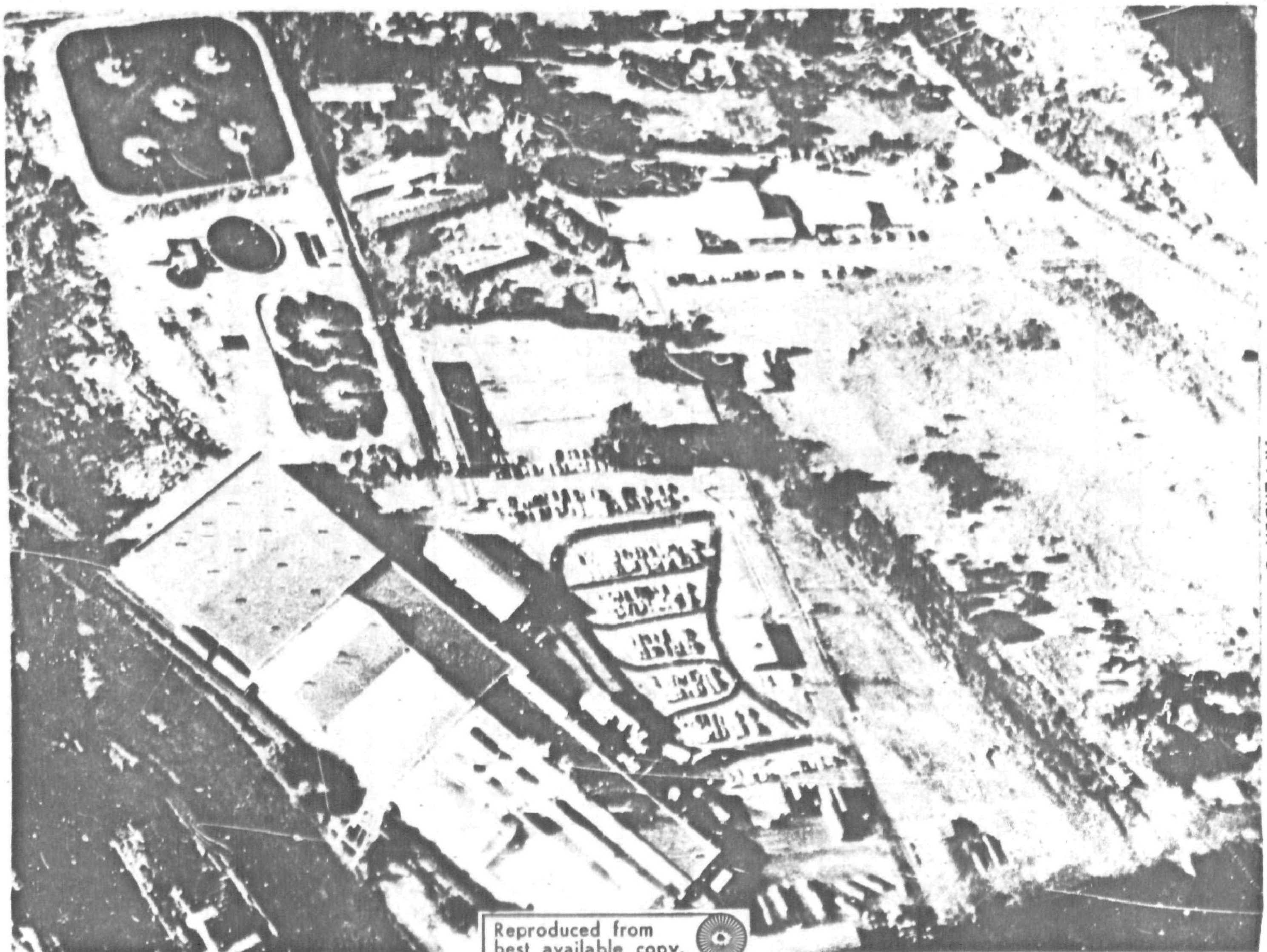

Figure C-1. Snokist Growers cannery and wastewater treatment system. Cannery buildings - lower left; Wastewater treatment - upper left; Yakima river - upper right corner.

Figure C-2. Snokist Growers cannery wastewater treatment plant. Aeration basin - left. Equalization - right. Clarifier & filter bldg - center.

