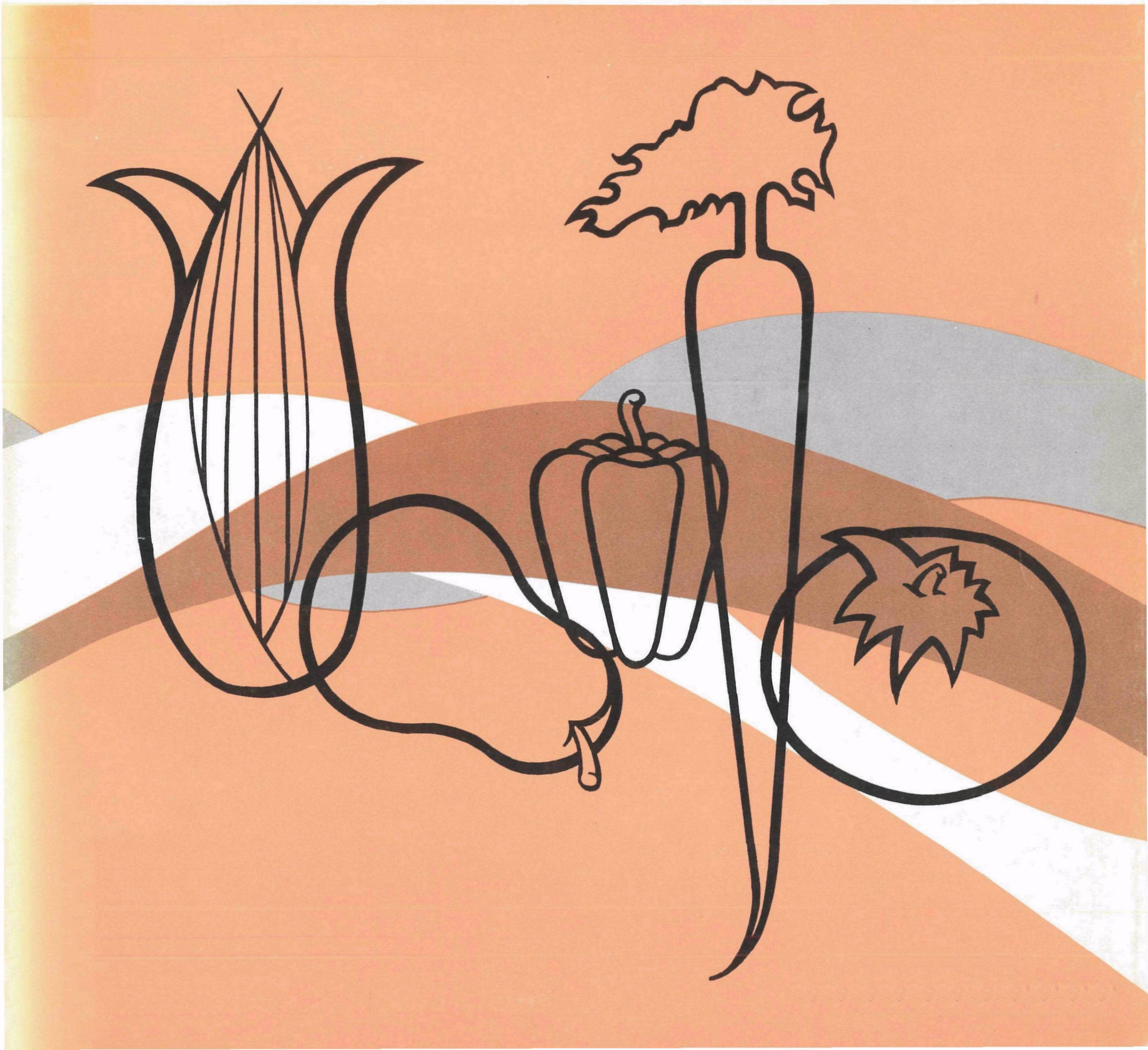
# Pollution Abatement in the Fruit and Vegetable Industry

Basics of Pollution Control/
Case Histories

EPA Technology Transfer Seminar Publication



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# POLLUTION ABATEMENT IN THE FRUIT AND VEGETABLE INDUSTRY

## Basics of Pollution Control/ Case Histories

**ENVIRONMENTAL PROTECTION AGENCY**

**Environmental Research Information Center • Technology Transfer**

July 1977

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# Chapter I

# INTRODUCTION

## WATER

Examination of the distribution of water on this planet (figure I-1) reveals that the greatest quantity (97.13%) exists in the oceans of the world. The second major quantity (2.24%) exists as ice and snow in the polar regions. These sources are, of course, unavailable for domestic use without extensive treatment and/or transportation. Of the remainder of Earth's water, the largest supply that is used for human consumption exists as ground or subsurface waters (0.612%). The widespread dependence on wells for fresh water attests to its distribution and availability. Only a relatively small portion, then, exists as surface water in the lakes (0.009%) and the streams (0.0001%) of the world.

Water in its pure state is a simple molecule consisting of two hydrogen atoms attached to a single atom of oxygen. However, water molecules have the unique property of being able to dissolve an extremely wide variety of substances. Therefore, in its natural state, water contains varying concentrations of dissolved minerals, organic matter and atmospheric gases.

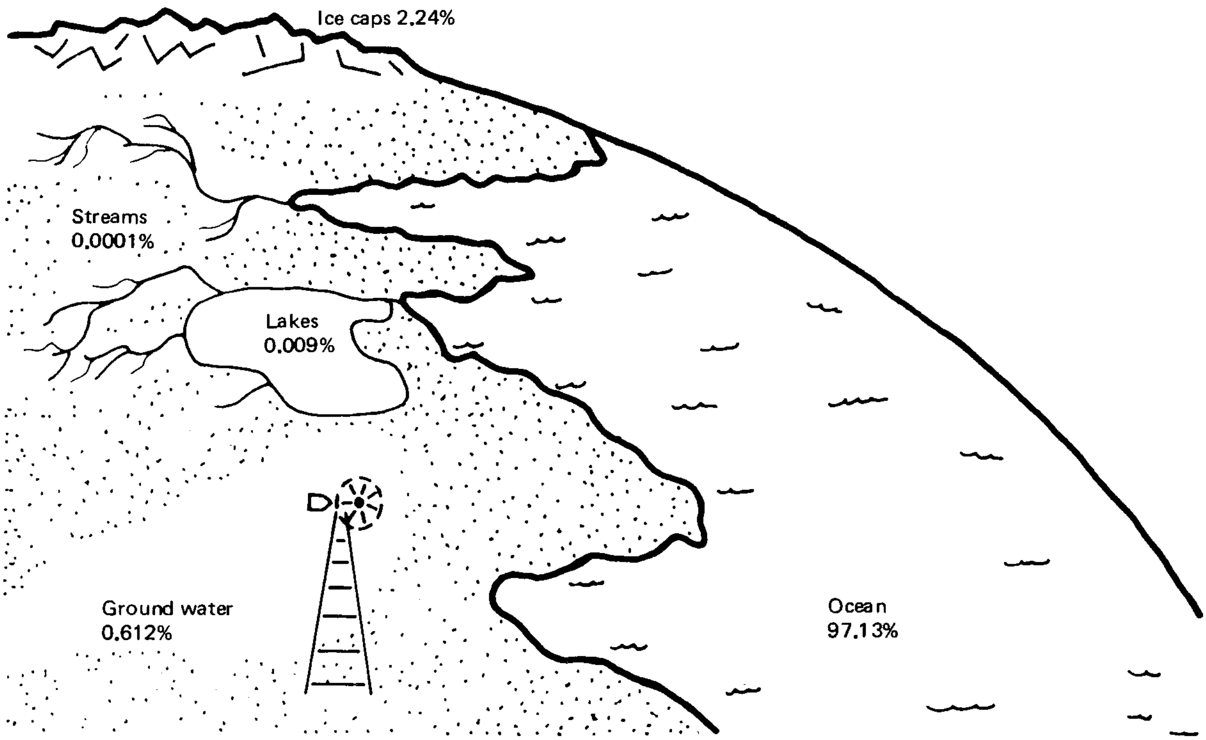


Figure I-1. Distribution of water on Earth.

Materials are continually added to water in a natural setting. Rocks and soil are eroded by the passage of the stream, adding suspended solids to the water; trees and plants shed their leaves, or die and fall to rot, adding organic matter; animals, birds and fish, all functioning naturally and living their normal life cycles, further add to the organic load imposed upon the stream. These normal and continual contributions of water contaminants have been termed *natural pollution.*

Each stream, however, also has the capability to purify itself of various materials. In the slow-flowing stretches, suspended solids settle to the stream bed, thereby forming sandy bottoms. As a stream tumbles and falls over rocks and other obstacles in its path, oxygen is entrained in and dissolved by the water. Even as a stream slowly flows through forest or meadow, oxygen is absorbed from the air at the water's surface. The dissolved oxygen not only sustains fish, plants and other large aquatic life, but also sustains a large group of microorganisms which are especially responsible for the stream's self-purification.

Aerobic bacteria (microorganisms which require oxygen) rely on organic matter in the water for food. These microorganisms, in utilizing the pollutants in the stream, convert the organic matter into cellular material during growth, or degrade the organics to nonputrescible compounds through their metabolic process. During the process, dissolved oxygen is consumed. In a free-flowing stream, the rate at which bacteria consume dissolved oxygen to stabilize natural pollutants only infrequently exceeds the rate at which the stream is physically oxygenated. Thus, sufficient dissolved oxygen is normally present to sustain the needs of a variety of aquatic life.

## ASSIMILATIVE CAPACITY

The rate at which dissolved oxygen is consumed is directly related to the concentration of pollutants present in water. That is, the higher the concentration, the more active are the bacteria, and hence the higher the rate at which oxygen is used; the lower the concentration, the lower the consumptive or deoxygenation rate. When the consumptive rate exceeds the oxygenation rate of a stream, the level of dissolved oxygen in the water begins to decrease. Since minimum levels of dissolved oxygen are required by fish and other aquatic life, excessive oxygen depletion will result in biological stress and, ultimately, fatality. The quantity of pollutants which may be added to a stream without deleterious effects on aquatic organisms is called the *assimilative capacity* of the stream.

## EFFECT OF WASTE DISCHARGES

Waste discharges, whether domestic sewage or industrial wastewaters, impose demands upon the assimilative capacity of the receiving water. When a heavy load exceeding the assimilative capacity is discharged, the dissolved oxygen content of the stream will be greatly depressed. However, provided no further waste discharges occur downstream, the dissolved oxygen content of the stream will eventually be re-established. A graph depicting the profile of the dissolved oxygen content in such a situation is called an oxygen-sag curve (figure I-2). Reoxygenation rates depend upon the number of factors, including the initial dissolved oxygen content of the stream, the pollutional strength of the waste discharge, the relative volumes of the two, and the characteristics of the downstream flow (fast or slow, smooth or turbulent).

Unfortunately, waste discharges occur at numerous points along most streams, thereby often precluding sufficient reoxygenation. Thus, the self-purification capabilities of such streams are seriously hampered. When excessive waste loads are discharged under these conditions, the consequences become evident by large fish kills and nuisance conditions with serious public health significances.

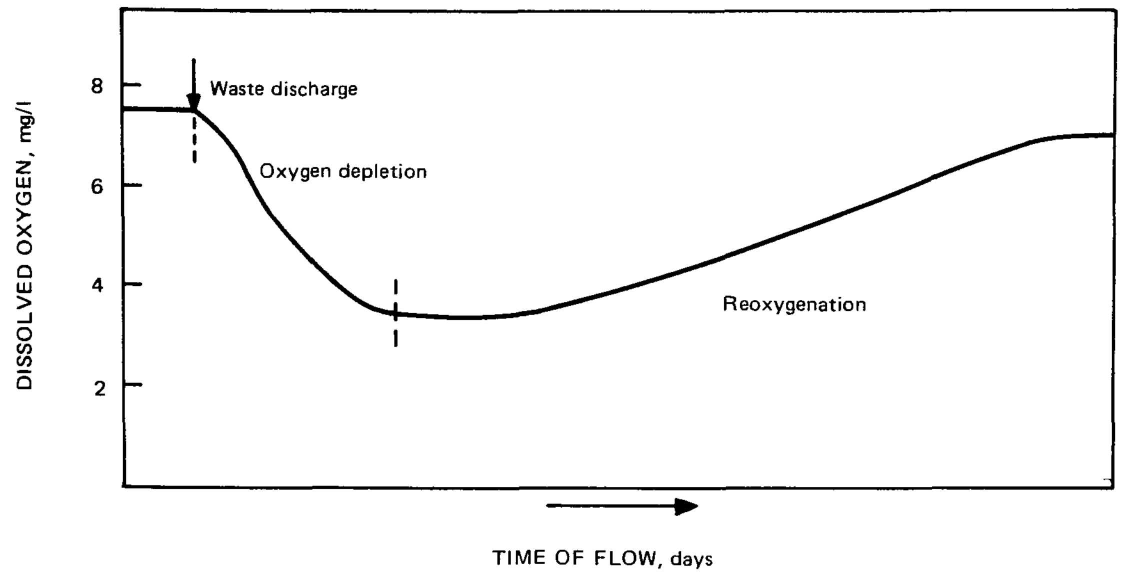


Figure I-2. A hypothetical oxygen-sag curve.

## ENVIRONMENTAL LEGISLATION

During the late 1950's and through the 1960's, several important Congressional acts were passed. Although some of these were not individually significant, they served as precursors to the most important piece of environmental legislation enacted to date. On October 18, 1972, Congress established Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972. This act essentially rewrote and consolidated several preceding laws in an effort to create a mechanism by which to attack and resolve the nation's water pollution plight.

The law establishes as a national goal the elimination of pollutant discharges into navigable waters by 1985. This is popularly called the "zero discharge" concept. In an effort to meet this goal, the Administrator of the EPA is directed to establish for each major industry group a set of effluent limitations—that is, specific restrictions on the quantity of pollutants that an industrial plant will be permitted to discharge. These limitations are to be based on reductions considered to be achievable through in-plant process changes, as well as end-of-pipe wastewater treatment.

PL 92-500 requires that by July 1, 1977, effluent limitations reflect the application of the "best practicable control technology currently available"; by July 1, 1983, the limitations are to be based on application of the "best available technology economically achievable"; and performance standards for all new sources must be based on the "best available demonstrated technology." Factors to be considered in the establishment of effluent limitations include the age of equipment and facilities, the processes employed, and costs to achieve the specified reductions.

PL 92-500 also establishes a permit program known as the National Pollutant Discharge Elimination System (NPDES). To assure that effluent limitations are being met and that designated water quality standards are maintained, all wastewater dischargers are required to obtain a permit. Although the permit program was initially administered by EPA, a mechanism is provided to shift administrative responsibilities to individual states. (Many states now have or will soon be granted administrative authority.)

When NPDES discharge permits are issued, conditions are prescribed to assure compliance with all appropriate regulations, including (but not limited to) protection of designated *beneficial uses* of the receiving water, specification of *effluent limitations*, and a *construction schedule* of adequate wastewater treatment facilities to meet the limitations. The permits also prescribe *self-monitoring* procedures required of all direct dischargers. The self-monitoring program generally consists of data collection and record keeping; reports must be periodically submitted to the appropriate regulatory agency.

Those provisions of PL 92-500 described in the preceding paragraphs relate primarily to direct dischargers, i.e., those industrial plants which discharge wastewater directly to receiving streams. The Act, however, also contains provisions which affect industrial users of publicly-owned treatment works. Industrial users can be significantly affected by performance standards and effluent limitations which are imposed upon publicly-owned facilities. Since industrial waste loads may constitute a significant portion of the total load being treated at a municipal plant, the type and size of that facility may be greatly affected by the industrial load, thereby influencing the total cost of new or expanded facilities to meet imposed regulations. For municipalities to take advantage of federal construction grants, the Act requires each municipality to establish a revenue recovery program which insures that industrial users will contribute their proportionate share of total capital costs. Additionally, each municipality is required to establish a schedule of user charges, based on flow rate and strength, which will assure that each recipient of wastewater treatment services, both industrial and non-industrial, will pay its proportionate share of total operating and maintenance costs. Therefore, industrial users of publicly-owned treatment works may incur significant costs for the privilege of utilizing such facilities.

# Chapter II

# WATER POLLUTION PARAMETERS

## MAJOR ASPECTS

The potential effect of wastewater discharges, either upon a receiving stream or a treatment system, is evaluated by accumulating specific information with which to determine the pollutant concentration, or *waste load*, associated with the discharges. Waste loads are used:

- By engineers to design appropriate wastewater treatment facilities.
- By regulatory authorities to specify effluent limitations.
- By municipalities to levy surcharges for sewer services.

There are two aspects of industrial waste loads which are of primary concern. The first is the volume or quantity of wastewater which must be treated and/or disposed. This is referred to as the *hydraulic load.* The second consideration is the pollutant concentration of the wastewater. For most fruit and vegetable processing wastes, the pollutant concentration can be measured through the use of biochemical oxygen demand (BOD) and suspended solids (SS). These are collectively referred to as the organic load. The hydraulic and organic loads comprise what is referred to as the *raw waste load (RWL).*

Other water pollution parameters which may be of concern to fruit and vegetable processors are listed in table II-1 and are also briefly described in the remainder of this chapter.

Table II-1. —*Water pollution parameters in fruit and vegetable processing*

| Major | Other[a] |
|---|---|
| Flow | Temperature |
| Biochemical oxygen demand | Total solids |
| Total suspended solids | Dissolved solids |
| Settleable solids | Chlorides |
| Chemical oxygen demand | Nitrogen |
| pH | Phosphorus |
| Dissolved oxygen | |

[a]May be major depending upon concentrations and/or circumstance.

## FLOW

Flow measurements are a basic requirement for monitoring all discharges. Hydraulic loads can only be determined by accurate flow records, preferably kept on a continuous basis. Since the hydraulic load largely dictates the required size of a treatment facility, each processing plant should provide some means for obtaining and recording this information.

Various equipment is commercially available for measuring flow, including meters, weirs, flumes, and special devices. This equipment, as well as simple flow measuring techniques, is described in detail in volume 2. (Flow measurement is also covered in the *Handbook for Monitoring Industrial Wastewater*[1] published by the EPA.)

## DISSOLVED OXYGEN

Dissolved oxygen is defined as oxygen which is dissolved in water or other liquid. This should not be confused with the presence of visible air bubbles since such bubbles are still in a gaseous state. Although dissolved oxygen is not generally a significant parameter when dealing exclusively with waste streams, it is of major importance in receiving waters and in certain waste treatment systems. Aerobic conditions must be maintained in the latter to preclude development of odors associated with stagnation.

Dissolved oxygen (DO) may be measured either by wet chemical analysis or by instrument (figure II-1); the procedures are discussed in volume 2. Dissolved oxygen concentrations are expressed as milligrams per liter (mg/l DO), which is approximately equivalent to parts per million (ppm).

The quantity of dissolved oxygen which can be maintained in water is directly related to atmospheric pressure and inversely related to water temperature. Thus, the lower the temperature and the higher the pressure, the greater the maximum maintainable DO level. Although it is possible to obtain relatively high concentrations of dissolved oxygen, 9 mg/l DO is generally regarded as the saturation level under ambient conditions. A minimum of 5 mg/l is considered to be desirable for sustaining game fish (trout, salmon, etc.).

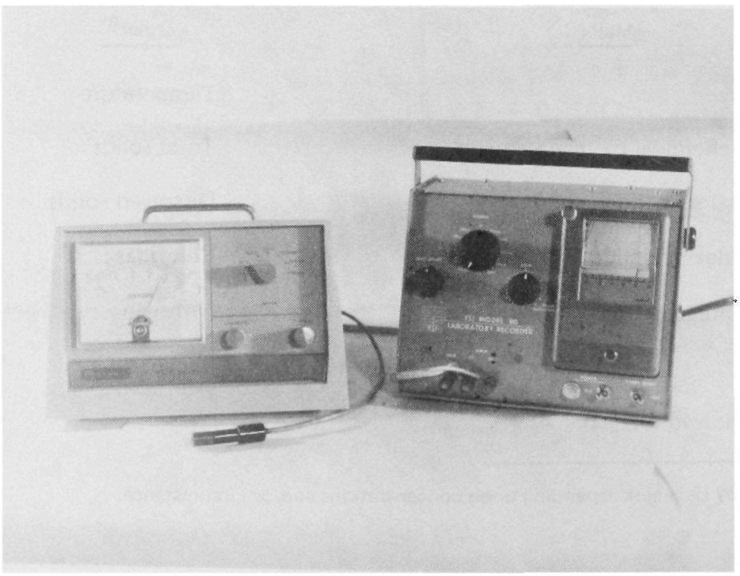

Figure II-1. Dissolved oxygen meter with recorder.

## BIOCHEMICAL OXYGEN DEMAND

For many years, investigators have attempted to measure the strength of wastewater containing *decomposable* organic compounds in terms of their effect upon streams or other bodies of water into which the wastes are discharged. The standard method for measuring this effect is the biochemical oxygen demand (BOD) test. The test was developed by determining the amount of oxygen required to microbially stabilize known quantities of decomposable organic matter.

The BOD test is based on an apparent direct relationship between the pollutional strength of organic wastes and the amount of oxygen that will be required (oxygen demand) in biochemical reactions to convert the materials to carbon dioxide, water and inorganic nitrogen compounds. The oxygen demand is related to the rate of increase in microbial activity which is, in turn, proportional to the concentration of nutrients in the organic wastes. These relationships also represent the mechanism responsible for the self-purification of streams.

In the standard laboratory BOD test, samples of wastewater are seeded with an inoculum, diluted with previously aerated water (if necessary), and incubated at 20°C. The initial DO is measured and after a specified period, the dissolved oxygen content is again determined; the BOD is based on the depletion of oxygen from the sample during the incubation period. Since complete stabilization of organic wastes requires prolonged periods (figure II-2), laboratory analysis is limited to two periods. The 5-day BOD, which is used most widely, represents most of the oxygen necessary to stabilize the carbonaceous and readily oxidized materials. Since fruits and vegetables are largely composed of carbohydrates, the 5-day BOD value is of greatest significance to this industry. The 20-day, or second stage, BOD value is used to estimate the ultimate BOD; this value represents oxygen required to stabilize nitrogenous and other slowly oxidized materials.

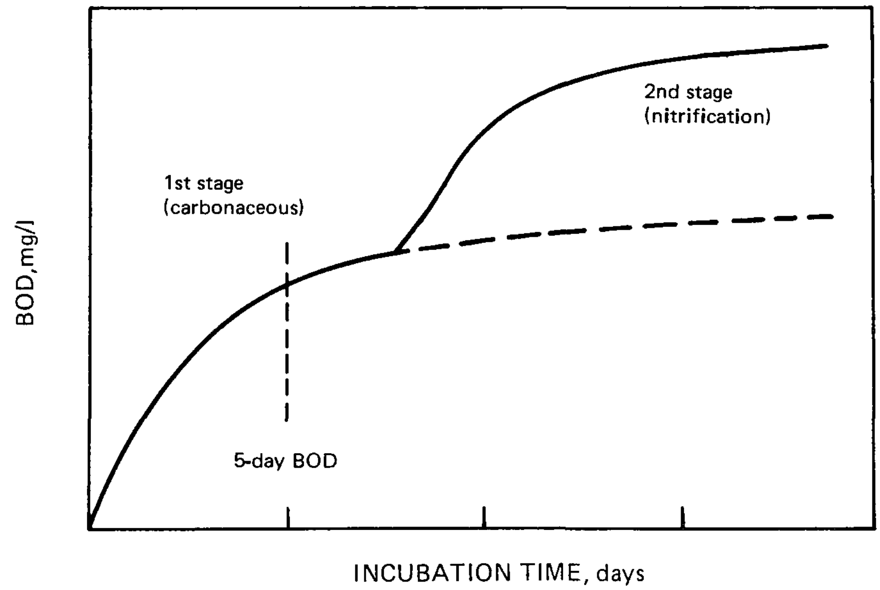


Figure II-2. First and second-stage BOD curve.

Laboratory results are reported as milligrams per liter (mg/l). However, effluent limitations and sewer service charges are based on pounds of BOD. To determine the latter quantity, accurate flow measurements must be available. Pounds of BOD may then be calculated as follows:

$$\text{pounds BOD} = \frac{\text{BOD (mg/l) X total flow (gallons) X 8.34}}{1{,}000{,}000}$$

For any waste, the concentration of pollutants can be readily reduced by simply using more water, but the increase in volume will result in the same number of total pounds of pollutants. Therefore it is apparent that "dilution is no solution to pollution." Instead, the BOD load can be effectively reduced only by simultaneously reducing water usage and BOD generation.

## CHEMICAL OXYGEN DEMAND

Chemical oxygen demand (COD) is an alternative to biochemical oxygen demand (BOD) for measuring the pollutional strength of wastewaters. Simply described, the COD test measures the amount of oxygen consumed during chemical oxidation of waste constituents. The test is relatively quick and highly reproducible, thereby eliminating the two primary disadvantages of the BOD test.

When considering the use of COD for measuring the pollutional strength of wastewater, one must bear in mind that the BOD and COD tests involve separate and distinct reactions. Chemical oxidation measures carbon and hydrogen but not amino nitrogen in organic materials. Furthermore, the COD test does not differentiate between biologically stable and unstable compounds. For example, cellulose is measured by chemical oxidation but is not measured biochemically under aerobic conditions. Despite these differences, a number of investigators have found a reliable and useful relationship between BOD and COD for certain types of wastes. The COD is especially useful for routinely monitoring wastewater discharges.

The primary disadvantage of the COD test is its susceptibility to interference by chloride. Thus, wastewaters containing high salt concentrations, such as sauerkraut and pickle brines, cannot be readily analyzed without modification. However, the standard method for COD is designed to remove interferences at low chloride concentrations and can be used for analysis of processing wastewaters.

## SOLIDS IN WASTEWATERS

Solids, or particulates, present in screened wastewaters are of concern for several reasons. When discharged into receiving streams, the particulates may remain in suspension to create turbid conditions. They may float and agglomerate to form unsightly scum blankets, or they may settle on stream beds to form anaerobic sludges. In wastewater treatment systems, settleable and floatable solids must be removed so that they will not interfere with the efficiency of treatment.

### Settleable Solids

Information on the amount of settleable solids in wastewaters provides a basis for predicting the sludge load in settling basins, clarifiers, stream beds, or sewer lines. The laboratory method is semi-quantitative and is useful only for estimating the volume of sludge which can be anticipated.

### Total Solids

Total solids determinations (figure II-3) measure all matter contained in a water or wastewater sample. Included in the determination are suspended materials, which contribute to the turbidity of water, as well as dissolved components, such as sugars and salts. Although some volatile organic compounds may be excluded in this analysis, which is conducted at the boiling point of water, total solids is a useful tool for the qualitative determination of the pollutants contained in wastewater samples.

Total solids is the residue remaining after evaporation of water from a sample. Solids can be further subdivided into fixed and volatile solids. The fixed solids, determined by weighing the residue remaining after combustion, are regarded as representing the inorganic matter contained in the sample. The volatile solids, which is that portion of the total solids lost upon combustion, represents the organic matter.

### Suspended Solids

Suspended solids (SS) in wastewater is the solid matter parameter of greatest interest. This parameter is used by regulatory agencies as an index of potential formation of sludge deposits and turbid conditions in receiving waters; effluent limitations are therefore placed on allowable SS discharges. Engineers and treatment plant operators utilize SS information to determine the quantity of solids which will require removal in activated sludge treatment systems (described under Treatment Methods). Suspended solids determinations reflect the operating efficiency of the system.

Suspended solids is defined simply as that matter which will not pass through a filter. For fruit and vegetable processing wastewaters, SS is considered to be all materials which pass through a 20-mesh screen but are retained on a filter. The laboratory determination is made by first filtering a wastewater sample, and then drying and weighing the residue retained on the filter. As with total solids, the total suspended solids (TSS) thus obtained may be further subdivided into fixed (FSS) and volatile (VSS) components by combustion.

Laboratory results are expressed as milligrams SS per liter (mg/l). However, as in the case of BOD, SS limitations are expressed in pounds. The conversion of units, which requires accurate flow data, is identical to BOD:

$$\text{pounds SS} = \frac{\text{SS (mg/l) X total flow (gallons) X 8.34}}{1{,}000{,}000}$$

Again, dilution will effect no change in the total pounds. Rather, the organic load, consisting of both BOD and TSS, can only be effectively reduced by simultaneous reductions in water usage and pollutant generation at in-plant sources.

### Dissolved Solids

Since as much as 85% of the BOD of fruit and vegetable processing wastewaters may be attributable to dissolved organic matter, the total dissolved solids (TDS) determination is often of interest. TDS measurements are made by filtering samples, and drying and weighing the residues in the filtrates. Fixed (inorganic) and volatile (organic) fractions may be determined by combustion. When brines (such as used for storing olives, pickles and sauerkraut) are discharged, the TDS test is often used to estimate the quantity of salt contained in the wastewater.

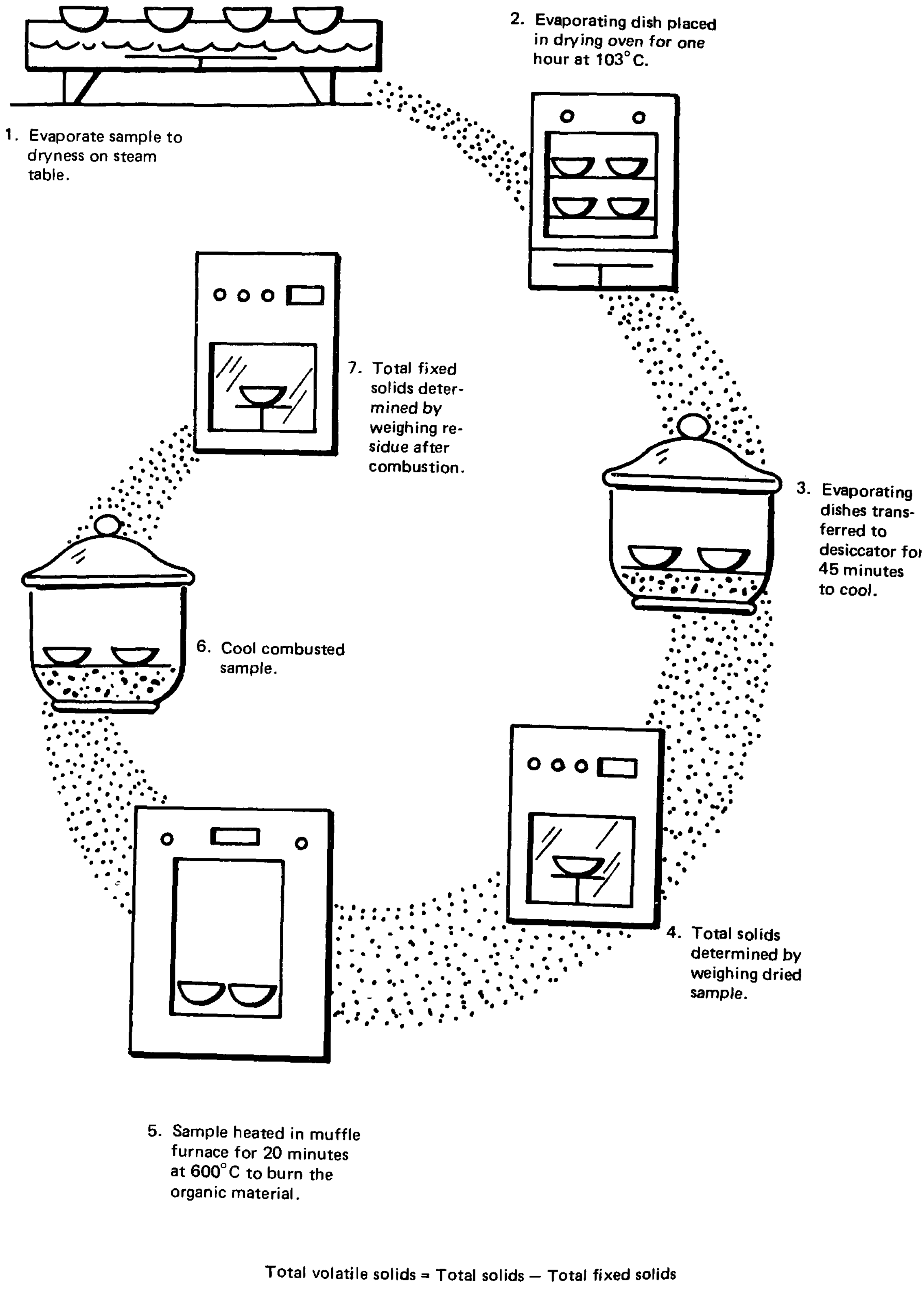


Figure II-3. Steps in the determination of total and fixed solids.

## pH

pH is a measure of the hydrogen ion concentration in water and indicates the acidic or alkaline character of the water. A pH measurement does not, however, indicate a liquid solution's buffering capacity, which is its capacity to accept acid or alkali without corresponding changes in the hydrogen ion concentration. The pH values are expressed by a numerical scale from 0 to 14, the midpoint, 7.0, being neutrality (figure II-4). The 0 to 7 range is the acid scale and the 7 to 14 range is the alkaline scale. Measurements are most suitably made potentiometrically with an appropriate pH meter.

The pH of fruit and vegetable processing wastewaters may vary from 3.5 to 11.5, depending upon the product being packed and the type of operations conducted within the plant. Natural waters generally have pH values between 5.5 and 8.5. Accurate pH measurement and control of plant effluents are often essential for successful treatment and disposal.

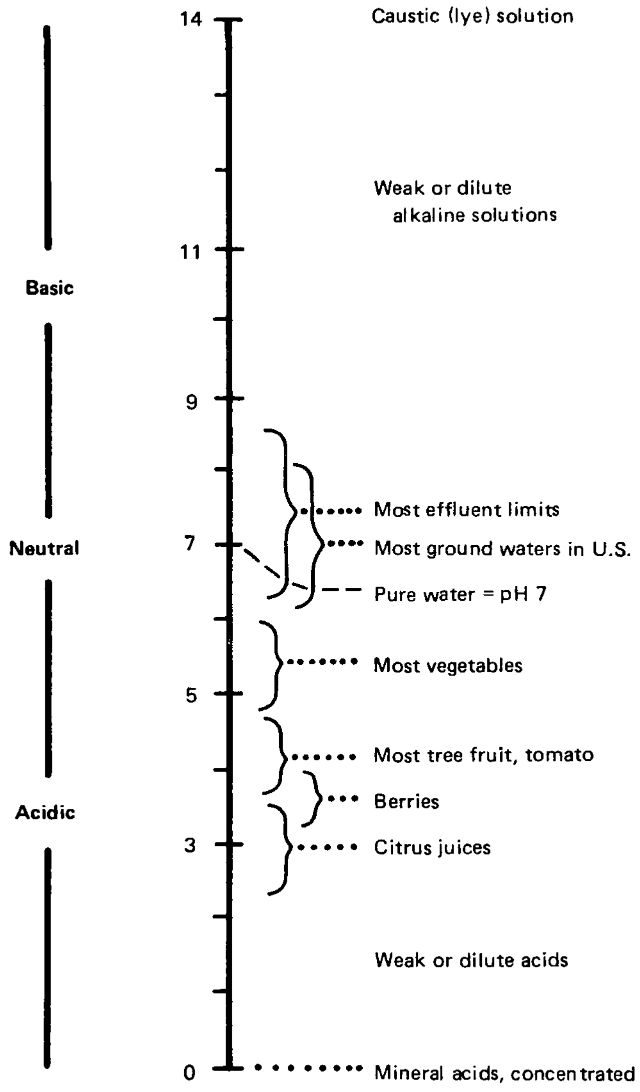


Figure II-4. The pH scale, with values of some materials.

## OTHER PARAMETERS

The tests discussed in the previous paragraphs constitute the parameters of major concern to fruit and vegetable processors. In specific situations, the tests described in the remainder of this chapter may also be of importance to this industry.

### Temperature

Since the dissolved oxygen concentration in water is inversely related to temperature, effluent limitations based on water quality standards generally include temperature limits. The temperature of plant effluents may be of little or no consequence to some processors but may be of significant concern to others. The degree to which temperature may be a problem is determined by the types of operations which contribute heat to the waste discharge and the relative flows between the plant effluent and the receiving stream.

Container and compressor cooling waters and evaporator condenser effluents are the major sources of heated wastewaters in fruit and vegetable processing plants. These effluents may be discharged in several fashions. When they are mixed with processing wastewaters prior to treatment, temperatures in the final discharge will have minimal effects on receiving streams. When mixed with treated wastewaters prior to discharge, the final temperature will depend upon the degree to which the heated effluent is diluted by the treated waste. The severest impact on a receiving stream will occur when heated wastewaters are discharged directly. In this case the effect will be determined by the flow and temperature of the discharge versus the flow and temperature of the receiving stream. Cooling ponds or towers may be required in extreme situations.

Temperature measurements can be manually taken by periodically checking the discharge with a mercury-filled glass thermometer or any number of commercially available temperature measuring devices. Where continuous readings are desirable, suitable temperature sensors and recorders are also available.

### Nutrients

Aside from carbonaceous organic matter (which is measured largely as BOD), the nutrients of primary concern are organic nitrogen and phosphorus-containing compounds. Both compounds are required for reproduction of microorganisms. Nitrogen (N) and phosphorus (P) are largely responsible for algal "blooms" which result from eutrophication of lakes and streams. To optimize efficiencies of biological wastewater treatment systems, nitrogen and phosphorus concentrations are adjusted according to the BOD concentration in the wastewater. The generally recommended ratio of BOD to total N to total P is 100:5:1. Fruit and vegetable processing wastewaters are normally nutrient deficient.

The laboratory nitrogen determination of greatest interest to this industry is the total kjeldahl nitrogen (TKN) analysis. Most of the organic nitrogen compounds are converted to ammonia which can then be measured colorimetrically or by titration. Results are reported as mg/l TKN.

Phosphorus occurs nearly always in the form of various types of phosphates ($PO_4$). Detergents used for product washing and plant cleanup are the primary sources of water soluble phosphates in fruit and vegetable processing effluents. Insoluble forms of phosphates may be found in sediments and in waste sludges. In the laboratory procedure, wastewater samples may be analyzed solely for soluble forms of phosphate or may be treated to solubilize all phosphates. All of the various available laboratory methods for measuring phosphate are colorimetric, with results being reported as mg/l P.

### Chlorides (Salt)

Chlorides, or more generally salt (NaCl), in fruit and vegetable processing effluents are associated with brining operations. Saline waters cause metal corrosion and are toxic to fresh water aquatic organisms. Salt in high concentrations will also exert deleterious effects on agricultural crops.

Brines from quality graders and fillers are generally diluted by sufficient volumes of processing wastewaters such that the final concentration is adequately low. However, the disposition of large volumes of brines (like those associated with olive, sauerkraut, and pickle processing) is frequently problematic. Such waste discharges will often be regulated by effluent limits for chloride.

Chlorides may be determined either colorimetrically with special reagents, or by potentiometric titration; results are reported as mg/l Cl. These results may then be used to calculate the salt concentration (as NaCl). For high salinity brines, an estimate of the salt concentration may be obtained from total solids or total fixed solids determinations.

### Analytical Procedures

EPA-approved procedures should be used to develop all analytical data, especially those required for compliance monitoring. These are contained in *Methods for Chemical Analysis of Water and Wastes*[2] and *Standard Methods for the Examination of Water and Wastewater*[3]. It is strongly recommended that companies performing their own laboratory analyses obtain both of these references.

# Chapter III

# SAMPLING

The most vital part of an effluent monitoring program is the procedure used to collect wastewater samples. Only with appropriate sampling procedures can laboratory analyses yield accurate information relative to a plant's discharge. Optimally, the best information can be developed by continuous in-line sampling with instantaneous analysis and recording. For some parameters, such as temperature and pH, this is very practical. However, the cost or the unavailability of suitable instrumentation renders continuous monitoring infeasible for most parameters. As a compromise, laboratory analyses are performed on samples which are collected and preserved in a manner that will yield representative or typical data.

## GRAB SAMPLES

A sample which is collected on a one-time basis is called a grab or discrete sample. A grab sample, as implied by its name, may be collected by manually dipping a container into a wastewater stream. However, laboratory results obtained from such a sample will provide but a single data point, reflecting only those conditions which exist at the time the sample is drawn. Since wastewater characteristics from fruit and vegetable processing operations vary widely throughout the production day, a single grab sample is of little value. If, on the other hand, numerous grab samples are collected and separately analyzed, temporal fluctuations in the waste load will be revealed (figure III-1). This type of information is extremely useful, not only for determining (or which periods of the day the loads tend to peak, but also for calculating meaningful daily (or other period) averages. Automatic sampling equipments capable of collecting a series of discrete samples are commercially available.

## COMPOSITE SAMPLES

As previously indicated, laboratory results from numerous grab samples taken within a period of time can be used to calculate meaningful averages for that time interval. However, this procedure for obtaining daily (or other) averages places a heavy burden on laboratory personnel. To minimize laboratory efforts while obtaining meaningful data, a single sample may be used by combining numerous discrete subsamples or aliquots. Such samples are referred to as composites. Composite samples will yield excellent average values, but cannot reveal peak and low data points within a specified temporal interval (figure III-1).

Composite samples can be readily obtained by merely collecting a containerful of wastewater at regular intervals. For example, a half-liter sample can be obtained each hour over a 24-hour period, thereby resulting in a composite sample of approximately 3 gallons. Laboratory results obtained by analyzing a single sample collected by this procedure, which can be referred to as fixed time-fixed volume ($T_F V_F$), will closely approximate the average obtained by individual analysis of each aliquot. Relatively inexpensive devices are available to automatically collect $T_F V_F$ composite samples. This procedure is quite satisfactory for nonfluctuating flows.

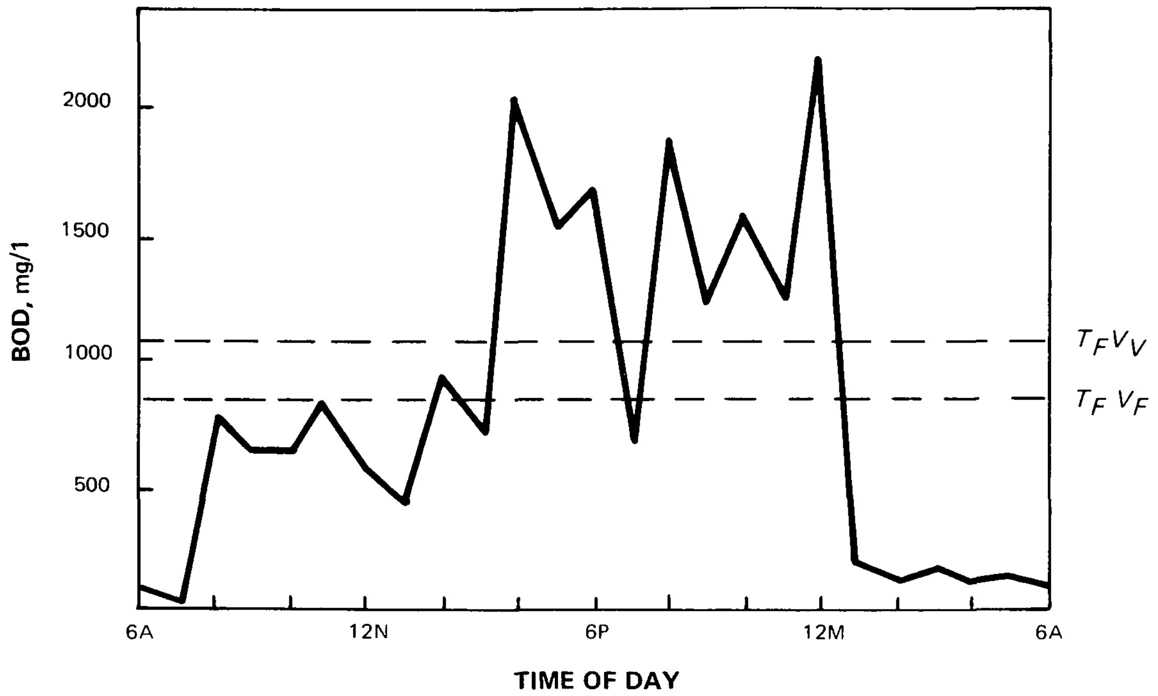


Figure III-1. Temporal fluctuations in a food plant waste load.

When discharge flows fluctuate widely, a single aliquot in a $T_F V_F$ composite may lead to a misinterpretation of the composite sample analysis. To minimize the effect of an individual aliquot, flow-proportioned aliquots are taken. For example, when aliquots are collected once per hour, the volume should be adjusted according to the flow rate at that time (1 liter at 1000 gpm, 250 ml at 250 gpm, etc.). This may be referred to as the fixed time-variable volume ($T_F V_V$) procedure. This procedure (for which a few automatic sampling devices are available) will yield laboratory results in close agreement with those obtained by the method explained in the next paragraph.

Best results short of continuous on-line analysis are obtained by analyzing samples composited on a "per unit flow" basis, which is a composite consisting of aliquots, each of which represents a unit volume of discharge (e.g., per 1000 gallons). Automatic sampling equipment operated in conjunction with various accurate flow-measuring devices are available for this purpose. These samplers obtain an aliquot of fixed volume for every 1000 gallons (or other unit) of wastewater discharged ($T_V V_F$). Thus, representative samples are obtained regardless of wide fluctuations in the discharge rate.

## SAMPLE STORAGE

Since organic matter in wastewaters can degrade rapidly, it is important to analyze samples as quickly as possible to assure sample integrity and valid results. Analysis of composite samples, by the nature of collection procedures, must inevitably be delayed. Therefore, these samples must be iced or held under refrigeration during compositing and up to the time laboratory analyses can be performed. When unavoidable prolonged delays are anticipated, other preservation techniques should be followed. These are discussed in greater detail in volume 2 of this series, in the *Handbook for Monitoring Industrial Wastewater*[1], and in *Methods for Chemical Analysis of Water and Wastes*[3].

# Chapter IV

# CASE HISTORIES

This chapter contains several case histories which illustrate what can and has been done both inside and outside the processing plant. In many instances, these case histories are examples of what was discussed in the first three chapters.

Some of the measures taken by the processors may, at first, not seem to be economical in themselves. However, when compared with the cost of constructing a waste treatment system, the steps taken inside the plant may be a most attractive alternative.

The case histories involve a variety of products and techniques. Examples are cited which reduce pollution, reclaim and recycle water, effect in-plant process modifications, reclaim valuable by-products, segregate and separate treatment of individual waste streams, and safely dispose of solid residuals.

## ENVIRONMENTAL MOTIVATION*

Top management alone makes the decision, "It is important. Let's do it." Top management must let everyone down below know exactly what is to be done and see that it gets done. It's the only thing that makes good safety and environmental programs. It does not start from the bottom and work its way up, but rather starts from the top and works all the way down or it does not work at all. What exactly happens in top management to get one of these shows on the road? First, you or somebody gets top management's attention. Sometimes with a club or something slightly more subtle, like a trip to the D.A.'s office, or a fine and a threat from some regulatory agency to close the plant. Something subtle like that.

When the preceding occurs, what is the thought process that causes top management to get with it? It is money. It is the fear of losing money. If this fear is great enough, money will be spent to overcome the potential loss, providing top management thinks the books will still balance after it is all over with. Otherwise, you close the plant and look for something else.

Are the environmental accomplishments in industry in direct proportion to the degree that top management fears financial loss, due to regulatory actions? I think so.

Look at environmental noise. About three years ago, most of us, at least in top management, knew very little about noise. That was someone else's problem in the engineering department. Then came OSHA. Did we learn in a hurry! See what I mean?

We had a big problem with acoustical surfaces being compatible as sanitary surfaces. We knew of no answers, but we were highly motivated and we found them. Most of us know that the 90 decibel level is just a place to catch our breath. We better darn well be forging toward an 85 decibel level because that's next. And we will do it for the same reason most of us are down to 90 now.

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**Mr. Granville Perkins - Artichoke Industries, Inc., Castroville, California*

It is amazing as we glance back for a moment how practical and innovative we have been. We just started working really hard on environmental noise in the industry a little while ago, and we started from a dead stop.

Our accomplishments are not due to the relative amount of knowledge and expertise in an environmental area. For example, we've known a lot about wastewater management and treatment for a long time. The fruit and vegetable processing industry has made some worthwhile accomplishments, but when measured against what kind of knowledge is available and what has to be done, many of us have not measured up very well.

Our in-plant environmental programs would be as good as most of our safety programs, if we had been motivated as we were by our Workmen's Compensation Insurance premiums. We all recognize the futile waste and the pain of a serious accident. But believe me, a high experience modification rating gets a lot of attention.

My message to you is very simple. It requires the involvement of top management to make these programs work. What is your company's environmental motivation?

Over at Artichoke Industries, we have been just as typical as anyone. We think we have a good record in safety. It was not always so. We think we have a good record in many of our environmental efforts. It was not that way in the beginning. We started just about at the bottom. It has been a long, hard, expensive way up. But it has been worth it, because halfway up we discovered that we were saving money, saving more money that we were spending. That really gets to top management.

We have proven this, time and again, and have preached about wastewater management and in-plant modification. We now believe it is true in some other areas. Perhaps safety engineers should concentrate on noise as a contributing cause of industrial accidents as much as they are preoccupying themselves with the critical day concept of the biorhythm theory.

Let's look at some profit for environmental programs. We need an experience modification to promote our environmental task, and saving money might just as well be it. I am not suggesting that we forget over-taxation and over-regulation, but while we are attempting to survive these burdens, there are some positive economic advantages in upgrading our work place environment.

None of us will deny that we have all contributed to various forms of environmental pollution. We agree that we have a moral obligation to clean it up. But it does cost money. If it is accepted that we must do it, we say it can be done profitably. How? Because you cannot afford to do what you're doing now. You cannot afford to treat it or quiet it; you have got to reduce it.

Our cost of energy is going up, up and up. It costs a great deal less to treat one fourth as much water at the same level of pollution. The same is true of noise and air pollution recovery systems. Don't put it up there and you won't have to get it back down.

The cheapest control measures available and the most effective usually attack the environmental problem right at its source, be it water, air or noise.

Now, I have just shared with you something you already knew, haven't I? The point is, I think it would be well for you to think about environmental motivation as it affects what you do and how you do it.

## CASE HISTORY I

## WASTEWATER TREATMENT AT ARTICHOKE INDUSTRIES 1955 - 1975*

Artichoke Industries is located in Castroville, a town of 4000 people near Salinas. The town's major industries are two food processing plants and several fresh produce shippers. Wastewaters resulting from these plants are discharged to the Castroville treatment facility which has a capacity of 800,000 gallons per day.

Artichoke Industries supports fresh artichoke shippers by converting small unmarketable artichokes into marinated and frozen artichoke hearts. The processing season covers twelve months of the year with peaks in the spring and fall.

In 1955, Artichoke Industries contributed approximately 100,000 gallons per day (gpd) of wastewater to the treatment plant. In the following 3 years, while artichoke tonnage increased five times, wastewater discharge rose to over 400,000 gpd. Concern over this large amount of water was secondary to production problems. Meanwhile, the Castroville treatment facility increased its capacity from 800,000 gallons to over 1,000,000 gallons. During these years the frequency of visits and telephone calls by the Sanitation District increased logarithmically. Sanitation officials were concerned that one morning they would find their plant in the ocean. Eventually, they managed to get Artichoke Industries' attention by threatening to fill the sewer line with concrete, unless action was taken to reduce the amount of water. Zero discharge way back in 1958! Impressive, isn't it? From then on, wastewater management became a part of doing business. At that point, water driven hydroughts were used to trim artichokes which were then flumed with fresh water. This was thought to be the only way to slow enzymatic browning. Much of the solid waste (approximately 60% in trimming an artichoke) was conveyed by water in gutters.

An inventory of water usage was conducted and a program of water reuse and recycling was instituted. Water was reused as much as nine times prior to discharge. Over a period of 1 year, water usage was cut from 400,000 to 300,000 gpd. However, due to the increased contact time of water and solids, the BOD concentration increased dramatically from 1500 mg/l to 4000 mg/l. Further reductions in water use had to be made. In 1961, the water-driven hydroughts were replaced with mechanical trimming machines, designed to incorporate pneumatic separation of product and solid waste. Additionally, screw conveyors were installed to carry the solid waste to a hopper from where it is trucked to two dairies and used as cattle feed. Fog sprays now wet the product to slow down the browning. This modification resulted in a 100,000 gpd water reduction. Blanched artichoke hearts in the freezer production line, which up to now had been cooled in a flume system, were now conveyed on a wire mesh belt through an ice water cooling tank, where the water is screened and recirculated. Instead of using fresh water in the blancher to compensate for what is lost by steam and carried out with the product, excess cooling water resulting from the melted ice is pumped into the blancher.

In 1965, a wastewater ordinance was put into effect by the Castroville Public Works Advisory Committee limiting BOD, suspended solids, ether soluble materials and total flow. A base flow of 60,000 gpd was established for Artichoke Indstries. For a fee, additional capacity could be purchased, if available. Total wastewater discharge at that time was still 120,000 gpd. In an effort

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*Mr. Peter Luthi - Artichoke Industries, Inc., Castroville, California*

to comply with these regulations, Artichoke Industries hired a consulting engineer who recommended chemical precipitation. The facilities built included a 6000 gallon precipitation tank, a 60,000 gallon holding tank and a centrifuge to concentrate the sludge. After a year of operation, performance of this precipitation unit was still far below desired levels. It was concluded that such large quantities of water could not be handled satisfactorily by this method. In addition, the high pH of between 10 and 11 (which resulted from the addition of precipitation chemicals) caused solids settling problems in the Castroville treatment facilities clarification process. Therefore, precipitation was abandoned in 1969. Based on an analysis of the specific gravity of the suspended solids, it was concluded that floatation would be a more effective process. In 1970, the precipitator was modified into an air floatation tank. Realizing the large amount of water used for the sanitation clean-up, efforts were channeled in that direction.

With the system of screw conveyors available, it was possible to handle all solid waste dry. The broom and squeegee became the two most important tools. All solid waste is pushed into the screws before any water is used. Then a gate is opened on a screw conveyor and water and solids resulting from the clean-up operation pass over a vibratory separating screen which removes any solids from the water. Steam mixing units with quick shut-off valves were installed to prevent the waste of any water from unmanned hoses. This procedure, together with the installation of the new clean-up stations, saved an amazing 20,000 gpd.

Water usage in 1970 was between 45,000 and 60,000 gpd. Of course you realize that I have not mentioned all changes that were involved in reducing water use to this level. There have been many minor changes forgotten over the years.

In 1971, with the help of another consulting engineering firm, a systematic survey of the plant was conducted.

- First, a diagram of the wastewater system was drafted.
- This was followed up with a complete laboratory study of all wastewater streams.
- Discharge requirements were given consideration before deciding on a plan.

A new wastewater ordinance passed in 1974 now limits BOD and suspended solids discharge to 500 mg/l. A record of daily water discharge is required, and not more than 50 gpm may be discharged for 90% of the time with maximum peaks of 100 gpm for the remaining 10%. Continuous composite sampling is required and fees are calculated on a per lb. BOD, SS and per 1000 gallon basis.

As a result of the plant survey, it was decided to segregate wastewater into three separate streams.

- Low BOD waters resulting from container coolers are now discharged directly. With a BOD of between 50 and 80/mg/l, this water could not be improved by treatment. At the same time, the fan sprays that were used to cool the containers were replaced with fog sprays and large blowers to make use of the latent heat of evaporation. Approximately 14,000 gpd were saved with this step, and small glass containers can even be cooled without any additional water, using only the steam condensate on the jars and air.
- The second category is medium strength wastewater between 1000 and 1500 mg/l BOD resulting from clean-up. This water is passed over a 40 mesh screen and is then treated in the air flotation unit. A maximum of 40% BOD and SS reduction can be achieved with this system.

- High strength BOD water is the third category resulting almost exclusively from the blanching operation, in which vinegar or citric acid is used. Here, BOD is between 20,000 and 30,000 mg/l. In order to cut back on the volume, the blancher water in the marinated heart operation is wasted only every 5 days. Fresh water leaches solids out of the product being blanched. This mass transfer slows down as solids build up in the water. Also, weight loss of the product slows down. This system uses five times less water than the old practice of using fresh water in the blancher every day.

Secondary treatment was definitely needed to reduce BOD to an acceptable level. An extensive pilot study was conducted in 1972 comparing an anaerobic digestion and an activated sludge system. The activated sludge system with extended aeration achieving 90 to 97% BOD reduction was ultimately chosen as a permanent system. Medium strength water is used to dilute the high strength water approximately 5:1. Nitrogen and phosphorus have to be added to achieve the correct BOD : N : P ratio. The addition of storage tanks enables us to virtually treat 100% of the plant effluent during the low production season. Total discharge from our plant is now about 20,000 GPD.

In summary, I would like to review the guidelines that we have used for improving our wastewater system.

- Always keep water usage in mind when adding or changing process procedures.

- When possible, keep product and solid waste out of the water or minimize contact time as much as possible.

- Keep different wastewater streams segregated.

- Secondary biological treatment is time consuming and expensive. The smaller the volume, the cheaper the price. The cost of our treatment amortized over a 10-year period at 10% interest on the capital investment. Operating and maintenance cost is approximately 50¢ per 1000 gallons. Thus, the cost works out to be only about 25¢ per ton of raw product.

Biological treatment should really be called bioconversion treatment, which implies a conversion of pollutants into something else (mostly solid waste) which has to be dealt with subsequently and is itself a difficult problem. In our 2-year experience with biological treatment, we have run into several problems partly due to inefficient solids removal.

In closing, keep in mind that it required 17 years of continuous effort to establish this impressive record of increasing production tenfold and reducing wastewater by 95%.

## CASE HISTORY II

## IN-PLANT CONTROL OF WASTES AT RED WING*

When thinking or talking about pollution, I'm reminded of a story about two kids from a village out our way who are lying in the tall grass, beneath a tree, on a hill which overlooks a local factory. It's autumn and the sky is blue. Farmers are in the vineyards harvesting the crop and the factory is issuing forth clouds of white vapor. Grapes are becoming wine. The aroma of the grape is in the air. One kid turns to the other and says, "Isn't it great to live in a town so small that even the pollution smells good!"

With the PSC, FPC, FDA, EPA and DEC, we can no longer use small or smell as the criteria for pollution.

Pollution has many characteristics as follows:

- Oxygen depletion
- Sediments
- Color
- Taste and odors
- pH
- Toxicity
- Heat
- Nuisance factor and aesthetic factors
- Chemical exotics
- Radioactivity

It is true that "definitions" change with time, increased knowledge, and changes in administration. So stay abreast of rules and regulations set forth by DEC, EPA, etc. A few years ago the village discovered abruptly that it had an overloaded waste treatment plant. They had a problem as did we because we are a substantial contributor to their system. The village retained engineers to design a new plant, that contained adequate allowances for our plant based on continued growth over the years. Outfall sampling compared to present production was extended to allow for future production. The estimated cost was astronomical! At this time, we asked to become involved in selecting the design criteria for that part of the new plant affected by our operations. We were hoping for some other less costly alternatives.

Four major courses were clear:

1. We could isolate our sewers from the village and construct our own waste treatment system, or
2. Construct a partial pre-treatment plant and discharge wastes to the village, or
3. Curtail or eliminate some departments, or
4. Remain with the village and use part of the new system.

*Mr. Ralph W. Wilson *The Red Wing Company, Inc., Fredonia, New York*

We formed an "Industrial Waste Study Committee", which included people from the village, our factory, village engineers and our consulting engineers. Our goal was the economical and efficient elimination of stream and lake pollution in accordance with present and proposed EPA and DEC trends.

We used a two-fold approach as follows:

- We would work with local village officials, county and state health officers, and consulting engineers to obtain optimum waste treatment systems.
- We would involve ourselves with definitions and control of the variables involved, a consideration of alternatives and future plant operations.