Figure C-3. Aeration basin - 22,700 cu. meter (6 MG), PVC lined with 4 - 60 hp and 1 - 150 hp aerators.

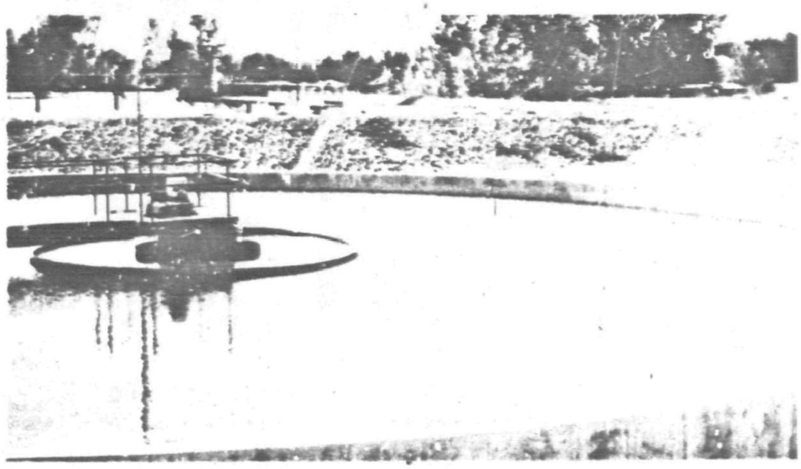

Figure C-4. Clarifier - 27.7 meter (90 ft) dia., 2.4 m (8 ft) side depth, hydraulic sludge removal.

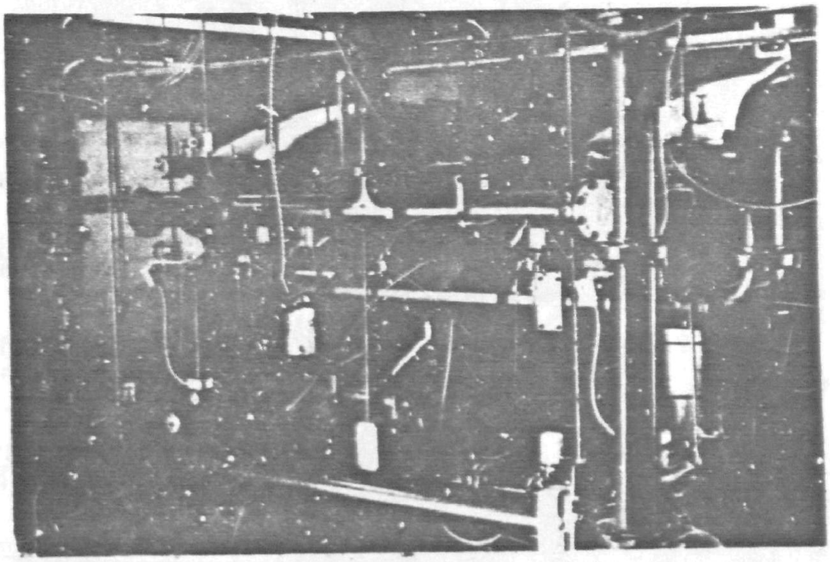

Figure C-5. Filters - 2.4 m (8 ft) dia., 1.8 m (6 ft) high, granular multi-media (anthracite, silica and garnet sands), pressure feed.