The action steps taken included:

1. Meeting with local administrators.
2. Initiating "Industrial Waste Study Committee".
3. Setting up sampling programs.
4. Deciding how to coordinate the program.
5. Paying for sampling.
6. Setting up sampling procedure, including such things as:
    a. Establishing flow rates.
    b. Waste characteristics.
    c. Techniques of sampling.
    d. Establishing industrial to domestic ratios - BOD's, etc.
    e. Establishing industrial waste cycles.
    f. Establishing peaks and lows for treatment plant.

Next we had to:

7. Determine methods to handle waste.
8. Work to establish meaningful ordinances.
9. Negotiate a workable contract.

Early on, we rediscovered that resource conservation is a source of company profit, although it is not as well recognized as other principal sources of profits such as raw materials, human productivity, facilities and market resources. As previously mentioned, considerable sampling had been conducted on the plant outfalls during the survey by the village's engineer. However, little of the sampling data had been analyzed in relation to the company's production. Furthermore, those sampling results had been extrapolated according to water use trends and production in order to estimate loads for 25 years into the future. Sampling was again conducted around the clock and flow samples were composited proportional to flow, with analyses performed on individual samples generally covering 4 to 8-hour shifts (although single days were periodically broken down into hourly composites). The significance of this sampling, when related to plant production, is that it confirmed the need for in-plant sampling. Wastewater sampling data must be related to plant operation. With this relationship in mind, it is possible to estimate the effect of increased production on future wastewater discharges.

The wastewater analysis program at the Red Wing Company was divided into two parts:

- First, an extensive in-plant analysis was undertaken of individual process lines and the unit operation in each line. Sampling conducted under this part of the program was of many types—grab samples with measured flows, grab samples with estimated flows, samples composited by flow, and samples composited with time.

- Second, to confirm the reliability of this in-plant analysis, the total wastewater loads calculated from production records were compared against the results of a second sampling program on the control plant effluent.

Results of our wastewater analysis program have been dramatic and very encouraging. The following are some examples of cost reduction projects that were generated by our in-plant sampling program:

1. Purchase and install chiller on catsup pasteurizer for recycling of cooling water.

2. Purchase and install screening system for tomato wastes.

3. Purchase and install water chiller for starch cooking-cooling system.

4. Purchase and install conveyors for pulping wastes (tomato and grape).

5. Provide for collection and re-processing of tomato products washup.

6. Provide for collection and disposal of preserve and jelly cleanup.

7. Programming of production schedules to reduce washups.

8. Pre-treatment and filtering of wash water from tank cleanups.

9. Provide a recycle system for compressor seal water to cold room defrost and back to seal water (recycled BTU's as well).

10. Pressurize recycle systems to compete with city water pressure.

11. Application and approval for permit to discharge.

12. Install solenoid valves, as a standard practice, on makeup, seal water, cooling water, and other systems which operate intermittently.

13. Pick up and shovel up—don't hose down!

14. Use cleaners that tend to neutralize your process. For tomato process, use caustic, not chlorides!

15. Provide separate recycle system for #4 refrigeration compressor and for cold rooms 1, 2, and 3.

16. Provide separate recycle system for #4 tank room defrost operation and for cold rooms 1, 2, and 3.

17. Provide recycle system for cookroom vacuum pump seal water.

18. Recycle cooling water from Cochrane Becker pumps.

19. Pipe spent cooling water from Joy compressor as makeup for defrost.

20. Install cooling tower for grape juice heat exchangers.

21. Send distilled water from essence unit to defrost, then to no-name creek.

22. Better control of overflow on #1 and #2 J&J pasteurizers.

23. Rapid repears on hoses, valves and fittings.

24. Standardize on pistol grip nozzles.

25. Eliminate slug loads.

The results have been encouraging, for it is now possible to accurately predict industrial wastewater discharge loading for a particular day. In addition, it is now known which production operations will result in large waste loadings and which operations do not. By knowing the individual flows that do attend each process, it is possible to recognize when processing personnel become careless and discharge more than is necessary for a given unit operation.

The plant engineering department has also worked very closely with the sales and production departments of the company to develop a production schedule that eliminates the peaks in wastewater discharge, while at the same time reducing the absolute quantity of waste discharge. This is possible because many of the wastewater discharges result from individual process lines and equipment washups. When equipment washups are eliminated, wastewater load goes down. The improved production scheduling system, called the "Rajat Plan" (after the business administration student who developed it), breaks down the plant operations in the jams and jelly department into a 32-day cycle of product manufacturing sequences. This incorporates four 8-day subcycles. Following this system, it has been possible to cut weekly discharges by hundreds of thousands of gallons in flow and by tons of BOD and suspended solids. As a result, production efficiency has increased, while saving thousands of dollars. Before the plan, there were 25 departmental washups per week as opposed to 10 per week now. This has produced $75 of product saved per washup and $200 in labor cost per washup.

Another in-house procedure that has resulted in great reductions of waste loading is in the catsup process lines. Prior to the waste analysis program, lines and tanks were flushed to the city sewer at the end of the production run. Analysis has shown that even after hundreds of gallons of wash water have passed through the system, the "wash water" still contains a much higher solids content than that of the original raw material. This is due to the concentration that occurs in evaporating tomatoes. By diverting the initial wash water to refrigerated storage vessels and recycling it into the next production run, the Red Wing Company has increased product yield. The savings amounts to $100 per day, while keeping 500 lbs of BOD out of the sewers.

In addition to the range savings accomplished because of in-house cleanup, as well as reduction in wastewater discharge through production scheduling, the company has been able to substantially revise the design loads for the new municipal wastewater treatment plant. The major strength in this program of "resource conservation through waste analysis" is that the responsibility for improvement is spread over hundreds of employees. Each departmental manager, foreman, and machine operator has the opportunity and responsibility for improving operating practices, upgrading equipment, improving maintenance, and taking other measures necessary to minimize the amount of waste discharged into the sewers. Many of the techniques have initial capital costs, but these costs are often repaid several fold over a very short period of time. This was the case in our "Rajat Plan". The development of resource conservation is indeed helping us to increase profits at the Red Wing Company.

# CASE HISTORY III

## WATER POLLUTION CONTROL – FRITO-LAY, INC.*

### INTRODUCTION

During the last three years, Frito-Lay, Inc. has been engaged in a study to develop the technology required to pretreat its wastewater. That portion of the study concerned with suspended solids removal is presented below.

### BACKGROUND INFORMATION

Frito-Lay, Inc. markets approximately 90 different snack foods. Most of these are manufactured by Frito-Lay, Inc. in nearly 40 manufacturing locations. Of the snack foods produced, only three utilize water in their manufacture: Lay's® brand potato chips, Fritos® brand corn chips, and Doritos® brand tortilla chips.

#### Potato Chips

In production of potato chips, the potatoes (either clean or covered with farm soil) are delivered by truck or rail car and placed into raw material storage. They are then taken from storage and conveyed to a degritter/destoner. The destoner removes the majority of dirt, sand, and bits of rock which come in with unwashed potatoes. After the potatoes have been initially washed, they go to a peeler which abrasively removes the outer skin. From the peelers, the potatoes move along the production line where they are inspected for quality, raised in a vertical lift, and conveyed to the slicer. The potato slices then drop into a washer which removes the starch and sugar clinging to the surface. From there, the potato slices are rinsed, fried, and packaged.

#### Corn Chips

In the corn chip production process, a special mixture of corn is cooked, steeped, and washed. The corn is then milled for frying. The chip is fried, salted, and packaged.

#### Tortilla Chips

In tortilla chip process, the corn is cooked, steeped, washed, and milled as in corn chips. Dough from the mill is pressed into a triangular shape and fried. Salt and necessary flavorings are added prior to packaging.

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*Mr. William F. Priebe - Frito-Lay, Inc., Irving, Texas

## HISTORY

Until recently, the company's basic philosophy of disposal of water-borne waste was to purchase these services from municipalities, since they could handle the effluent more efficiently than Frito-Lay, Inc. In light of this approach, the company located plants in or near municipalities which had adequate treatment facilities.

Several events occurred which caused a basic change in this philosophy. One was the passage of the 1972 water pollution act which included provisions opening the door for substantial increases in sewage rates. Another was the fact that some of the municipal treatment plants had become inadequate to handle the demands placed upon them by the city's growth.

In many of the smaller communities where the problem was most acute, we were significant contributors. In these communities, we were faced with both moral and economic incentives to ease the burdon on local treatment plants. A good example was Irving, Texas, where one of the company's plants is located. The lagoon system, operated by the Trinity River Authority (TRA), had become overloaded due to rapid growth of the city of Irving. Frito-Lay was requested to aid in solving the problem. After exploring various alternatives, it became evident that the best solution was to provide pretreatment at our Irving facility easing the waste burden to the TRA plant. At this time, the company had basically no technology which would make pretreatment possible. In order to allow time to develop the needed technology, liquid cyclones and screens were temporarily installed on processing lines. A program was immediately initiated within Frito-Lay to develop more satisfactory wastewater treatment systems.

## DETERMINATION OF A BASIC APPROACH

There were two basic approaches as follows:

- One, develop a system which combined all effluent into a single stream, treat and dump it into the city sewer.
- Two, to separate the various waste streams allowing recovery of valuable by-products and reuse of some of the wastewater.

Even though the latter solution required a larger capital expenditure, the potential return on investment of the divided flow system influenced the company to orient its research in this direction.

In dividing flows, it became a matter of choosing which flows carried the greatest possibility of by-product recovery. It was decided to split the stream from the plant into three wastewater flows—potato preparation water, the potato chip slice wash water, and the corn wash from both tortilla chips and corn chips. The potato preparation water contained potato peels which had value as animal feed. The potato chip slice wash contained potato starch, and the corn wash contained corn fibers, protein, and corn starch which had use as animal feed.

## CHARACTERIZATION OF WASTE

The first step in developing pretreatment was to characterize the wastewaters. It became immediately evident that the high concentration of suspended solids in each waste stream was partially responsible for the high BOD. If the suspended solids could be removed, it would remove large quantities of BOD.

The first stream to be characterized was the potato preparation water. The potato preparation area consisted of washing, peeling, and rinsing operations. The operations generated about 90 gallons per minute of wastewater. The wastewater had moderate-to-high suspended solids, but somewhat lower BOD since most of the suspended solids were sand and soil (see table IV-1).

Table IV-1.—*Characterization of wastewater*

| Process | Flow gpm | SS mg/l | BOD mg/l |
|---|---|---|---|
| Potato preparation wastewater | 90 | 2000 | 1100 |
| Potato chip slice wash | 100 | 2900 | 2200 |
| Tortilla/corn chip wash water | 200 | 2800 | 3600 |

The potato chip slice wash was the second stream to be characterized. This was starchy water with high BOD and suspended solids. The material in the water was made primarily of the potato starch granuals released during the slicing process. The BOD, suspended solids, and flow values are given in table IV-1.

The third waste stream to be characterized was the corn water generated by the corn chip and tortilla chip process. This water had a fairly high pH and consisted primarily of products of corn degenerating during the cooking process (gelatinized starch, the germ and cellulose). This waste was characterized by extremely high BOD and suspended solids. The BOD was also different in nature from the potato streams in that the starch was typically gelatinized which made it much more soluble and the suspended solids had a gelatin-like consistency. The BOD, suspended solids, and flow values are also shown in table IV-1.

## PILOT TREATMENT STUDIES

From waste characterization data, the decision was made to concentrate initial efforts on suspended solids removal. Based on laboratory tests, two pieces of equipment were leased for testing at the Irving plant. The equipment consisted of a settling basin for the potato processing streams and a flotation unit for the corn processing stream.

### Potato Preparation Water

Laboratory studies indicated that with the addition of alum and an anionic polymer, the suspended solids could be reduced 90% by settling. A lamella type settling basin was used to pilot test the lab results because of space limitations. The results, shown in table IV-2, indicated greater than 90% removal of suspended solids and greater than 50% removal of BOD.

### Potato Chip Slice Wash

The laboratory studies indicated that the slice wash suspended solids would settle although no suitable flocculents were found. The lamella type clarifier, when used, reduced suspended solids over 90% (table IV-2), and the BOD by over 75%. The starch removed by the clarifier was found to be marketable.

Table IV-2.—*Pilot test results*

| Process | Parameter | Influent | Effluent | % Removal |
|---|---|---|---|---|
| Potato preparation water clarifier | Flow | 90 gpm | | |
| | SS | 2000 mg/l | 150 mg/l | 92 |
| | BOD | 1100 mg/l | 520 mg/l | 53 |
| Potato slice wash clarifier | Flow | 100 gpm | | |
| | SS | 2900 mg/l | 200 mg/l | 93 |
| | BOD | 2200 mg/l | 500 mg/l | 77 |
| Corn wash flotation unit | Flow | 200 gpm | | |
| | SS | 2800 mg/l | 400 mg/l | 86 |
| | BOD | 3600 mg/l | 2200 mg/l | 39 |

### Corn Wash

Also based on lab studies, a pilot scale flotation unit was leased for testing on the corn wash. The flotation unit was equipped with lamella plates to decrease the Reynold's Number. Over 85% of the suspended solids were removed (table IV-2) and almost 40% of the BOD.

## FINAL INSTALLATION

The treatment schemes shown in figures IV-1, IV-2, and IV-3 were the ones used in the final design. Because of the company's intention to conserve water by means of recycle after pretreatment and to sell the by-products, all chemicals used had to be potable water or food grade and all equipment had to be made of either plastic or stainless steel.

### Potato Preparation Water

The water from the potato preparation area was taken to the wastewater treatment room where it was screened to remove the peels. Chemicals were added for flocculation and the solids were settled in a lamella clarifier. Some of the overflow was recycled back to the peelers. The remaining water was discharged. The sludge from the clarifier was dewatered, mixed with other sludge from the treatment plant and sold. The final installation failed to give the anticipated effluent quality (table IV-3). A surging problem caused by an oversized pump caused some of the lighter particles to remain suspended. A replacement pump is scheduled to rectify the problem.

### Potato Chip Slice Wash

The water from the slice washers was taken to the waste treatment room where the slices and slivers were screened. The water was then settled in a lamella type clarifier. Part of the overflow was returned to the vertical lifts; the rest was discharged. The underflow was collected and sold as potato starch.

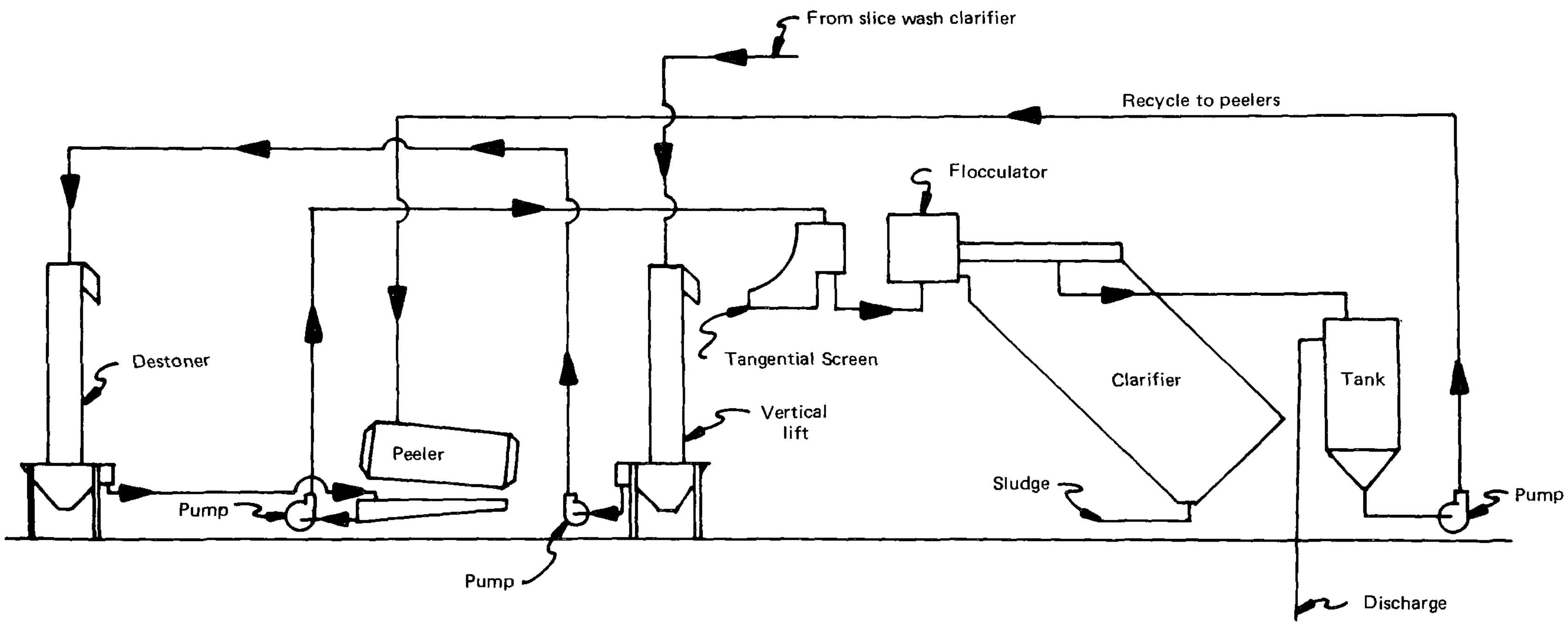


Figure IV-1. Treatment scheme for potato preparation water with recycle.

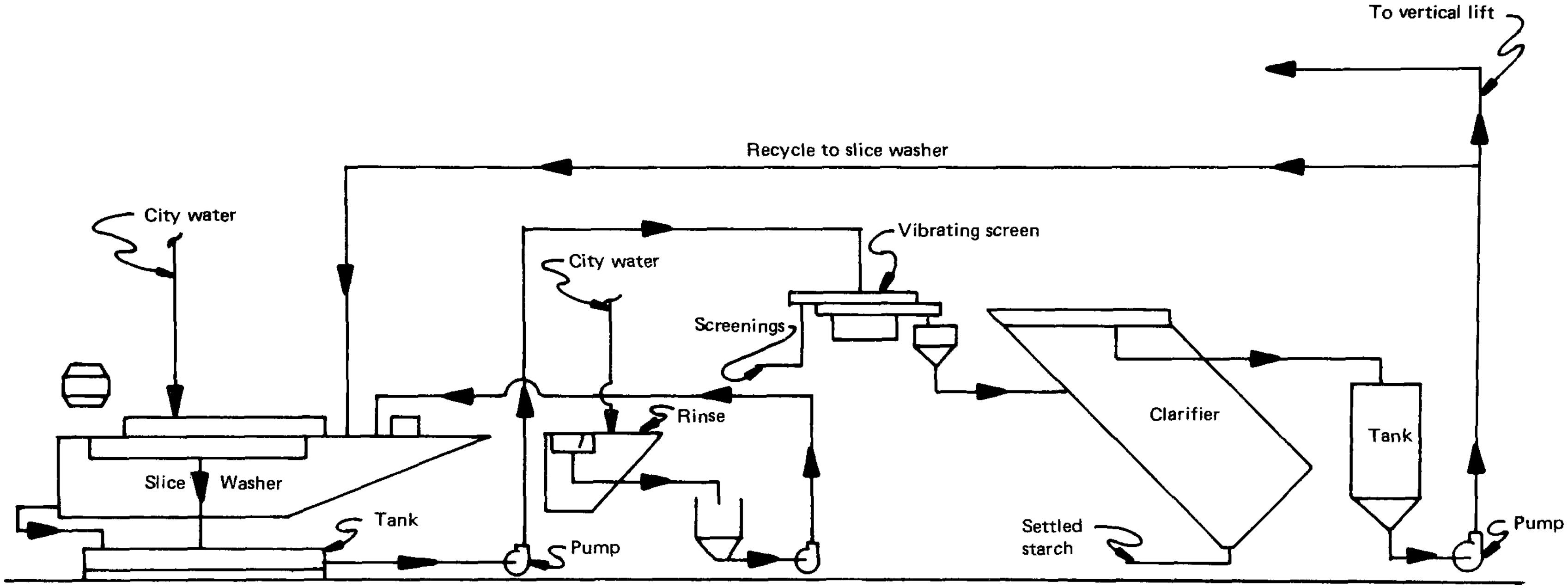


Figure IV-2. Treatment scheme for potato chip slice wash water with recycle.

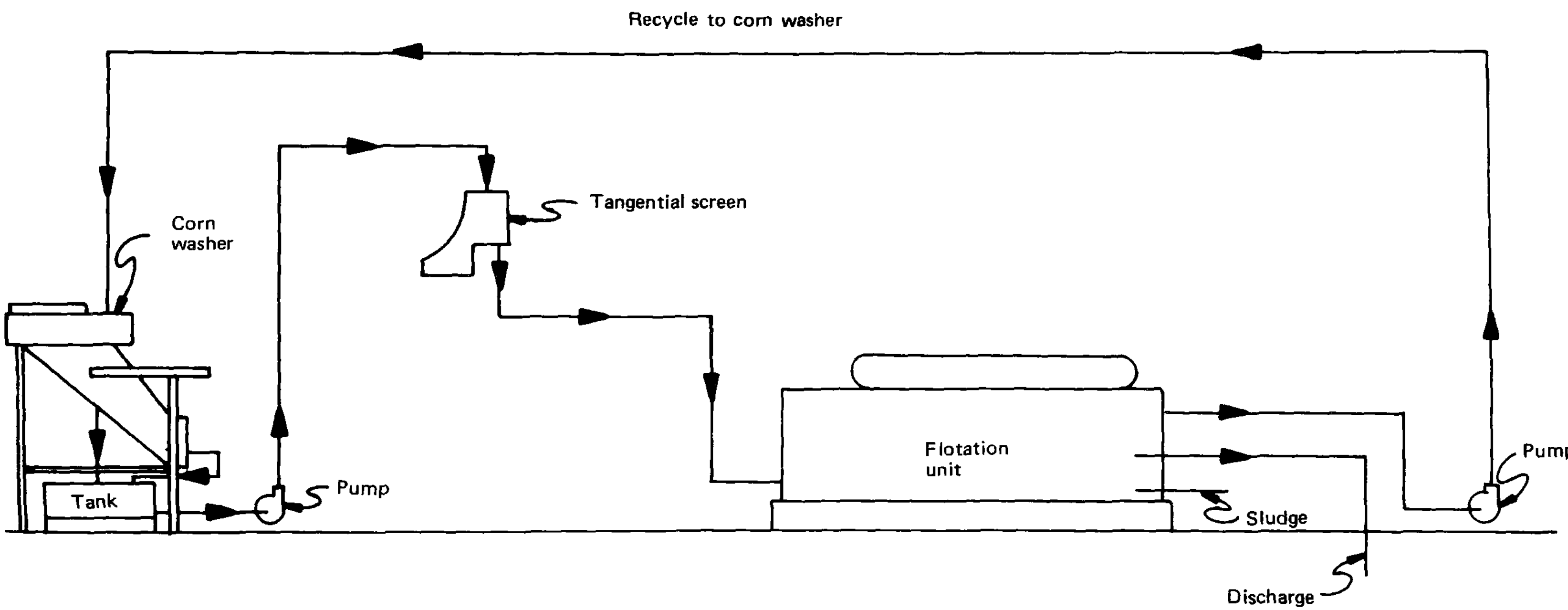


Figure IV-3. Treatment scheme for corn wash water with recycle.

Table IV-3.—*Results from full scale installation*

| Process | Test | Anticipated effluent | Actual effluent |
|---|---|---|---|
| Potato preparation water clarifier | SS<br>BOD<br>Flow | 150 mg/l<br>520 mg/l<br>90 gpm | 370 mg/l<br>400 mg/l<br>90 gpm |
| Potato slice wash clarifier | SS<br>BOD<br>Flow | 200 mg/l<br>500 mg/l<br>100 gpm | 281 mg/l<br>640 mg/l<br>170 gpm |
| Corn wash flotation unit | SS<br>BOD<br>Flow | 400 mg/l<br>2100 mg/l<br>200 gpm | 420 mg/l<br>1200 mg/l<br>200 gpm |

The BOD and suspended solids in the overflow from the clarifier were slightly higher than expected (table IV-3). Since the pilot testing, installation of a new slice washer caused the flow to increase by 70%, overloading the clarifier.

### Corn Wash Water

The corn wash water was screened in the wastewater treatment room. After chemical addition, it entered the flotation unit. Part of the underflow from the flotation unit was recycled back to the corn washers and the rest was discharged. The sludge was combined with the potato preparation sludge, dewatered and sold as animal feed. The flotation unit performed as expected in suspended solids removal, but did substantially better in BOD removal (table IV-3).

## INSTALLATION ANALYSIS

The final installation accomplishes the objectives of the Frito-Lay pretreatment study. Suspended solids have been reduced to levels slightly above predicted values. BOD has been reduced to less than anticipated concentrations. Fifty percent recycle has been achieved thus far. Investigation is still in progress to determine where recycle can be increased. The sludge from the potato preparation clarifier and flotation unit is being sold as animal feed and the slice wash clarifier underflow has been processed into edible potato starch. Data from the installation indicates that the effluent from plants processing potato chips, corn chips, or tortilla chips can be successfully pretreated with the systems described.

# CASE HISTORY IV

## IN-PLANT CONTROL TECHNOLOGY FOR A CARROT PROCESSOR*

Plant "A" processes frozen carrots. The plant operates on a typical schedule of 5 days per week, 10 to 11 months each year. Normal production is set for two shifts per day with additional cleanup time as needed. Average throughput is approximately 8 raw tons per hour.

Figure IV-4 is a flow diagram of this plant's operation prior to 1974. As shown, the manufacturing processes were quite typical. Carrots were delivered in bins either directly from the field or from a fresh sorting shed. They were washed, trimmed, conventionally lye peeled and diced or sliced. Blanching was accomplished by means of a water blancher; post blanch cooling was by water. Water usage was high with a daily average approaching 1.5 mgd. BOD levels were similarly high averaging about 2400 mg/l.

This plant, landlocked by city growth, was already paying a surcharge for its effluent disposal, but the city, recognizing that expansion was needed for industrial users, initiated discussions for a revised surcharge system. The tentative proposed surcharge formulae indicated that if this system was adopted, monthly discharge rates would approach $4,000.

At this point, corporate management decided to institute changes in the form of capital investments. The engineers, when designing modifications, considered each waste-contributing point within the processing sequence. Figure IV-5 shows the results of these efforts, while table IV-4 shows the benefits.

### CARROT WASHING

Water used to wash the incoming carrots had previously been combined with the main plant effluent stream. However, observation and testing of this stream indicated that its chief components were sand and dirt, some field debris, and occasional carrot particles. Because of the plant's location, they decided to isolate this stream from the higher concentration waste streams and discharge it separately under NPDES permit. A double screening system was installed to effectively remove the various solid particles from the waste stream. This not only lowered the suspended and settleable solids but also, in part, contributed to reduced BOD discharge. Freezer defrost water was also diverted to merge with this stream.

The effect of this separation should not be underestimated. These two components are responsible for approximately 60% of the total plant flow or about 350,000 gallons per day. The alternative discharge of this large volume of water to a city sewer system would have been extremely expensive.

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*Mr. Kenneth V. LaConde and Mr. Curtis J. Schmidt — SCS Engineers, Long Beach, California

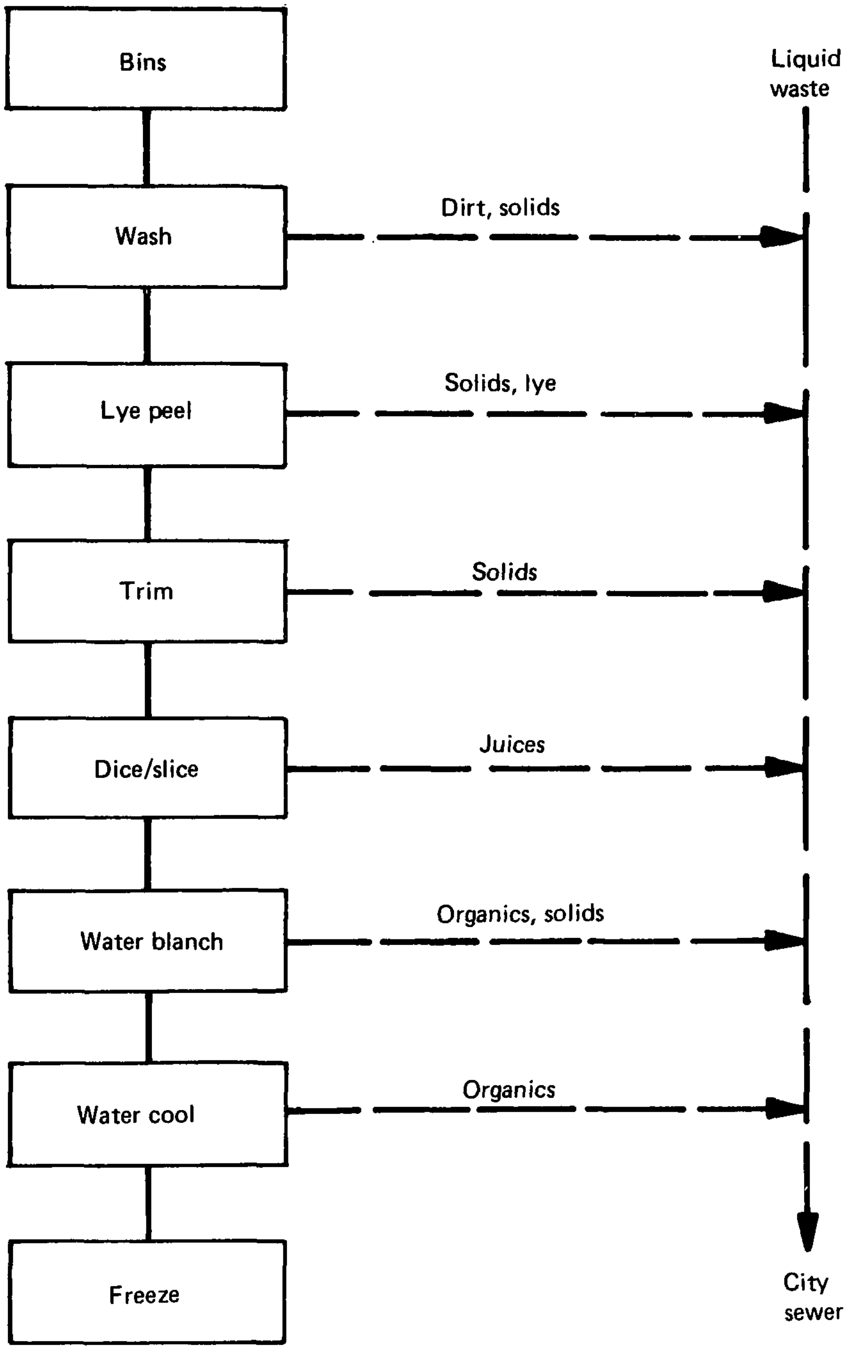


Figure IV-4. Original flow, carrot processor "A".

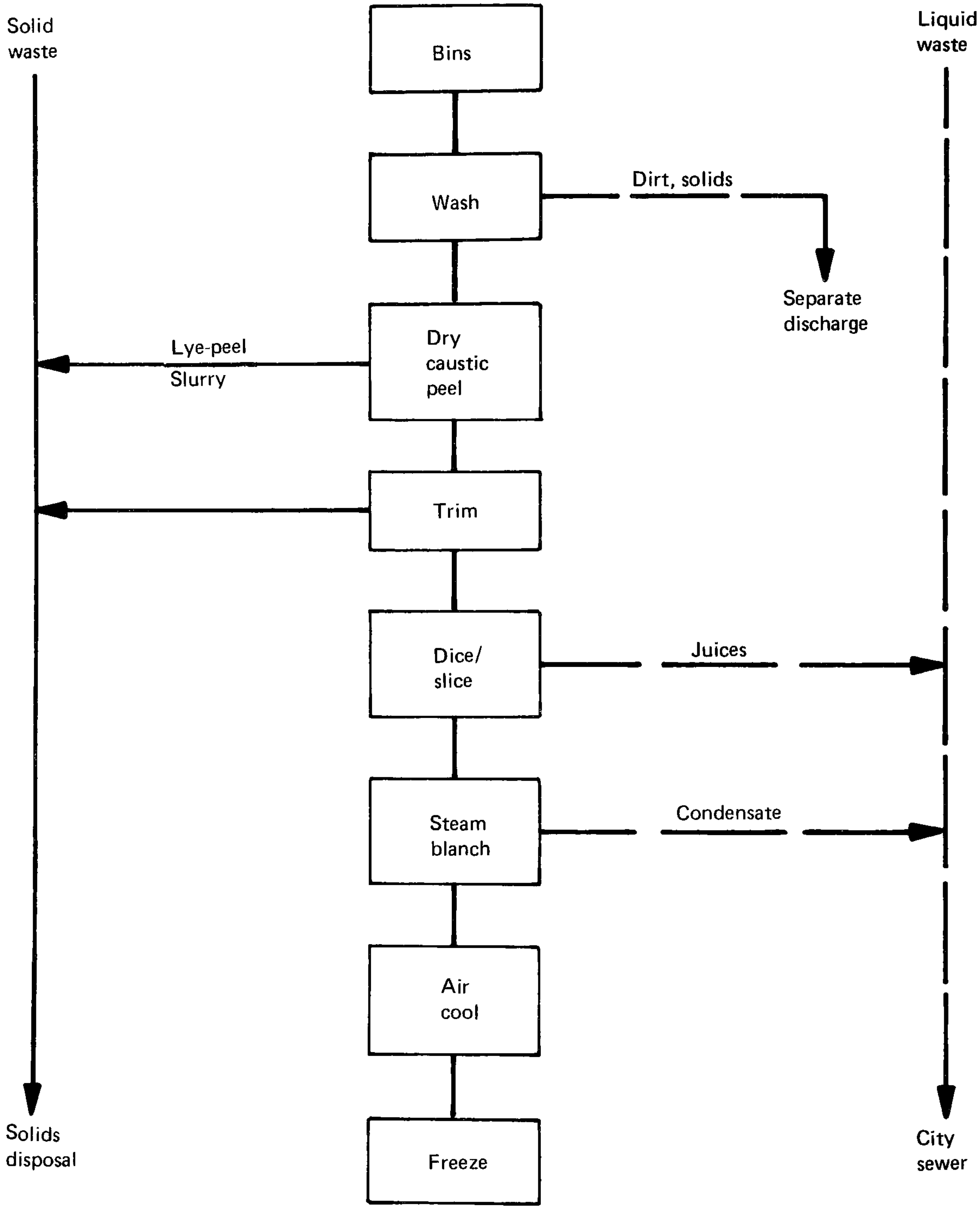


Figure IV-5. Modified flow, carrot processor "A"

Table IV-4. – *Carrot process "A", parameter differences*

| Parameter | Before | After |
|---|---|---|
| Flow (mgd) | 1.5 | 0.6[a] |
| Flow ratio (gal/ton) | 9375 | 3750 |
| BOD (mg/l) | 2400 | 1600 |
| Sliced recovery (%) | 50 | 62 |
| Diced recovery (%) | 65 | 72 |
| Monthly surcharge ($) | 4000* | 500 |

*Estimated

[a]0.35 mgd discharged under NPDES permit, 0.25 mgd to city.

## PEELING

The peeling process was identified as the main source of BOD and SS generation. The water required for peel removal was a substantial percentage of the plant's total effluent. A new lye peeler (ferris wheel type) was purchased and installed. The conventional, high-pressure water, lye peel removal system was replaced with a Magnuscrubber. The resultant peel waste slurry was pumped directly to a holding tank. Ultimate disposal of this waste fraction is to a sanitary land-fill. Note in table IV-4 that in addition to the expected water usage and BOD reductions, finished product recoveries increased for both sliced and diced. These increased yields are a direct result of the new peel removal system. Although numbers were not available, the plant personnel were also aware of a reduction in lye consumption.

## DRY SOLIDS HANDLING

The plant engineers recognized that every attempt should be made to stop the introduction of solid wastes into the effluent stream. The original plant flow allowed for trimmings and solid waste to be flushed into gutters with final screening before discharge to the city sewer system. This allowed for additional leaching of soluble solids and was, in part, responsible for the plant's high BOD. To overcome this problem, a separate series of dry solids conveyors were installed to transport trimming table and other wastes directly to outside waste bins. Further, a concerted effort was made by management to instruct plant employees on proper methods of solid waste handling.

## BLANCHING

As shown in figure IV-4, a hot water blancher had been used over the years. Enzyme deactivation and product quality met the necessary criteria for continued use. Water blanchers, however, have been shown to be a major source of water pollution. The action of solids leaching, continuous spillage and overflow contribute heavily to a plant's BOD and SS loads. The waste stream is not only concentrated, but is of substantial volume. The old water blancher was removed and a steam blancher was installed. The only effluent from this unit process is a highly concentrated 1-2 gpm condensate. The effect on total BOD and SS load has been considerably lessened, while maintaining desirable product quality characteristics.

## COOLING

Similarly, post blanch hydrocooling, which is necessary to prepare carrots for freezing and to optimize freezer efficiencies, was determined to be a contributor to the plant's effluent load. Total elimination of the flow was the objective. The conventional hydrocooling system was replaced with an ambient air cooler. Working on a fluidized bed principle, the product exits the blancher and is blown and vibrated over perforated screens by the action of air jets blowing through and upward to contact the product. The action of the air and the mechanical vibrations of the screen move the product across the screen during which the required cooling gradient is achieved. The use of air eliminates almost all water contact after blanching, with the exception of one or two fine water sprays between the blancher and cooler. Water usage at this stage was estimated at no more than 2 gallons per minute.

## CAPITAL INVESTMENT

The plant estimates their total expenditure for all the improvements and modifications to be approximately $90,000. Although no attempt was made to calculate paybacks on investment capital, it can be seen in table IV-4 that savings due to reduced discharged volume and pounds of pollutants to the city, amount to approximately $42,000 per year. If one were to add a monetary value to the increased yields, the investment looks even more attractive.

## WASTE MANAGEMENT

We have briefly reviewed the components of a revised, modified and updated carrot processor. We have alluded to an active management role and corporate confidence in terms of capital invested. One personal observation should be added at this point. All of the employees seemed to be cognizant of management's attempt to reduce both solid and liquid wastes. The plant was a model of cleanliness. They all appeared involved, concerned and willing to do their share to help management achieve its goals.

## CASE HISTORY V

## IN-PLANT WATER AND WASTE CONTROL*

To me there are two basic methods of in-plant water control:

1. Training of personnel.

2. Plant and equipment design technology.

The water used in each of these two methods can be categorized as cleanup water and process water.

Consider process water first since its method of conservation lies primarily in the plant and equipment design fields. Equipment manufacturers have made great strides in the construction and design of food processing machinery to facilitate minimum use of process water. This is being accomplished through cooperation and testing by the food processor.

At Stayton, we are continuously striving to design, construct, and purchase equipment which lends itself to pollution abatement. One such piece of equipment is the air cooler which has taken the place of water spray cooling and flume cooling in many areas. Stayton was one of the pioneers in this field and experimented with its first air cooler in 1969. Since then air coolers have become a commercially manufactured item and Stayton operates seven units at three of its plants. Water savings is estimated at about 87% in terms of volume. Another process currently being used at the Stayton plant is the dry lye peeling of carrots. This process results in less water being used but poses a problem of pH neutralization and utilization of the sludge being generated. We are now working with several organizations to find an effective means of developing this sludge into a useable by-product.

Isolation of receiving areas can also play an important part in water conservation. In many cases, large receiving areas are necessary to keep enough product on hand for optimum plant production. It is often economically feasible to divert runoff from these receiving areas to storm drains during winter months. It is not uncommon to find roof gutters and downspouts which discharge to process gutters in the plant. These should be relocated and/or rerouted to appropriate storm drain areas to eliminate treatment.

Cleanup and sanitation is of primary importance and concern to all food processors. Strict regulations imposed by FDA and USDA make it imperative that plants be clean and sanitary. How do we accomplish this? We use water. No matter how many conveyors are eliminated, no matter how many water saving devices are manufactured, they all have to be cleaned at regular intervals.

Many things can be implemented to reduce water consumption, such as trigger nozzles on cleanup hoses, dry collection of solids where possible, and the elimination of water as a conveying medium. In addition, high pressure, low volume cleanup systems are commercially available but these may be detrimental to bearings and paint on conveyors and equipment.

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*Mr. Joseph E. Cogar — Stayton Canning Company Cooperative, Stayton, Oregon

One of the most important methods of water reduction is a complete and comprehensive training program of everyone involved in production and sanitation. Nearly all plumbing and piping systems are over designed, i.e., pipes are usually selected at the next larger size to assure adequate volume to a piece of equipment. I don't know about other plants but I can seldom go into one of our plants and find a globe or gate valve 1/2 or 3/4 open. They're either open or closed. In most cases, this is unnecessary. One way to get an employee's attention is to point out that the water being used is being paid for twice: once to obtain it and once to get rid of it. Last year at our Salem plant, for instance, incoming water cost in excess of $8,000 with a proposed rate increase upcoming. Proposed sewer charges for the same plant are to be more than $120,000. The Stayton plant pays more than $35,000 per year for its water and about $160,000 for expansion of the spray irrigation disposal facilities.

In conclusion, it is hard to imagine a drastic overall reduction in water usage if food processors intend to keep pace with the growing population. The cost of treatment can come only from the consumer. However, the industry must make every effort possible to keep these costs at a minimum.

## CASE HISTORY VI

## HEAT RECOVERY AND WATER RECYCLE*

The Aunt Nellies company was faced with the problem of discharging hot, relatively clean can cooling and "cushion" water. The permit for its discharge called for the water not to exceed 89° F. The permit also had a BOD limitation which could not be exceeded, with few exceptions. Rather than simply install a cooling tower to remove the heat and then discharge the water, consideration was given to methods of using the heat and water to the company's advantage.

The first step was to take an inventory of in-plant operations which used hot water and to develop the necessary mass balances. Next was to develop the available sources of hot water and potential reuse sites, providing heat was removed and the water was re-chlorinated.

After several months of planning and gathering of the data, a system was designed to incorporate heat recovery and reuse of water from the retorts and cooler systems. A schematic of the system is indicated in figure IV-6. Temperature, volume and source of water are also given Values which indicate temperature changes, and to some extent the volume of water, are engineering estimates. The system is nearing completion and will soon be tested. From this test, some adjustments may be made in the temperatures or in the volumes of water. An 8000-gallon cooling canal was constructed to cool cans from the still retorts. Two 8000-gallon holding tanks were also constructed adjacent to the cooling canal. Some 1400 feet of 2-inch pipe was installed in the two holding tanks. Water from holding tank 1 overflows into tank 2. Excess cooling canal water also overflows into tank 2.

The sequence of operations, as depicted in figure IV-6, is as follows:

- The retort cooling water is collected and discharged into the first holding tank. This water comes from continuous cooker-coolers and is estimated to be 150° F at a rate of 400 gpm. Provisions have been made to divert from the system water less than 150° F.

- Water is withdrawn from the entrance of tank 1 and is pumped to the still retorts. This water is used to cushion the cans as the retorts are being filled. The temperature of this water is approximately 160° F. Once the retorts are filled, the water is returned to holding tank 1. The volume of this water is not recorded because equal quantities are removed and then returned to tank 1 for each cycle of operation. One purpose in returning the hot water back to tank 1 is to increase the temperature of water being pumped through the 2-inch coiled pipe.

- Water exiting from tank 2 will be approximately 120° F. This water will pass over a cooling tower at 500 gpm. It is expected that there will be a 40-degree drop in temperature, resulting in water being cooled to 80° F. The 500 gpm rate is a composite of the 400 gpm from the retorts and the 100 gpm from the cooling canal.

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*Mr. David D. Albright and Edwin F. Pleus – Aunt Nellies Foods, Clyman, Wisconsin

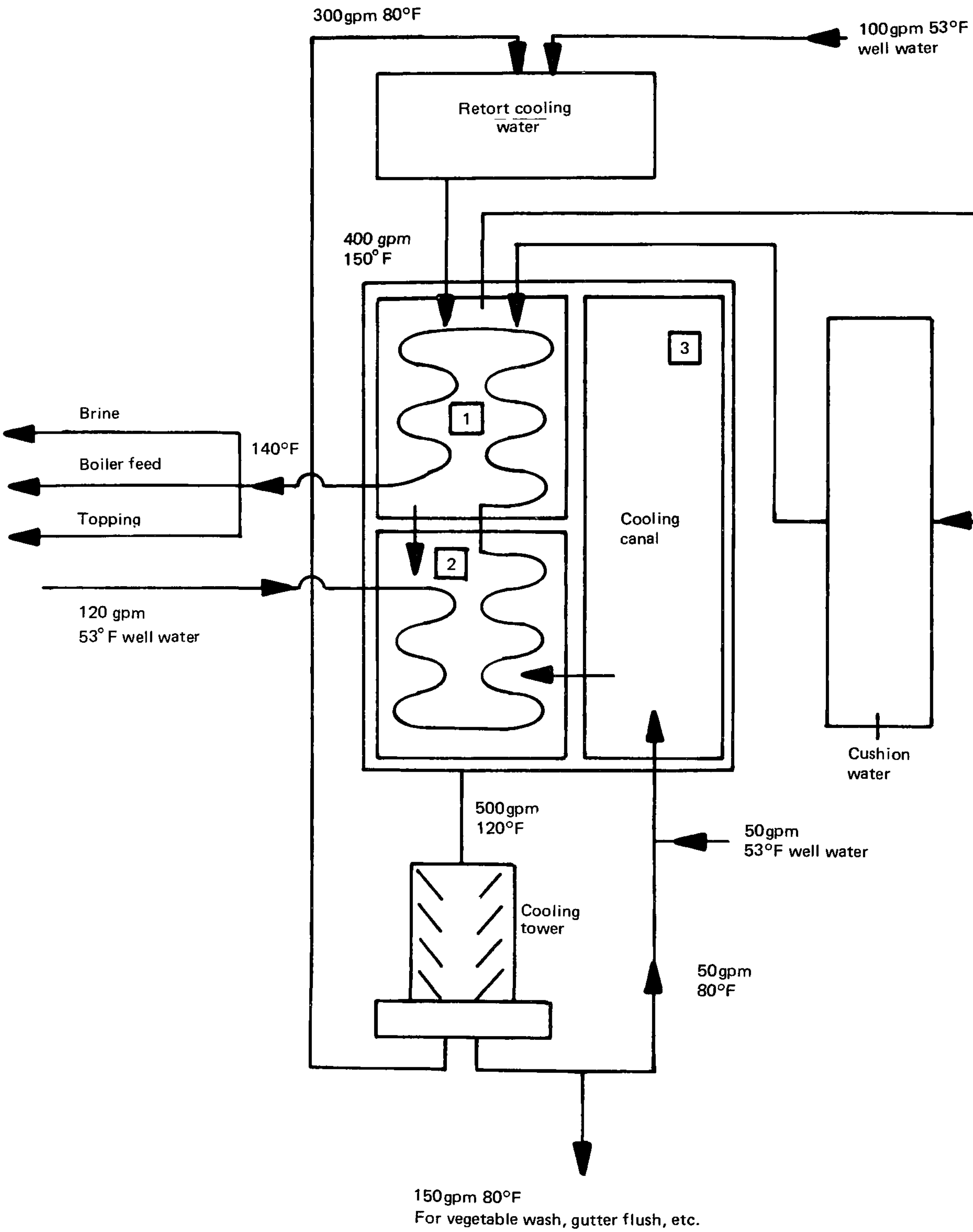


Figure IV-6. Schematic for heat recovery and water recycle.

- The 80°F water from the cooling tower will be collected in a surge tank and used in three ways. After filtration and chlorination, some 300 gpm will be recycled back as retort cooling water. While there, some 100 gpm of well water will also be used in the coolers. Some 50 gpm of this cooling tower water and 50 gpm of well water will be introduced into the cooling canal. The remaining 150 gpm, which is excess water from the system, will be used for initial raw product washing, flushing of gutters and other plant uses which do not require potable water. This excess 150 gpm is the result of using 100 gpm of well water for the coolers and 50 gpm for the cooling canal. Rather than simply being discharged to the gutters directly, secondary uses have been found for it.

- Well water, at 53°F and at 120 gpm, will be pumped through the 2-inch pipe that is placed in holding tanks 1 and 2. It is expected that the water will exit from tank 1 with a temperature of 140°F. This water will then be used principally for brine make-up with smaller quantities used for boiler feed make-up, as topping water, and possibly other areas in which hot, potable water is required. The well water as it passes through the pipe takes up heat and cools the retort and cushion water. The advantages of this approach are to obtain heated water without putting energy into the system and to reduce the temperature of water to be treated by the cooling tower.

The projected cost for the entire system is $50,000. It is estimated that there will be a water savings of at least 375 gpm or 54,000,000 gallons per year. This will amount to a savings of $10,800 per year, using a cost of 2 cents per 1000 gallons of water. Savings in water costs would be greater in areas which have fresh water costs greater than 2 cents per 1000 gallons. The estimated fuel savings for the system is $33,000. This is a result of the 53°F water being increased to 140°F. The cost estimate is based on using $2.50 per million BTU's. With fuel costs rising, and given the ever increasing need to conserve energy, this part of the system appears to be very attractive. The total savings are projected to be $43,800 per year for a $50,000 investment.

## CASE HISTORY VII

## SNOKIST GROWERS CANNERY*

### INTRODUCTION

Snokist Growers, a cooperative, operates a pear, apple, peach, plum, cherry and apricot cannery in Yakima, Washington. The principal products are pears and apples. The pear processing occurs in the fall when the cannery capacity is upwards of 250 tons per day. Apple processing occurs later in the fall and through the winter at from 50 to 150 tons per day in a variety of products including apple rings, apple slices and apple sauce. Unit wastewater flows and waste loads from the cannery are shown on table IV-5. Total discharge from the cannery amounts to from 1.5 to 2.0 million gallons per day of flow during peach and pear processing and from .5 to 1 mgd during apple processing.

Table IV-5.—*Unit waste contribution*

| Product | Flow (gal/ton Material processed) | COD (lb/ton Material processed) | BOD (lb/ton Material processed) |
|---|---|---|---|
| Pears | 5,800 | 105 | 78 |
| Peaches | 7,500 | 98 | 66 |
| Apples | 8,200 | 71 | 53 |

During 1966, the state of Washington's Water Pollution Control Commission (WPCC) directed Snokist Growers to upgrade their effluent to a BOD reduction of 90% by the 1968 processing season. The WPCC also wanted 70% BOD reduction by the 1967 processing season. Snokist Growers embarked on a research, development and demonstration project which was partially funded by a grant from the Federal Water Quality Administration. The project was to provide biological treatment for the company's wastewaters. Aerated lagoon treatment systems and activated sludge pilot studies were to be accomplished during the 1967 processing season, and a full scale activated sludge plant was to be in operation during 1968 for demonstration of biological treatment technology.

**Dr. Larry A. Esvelt — Bovay Engineers, Spokane, Washington*

## BIOLOGICAL TREATMENT OF FRUIT PROCESSING WASTES

During the 1967 processing season, parallel systems of an aerated lagoon for about 85% of the wastewater and activated sludge for 10-15% of the wastewater were used to treat Snokist Growers effluent (see figure IV-7). The results of this testing are shown on table IV-6. The aerated lagoon was constructed with surface aerators and was provided with a PVC lining. The lining failed during that operating season and was replaced during the following season with the same material containing a rock cover to prevent flotation and to prevent hydraulic stresses from separating the seams.

Table IV-6.—*Treatment system performance 1967-1968 processing season*

| | Screened waste | | | Aerated lagoon effluent | | |
|---|---|---|---|---|---|---|
| | Flow (mgd) | BOD (mg/l) | COD (mg/l) | BOD (mg/l) | COD (mg/l) | SS (mg/l) |
| Pear processing | 1.03 | 2,040 | 3,050 | 370 | 1,040 | 770 |
| Peach processing | 1.36 | 1,810 | 2,150 | 340 | | 830 |
| Apple processing (Nov., Dec.) | 0.60 | 1,230 | 1,520 | 190 | 760 | 540 |
| Apple processing (Jan., Feb.) | 0.52 | 950 | 1,400 | 110 | 620 | 470 |
| | Screened waste | | | Activated sludge effluent | | |
| Pear processing | 0.21 | 2,040 | 3,050 | 250 | 490 | 375 |
| Peach processing | 0.30 | 1,810 | 2,150 | 360 | | 370 |
| Apple processing (Mar., Apr., May) | 0.40 | 1,390 | 1,830 | 130 | 570 | 470 |

A full scale, activated sludge system was used during the 1968 processing season. It had the capability for sludge reaeration by upgrading the aerated lagoon to an aeration basin with additional aerator capacity, clarification and sludge return pumping capabilities and a sludge thickener (see figure IV-8). Results from the 1968 treatment experience are shown on table IV-7.

Snokist Growers' studies during the 1967 and 1968 processing seasons resulted in the collection of considerable data which was analyzed for use by other fruit processors in the development of biological wastewater treatment systems. The rate of pollutant uptake by the biological organisms was developed and presented. This is shown on figure IV-9. The temperature relationship of the substrate removal rate for the biological organisms is shown on figure IV-10. Table IV-8 shows the summary of the sludge yield coefficients for various fruits processed. Figure IV-11 shows the endogeneous respiration rate of the organisms according to temperature.

Table IV-7.—*Treatment system performance 1968-1969 processing season*

| | Screened waste | | | Effluent | | |
|---|---|---|---|---|---|---|
| | Flow (mgd) | BOD (mg/l) | COD (mg/l) | BOD (mg/l) | COD (mg/l) | SS (mg/l) |
| Pear processing aerated lagoon | 1.48 | 2,080 | 2,870 | 460 | 1,050 | 640 |
| Peach processing aerated lagoon | 2.02 | 860 | 1,510 | 115 | 710 | 520 |
| Peach processing activated sludge | 2.02 | 860 | 1,510 | 20 | 120 | 66 |
| Pear processing activated sludge | 1.87 | 1,600 | 2,290 | 9 | 55 | 15 |
| Pear processing activated sludge w/sludge reaeration | 1.58 | 2,150 | 2,910 | 4 | 23 | 6 |
| Apple processing activated sludge | 0.43 | 1,190 | 1,500 | 5 | 28 | 11 |

Table IV-8.—*Sludge yield coefficients*

| Product being processed | Sludge growth constant mg VSS/mg COD removed | Sludge growth constant mg VSS/mg BOD removed |
|---|---|---|
| Pears | 0.49 | 0.66 |
| Peaches | 0.46 | 0.69 |
| Apples | 0.57 | 0.76 |

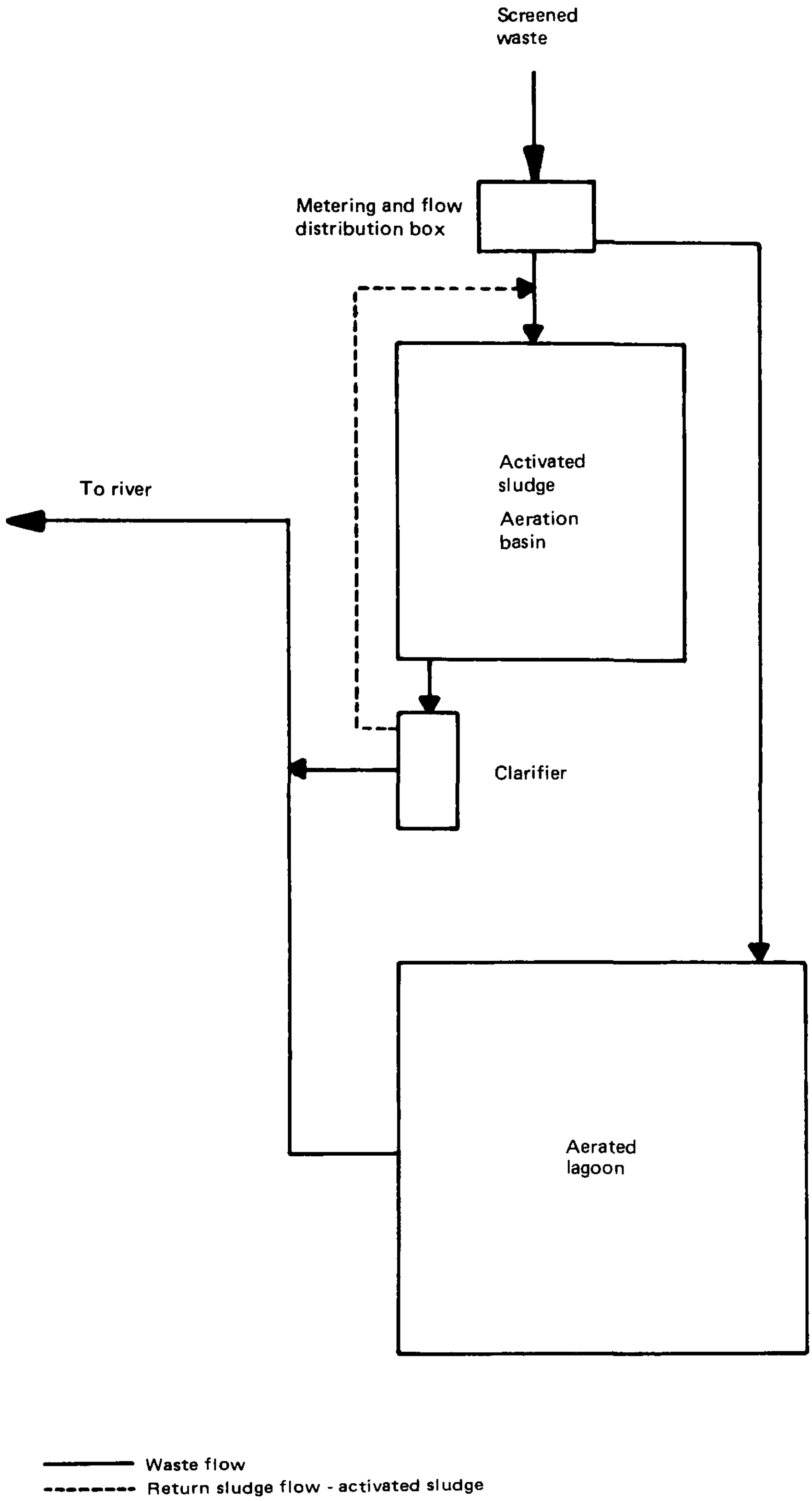


Figure IV-7. Schematic flow diagram 1967-1968 processing season.