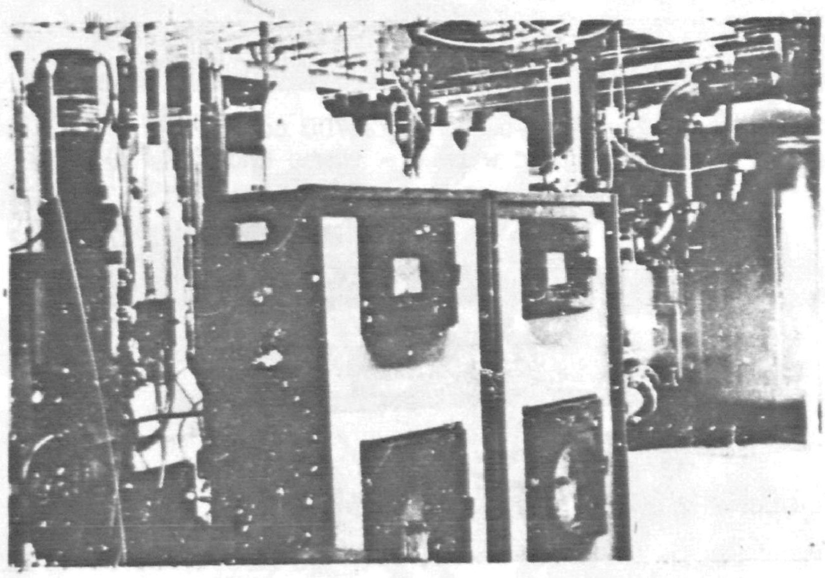

Figure C-6. Dual chlorine residual analyzers and turbidity monitor for reclaimed water. Filters in background.

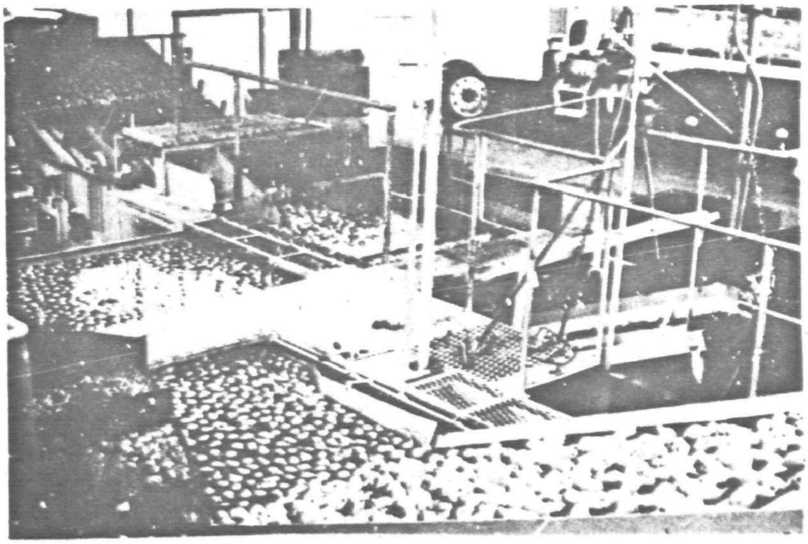

Figure C-7. Fruit dump and initial wash using reclaimed water. Bins enter upper left, are submerged where fruit floats out and is floated to conveyor to spray wash and into cannery.

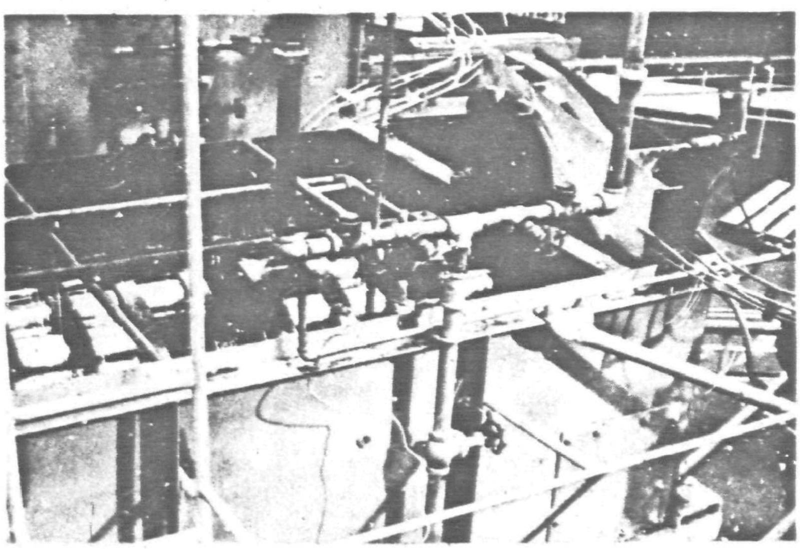

Figure C-8. Can cooler using reclaimed water. Cans (#10 shown) are rotated and conveyed, alternately submerged and sprayed. Note dual vert. water feed pipes (reclaimed and house water), and temp. control valve (far cooler).