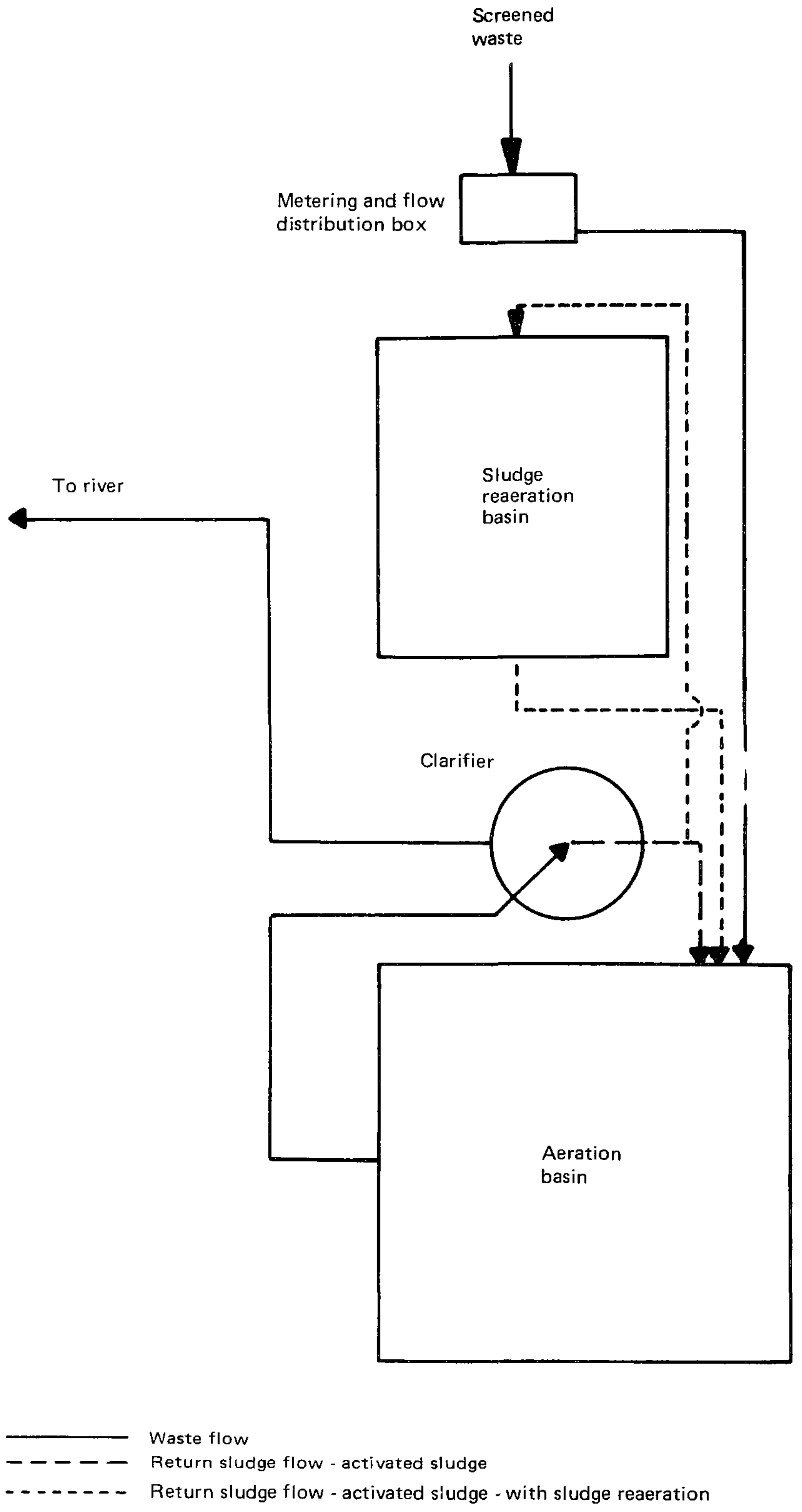


Figure IV-8. Schematic flow diagram 1968 processing season.

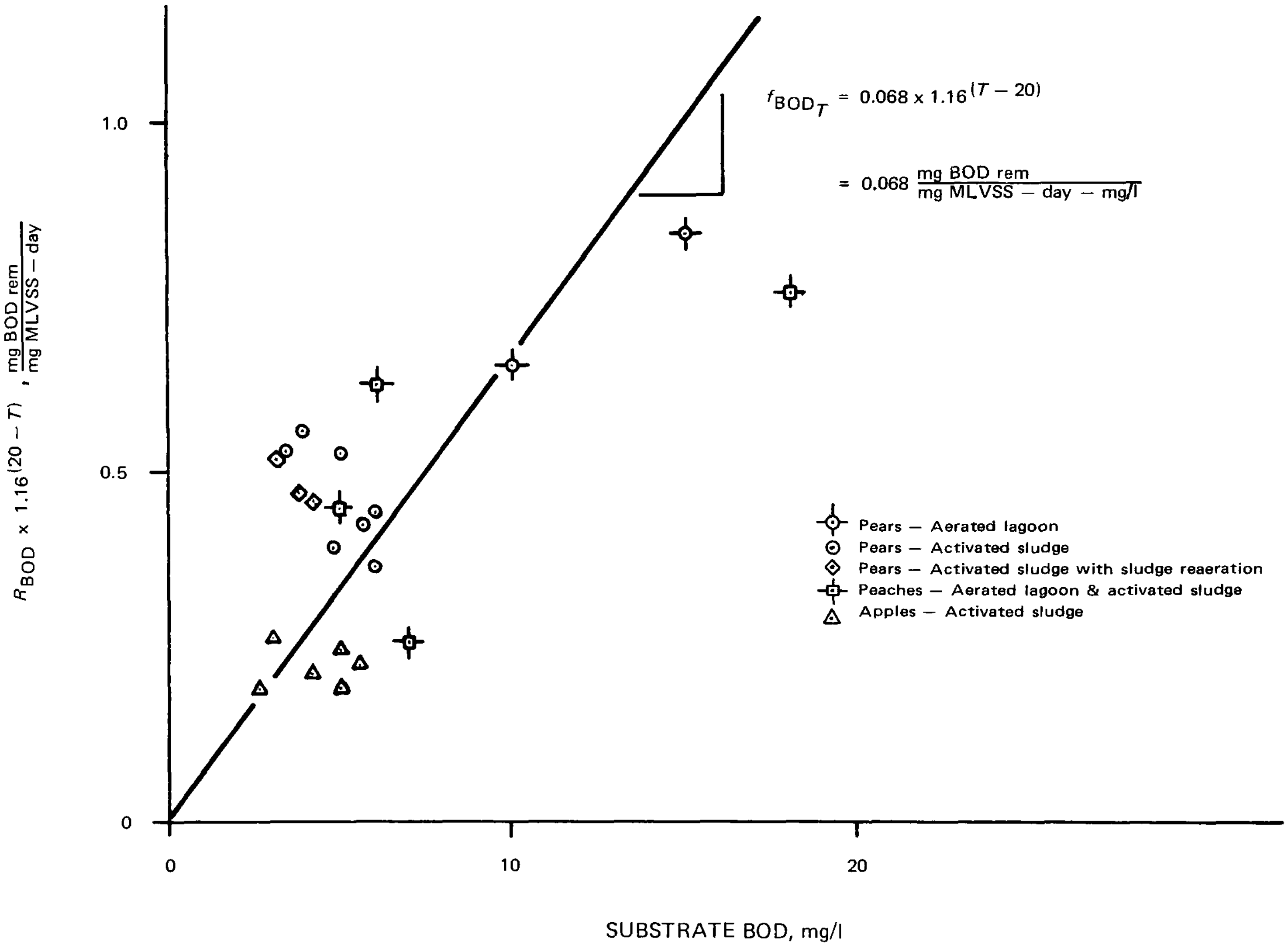


Figure IV-9. BOD removal rate vs concentration at 20°C.

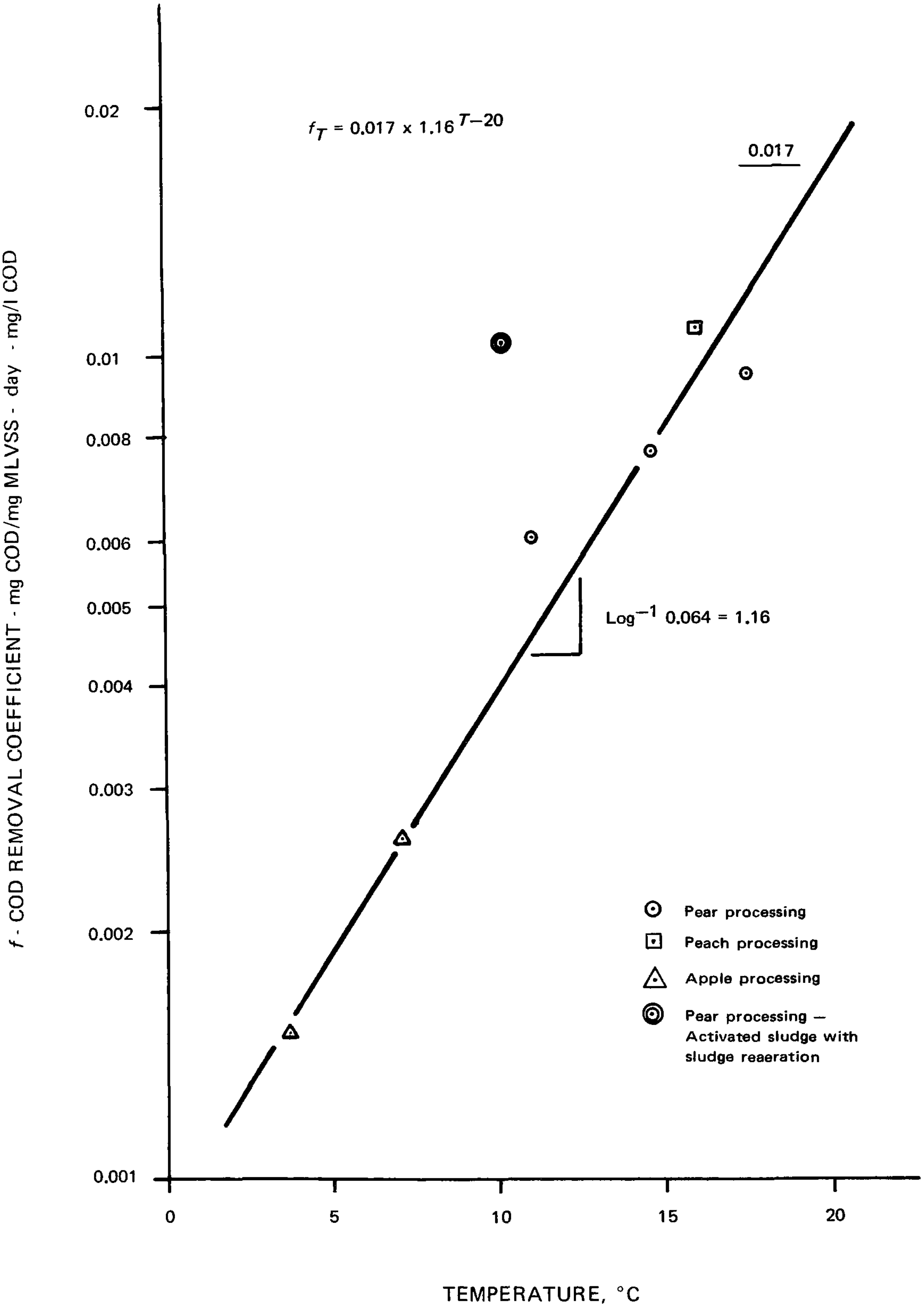


Figure IV-10. COD removal coefficient vs temperature.

The following are significant conclusions and recommendations resulting from the 1967-1968 studies of fruit processing waste treatment at Snokist:

- The fruit processing wastewaters were treatable by biological treatment.
- Nutrients were deficient. Both phosphorous and nitrogen additions were necessary for successful biological treatment.
- Kinetic constants derived (figures IV-9, IV-10, IV-11), including their temperature dependency, were suitable for design of biological systems for fruit processing wastes.
- In a biological treatment system, sludge settling was extremely critical to the overall process and clarification rates at less than 400 gal/ft$^2$/day were necessary in order to get proper operation.
- Sludge recirculation rates, because of the low compacting characteristics of the sludge, were necessarily high, and sludge recirculation rates equal to or greater than the raw influent waste flow were necessary.
- Sludge wasting was difficult with this system because the sludges developed were very difficult to thicken and dewater.

Operating experience since 1968 has indicated that the biological treatment system can capably meet the effluent standards defined as Best Practicable Treatment by the EPA. Results from the 1974 operating season shown on table IV-9 illustrate this capability.

Table IV-9.—*Summary of activated sludge process — 1974*
[Mean/standard deviation]

| | Pear processing (59 days) | Peach processing (4 days) | Apple processing (23 days) |
|---|---|---|---|
| Influent COD, mg/l | 2740/440 | 1670/220 | 550/100 |
| COD loading on MLVSS, day$^{-1}$ | 0.14/0.04 | 0.07/0.01 | 0.024/0.009 |
| Effluent COD, mg/l | 52/43 | 24/6 | 52/39 |
| Effluent SS, mg/l | 19/17 | 7/1 | 20/12 |
| Flow, $10^3$ $m^3$/day | 5/9/0.6 | 6.9/1.3 | 3.8/1.4 |
| Ave. processing rate, kkg/day | 260 | 200 | 100 |

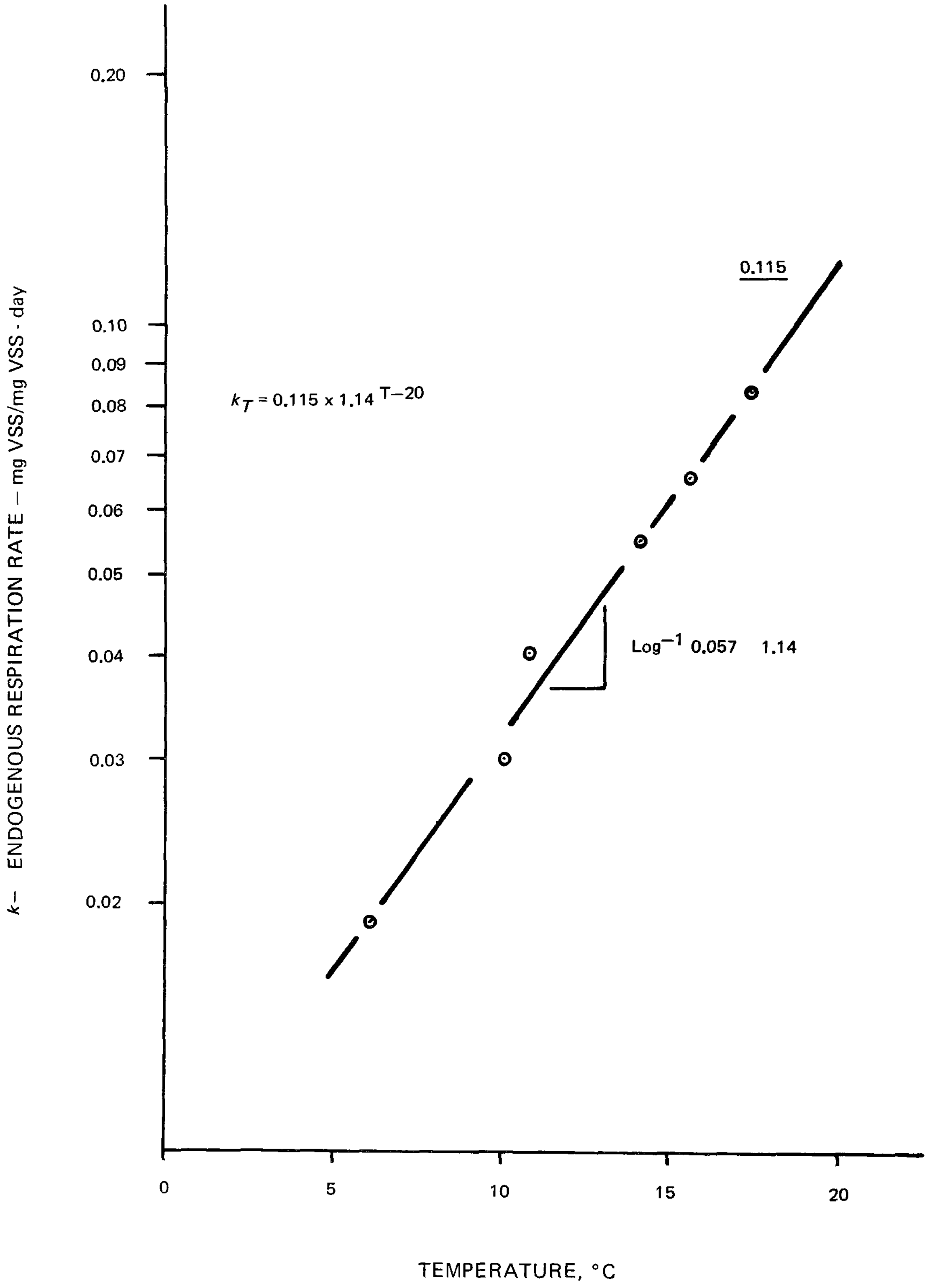


Figure IV-11. Endogenous respiration rate vs temperature.

One problem encountered from time to time is the use of chlorine in the cannery which has escaped into the wastewater treatment system. These leaks have been responsible for selectively killing off portions of the biological population that have normally promoted high clarity in the effluent. The in-plant chlorination is prompted by requirements from the FDA for a lack of machinery mold on all components of the cannery and subsequent advice by USDA to chlorinate to prevent machinery mold development. Severe problems were encountered during one of the operating seasons which led to a marked deterioration of wastewater effluent. During the 1975 processing season a lesser deterioration (allowing the effluent to still meet the 1977 guidelines) was experienced. This deterioration did affect other objectives for the wastewater system and impact the operation.

## SLUDGE UTILIZATION AS CATTLE FEED

The Snokist Growers biological treatment system for fruit processing waste has resulted in the production of biological solids which must be disposed of. During the 1974 processing season Snokist Growers, with the assistance of a grant from the EPA, investigated utilization of the waste biological solids as a cattle feeding supplement. Waste sludges were dewatered on basket centrifuges from the approximate 1/2 to 1 percent clarifier underflow concentration and the approximate 2 to 2-1/2 percent sludge thickener solids concentration up to about 8 percent solids. The sludges were fairly high in crude protein with approximately 40 percent on the dry solids basis. The solids dewatering was conducted as shown in figure IV-12 and resulted in a fairly consistent product at about 8 percent total solids.

The cattle feeding portion of the investigation was conducted by Washington State University's Irrigation, Agricultural, Research and Extension Center in Posser, Washington, under contract to Snokist Growers. The first part of the feeding investigation was a metabolizability and digestibility trial utilizing eight head of cattle in a latin square distribution with a control feed and rations containing 2-1/2, 5 and 10 percent dry solids from the waste sludges. The digestibility (defined as the intake minus the fecal matter) and the metabolizability (defined as the intake minus the fecal, urine and respiration matter) were determined utilizing the eight steers in a confined area where all intake and excrement was monitored. The digestibility and metabolizability of the rations containing the sludges were equal to that of the control ration up through the 5 percent level and nearly equal at the 10 percent level as shown on figure IV-13 and figure IV-14.

To determine the value of the sludge as a feed for cattle being finished for slaughter, 24 head of cattle were divided into four groups of six each and fed to a finished state (approximately 265 days) on control rations and rations containing 2.3, 4.6 and 8.9 percent total solids from the biological treatment system. The weight gain rate of steers fed the ration containing 2.3 percent biological solids seemed to be enhanced by the presence of the solids, and the weight gain for the steer groups receiving 4.6 and 8.9 percent solids was at least equal to that of the control group as shown by figure IV-15. Following slaughter, the carcass quality of the steer groups was determined. The carcass quality of the groups containing sludge actually appear to be slightly higher than that of the control group, especially at the 2.3 percent biological solids level as shown by figure IV-16.

No harmful constituents were found in the biological solids fed to the animals, and FDA approval for slaughter and marketing of the carcasses was obtained. Prior to full scale inclusion of the biological solids into a cattle feeding ration, it would be necessary to obtain a permit from FDA. One of the principal criteria in obtaining such a permit is the assurance that no human wastes entered the treatment system where the biological solids were produced.

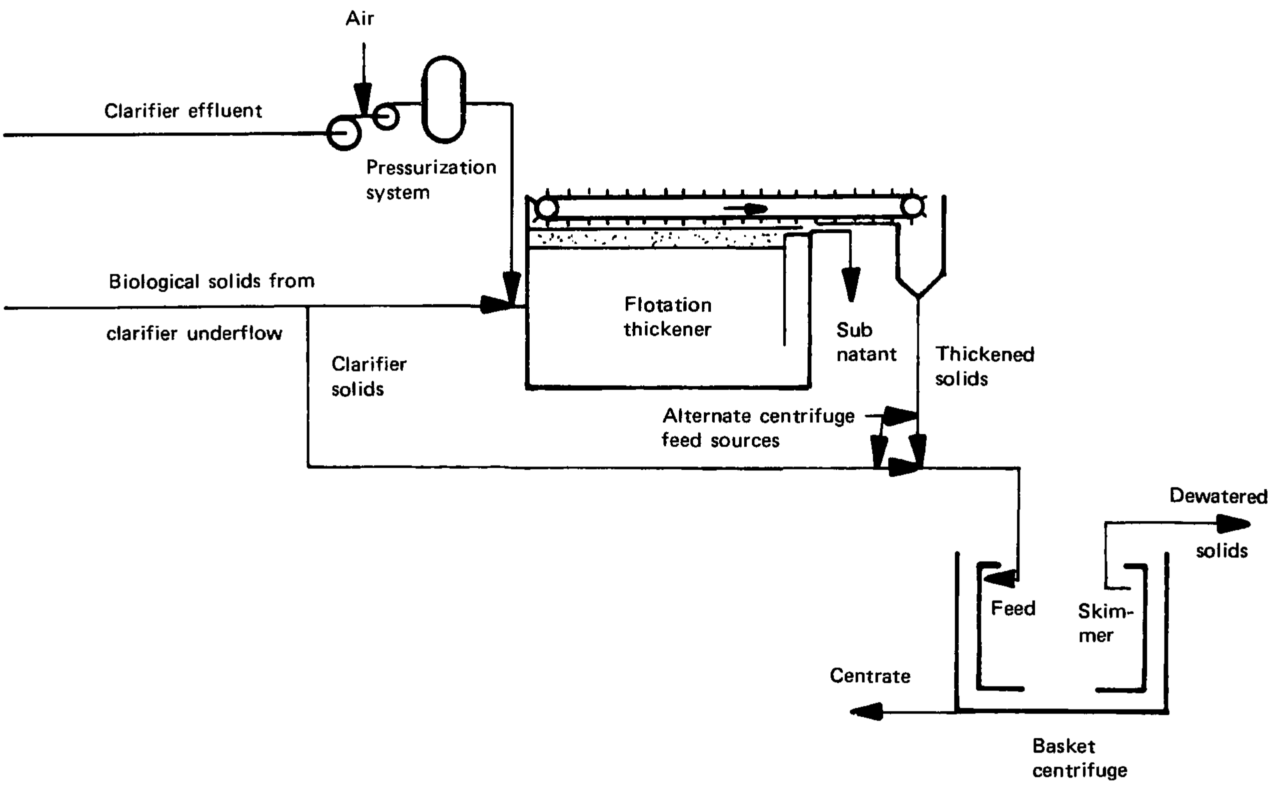


Figure IV-12. Schematic flow diagram — solids dewatering.

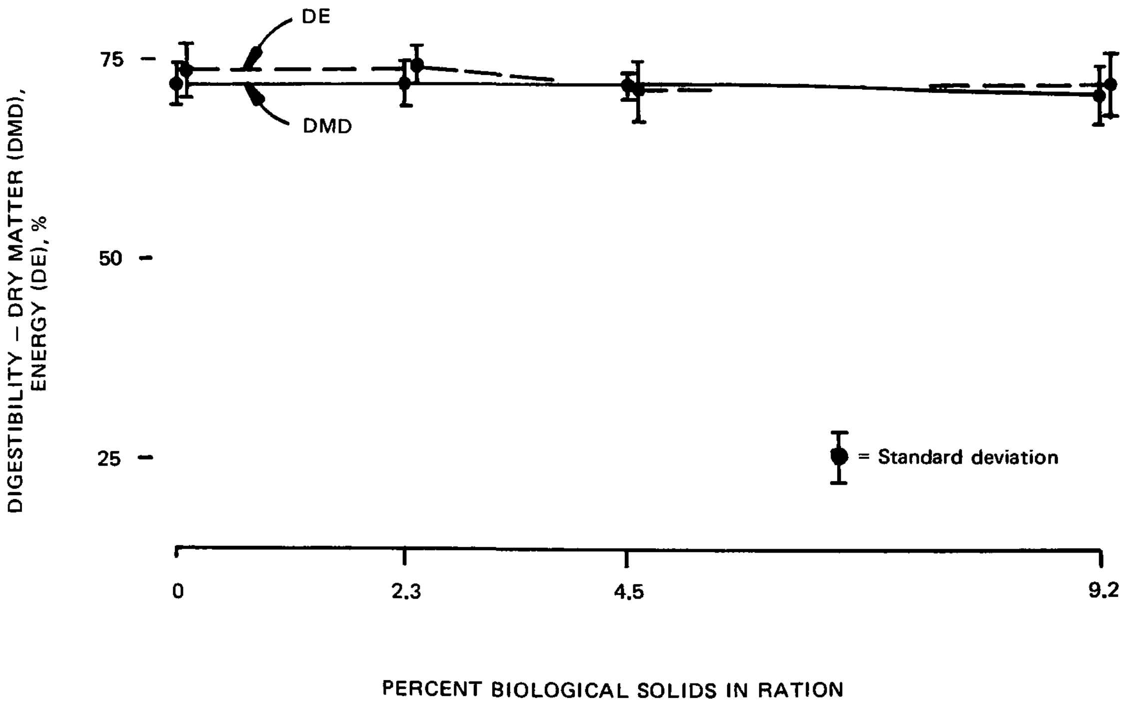


Figure IV-13. Digestibility of rations by biological solids content.

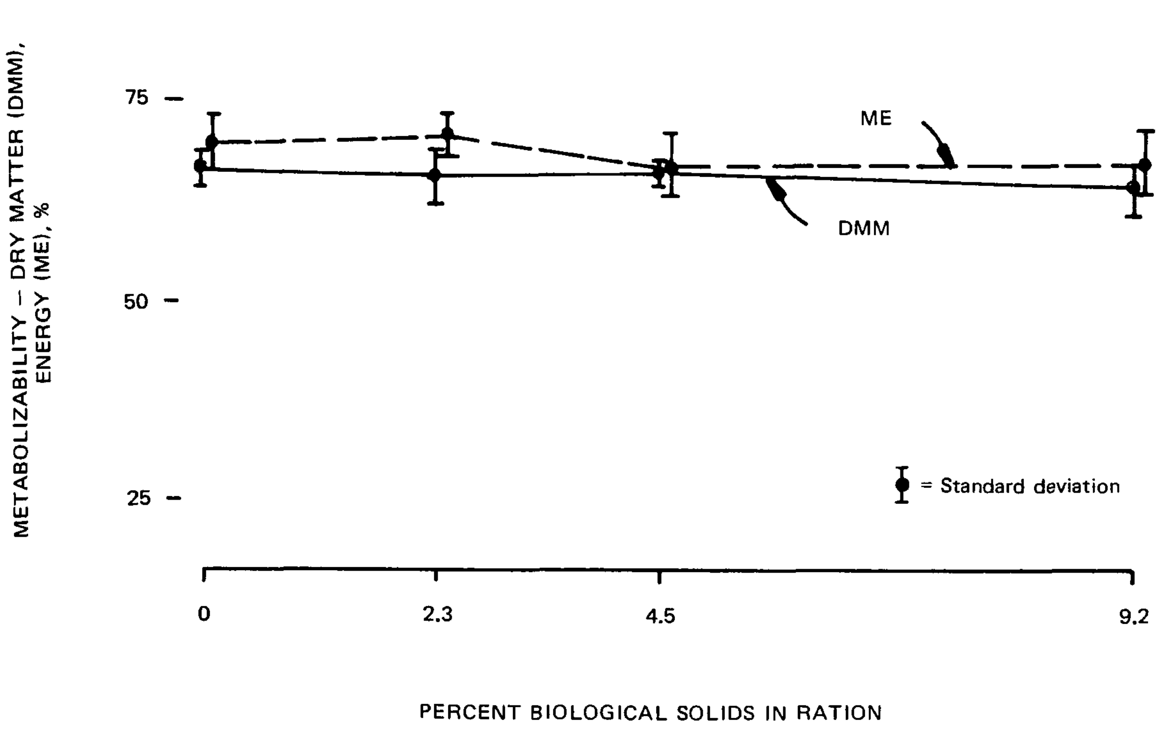


Figure IV-14. Metabolizability of rations by biological solids content.

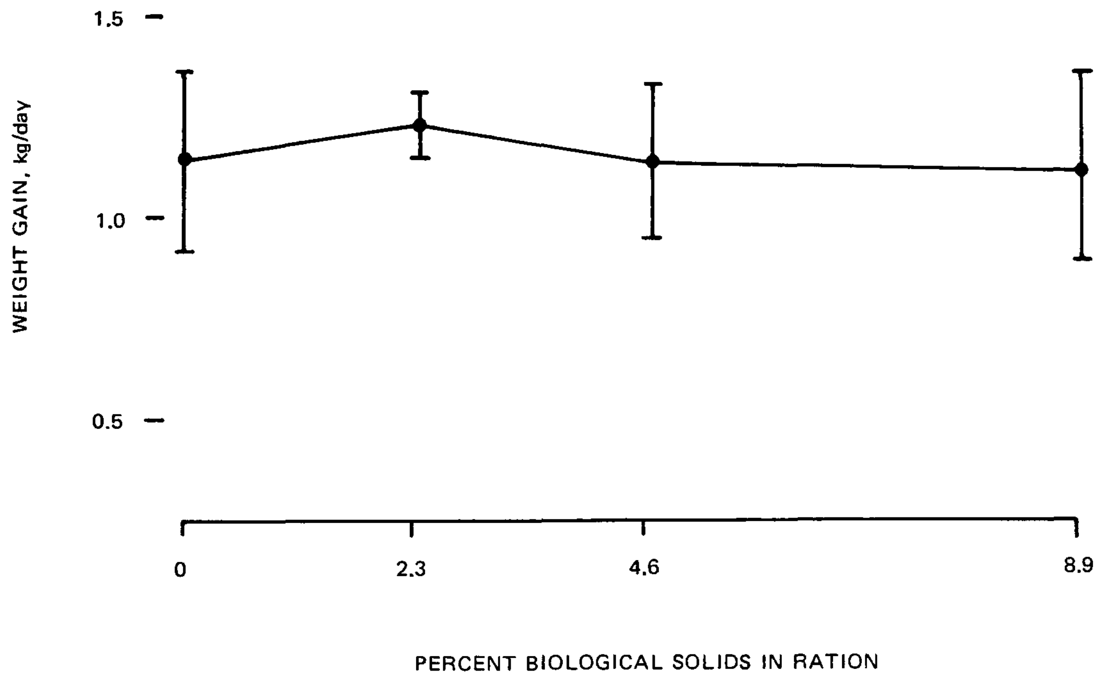


Figure IV-15. Weight gain by ration biological solids content.

## TREATED EFFLUENT REUSE

Snokist Growers is currently investigating, with EPA assistance, reuse of the biologically treated process effluent from their cannery. Additional treatment facilities for effluent polishing, including mixed media filtration and chlorination, have been added. The effluent was reused principally for gutter wash and floor wash purposes and experimental uses for other areas such as can cooling, equipment washdown, and belt washdown, during the 1975 processing season. An overall 30% reduction in discharge to the river was accomplished during the 1975 season due to the wastewater recycling and reuse in the cannery. During the 1976 season additional objectives included demonstration of use of the water for boiler feed to produce steam for cooking and line cleanup. Additional can cooling demonstrations will be performed as well as raw fruit conveying to the process lines on a trial basis.

As mentioned previously, chlorination in the plant during the 1975 season resulted in a change in biological solids characteristic of the treatment system, which in turn resulted in some solids carry over in the effluent and a subsequent deterioration in the quality of the effluent treated by the mixed media filtration system. Additional problems in the wastewater reuse system were encountered in the mechanical equipment during its startup and break-in period. It is anticipated that during the 1976 season, better in-plant chlorination control and better reliability of equipment will result in even higher percentages of wastewater reuse. With the present capability of the system, it may be feasible for up to 50 percent reuse of wastewater during pear processing and an even greater percentage during apple processing.

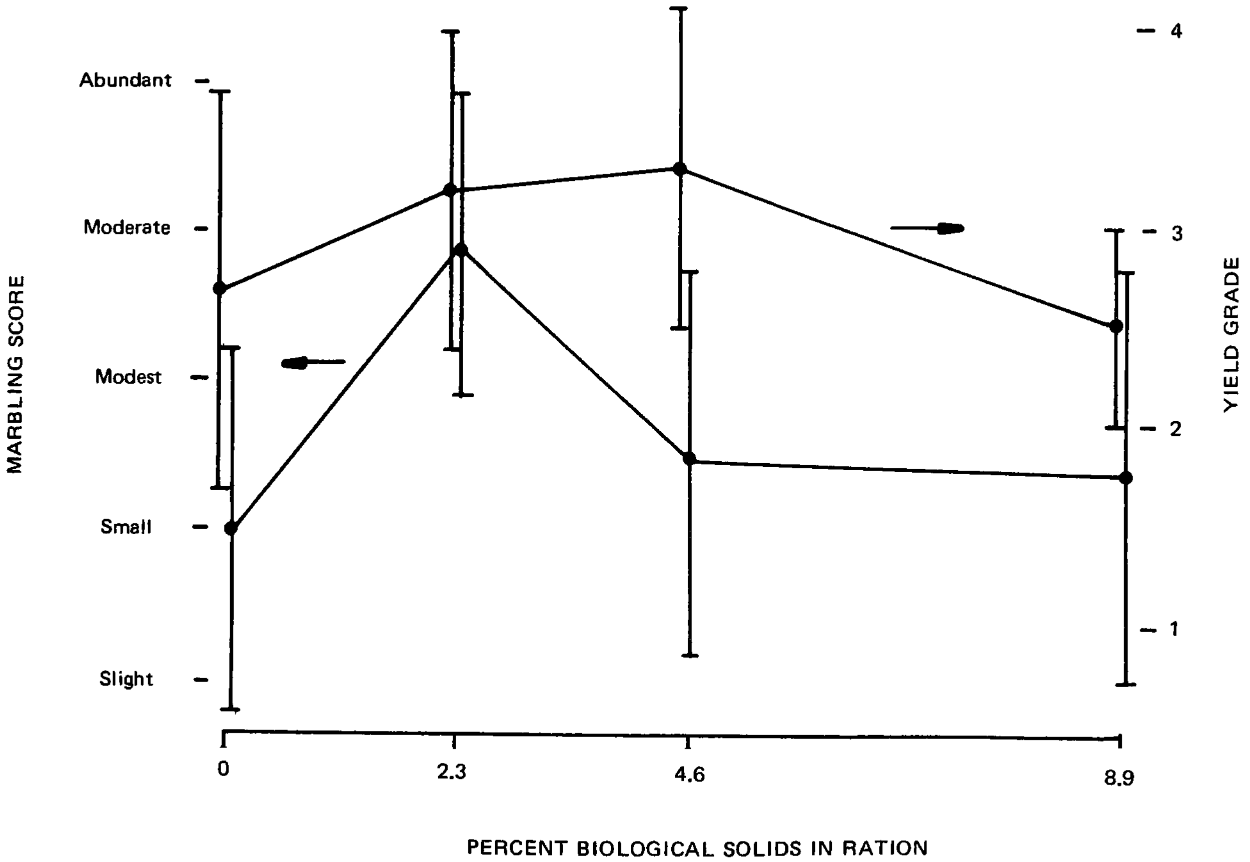


Figure IV-16. Carcass yield grade and marbling score by ration.

## CASE HISTORY VIII

## CASE HISTORY OF TOMATO PROCESSING WASTEWATER MANAGEMENT AT HICKMOTT FOODS, INC.*

### INTRODUCTION

Hickmott Foods, Inc. is a small independent cannery located in Antioch, California. In the past, the principal items processed were tomatoes, asparagus, and sweet potatoes. The sweet potato and asparagus operations were abandoned after the 1973 and 1974 seasons respectively, leaving tomatoes as the only commodity to be canned in 1975. Tomatoes are canned in an 80-day operating season during the months of July through October. With the exception of a week or two at the beginning and end of the season, the canning operation is continuous around the clock. In 1971, to meet waste discharge requirements established by the Central Valley Water Quality Control Board, Hickmott Foods undertook a program of wastewater management to clean up its wastewater discharge to the San Joaquin River. Because no municipal system was available to handle the cannery wastes, Hickmott Foods was forced to develop its own waste treatment system or cease to operate.

### WASTE QUANTITIES

Approximately 1,200 tons of mechanically and hand harvested tomatoes are processed daily at Hickmott Foods. Production data for the 1973, 1974 and 1975 seasons are summarized in table IV-10. Of the daily total, 55 to 65 percent of the raw fruit was peeled.

Table IV-10.—*Tomato processing production data for the 1973, 1974, and 1975 canning seasons*

| Item | Season | | |
|---|---|---|---|
| | 1973 | 1974 | 1975 |
| Raw product delivered | | | |
| Daily average[a], tons/day | 870 | 1,050 | 1,200 |
| Season total, tons | 54,500 | 66,000 | 85,000 |
| Percentage increase | — | 21 | 29 |
| Peeled product | | | |
| Percentage of season tonnage | 55 | 57 | 65 |

[a]Average for full 24-hour operating day.

*Mr. Ed Fernbach – Trotter-Yoder and Associates, Lafayette, California
Dr. George Tchobanoglous – University of California at Davis, Davis, California
Mr. Bill Ostertag – Food Industry Consultant, Pittsburg, California

Wastes from the tomato canning operation at Hickmott Foods are in three forms:

1. Solid wastes such as whole tomatoes and tomato skins, seeds, and stems.

2. Sludge from the caustic peeling of raw tomatoes.

3. Wastewaters which contain suspended and soluble tomato components, sand, and silt.

The quantities of these wastes are shown in table IV-11 for the 1974 canning season. Of the 170 tons of tomato components that went to waste each day, 39 tons are hauled away as solids for cattle feed, 120 tons of caustic tomato sludge are generated per day from the dry peeling operation, and approximately 11 tons per day of raw product is lost in the wastewater flow stream. The characteristics of the wastewater that would have to be treated if the peeling sludge were to be dumped into the plant sewer (as was the practice before the 1974 canning season) is shown in tables IV-12 and IV-13. As shown in table IV-12, a significant reduction in wastewater generation occurred between 1974 and 1975. This reduction was a result of the following:

- The rearrangement of the production area, reducing spray requirements.

- The running of the cannery at full production capacity which reduced the per ton water usage.

Table IV-11.—*Waste generation during 1974 tomato canning season*

| Item | Value | | Unit value[a] | |
|---|---|---|---|---|
| | With peel recovery[b] | Without peel recovery[c] | With peel recovery[b] | Without peel recovery[c] |
| Solid wastes, tons/day | 39 | 37 | 74 | 70 |
| Peeling sludge at 7% solids, tons/day[d] | 120 | 0 | 228 | 0 |
| Loss of tomato in wastewater, tons/day[e, f] | 11 | 133 | 21 | 253 |
| Total loss of raw product as waste, tons/day[g] | 170 | 170 | 323 | 323 |
| Percentage of total | 16 | 16 | — | — |

[a]Unit production values are on a gal/ton or lb/ton of raw tomato basis (whichever is applicable).

[b]Current method of operation.

[c]Predicted quantities based on measured values for peeling sludge COD, suspended solids, and flow rate.

[d]32,400 gal/day.

[e]Based on waste characteristics given in table IV-12.

[f]1.0 pound of whole tomato yields 1.3 pounds of COD (COD of whole tomato = 73,000 mg/l, TSS of whole tomato = 55,000 mg/l).

[g]Checked with pack reports using standard case per ton conversion factors and estimated loss in evaporation and waste.

Table IV-12. —*Wastewater characteristics during 1973, 1974, and 1975 canning seasons*

| Item | Season | | |
|---|---|---|---|
| | 1973[b] | 1974[c] | 1975[c] |
| Wastewater flow rate, mgd | 1.7 | 1.14 | 1.0 |
| unit value, gallons/ton[a] | 1,950 | 1,090 | 850 |
| reduction, percent | – | 44 | 24 |
| Biochemical oxygen demand ($BOD_5$), mg/l | 2,400 | 1,300 | 1,200 |
| unit value, pounds/ton[a] | 39 | 12 | 8 |
| reduction, percent | – | 69 | 33 |
| Chemical oxygen demand (COD)[d], mg/l | 5,500 | 3,000 | 2,800 |
| unit value, pounds/ton[a] | 90 | 27 | 19 |
| reduction, percent | – | 69 | 30 |
| Total organic carbon (TOC), mg/l | 2,000 | 1,100 | 1,000 |
| unit value, pounds/ton[a] | 32 | 10 | 7 |
| reduction, percent | – | 69 | 30 |
| Total suspended solids (TSS), mg/l | 1,800 | 1,000 | 1,000 |
| unit value, pounds/ton[a] | 29 | 9 | 7 |
| reduction, percent | – | 69 | 22 |

[a]Unit production values are reported on a per ton of raw tomato basis.

[b]Includes peeling sludge.

[c]Peeling sludge isolated from waste stream.

[d]1.0 pound of peeling sludge yields 1.3 pound of COD (see table IV-11).

Table IV-13. —*Effect of peeling sludge on wastewater characteristics*

| Item | 1974 | | 1975 | |
|---|---|---|---|---|
| | With[a] peel recovery | Without[b] peel recovery | With[a] peel recovery | Without[b] peel recovery |
| Wastewater flow rate, mgd | 1.14 | 1.17 | 1.0 | 1.04 |
| Biochemical oxygen demand ($BOD_5$), mg/l | 1,300 | 2,400 | 1,200 | 2,880 |
| Chemical oxygen demand (COD)[c], mg/l | 3,000 | 5,500[c] | 2,800 | 6,600[c] |
| Total organic carbon (TOC), mg/l | 1,100 | 2,000 | 1,000 | 2,400 |
| Total suspended solids (TSS), mg/l | 1,000 | 1,200 | 1,000 | 1,500 |

[a]Current method of operation.

[b]Predicted quantities based on measured values for peeling sludge COD, suspended solids and flow rate.

[c]1.0 pound of peeling sludge yields 1.3 pound of COD (See table IV-11).

### Discharge Requirements

Hickmott Foods was given its first set of discharge requirements in 1971 and was issued a NPDES permit on January 1, 1975. These requirements are shown in table IV-14. Based on the requirements set forth in table IV-14, Hickmott Foods must remove 94 percent of the $BOD_5$ and 91 percent of the total suspended solids from its wastewaters before discharge.

Table IV-14.—*Tomato processing waste discharge requirements*[a]

| Constituent | Value[a] | |
|---|---|---|
| | 30-day[a] Average | Daily maximum |
| Process wastewater | | |
| Daily flow, mgd | | 1.3 |
| $BOD_5$ lbs/day | 800 | 1,890 |
| Total suspended solids, mg/l | 75 (50) | 125 (75) |
| lbs/day | 820 | 1,360 |
| Settleable matter, mg/l | 0.2 (0.5) | 0.5 (1.0) |
| Oil & Grease, mg/l | 10 | 15 (10) |
| pH | | 6.5-9.5[b] |
| 96-hour Bioassay, % survival | | |
| Minimum, any one bioassay | 70 (100) | |
| Median, three or more consecutive | 90 | |
| Cooling water | | |
| COD, mg/l | — | 50[c] |
| Temperature, °F | — | 20° above background[d] |

[a]Effective January 1, 1975; previous requirements shown in parenthesis.

[b]Range.

[c]Average value above background.

[d]Combined process and cooling water discharge shall not exceed 20° F above the temperature of the San Joaquin River or 85°—90° F.

## WASTE MANAGEMENT IN CANNERY

Significant reductions in the wastewater flow rate and strength have been accomplished by modifying various operations within the cannery production area. These changes and their impact are discussed in this section.

### Wastewater Flow Reduction

The two principal components of the wastewater produced during the 1973 and 1974 tomato canning seasons are the process water and the water from the evaporators and retorts (see table IV-15). Water used in the production process is derived primarily from the domestic water supply of the City of Antioch, whereas the water used to cool the evaporators and retorts is filtered from the San Joaquin River.

Several steps were taken between 1973, 1974 and 1975 to reduce the quantity of water used by the cannery and to reduce the wastewater flow rates. The cooling water was analyzed and found to be suitable for direct discharge to the river after cooling (COD less than 50 mg/l). Eliminating the cooling water from the waste stream reduced the flow requiring treatment from 3.1 mgd to 1.14 mgd, while cannery production increased 20 percent between 1973 and 1974.

The installation of four dry peel removal machines in 1974 reduced the total water needed for peeling from 306 to 124 gpm. The quantity of peel sludge produced dropped from 150 to 24 gpm while cannery production increased 20 percent. This reduced amount of peeling sludge now made it possible to isolate this material and process it separately.

All low pressure-high volume washdown hoses were removed and a high pressure hose system with nozzles that shut off upon release was installed. This change resulted in a washdown flow reduction of at least 80 gpm (see table IV-15). As low pressure hoses are usually left to run on the floor, the reduction was probably somewhat larger. Some employees objected to the use of the high pressure spray, as it is harder to control, but eventually became accustomed to using these nozzles. No degradation in the quality of the product or plant sanitation was observed. Cooling water discharge was reduced by 200 gpm by reusing the retort cooling water for can washing. Besides reducing the amount of water to be cooled before discharge to the river, the amount of river water that must be filtered and chlorinated for use in the can washing system was also reduced.

### Dry Peeling

The installation of four dry peel removal machines and modifications in the operation of caustic peelers has resulted in a reduction in chemical usage and the quantity of waste that must be treated. This has been accomplished with no deterioration in product quality. Dry caustic peeling, using rotating rubber discs to mechanically rub peel from tomatoes dipped in sodium hydroxide, replaced the conventional water rinse peeling operation. Effective peeling was obtained with this method while reducing the concentration of caustic in the peelers. Operational data for the peelers are summarized in table IV-16 for the 1973 and 1974 seasons. Data were not collected during the 1975 canning season. Through a combination of reducing the peeler speed (resulting in more tomatoes per bucket but a longer contact time with the caustic per tomato) and using mechanical peeling, it was possible to use a caustic solution of 7 to 10 percent in 1974 as opposed to an 18 to 20 percent solution in 1973. This mode of operation resulted in a reduction in caustic usage (6.9 lbs/ton in 1974 as opposed to 11.7 lbs/ton previously) and reduced chemical requirements for neutralization of the resulting wastewater.

Dry caustic mechanical peeling requires about 80 gallons of potable water per ton of tomatoes as opposed to 720 gallons per ton using conventional methods. The 80 gallons per ton, which amounted to 24 gal/min of caustic sludge in the Hickmott Foods operation, is small enough to be disposed of in a land spreading operation. The exclusion of this sludge from the waste stream to the water pollution control plant reduced the $BOD_5$ load on the treatment facility by 46 percent. As shown in table IV-13, if the peeling sludge had not been handled separately, the $BOD_5$ of the wastewater in 1974 and 1975 would have been 2,400 to 2,880 mg/l as opposed to the 1,200 to 1,300 mg/l actually measured.

Table IV-15.—*Daily water usage during 1974 canning season and percent reduction data over 1973 canning season*[a]

| Item no. | Description of source | 1974 Flow rate, gpm | Percent reduction over 1973 |
|---|---|---|---|
| | **Process wastewater**[b] | | |
| 1 | Seals on sump pump (1/2" line, 2 @ 8.8 gpm) | 18 | – |
| 2 | Bin washing system (2 @ 17.5 gpm) | 35 | – |
| 3 | Incoming product sprays (2 @ 10 gpm) | 20 | – |
| 4 | Small tomato dropout fluming to product tables | 35 | – |
| 5 | Make-up water to lye peelers (2 @ 10 gpm) | 20 | – |
| 6 | Rinse tanks after peeling (2 @ 50 gpm in 1973) | 0[c] | 100 |
| 7 | Dry scrubbers (4 @ 6 gpm)(1 @ 50 gpm in 1973) | 24[b] | 52 |
| 8 | Rinse water on roller washers (4 @ 20 gpm) (4 @ 35 gpm in 1973) | 80[d] | 43 |
| 9 | Belt lubrication and cleaning | 50[e] | – |
| 10 | Can washers, 7 peeling, 3 product (10 @ 18 gpm) | 180[h] | – |
| 11 | Kettles (1" line, 1 @ 30 gpm) | 30 | – |
| 12 | Washdown lines, low pressure (4 @ 35 gpm in 1973) | 0[c] | 100 |
| 13 | Washdown lines, high pressure (6 @ 10 gpm) | 60[f] | – |
| 14 | Can cooling, outside coolers (7 @ 35 gpm) | 245 | – |
| 15 | Cooling water, vacuum pumps (3 @ 8.8 gpm) | 27 | – |
| | Total wastewater generated, gpm (1126 gpm in 1973) | 800 | 29 |
| | **Evaporators & retorts**[g] | | |
| 16 | Evaporator no. 1 | 550 | – |
| 17 | Evaporator no. 2 | 350 | – |
| 18 | Retorts | 100[h] | 69 |
| | | 1,000 | 17 |
| | **Fluming water**[i] | | |
| 19 | Tomato fluming | 600 | |

[a]Based on individual flow rate measurements during 1973 and 1974 peak production periods.

[b]All process wastewater must be treated by the wastewater treatment facilities except item 7. See following section on dry peeling.

[c]Eliminated from 1973 operation.

[d]Reduced by lowering spray pressure.

[e]To be reduced in 1975 by shortening belt runs.

[f]Nozzles shut off when not in hand of operator.

[g]Water from evaporators and retorts is discharged directly to river after passing through cooling tower.

[h]Retort water is recovered and used for can washing.

[i]Fluming water is recycled internally. Make-up water is obtained from items 3 & 4.

Table IV-16. – *Summary data on caustic tomato peeling operation and acid usage at Hickmott Foods, Inc.*

| Parameter | Season | | Reduction 1974 over 1973, percent |
|---|---|---|---|
| | 1973 | 1974 | |
| No. caustic peelers | 4 | 4 | |
| Peeler speed, buckets/min, each | 40-44 | 24-28 | |
| Loading rate, tons/min, each | 0.33 | 0.33 | |
| Caustic solution in peeler, percent | 18-20[a] | 7-10[a] | |
| Total season throughput, tons | 29,000 | 35,000 | |
| Caustic usage, tons | 198[b] | 121[b] | |
| Unit caustic usage, lbs/ton | 11.7 | 6.9 | 41 |
| Acid usage, tons | 71[c,d] | 53[c,e] | |
| Unit acid usage, lbs/ton | 4.9 | 3.0 | 39[e] |

[a]Estimated average from operator titrations.

[b]50 percent sodium hydroxide used.

[c]93 percent sulfuric acid used for neutralization of wastewater at treatment facilities.

[d]All caustic peeling sludge entered treatment system.

[e]Only a small portion of the caustic sludge entered the waste treatment system. Tighter restraints imposed on neutralization system offset expected acid usage reductions.

## Floor Waste Management

Because tomatoes are, for the most part, a water soluble fruit, the longer they remain on the cannery floor or in a wastewater conveyance facility, the more the tomato solids and juices contribute to the soluble COD and $BOD_5$ of the wastewater. If processing wastes are picked up in solid form, they can be fed to livestock or at least trucked to disposal sites as solid wastes. Manual collection of large solid tomato parts was stressed during the 1974 and 1975 seasons. Gratings on all floor drains were also bolted down. Reliable solid waste per ton data were not available for the 1973 season, but it is estimated that considerably more solid waste was trucked to cattle for feed during the 1974 season. This is waste that does not reach the treatment facility as fine suspended matter or soluble organics.

## Wastewater Characteristics

Eight and 24-hour composite samples of the wastewater were taken weekly during the 1974 and 1975 operating seasons. Constituent concentrations determined for both the raw wastewater and treatment process effluent are reported in table IV-17. As shown, the COD of the raw wastewater is about 2.3 times the $BOD_5$ as compared to 2.5 for most domestic wastes. The $BOD_5$ values shown in table IV-17 are those obtained from the $BOD_5$ test as delineated in Standard Methods[2]. The $BOD_5$ values were found to increase by about 20 to 25 percent when the bacterial seed for the test was acclimated to tomato peeling sludge. It was also found that the $BOD_5$ value was approximately 55 to 65 percent of the ultimate BOD value when using acclimated seed. If it is assumed that a reported $BOD_5$ value of 1,300 mg/l is about 80 percent of the acclimated value and that the acclimated value is 60 percent of the ultimate BOD value, the ultimate value would be

Table IV-17.—*Influent and effluent wastewater characteristics during the 1974 and 1975 tomato canning season*

| Constituent | Normal operation without peeling sludge | | With peeling sludge in waste stream[a] | |
|---|---|---|---|---|
| | Influent[b] | Effluent[c] | Influent[b] | Effluent[c] |
| Total flow, gpm | — | 800 | — | 825 |
| mgd | | 1.14 | | 1.18 |
| Suspended solids, | | | | |
| total, mg/l | 1,000 | 60 | 1,200 | 60 |
| volatile, mg/l | 400 | 20 | — | 20 |
| fixed, mg/l | 600 | 40 | — | 40 |
| $BOD_5$, total, mg/l | 1,200-1.300 | 30 | 1,800-2,800 | 30 |
| soluble, mg/l | 1,100 | 20 | — | 20 |
| TOC, total, mg/l | 1,000-1,100 | 50 | 1,600-2,400 | 60 |
| soluble, mg/l | 900 | 30 | — | — |
| COD, total, mg/l | 2,800-3,000 | 120 | 5,500-6,600 | 200 |
| soluble, mg/l | 2,700 | 90 | — | 150 |

[a]Values based on limited operational data obtained during periods when peeling sludge was discharged to waste stream.

[b]After screening with a 20 mesh vibrating screen.

[c]After biological treatment.

computed to be 2,710 mg/l. This compares reasonably well with the COD value of 3,000 mg/l. The total organic carbon values are slightly less than the conventionally determined $BOD_5$ values. For this particular tomato waste, the TOC can be used as a quick indication of the $BOD_5$.

Over 50 percent of the influent suspended solids are fixed solids such as clay, silt and sand. Because separate dirt removal facilities are not used, all of the dirt (except what is settled out in the dump tank or a very small settling bin) is pumped to the treatment process. The impact of this inert material is discussed in the sections dealing with nutrient requirements and sedimentation basin performance.

### Treatment Process Flowsheet

Hickmott Foods initiated the design and construction of wastewater treatment facilities in 1972. In the original design, large solids were removed with vibrating screens before the wastewater was sent through a series of centrifugal screen separators. From there, the waste was neutralized and discharged into a two-stage aerated lagoon system which was mixed and aerated by circulating the lagoon contents through pressurized tanks. Sedimentation facilities were not included in the original design. It was soon realized that this system could not meet discharge requirements. Unfortunately, the wastewater had not been characterized adequately before the plant was constructed. Because the centrifugal screens were overloaded hydraulically, it was not possible to produce a tomato sludge thick enough to make hauling feasible. Although the treatment process did reduce the soluble organic content of the waste, liquid-solids separation facilities were not provided and the suspended solids concentration in the effluent was as high or higher than the original waste flow. In addition, the cooling water discharge was part of the waste flow. This put an additional hydraulic loading on the treatment plant and reduced the detention time in the treatment system.

A new consultant was retained by Hickmott Foods, the treatment flowsheet was modified, and the necessary construction was completed in time for the 1974 operating season[4]. The modified process flowsheet currently in use is shown in figure IV-17. The vibrating screens, neutralization facilities and the effluent disposal portion from the original flowsheet were retained. The two lagoons have been converted to aeration and sedimentation basins. Sludge is recycled from the sedimentation basins back to the aeration basin. Cooling water is treated separately but is discharged through a common outfall. A pictorial view is presented in figure IV-18.

## UNIT OPERATIONS AND PROCESSES

The individual unit operations and processes that comprise the treatment system of Hickmott Foods are considered in this section. They include:

- Raw solids separation
- Neutralization and nutrient addition
- Activated sludge process
- Sedimentation
- Activated sludge waste solids thickening
- Sludge disposal
- Cooling water treatment

### Raw Solids Separations

The raw solids separation facilities consist of two 60-inch diameter two-stage vibrating screens. The screens are cleaned by the vibratory motion of the screens and the rotating spray headers. Approximately 5 tons per day of raw tomato solids, twigs and cans are removed from the waste stream using 20-mesh stainless steel screens. About 50 percent of the total suspended matter that reaches the treatment facility is removed with the screens. This material is discharged directly into a storage hopper. Screened solids are trucked to nearby ranches for cattle feed or for land disposal.

### Neutralization and Nutrient Addition

Before further treatment, the wastewater pH is adjusted to between 6.5 and 8.5. Neutralization is accomplished in a two-compartment tank. The detention time in each compartment at average flow is about 20 minutes. Sulfuric acid addition to each compartment is controlled with a pH probe and individual controllers are used for rough and fine pH adjustment. Sulfuric acid usage during the 1973 and 1974 canning seasons is shown in table IV-16. During the 1975 canning season, the acid usage was reduced further through more efficient handling of the caustic peeling sludge. Mishaps with the neutralization system during the 1975 season are discussed in a later section of this case history.

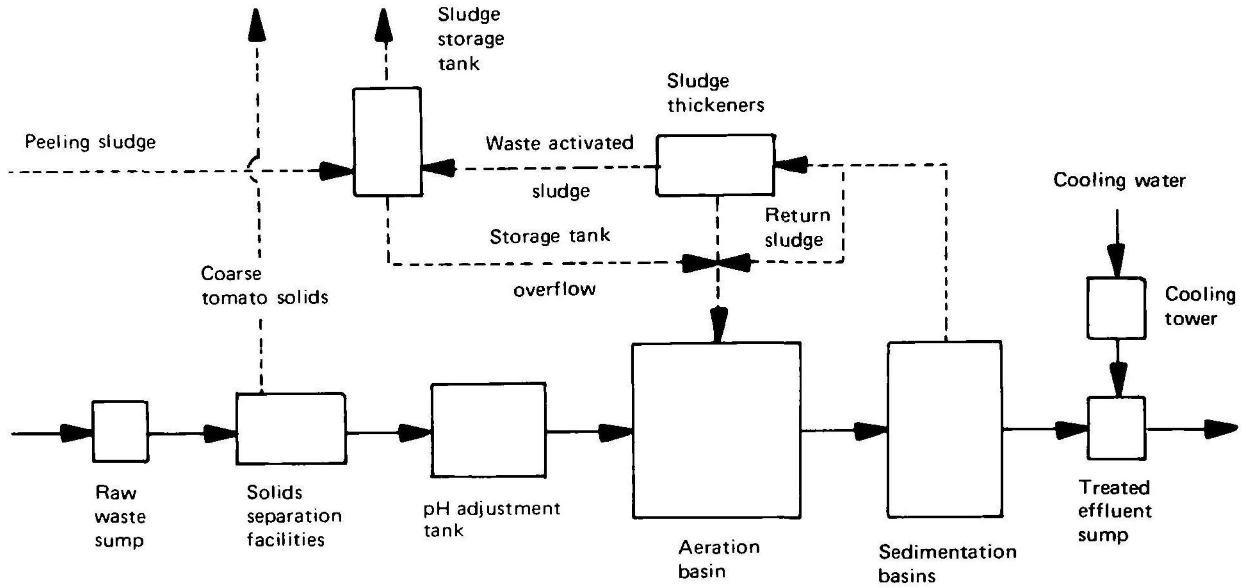


Figure IV-17. Flowsheet for wastewater treatment process (put into operation in 1974).

Figure IV-18. Aeration basin with surface aerators in operation.

Nitrogen and phosphorus as well as many trace elements are essential to the growth of microorganisms in the aeration basin[5]. The estimated nitrogen and phosphorus requirements, as well as the range in concentrations of these nutrients measured in the tomato wastewater, are reported in table IV-18. During most of the canning season, the nitrogen and phosphorus levels in the wastewater are near the upper end of the ranges shown in table IV-18. However, during the early part of the canning season when tomatoes are harvested from the southern portion of California's Central Valley, nutrients must be added because the sandy soils in this area contain few, if any, adsorbed nutrients. As Hickmott Foods has no prior removal of sand, silt and clay, the $NH_4^+$ and $PO_4^{-3}$ associated with the inorganic solids serve as a major nutrient source. The clay and silt content of the soil increases as harvesting moves up the Central Valley and nutrient addition is not required. The reduced nitrogen and phosphorus levels also occur at the time of process start-up. The presence of filamentous organisms (associated with sludge bulking) and the absence of the protein foam (usually present on top of the aeration basin) were observed until supplemental nutrients were added. When nitrogen and phosphorus are added in the form of aqueous ammonia and phosphate fertilizer, bulking is eliminated and the surface foam reappears (nitrogen and phosphorus are added until traces of ammonia, nitrate or phosphate are observed in the effluent).

Table IV-18.—*Nutrient requirements of activated sludge process and quantities available in wastewater from tomato canning operations*

| Constituent | Amount required, lb/day | Amount available in wastewater | |
|---|---|---|---|
| | | Conc., mg/l | Total,[a] lb/day |
| Total kjeldahl nitrogen as N | 417[b] | 20-90 | 190-856 |
| Total phosphorus as P | 85[c] | 4-12 | 38-114 |

[a]Average daily flow of 1.14 mgd.

[b]12.4 percent of the total daily volatile solids production in activated sludge process during normal operation.

[c]2.5 percent of the total daily volatile solids production by activated sludge process during normal operation.

## Activated Sludge Process

After neutralization, the wastewater flows into the aeration basin where waste tomato organics are converted to bacterial cell material. Six 60 hp, floating, high-speed aerators are used to provide oxygen and completely mix the contents of the basin. Normally all six aerators are operated continuously. However, to save power costs, the units could be turned on and off with the demand. A Hypalon liner is used to prevent erosion by the aerator turbulence. Biological solids are separated from the flow stream in sedimentation basins and are then returned to the aeration basin. The net biological solids produced are removed daily from the treatment system.

The physical characteristics of the aeration basin and the operational parameters of the activated sludge processes are reported in table IV-19. As shown, the process can be classified as extended aeration of activated sludge (mean cell residence time typically greater than 12 days). With the existing aeration and mixing capacity, it was possible to maintain mixed liquor SS concentrations ranging from 9,000 to 15,000 mg/l, while holding a dissolved oxygen concentration of 4 to 5 mg/l. High solids concentrations, however, may result in problems in the design and operation of sedimentation facilities. This subject is discussed further in the following section.

Table IV-19. —*Physical characteristics and operational parameters for the activated sludge process measured during 1974 tomato canning season*

| Item | Range | Average |
|---|---|---|
| Aeration basin characteristics | | |
| Volume, million gallons | — | 1.10 |
| Aeration time, hrs. | — | 24 |
| Aerators, | | |
| number | — | 6 |
| horsepower (6 @ 60 hp/aerator) | — | 360 |
| Oxygen transfer rate[a], lb $O_2$/hp-hr | 2.0-4.5 | 3.0 |
| Mixing, hp/1,000 gallons | — | 0.33 |
| Dissolved oxygen concentration, mg/l | 2.0-6.0 | 4.5 |
| Process operational parameters | | |
| MLSS[b] under aeration, | | |
| mg/l | 8,000-15,000 | 10,000 |
| percent volatile | 40-75 | 55 |
| F/M (food to microorganism ratio), | | |
| lb $BOD_5$/lb MLVSS[c] | — | 0.28 |
| lb COD/lb MLVSS[c] | — | 0.49 |
| Mean cell residence time[d], days | 8-20 | 12 |
| Yield coefficient, | | |
| lb cells/lb $BOD_5$ | 0.30-0.60 | 0.58 |
| lb cells/lb COD | 0.13-0.26 | 0.24 |
| Sludge production[e], lb VSS/day | 3,700-7,400 | — |

[a]Calculated on the basis of COD satisfied (see table IV-16).

[b]Mixed liquor suspended solids.

[c]Mixed liquor volatile suspended solids.

[d]Calculated on basis of cells in aeration basin only.

[e]Sludge production varies with mean cell residence time.

The observed advantages of this process in terms of process performance and reliability are as follows:

- Because of the low food-microorganism ratio, the process is less susceptible to upsets caused by high organic shock loadings.
- Because high levels of dissolved oxygen can be maintained, higher forms of microorganisms are present and a very clear effluent is produced (3 to 4 ft. on a standard secchi disc).
- Because the process can be operated in the extended aeration mode, a sludge is produced that settles well and carries down colloidal silt and clay particles.
- Because the process can be operated in the extended aeration mode, nutrient requirements are reduced.

Daily observations of the bacterial population were made because it was found that process changes and stress conditions could be observed before they would affect overall treatment efficiency. Under normal operations, the bacterial population is composed primarily of small bacteria with large numbers of stalked ciliates *(Vorticella)* and many free swimming ciliates and rotifers *(Philondina)*. The presence of these higher forms was used as an indication that the process was operating properly. The following conditions would cause the disappearance of the higher forms:

1. Dissolved oxygen levels below 3.0 to 4.0 mg/l. It is possible that with high mixed liquor solids, the oxygen transfer efficiency is impaired at lower concentrations.

2. High organic loadings. When the process was in the dispersed growth phase, it was observed that the higher forms did not compete as well as the simpler bacterial forms.

3. Toxic substances or nutrient deficiencies. These problems were also found to affect the higher forms.

4. pH control. If the pH control system was turned off or acid spillage occurred (1975), it was observed that the ciliates and rotifers could not adapt to pH fluctuations and would soon disappear.

Filamentous bacteria were not present under normal operation unless the following conditions prevailed:

1. Nutrient deficiencies. When the supply of nitrogen and phosphorus was below that required by the process for extended periods of time, filaments would begin to predominate and cause sludge bulking.

2. Low DO levels. When dissolved oxygen concentrations remained below 2.0 mg/l for extended periods, the population of filamentous organisms would rise.

### Sedimentation Facilities

The sedimentation facility was constructed in a pond which was once used as an aerated lagoon. Modifications to the old lagoon included the addition of concrete and walls, the fabrication of an inlet manifold, center rail support structure and effluent weir troughs, scum collectors, and the installation of two electric motor-driven, traveling bridge mechanisms for removing sludge. The dirt basin is lined with Hypalon. Neoprene rubber skirts are used to push sludge to the pick-up points on each bridge.

Sedimentation basin loadings and performance characteristics are summarized in table IV-20. The high mixed liquor SS levels and the settling characteristics of this sludge result in a solid-liquid separation process that is solids limited. The activated sludge process could not be operated in the extended aeration mode or with the high mixed liquor SS levels with a smaller sedimentation basin.

The traveling sludge-return mechanism allows for flexible operation of the sedimentation facility. The sludge-return rate can be varied by adjusting the self-priming sludge pumps on each bridge. Under normal operation, the bridge travel rate is 5 feet/min. Return sludge is discharged into an overhead trough and flows by gravity back to the aeration basin or is pumped to the sludge-wasting facilities.

Table IV-20.—*Sedimentation basin characteristics, loadings and performance data*

| Item | Value |
|---|---|
| Basin characteristics | |
| Number | 2 |
| Average surface area, sq ft, each | 4,080 |
| Liquid depth, ft | 6.5 |
| Volume, million gallons, each | 0.20 |
| Detention time at 2.28 mgd, hr, total | 4.2 |
| Design loadings | |
| Hydraulic loading rate including 100 percent recycle flow, gal/sq ft/day | 280 |
| Solids loading rate including 100 percent recycle flow, lb/sq ft/day | 23 |
| Weir loading gal/day/lineal ft | 11,400 |
| Return sludge, | |
| flow rate, gpm | 800 |
| percent of average flow | 100 |
| Effluent quality | |
| Suspended solids, | |
| range, mg/l | 9-75 |
| average, mg/l | 60 |
| volatile fraction | 33 |
| Secchi disc readings, ft | 1-4 |

Because the sedimentation facility was solids limited, hydraulic surges caused the transfer of solids from the aeration basin into the sedimentation basin at a rate much faster than they could be settled and pumped back to the aeration basin. If the surges were of short duration, the sludge-return facilities would catch up with the rising sludge blanket. However, if the duration of the flow surge was too large, a deterioration in effluent quality would ultimately result. As noted previously, Hickmott Foods has no sand, silt, and clay separation from its wastewaters. During periods of stable process operation, it was observed that the small colloidal clay particles present in the wastewater are carried down with the bacterial flow. But during periods when the sludge is not settling well, when the bacterial process is in the log growth phase (such as when the cannery is starting up after being down), some of the clay particles escape into the effluent. This resulted in a decrease in the ratio of volatile to total SS in the final effluent. This ratio was as low as 0.25 when the corresponding total effluent SS was 75 mg/l (normal value of volatile to total SS ratio in mixed liquor was approximately 0.55).

## Activated Sludge Waste Solids Thickening

To maintain process control, the bacterial cells grown each day must be wasted. Wasting is accomplished by pumping return sludge through a three-stage, centrifugal-screen thickening operation. In the centrifugal screen, the sludge is pumped through a distributor against a rotating polyester screen with 43-micron openings. Water and some solids pass out through the rotating screen (rotating at 200 to 400 rpm), with the thickened sludge being discharged out the bottom. The capture efficiency of each of these units is approximately 50 percent. After a single pass through the sludge, it is thickened by approximately 25 percent. A schematic with the various flow rates, sludge concentrations and total pounds wasted daily is shown in figure IV-19. Because the clay and silt particles in the waste sludge blind the screens, a thicker final sludge could be obtained if this material were eliminated.

### Sludge Disposal

Raw tomato solids are trucked away to nearby ranches for cattle feed. Sludge from the peeling operation is combined with the waste-activated sludge and approximately 20 loads per day (3,000 gal/load) are hauled away by tanker for land spreading at the disposal site. The waste-activated sludge neutralizes the caustic peeling sludge. After spreading, the sludge is allowed to dewater for 24 hours before being disced into the soil.

### Cooling Water Treatment

Cannery cooling water is treated in a single cooling tower and discharged with the wastewater effluent into the San Joaquin River through a common outfall. The Central Valley Regional Water Quality Control Board tentatively set 50 mg/l as the maximum COD increment concentration to be allowed in cooling water discharge. This value is subject to change after more data are gathered during the 1975 operating season. Data gathered during 1975 showed the average COD of the cooling water discharge to be 45 mg/l or less.

## TREATMENT COSTS

The purpose of this section is to

1. Briefly summarize the capital expenditures involved in the construction of the Hickmott waste treatment facility.

2. Identify the daily operation costs.

3. Put these costs into perspective with respect to production costs.

### Capital Costs

Capital expenditures for the Hickmott Foods wastewater treatment facility are reported in table IV-21. As shown, the total cost of the plant at $885,000 (ENRCC Index = 2,240) is about one-half that of a comparable conventional secondary treatment plant design. The use of earthen basins for both aeration and sedimentation is most significant in terms of cost savings. Use of traveling sludge-pick-up mechanisms in a lined earthen basin makes possible an efficient and flexible sedimentation operation at a considerable cost savings over conventional designs employing concrete or steel tanks. Hickmott Foods was also able to reduce construction costs by doing the majority of the general contracting and labor with cannery personnel.

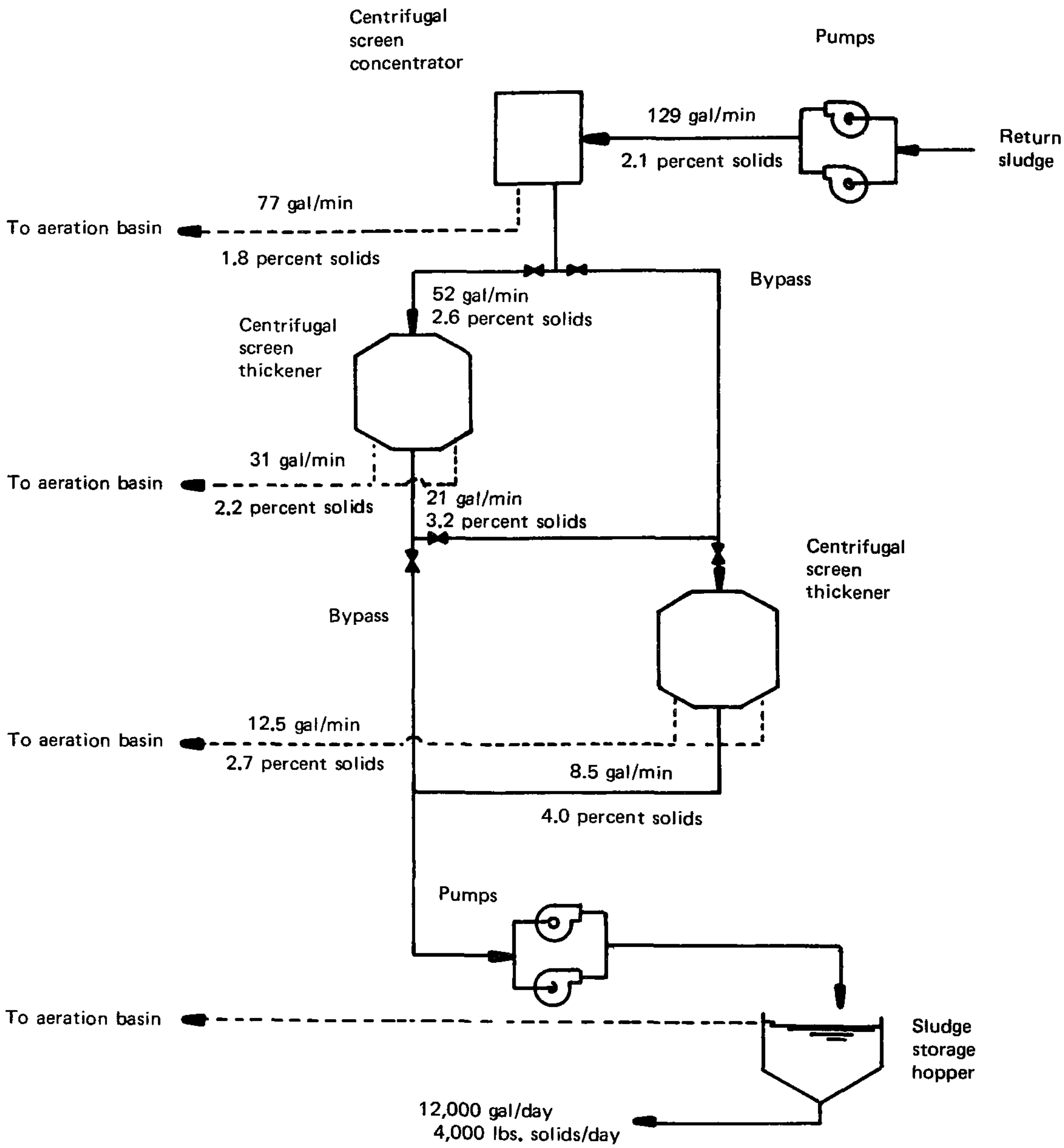


Figure IV-19. Flowsheet for waste sludge thickening facilities.

Table IV-21.—*Summary of capital costs of wastewater treatment facilities*[a]

| Item | Cost, dollars |
|---|---|
| Major equipment | |
| Aerators | $ 36,000 |
| Clarifier mechanisms | 76,000 |
| Sludge thickeners | 45,000 |
| Other equipment | 101,000 |
| Soil excavation, filling, grading, paving, etc. | 70,000 |
| Concrete work | 200,000 |
| Structural steel & supports | 47,000 |
| Pond liners | 21,000 |
| Piping, fittings & installation | 95,000 |
| Crane & rigging | 5,000 |
| Fencing & landscaping | 7,000 |
| Electrical sub-station, hook-ups, equipment & installation | 74,000 |
| Permits, impact report & other governmental fees | 1,500 |
| Sub total | $778,500 |
| Plant labor | 58,000 |
| Design, civil, soil, marine engineering & general contracting expenses, etc. | 49,000 |
| Total | $885,500 |

[a]Engineering news record construction cost (ENRCC) index for San francisco Bay region = 2240 (January, 1974).

## Operational Costs

Operational costs for wastewater treatment are associated with the following:

- The operation and maintenance of the wastewater treatment facilities.
- The hauling and disposal of sludge.

Daily costs for the 1974 tomato canning season are summarized in tables IV-22 and IV-23. From these tables, it can be seen that one-half of the daily operating expenses are associated with the disposal of waste solids and sludge.

Table IV-22.—*Summary of daily operating costs for wastewater treatment facilities during 1974 canning season*

| Item | Cost, dollars/day |
|---|---|
| Power (520 hp x 24 hr x 0.746 kw/hp x 0.02 kwh) | $186 |
| Chemicals (acid, ammonia and phosphate) | 130 |
| Supplies | 50 |
| Testing & monitoring operations (24 hr/day x $5.50/hr) | 132 |
| Mechanic-operator (10 hr/day x $8.00/hr) | 80 |
| Total | $628 |

Table IV-23.—*Summary of daily solids and sludge disposal costs during 1974 canning season*

| Item | Cost, dollars/day |
|---|---|
| Truck driver (1 x 24 hr/day x $7.50/hr) | $180 |
| Truck operation (solids) (4 trips/day x 14 miles/trip x $0.30/mile) | 17 |
| Truck operation (sludge) (20 trips/day x 20 miles/trip x $0.35/mile) | 140 |
| Solids disposal fees (4 loads/day x $3.60/load) | 14 |
| Sludge disposal fees | 67 |
| Discing tractor & operator (1 x 16 hr/day x $13/hr) | 208 |
| Total | $626 |

### Annual Cost

An estimate of the total daily cost to Hickmott Foods including the construction and operational costs is given in table IV-24. For the 1974 tomato canning season, the cost of treatment amounted to 13.0 cents per case of tomato product. On a per can basis, the cost of wastewater treatment at Hickmott Foods is approximately 0.5 cents.

Table IV-24.—*Summary of total daily cost for wastewater treatment during 1974 tomato canning season*[a]

| Item | Cost |
|---|---|
| Capital cost, dollars/day ($885,500[b] x 1627[c]/90 day/yr) | $1,601 |
| Treatment plant operation[d], dollars/day | 628 |
| Solids and sludge disposal[e], dollars/day | 626 |
| Total, dollars/canning day | $2,855 |
| Cost/case[f], cents/case | 13.0 |
| Cost/can, cents/can | 0.5 |
| Cost/ton of raw tomatoes, dollars/ton[g] | $4.28 |

[a]Based on a 90-day canning season.

[b]Capital cost from table IV-21.

[c]Capital recovery factor = 0.1625 (10 yrs @ 10 percent).

[d]Cost data from table IV-22.

[e]Cost data from table IV-23.

[f]Based on two million cases of number 2-1/2 cans.

[g]Based on 60,000 tons.

## PROBLEMS, FUTURE IMPROVEMENTS AND WASTE REDUCTIONS

With the measures Hickmott Foods has instituted to reduce and treat the wastes generated from canning operations, the company is now in compliance with state and federal discharge requirements. Nevertheless, additional steps are being taken or considered to increase process reliability, to reduce waste loads and treatment and/or disposal costs. These developments are outlined in the following paragraphs.

### Acid Spills

Twice during the 1975 canning season, several hundred gallons of sulfuric acid were accidentally dumped into the aeration basin. These spills were caused by (1) the delivery truck driver's failure to pay attention to what he was doing, and (2) failure of an air operated valve which allowed the storage tank to drain. Both these spills caused a major failure in biological process efficiency (pH in the aeration basin dropped to 3.0 for a short period of time). Within 4 days, the process had fully recovered from both these incidents. Audio alarms were installed on the pH controller to assure that incidents like these will not occur again without the operator's knowledge.

### Reduction in Water Usage

Because Hickmott Foods has abandoned its sweet potato and asparagus operations, daily water usage was reduced further by shortening the lengths of belts on which peeled tomato products must travel. This change eliminated about 50 gpm of water now used for belt lubrication. In turn, this reduced the peak water usage in the cannery to about 750-800 gpm. This quantity is considered to be the minimum water usage possible to maintain sanitary conditions. Heightened concern by USDA and FDA over the issue of machine mold may ultimately result in increased water usage per ton.

### Flow Equalization

In activated sludge systems such as the one employed at Hickmott Foods, hydraulic surges cause large amounts of mixed liquor solids to be transferred from the aeration basin to sedimentation basin in a short amount of time. If these surges are sustained and are of large enough magnitude, a deterioration in effluent quality can result as the sludge blanket builds up. With the high concentration mixed liquor solids employed at Hickmott Foods, increasing the sludge return rate does not effectively draw down the sludge blanket because of the very low settling velocity of the mixed liquor at a concentration of 10,000 mg/l TSS. To reduce the impact of the flow surges, the top 18 to 24 inches of the aeration basin is to be used for flow equalization. A floating weir will be used to maintain a constant flow to the sedimentation basin regardless of the water level in the aeration basin.

### Solids Disposal

Currently, all solid and sludge wastes must be hauled away for disposal. As long as nearby disposal sites are available, this method is cost effective. If, however, the present system proves to be unworkable, then further sludge dewatering must be considered. Because a large amount of concentrated carbonaceous waste is produced, the use of a pyrolysis process to produce activated carbon is now being evaluated by personnel from the Jet Propulsion Laboratory of the California Institute of Technology. The production of a useful and marketable by-product would reduce an otherwise prohibitively high operating cost for this method of sludge processing.

### Raw Product Transportation

Hickmott Foods has also contemplated the installation of bulk tub dumping facilities (bins are now used). However, based on preliminary studies, it was found that when ripe tomatoes are stacked 30 to 36 inches high, the bottom one quarter by weight are broken or cracked. In a plant such as Hickmott where over 50 percent of all tomatoes are peeled, this amount of damaged product and extra waste cannot be tolerated.

## CASE HISTORY IX

## PERMIT REQUIREMENTS FOR STARTING A NEW FOOD PROCESSING PLANT*

My remarks will be confined to starting a new plant in the Central Valley of California. The requirements may be, and probably are, different in other states and even in other sections of California.

In any new or existing plant, it is Tri/Valley's philosophy to reduce waste to a minimum consistent with acceptable operating procedures. This philosophy includes both liquid and solid waste.

It is another Tri/Valley philosophy that waste or residual material is generally best handled through land application on Tri/Valley property. Four of our five plants totally or partially handle all of their residual material. Tri/Valley and the food processing industry have a residual material that is generally compatible with land disposal. We at Tri/Valley Growers believe that the disposal costs associated with land disposal will be the most reasonable in the long run. In addition, the regulations probably will be less stringent. Through land disposal we gain the added benefit of controlling what happens to the residual material and are generally cognizant of it. Through land disposal we are investing in land and not concrete and steel as with conventional treatment plants. If and when a plant is closed, land is an asset while a more conventional treatment plant may be a liability. Thus, in the disposal of residuals, it is Tri/Valley's policy to utilize land disposal.

When Tri/Valley decided to build a new processing facility, several criteria were established for the plant. The plant would not be municipally sewered. It would be totally self-contained in its ability to dispose of all liquid and solid residuals. The plant would be located in an agricultural area but would not be located on prime agricultural land. The location would have to be near major highways and have access to a railroad. Since this would be a tomato processing plant, it had to be located near the tomato growing area. Thus, the guidelines for locating the plant were set.

The plant was actually located near Los Banos in western Merced County. It was located on 840 acres of marginal land with alkalinity problems (pH 8-9), salinity problems and high ground water. Eight hundred and forty acres give Tri/Valley the ability to adequately handle liquid and solid residual loads. The plant is near I-5 and State 152. Also, the Southern Pacific tracks are along one side of the property. By being located in western Merced County, the plant is located in the center of three major tomato growing areas.

The plant, which first operated during the 1975 season, processes tomatoes into tomato paste and packages the paste into 55 gallon drums. The plant has a nominal throughput of 200 tons per hour. There are three Rossi-Catelli T-120 evaporators producing tomato paste and six Fran Rica drum fillers packaging the paste. The plant is located on approximately 20 acres.

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*Mr. Robert Parodi — Tri/Valley Growers, San Francisco, California

The liquid residuals are disposed of by sprinkler irrigation of a cover crop. The solid waste is disposed of by spread and disc. Spreading is accomplished with a spreader truck. Thus, the plant did operate during 1975 and accomplished the objectives set by management.

Now I will describe how we manuevered through the maze of requirements and permits to build the plant and operate it during 1975. It was approximately 18 months from the time we decided to build the plant until we actually began operation. This is the minimum time required. If you want to be on the safe side, allow two years from conception to operation. Any shorter period of time would be pressing the issue, as I will show.

The first order of business in building our plant was a county use permit. This was required since the plant site property was zoned agricultural and was in an exclusive agricultural area. We were required to prepare an Environmental Impact Report as the first step to obtain the use permit. Merced County requires that the applicant prepare the EIR. Other counties write the EIR for the applicant, either directly or through a consultant. Even though we were responsible for preparation, we still hired a consultant from Merced who was familiar with the area and had worked closely with the County Planning Department.

Coincidentally, we purchased the plant site with two contingencies: (1) that we obtain the use permit, and (2) that we could obtain well water of adequate quality and quantity. We worked closely with the consultant in preparing the EIR. The consultant worked closely with County Planning (the lead agency), County Health, Public Works and Agriculture Extension.

The County Planning Commission met in a public hearing to review the EIR and rule on our use permit application. It took three Planning Commission hearings and several months to resolve the issue. Most of the local communities and the agricultural interests in the area were in favor of the plant and we helped foster the favorable opinion when we could. A major point was the reclaim of the marginal land. The county agencies felt that the plans associated with the plant were environmentally sound and they had the means to control the plant if problems developed. Some of the local environmental groups were opposed to the plant. The State Department of Fish and Game (DFG) was opposed to the plant site since it was next to the Volta Wildlife Refuge. We had several meetings with the various groups to try to resolve differences. Some were productive while others were not, but they were all worthwhile from the standpoint that we attempted to resolve any and all questions or areas of contention. Also, in the midst of the EIR proceedings, we engaged a local attorney. This we felt was necessary in order to ensure that we met our legal obligations and that the county met their legal obligations. We did not want to be challenged in court for failing to meet some legal stipulation. The EIR was approved as adequate by the Planning Commission and the permit was issued. Both actions were taken unanimously.

There was a waiting period between the commission's action and deliberation by the Board of Supervisors. The use permit has to be approved by the Board prior to being granted. We again tried to present our position to local communities and groups. We also had another meeting with Department of Fish and Game trying to resolve our differences. When the Supervisors met, we had broad local support. We were still opposed by some local interests and DFG. The Board weighed the issue and granted the use permit unanimously. We wanted a decision and not a postponement. Thus, about six months after starting on the EIR, we had a use permit to begin construction. Yet we had to wait another thirty days until the judicial review period expired. After 30 days, a suit could still be filed but it would not halt construction. Thus, about 12 months prior to processing tomatoes, we broke ground and began preparing the site.

The next order of business was a building permit. Again we used the firm that prepared the EIR. With their local insights, they were able to expedite processing of the building permit. We obtained only one building permit for the entire installation. This meant that a complete design was submitted with the application. In the long run, it saved considerable time. One item of concern that we had not anticipated in the building permit was the disposal of domestic waste. The size, type, and extent of septic tanks and leach lines had to be reviewed. This aspect of the building permit came under the jurisdiction of the County Health Department. Again we met with this group and finally resolved the problems caused in our case by very tight clay soil and high water table. Other than some minor problems and some delays in receiving equipment, the building of the plant proceeded on schedule. It is important to note that because of long lead times and delays in the EIR process, certain pieces of equipment had to be ordered before the building permit or use permit was issued.

Next we applied for Waste Discharge Requirements from the Central Valley Regional Quality Control Board. The discharge of both the solid and liquid residual is controlled by regional boards in California. The solid waste had to be disposed of in a manner similar to the Santa Clara and San Joaquin experience. The operating parameters used at these sites were imposed upon us. The only difference was that we transported and spread with the same piece of equipment, our spreader truck. The liquid residual requirements were, primarily, written to prevent avian botulism since the wildlife refuge is a neighbor. In many areas the Board staff deferred to the Department of Fish and Game. In essence, if we obtained DFG approval on certain approaches and methods, the Water Quality Control Board staff would concur. Thus, we started another round of meetings with Department of Fish and Game and Board staffs. In the end we were able to petition the Central Valley Regional Water Quality Control Board with a plan and set of requirements that were acceptable to Tri/Valley Growers, DFG, and Water Quality Control. Under the requirements, we have certain operating conditions such as no standing water over 60 hours. We also have monitoring requirements for our wastewater, ground water and rain water. Thus, we did obtain reasonable requirements through our work with DFG and the Board staff.

I cannot emphasize enough the need for a well-conceived, documented plan to present to the Board staff. This will certainly aid in the entire permit application. It is also helpful when you have a good track record with the Board staff.

In regard to air pollution requirements, we had to work with the County Health Department. In the area of the State that I am familiar with, the health agency is the enforcement group. At about the time we obtained the building permit, we obtained a permit to construct our boilers. At that time we provided the Health Department with the required data regarding our two 125,000 pound boilers. After the boilers were installed and before the plant operated, we applied for a permit to operate. At that time the staff inspected the installation of the boiler and the control equipment. There was a question regarding the burning of oil but this was resolved administratively. The entire permitting procedure was handled administratively by the Health Department. I am not sure how long this will continue, especially with the new source review rules on the horizon.

There were several unique requirements that were imposed upon us before and during construction of the plant. Some could have been disastrous if they went against us. First, a natural gas line had to be brought 6 miles from the main Pacific Gas & Electric (PG&E) line. In order to do this, we had to gain permission from the California Highway Department to go under I-5, and from the Central California Irrigation District to go under and along their main canal. Regarding the gas line, PG&E had to obtain approval from the California PUC to serve our plant. This certainly caused apprehension on our part. As I understand it, this type of approval for our industry could be a thing of the past. Tri/Valley Growers had to purchase the gas line and also had to pay for the maintenance of the line for the first five years. We also had to have rail access because we have to cross the tracks to get into our plant site. We had to obtain permission from the railroad to cross the track with vehicles. Tri/Valley Growers had to install a safety crossing and has to pay for the maintenance of the crossing. Thus, be cognizant of what other requirements could be imposed and deal with them as early as possible.

In conclusion, the best advice that I can give you when building a new food processing plant is to allow enough time. At a minimum, two years are required to build a plant in agriculturally zoned land. We were extremely fortunate to build the plant and operate in 18 months. Secondly, do your homework. Know what permits and operating requirements are needed and what needs to be done to obtain them (the requirements and agencies are summarized in table IV-25). Employ a local firm or group to assist you if you do not have extensive knowledge and insight of the area. This can help from a technical as well as a public relations aspect. Tell your story in a positive manner. Also, tie down the property and make the purchase contingent upon obtaining a use permit and any other particular requirement. After you have covered the bases, be prepared to go through the agonizingly slow process of obtaining the proper permits and approvals. Again, allow enough time!

Table IV-25.—*Requirements for starting a new food processing plant*

| |
|---|
| I. Use permit<br>A. Environmental Impact Report<br>B. Planning Commission<br>C. Board of Supervisors |
| II. Building permit<br>A. Building Department<br>B. Health Department |
| III. Waste discharge requirements<br>A. Regional Water Quality Control Board<br>B. Department of Fish and Game |
| IV. Air pollution requirements<br>A. Permit to construct<br>B. Permit to operate |
| V. Other requirements<br>A. Highway Department<br>B. Irrigation District<br>C. Public Utility Commission<br>D. Railroad |

## CASE HISTORY X

## LAND SPREADING AND DISCING OF FOOD RESIDUALS*

### INTRODUCTION

The Cooperative for Environmental Improvement (CEI), Inc., was established in late 1969 by a group of California canners in Santa Clara County. Its sole purpose was to manage fruit and vegetable processing residuals from canning and freezing operations in an improved and environmentally-sound manner. The CEI operation was initiated in 1970 and has since proven highly successful.

The spread-and-disc operation for returning agricultural residuals to soils is now a widely accepted practice and readily adaptable to most areas. However, the nature and quantity of materials handled at a site used exclusively for food processing residuals requires special attention and equipment to preclude creation of nuisance conditions.

### THE LAND

The CEI land, located in Santa Clara and San Benito Counties, is relatively flat and is located in a sparsely populated farming and grazing area which is subject to frequent winter flooding. The spread-and-disc sequences and the equipment items described are those required for the operation of this site. Suggestions for modifications to suit other conditions are offered.

A site could undoubtedly be successfully operated in much closer proximity to developed and settled areas. The operation can be conducted on all soil types and in all but extremely wet areas. With modifications of the handling equipment, the spread-and-disc operation can also be conducted on hilly land. The solid residuals handled on the CEI site are primarily from the processing of cherries, apricots, peaches, pears, and tomatoes. During the past four years, the disposal operation has returned these residual materials to the soil in a nuisance-free manner, resulting in improved soil tilth and crop productivity. The loading rates are dictated by soil characteristics, climatic conditions, the nature of residual materials handled, and the method and diligence of spreading and working.

### EQUIPMENT

The tractor used in the CEI operation is a four-wheel drive unit (John Deere, International Harvester, or equivalent), equipped with 26.00 X 28 single tires. A similar tractor, equipped with 18.4 X 38 dual wheels, has been successfully used in another operation. However, caution should be exercised to avoid excessively wet clay soil when using dual wheels. "Track layers" are not recommended since this type of equipment will tend to excessively mix the soil and residual materials, thus hampering drying.

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* *Mr. Allen M. Katsuyama — National Canners Association, Berkeley, California*

The weight of the tandem drag is important. Too heavy a drag will tend to move soil as well as the residuals, while too light a drag will simply ride over all materials. The drags used at the CEI site were fabricated from 10-inch heavy wall (3/8-inch) steel pipe, 18 feet in length. When operations are conducted on slopes, the length of the drags should be shortened as necessary to obtain even spreading.

Railroad iron (90 pounds per foot) was welded to the entire length of each tubing. Additionally, a 5- to 6-foot length of rail (116 pounds total weight) was welded to the back center of the rear drag. This piece (the actual length of which must be determined by trial-and-error) imparts a wobbling action to the rear drag; the motion facilitates spreading and crushing of large fruit pieces. All ends of the tubings were capped with steel plates. The two sections are connected by 46-inch lengths of 1-inch chain. The connecting length is critical for proper spreading. The entire unit is connected to the tractor with 20 feet of 1-inch cable and an appropriate coupling. The cable length is also critical in providing proper maneuverability to the tractor, especially when large piles are encountered.

The recommended discs are off-set, not tandem, and equipped with notched blades. The unit is also equipped with four hydraulically-adjustable rubber tires to control the depth of cut. This is an essential feature to avoid excessive depths in wet soil. When operating on clay soils, the unit must be provided with additional weight. When maneuvering at the ends of a field, care must be exercised to avoid creating "dead furrows." Materials deposited in such furrows will anerobically decompose, thereby creating odors and attracting flies.

Where soil characteristics dictate the need for breaking clods of soil, a Schmeizer or equivalent should be provided. This apparatus not only evens out the soil texture but also helps to settle the soil, thereby enabling trucks to operate in the field without becoming bogged. Use of a clod breaker also facilitates spreading of residuals. A variety of trucks are used to deliver food processing residuals to the CEI site. These range from bottom-dump rigs to tank trucks containing a slurry of ground material.

The ideal equipment is a rear-dumping bed with hydraulically-operated gates. Hydraulic cylinders with two-way valves should be protected within the bed walls and connected to the gate at mid-height. By locating the control within the truck cab, close regulations of discharge rates may be obtained. Dump trucks without hydraulically-operated gates must be carefully unloaded to avoid piles of moist materials. Chains used to limit the opening of the gates have not worked well as a means to regulate discharge rates because residual characteristics vary widely.

Long-bed trailers with up to 36-cubic yards capacity have posed problems with uniform discharging of loads and must be carefully operated. These have a tendency to tip or shift while unloading, thereby delaying site operations, increasing their costs, and increasing nuisance liabilities by creating "wet" piles. Bottom-dumping rigs are quite satisfactory since these are generally equipped with hydraulically-operated gates. Positive control provided by the hydraulic system enables these units to discharge materials in a narrow and uniform ribbon. However, most existing canneries cannot accommodate the double rigs.

When slurries of ground residuals are delivered in tank trucks, proper spreading (light and even distribution) is especially critical. A truck with a multi-valved discharge manifold should be used. If ground materials are discharged through a single valve, splash plates to spread the discharge should be provided.

## LAND PREPARATION

To maximize the receptive capacity of the soil and to minimize problems, the land must be prepared annually prior to disposition of any residuals. The soil should be worked to a depth of 8 to 10 inches with the discs. Compacted soils may require initial plowing. When large clods occur, a suitable clod breaker should be employed.

Although land planning is unnecessary, the soil surface must be leveled to the extent that no pocket holes exist. The tandem drag used for residuals spreading may also be used for this purpose. It is vitally important that all holes and furrows be filled before residuals are applied, thereby eliminating the possibility of excessive accumulations of residuals and providing a uniform and moderately compacted surface for truck travel.

Timing of the land preparation step is important. Unlike normal farming practices where soils are worked to retain moisture, the land must be prepared to obtain maximum dryness. (Dry soils will have greater capacities for assimilating high moisture residuals.) Therefore, land preparation should be delayed as late as possible.

## OPERATION

Undue delays in deliveries must be avoided, especially with fruit residuals. When these materials are allowed to sit either at the processing plant or in an open truck, flies will inevitably be attracted and begin to breed. In such a situation, fly problems at the disposal site will be unavoidable and difficult to control. Past experiences indicate that pear residuals quickly develop fruit fly populations and must be handled quickly.

Non-processing residuals (cans, wood and metal scraps, paper) must be absolutely precluded from the loads. The materials will interfere with the field operations and equipment and will hamper subsequent agricultural uses of the land. In the CEI operation, the site manager is given full authority and responsibility to control unloaded materials.

When residuals from numerous canneries are being delivered by several contract haulers, it is virtually impossible to schedule deliveries to the site. Therefore, a full-time field supervisor is required, especially during the peak of the season. The supervisor must be responsible for directing each truck to the appropriate spot in the field and assure that each load is properly discharged and spread.

A fluorescent triangular sign is used at the CEI site to direct and align arriving trucks. Night deliveries are further assisted by lights. The sign is positioned at the end of a discharge lane so that each load will be discharged in line with the preceding load. The discharge lanes should be located on not less than 20-foot centers.

The discharge of each load should be started sufficiently beyond the end of the previously deposited load to avoid overlapping of spread materials. The residuals must be discharged from the trucks as thinly and evenly as equipment and the driver's skill allow. Hydraulically-operated tailgates will greatly facilitate obtaining desirable distributions. Trucks without this feature must be carefully operated, i.e., the rate of discharge and the forward speed of the truck must be well coordinated to avoid piles. Ideally, the residuals should be distributed in a 4- to 8-inch layer.

Residuals should never be deposited in piles. Free moisture will seep from such piles making it extremely difficult to dry the soil at that spot. These wet spots, popularly referred to as "hot spots," generate odors and provide ideal conditions for fly breeding. Piles delay field operations: they necessitate additional costly work and additional time for drying.

The residuals must be spread and crushed with tandem drag soon after discharge. It is vitally important to immediately spread any materials which have been deposited in piles. Residuals which have been distributed in thick layers may require several passes with the drags to obtain a spread that is as thin as practicable.

The residuals should be allowed to dry for a period of up to 48 hours. This initial drying is important to reduce the moisture content within the materials, thus accelerating subsequent aerobic decomposition of the residuals by soil microorganisms. Using the drag for initial spreading aids the drying process by crushing the larger residual fragments.

Between the initial and later dragging steps, the residual materials are incorporated into and mixed with the surface soil by repeated passes with the discs. The soil should be worked to a depth of 6 to 8 inches. Dual rubber tires mounted on the discs are used to control the maximum depth; the tires are especially required when wet soil conditions are encountered.

As with initial land preparation, the discings are designed to maximize drying. The frequency and the number of passes will be determined by those local conditions which affect the drying rate.

## END-OF-SEASON PROCEDURES

### Final Site Preparation

To preclude the occurrence of problems during the first rains following an operating season, the residuals must be adequately stabilized. The operation must be continued until it is evident after discing that the residuals are sufficiently degraded or dried. Leveling the soil will aid surface drainage and minimize rainwater ponding which may contribute to later problems.

Special attention must be given to preventing soil erosion of hilly sites during the off-season. It is recommended that such areas be dry planted with barley, wheat, or other similar crops immediately after the seasonal operation.

### Equipment Maintenance

In addition to the normal maintenance program, the tractor must be thoroughly washed, steam cleaned, and painted at the conclusion of each season. The underside of the pickup truck should also be steam cleaned and undercoated. Without diligent care, metal corrosion due to fruit acids will be extremely severe and costly.

## CONCLUSION

The spread-and-disc operation can be conducted in virtually any geographic area. The operation is basically one of good applied farming practices. It is actually "farming" of food residues. It consists of preparing the soil, working the disposal "crop" and the land relative to the material concentration, moisture content, and absorption, and doing this in a prompt and thorough manner. Good control of hauling truck performance is also mandatory.

CEI considers its program to be one of soil enrichment. With careful and constant attention, most food processing residuals will be readily assimilated into the soil without creating environmental problems. As a result of this operation, definite improvements in soil tilth and crop productivity will be achieved.

The procedure which is followed must be tailored to each site, with consideration given to climatic conditions, soil characteristics, topography, and the nature of residuals. The key to a successful operation lies with a diligent and knowledgeable site manager. His efforts will assure the achievement of a viable program for recycling agricultural organic materials back to the soil.

A manual which illustrates the equipment at this site and complete details of the operational sequences involved can be obtained by writing to:

Cooperative for Environmental Improvement, Inc.
c/o Canners League of California
1007 L Street
Sacramento, CA 95814

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# Chapter V

# GLOSSARY

A

**Acidity** — The quantitative capacity of aqueous solutions to neutralize bases caused by carbon dioxide, mineral acids, and the salts of strong acids and weak bases.

**Activated carbon** — An amorphorus form of carbon obtained by carbonization of cellulosic material possessing a high adsorptive capacity.

**Activated sludge** — Sludge floc produced by the growth of zoogleal bacteria and other organisms in the presence of oxygen and accumulated in sufficient concentration by returning floc previously formed.

**Activated sludge process** — A biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation and is wasted or returned to the process as needed.

**Adsorption** — A taking up of gases or liquids by the surfaces of solids or liquids with which they are in contact.

**Advanced waste treatment** — A term including any treatment process applied for renovation of wastewater that goes beyond the usual 90- to 99-percent oxygen demand and organic solids removal of secondary treatment. May include nitrogen, phosphorus, other minerals, taste, odor, color, and turbidity removal by a variety of conventional and special processes as required to renovate wastewater for intended reuse.

**Aerobic** — Living or taking place only in the presence of oxygen.

**Alkalinity** — The capacity of water to neutralize acids, imparted by the content of carbonates, bicarbonates, hydroxides, borates, silicates, and phosphates, expressed in milligrams per liter or equivalent calcium carbonate.

**Alum** — A trade name for the chemicals aluminum ammonium sulfate or aluminum sulfate, used as a flocculentor sludge thickening agent.

**Anaerobic** — Living or taking place in the absence of oxygen.

**Anaerobic digestion** — The degradation of organic matter by the action of microorganisms in the absence of oxygen.

**Assimilative capacity** — The maximum capacity of a natural body of water to receive wastewaters or toxic materials without deleterious effects.

**Available chlorine** — A measure of the total oxidizing power of chlorinated compounds used for chlorination.

B

**Biochemical oxygen demand (BOD)** – A measure of the potential of a wastewater to utilize oxygen while experiencing microbial degradation; a semiquantitative measure of the organic content of a waste. $BOD_5$ is the standard test conducted over a 5-day period.

**Biological oxidation** – The process whereby living organisms in the presence of oxygen convert the organic matter contained in wastewater into a more stable or a mineral form.

**BOD load** – The BOD content, usually expressed in pounds per unit of time, of wastewater passing into a waste treatment system or to a body of water.

**BOD:N:P ratio** – A ratio calculated from analysis of the BOD to total nitrogen and total phosphorus contained in the waste stream. (To assure a nutrient balance within a biological treatment system, a ratio of 100:5:1 is generally recommended.)

**Brackish water** – Water having excessive chloride content ( $>$10,000 mg/l) in the general range between fresh water and seawater.

**Breakpoint chlorination** – The process of applying chlorine to the wastewater containing free ammonia in order to provide free residual chlorine.

**Buffer action** – The capacity exhibited by dissolved minerals that resists a large change in the pH of a solution. In surface water, the primary buffer action is related to carbon dioxide, bicarbonate and carbonate equilibria.

**Bulking sludge** – A sludge that settles poorly because of a floc with excessive volume and low density.

C

**Chemical oxygen demand (COD)** – A measure of the potential of a wastewater to utilize oxygen while experiencing chemical oxidation; a semiquantitative measure of the organic content of a waste. It does not necessarily correlate with the BOD.

**Chloramines** – Compounds of organic or bounded nitrogen and chlorine.

**Chlorine demand** – The difference between applied chlorine and residual chlorine remaining at the end of a specific contact time. Chlorine demand varies with dosage, time, temperature and nature of the water impurities.

**Clarification** – Any process or combination of processes which reduces the concentration of suspended matter.

**C/N ratio** – The calculated weight ratio of carbon to nitrogen, from analytical determinations.

**Coagulation** – The process of reducing the repelling forces between colloidal particles in order that they may combine into larger particles that are more easily settled.

**Coliform group** – A group of bacteria made up of several genera of which *Escherichia coli (E. coli)* and *Aerobacter aerogenes* are dominant. The *E. coli* predominantly inhabit the intestines of man and animals and have therefore been used as evidence of sanitary contamination.

**Colloidal particles** – Finely divided solids which will not settle due to gravity alone but which may be removed from a wastewater by coagulation, filtration, or biological action.

**Composite wastewater sample** — A sample made up of a series of individual grab samples or continuous portions of wastewater with respect to some measure of flow or time.

**Contact stabilization process** — A modification of the activated sludge process in which raw wastewater is aerated with a high concentration of activated sludge for a short period, usually less than ˜0 minutes, to obtain suspended removal by absorption. The solids are subsequently removed by sedimentation and transferred to a stabilization tank where aeration is continued further to oxidize and condition them before their reintroduction to the raw wastewater flow.

D

**Denitrification** — 1. The removal of nitrogen from the water by conversion of oxidized nitrogen (nitrate and nitrite-N) to nitrogen gas. 2. A reduction process by chemical or biological reduction.

**Detritus** — The coarse debris, such as sand and grit, carried by wastewater.

**Diatomaceous earth** — A fine, siliceous earth consisting mainly of the skeletal remains of diatoms (unicellular organisms). Also called *diatomite.*

**Diffuser** — A porous plate, tube, or other device through which air is forced and divided into minute bubbles for diffusion in liquids.

**Digested sludge** — The solids from either aerobic or anaerobic processes in which the volatile content has been reduced.

**Dissolved oxygen (DO)** — Uncombined oxygen in solution in a liquid. A minimum of 4 or 5 parts per million (ppm) DO is necessary for the survival of fish in streams, and a minimum of 1 or 2 ppm is necessary to avoid odors in wastewater.

**Dissolved oxygen-sag curve** — A curve that represents the profile of dissolved oxygen content along the course of a receiving water from deoxygenation associated with biochemical oxidation of organic matter and reoxygenation through the absorption of atmospheric oxygen and biological photosynthesis. Also called *oxygen-sag curve.*

**dissolved solids** — The total amount of soluble material, organic and inorganic, contained in water or wastes (TDS).

**Drinking water standards** — 1. Standards prescribed by the US Public Health Service for the quality of drinking water supplied to interstate carriers. 2. Standards prescribed by state or local jurisdictions for the quality of drinking water supplied from surface water, groundwater or bottled-water sources.

E

**Effluent** – The liquid which flows out of a unit process or point.

**Estuary** – The mouth of a river, where tidal effects are evident and where fresh water and sea water mix.

**Eutrophication** — The photosynthetic overproduction of biological material due to enrichment of the body of water with an abundance of nutrients, such as nitrogen and phosphorus.

**Evapotranspiration** — Water withdrawn from soil by evaporation and/or plant transpiration.

**Extended aeration** — A modification of the activated sludge process which provides for aerobic sludge digestion within the aeration system.

## F

**Facultative bacteria** — Bacteria that can adapt themselves to growth and metabolism to either aerobic or anaerobic conditions. Many organisms of interest in wastewater stabilization are among this group.

**Fats** — Any of a number of triglyceride esters of fatty acids.

**Filter** — A device or structure for removing solid or colloidal material that cannot be removed by sedimentation.

**Filtrate** — The liquid which has passed through a filter.

**Filtration** — The process of passing a liquid through a porous medium for the removal of suspended or colloidal material contained in the liquid by a physical straining action.

**Fixed solids** — The residue remaining after ignition of suspended or dissolved matter.

**Floc** — Solids formed by chemical, biological, or physical agglomeration of fine materials into larger masses that are more readily separated from the liquid. The process is called *flocculation*.

**Flotation** — The raising of suspended matter to the surface of the liquid and the subsequent removal by skimming.

**F/M ratio** — Food to microorganism ratio: the weight ratio of BOD (food) in wastewater to suspended solids (microorganisms) within an activated sludge treatment system.

**Fouling** — A gelatinous, slimy accumulation on the waterway of a conduit, resulting from the activity of organisms in the waters. Fouling is more easily removable than tuberculation. Fouling may be found on concrete, masonry, and metal surfaces, but tuberculation is found only on metal surfaces.

**Free residual chlorination** — The application of chlorine or chlorine compounds to water or wastewater to produce a chlorine residual.

## G

**Grease** — A group of substances including fats, waxes, free fatty acids, calcium and magnesium soaps, mineral oils, and certain other nonfatty materials. The type of solvent and method used for extraction should be stated for quantitation.

**Grit** — The heavy suspended mineral matter present in water or wastewater, such as sand, gravel, and cinders.

## H

**Hardness** — The sum of the polyvalent cations of calcium, magnesium, and iron such as bicarbonates, carbonates, sulfates, chlorides and nitrates, expressed as the equivalent quantity of calcium carbonate.

**Hydrolysis** — A change in the chemical composition produced by a reaction with water to form one or more new substances.

I

**Infiltration** — 1. The penetration of water through the soil from surface precipitation, stream or impoundment boundaries. 2. The entrance of groundwater into a sewer through breaks, defective joints or porous walls.

**Influent** — Water, wastewater, or other liquid flowing into a reservoir, basin, or treatment plant, or any unit thereof.

**Integrator** — A device for indicating the total quantity of flow through a measuring device, such as a Parshall flume or weir.

**Intermediate treatment** — Wastewater treatment such as aeration or chemical treatment, supplementary to primary treatment. Such treatment removes substantial percentages of very finely divided particulate matter, in addition to the suspended solids removed by primary treatment. Supplementary processing improves the efficiency of treatment so that about 60 percent of both BOD and suspended solids are removed.

**Iodophor** — A germicide consisting of a mixture of iodine and a carrier. The carrier is a surfactant which stabilizes the iodine. Reaction of iodophors is similar to chlorine.

**Ion-exchange** — 1. A chemical process involving reversible interchange of ions between a liquid and a solid but no radical change in structure of the solid. 2. A chemical process in which ions from two different molecules are exchanged. 3. Ion-exchange treatment of water or wastewater involves the use of ion-exchange materials such as resin or zeolites to remove undesirable ions from a liquid and substitute acceptable ions.

K

**Kraus process** — A modification of the activated sludge process in which aerobically conditioned supernatant liquor from anaerobic digesters is added to activated sludge aeration tanks to improve the settling characteristics of the sludge and to add an oxygen resource in the form of nitrates.

L

**Land disposal** — 1. Disposal of wastewater onto land by spray or surface irrigation. 2. Disposal of solid waste materials by incorporating the solid waste into the soil by cut-and-fill techniques or by sanitary landfill operations.

**Leaching** — 1. The removal of soluble constituents from soils or other material by percolating water. 2. The removal of salts and alkali from soils by abundant irrigation combined with drainage. 3. The disposal of a liquid through a non-watertight artificial structure, conduit, or porous material by downward or lateral drainage or both, into the surrounding permeable soil. 4. The loss of soluble constituents from fruits, vegetables, or other material into water or other liquid in which the material is immersed. 5. The escaping of free moisture from a solid waste land disposal site into the surrounding environment, frequently causing odors and other nuisance conditions of public health significance.

**Loading** – The quantity of waste, expressed in gallons (hydraulic load) or in pounds of BOD, COD, suspended or volatile solids (organic load), which is discharged to a wastewater treatment facility.

$$(X) \text{ loading (pounds)} = \frac{\text{mg/l } (X) \times Q \text{ (gallons)} \times 8.34}{1{,}000{,}000}$$

where $X$ = BOD, COD, SS, P, N, etc.

M

**Membrane filtration** – A method of quantitative or qualitative analysis of bacterial or particulate matter in a water sample by filtration through a membrane capable of retaining bacteria.

**Mesh** – One of the openings or spaces in a screen. The value of the mesh is usually given as the number of openings per linear inch. This gives no recognition to the diameter of the wire, and thus the mesh number does not always have a definite relation to the size of the hole.

**Mesophilic range** – Operationally, that temperature range most conducive to the maintenance of optimum digestion by mesophilic bacteria, generally accepted as between 27° and 32° C (80° and 90° F).

**mg/l** – Abbreviation for milligrams per liter. A unit of the concentration of water or wastewater constituent. It is 0.001 g of the constituent in 1,000 ml of water. It has replaced the unit formerly used, parts per million, to which it is approximately equivalent, in reporting the results of water and wastewater analysis.

**Mixed liquor** – A mixture of activated sludge and organic matter undergoing activated sludge treatment in the aeration tank.

MLVSS – Abbreviation for *mixed liquor volatile suspended solids* contained in the mixed liquor of an activated sludge treatment system which is lost on ignition of the dry solids at 600° C.

Modified aeration – A modification of the activated sludge process in which a shortened period of aeration is used with a reduced quantity of suspended solids in the mixed liquor.

**Most probable number (MPN)** – That number or organisms per unit volume that, in accordance with statistical theory, would be more likely than any other number to yield the observed test result or that would yield the observed test result with the greatest frequency. Expressed as density of organisms per 100 ml. Results are computed from the number of positive findings of coliform-group organisms resulting from multiple-portion decimal-dilution plantings.

N

**Natural purification** – Natural processes occurring in a stream or other body of water that result in the reduction of bacteria, satisfaction of the BOD, stabilization of organic constituents, replacement of depleted dissolved oxygen, and the return of the stream biota to normal. Also called *self-purification.*

**Navigable water** – Any stream, lake, arm of the sea, or other natural body of water that is actually navigable and that, by itself or by its connections with other waters, is of sufficient capacity to float watercraft for the purposes of commerce, trade, transportation or even pleasure for a period long enough to be of commercial value; or any waters that have been declared navigable by the Congress of the United States.

**Nitrification** – 1. The conversion of nitrogenous matter into nitrates by bacteria. 2. The treatment of a material with nitric acid.

**Nitrogen cycle** – A graphical presentation of the conservation of matter in nature, from living animal matter through dead organic matter, various stages of decomposition, plant life, and the return of living animal matter, showing changes which occur in course of the cycle. It is used to illustrate biological action and also aerobic and anaerobic acceleration of the transformation of this element by wastewater and sludge traetment.

**Nitrogenous wastes** – Wastes of animal or plant origin that contain a significant concentration of nitrogen.

**Nutrient** – A substance that promotes cellular growth in organisms. Compounds of nitrogen and phosphorus are of concern in wastewaters due to their encouragement of overenrichment of water bodies.

O

**Oils** – 1. Liquid fats of animal or vegetable origin. 2. Oily or waxy mineral oils.

**Outfall** – 1. The point, location, or structure where wastewater or drainage discharges from a sewer, drain, or other conduit. 2. The conduit leading to the ultimate disposal area.

**Oxidation process (treatment)** – Any method of wastewater treatment for the oxidation of the putrescible organic matter. The usual methods are biological filtration and the activated sludge process. Living organisms in the presence of air are utilized to convert the organic matter into more stable or mineral form.

**Oxygenation capacity** – In treatment processes, a measure of the ability of an aerator to supply oxygen to a liquid.

**Oxygen demand** – The quantity of oxygen utilized in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. See *BOD.*

**Ozone** – Oxygen in molecular form with three atoms of oxygen forming each molecule ($O_3$).

P

**Parshall flume** – A calibrated device developed by Parshall for measuring the flow of liquid in an open conduit. It consists essentially of a contracting length, a throat, and an expanding length. Flows through the device are determined by measuring the head of water at a specific distance from a sill over which water passes.

**Particulate matter** – Refers to detectable solid materials dispersed in a gas or liquid. Small sized particulates may produce a smoky or hazy appearance in a gas or a milky or turbid appearance in a liquid. Larger particulates are more readily detected and separated by sedimentation or filtration.

**Parts per million (ppm)** – The number of weight or volume of units of a minor constituent present with each one million units of the major constituent of a solution or mixture. Formerly used to express the results of most water and wastewater analyses, but more recently replaced by the ratio milligrams per liter. See *mg/l.*

**Percolation** — 1. The flow or trickling of a liquid downward through a contact or filtering medium. The liquid may or may not fill the pores of the medium. Also called *filtration*. 2. The movement or flow of water through the interstices or the pores of a soil or other porous medium. 3. The water lost from an unlined conduit through its sides and bed.

**Permeability** — 1. The property of a material that permits appreciable movement of water through it when it is saturated and the movement is actuated by hydrostatic pressure of the magnitude normally encountered in natural subsurface water. Perviousness is sometimes used in the same sense as permeability. 2. The capability of a rock or rock material to transmit a fluid.

**pH** — The negative logarithm of the hydrogen ion concentration. The concentration is the weight of hydrogen ions, in grams, per liter of solution. pH values reflect the balance between acids and alkalies. The extreme readings are 0 and 14. The pH of most natural waters falls within the range 4 to 9. Neutral water, for example, has a pH value of 7.0 and a hydrogen ion concentration of $10^{-7}$. Slight decrease in pH may greatly increase the toxicity of substances such as cyanides, sulfides, and most metals. Slight increase may greatly increase the toxicity of pollutants such as ammonia. Alkaline water will tend to form a scale; acid water is corrosive.

**Pollutional load** — 1. The quantity of material in a waste stream that requires treatment or exerts an adverse effect on the receiving system. 2. The quantity of material carried in a body of water that exerts a detrimental effect on some subsequent use of that water.

**Polymer** — Any one of several commercially available high molecular weight, water-soluble polymeric flocculation agents. When added to water, these substances form a flocculent precipitate which will agglomerate or coagulate suspended matter and expedite sedimentation.

**Population equivalent** — 1. The calculated population which would normally contribute the same amount of biochemical oxygen demand (BOD) per day. A common base is 0.167 lb. of 5-day BOD per capita per day. 2. For an industrial waste, the estimated number of people contributing sewage equal in strength to a unit volume of the waste or to some other unit involved in producing or manufacturing a particular commodity.

**Potable water** — Water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for domestic consumption.

**Precipitate** — The formation of solid particles in a solution, or the solids that settle as a result of chemical or physical action that caused solids separation.

**Preliminary treatment** — 1. The conditioning of a waste at its source before discharge, to remove or to neutralize substances injurious to sewers and treatment processes or to effect a partial reduction in load on the treatment process. 2. In the treatment process, unit operations (such as screening and comminution) that prepare the liquor for subsequent major operations.

**Primary settling tank** — The first settling tank for the removal of settleable solids through which wastewater is passed in a treatment works.

**Primary treatment** — The first major treatment designed to remove from wastewater organic and inorganic solids by the physical process of sedimentation.

**Process water** — Water (liquid or vapor) that comes in contact with an end product or with materials incorporated in an end product.

## R

**Rapid sand filter** — A filter for the purification of water, in which water that has been previously treated, usually by coagulation and sedimentation, is passed downward through a filtering medium. The medium consists of a layer of sand, prepared anthracite, coal, or other suitable material, usually 24 to 30 inches thick, resting on a supporting bed of gravel or a porous medium such as carborundum. The filtrate is removed by an underdrainage system which also distributes the wash water. The filter is cleaned periodically by reversing the flow of the water upward through the filtering medium, sometimes supplemented by mechanical or air agitation during washing, to remove mud and other impurities which have lodged in the sand. It is characterized by a rapid rate of filtration, commonly from 2 to 3 gallons per minute per square foot of filter area.

**Receiving waters** — A natural watercourse, lake, or ocean into which treated or untreated wastewater is discharged.

**Residual chlorine** — Chlorine remaining in water or wastewater at the end of a specified contact period as combined or free chlorine.

**Reverse osmosis** — A process in which, if pressure is put on the concentrated side of a liquid system in which liquids with different concentrations of mineral salts are separated by a semipermeable membrane, molecules of pure water pass out of the concentrated solution to the weak or fresh water side (contrary to the case of normal osmosis).

**Riprap** — Broken stone or boulders placed compactly or irregularly on dams, levees, dikes, or similar embankments for protection of earth surfaces against the action of waves or currents.

**Roughing filter** — In wastewater treatment, a trickling filter containing coarse material or plastic medium operated at a high rate to afford partial treatment preliminary to a secondary treatment operation. By using a roughing filter, the organic loading imposed on the subsequent biological system is significantly reduced.

**Runoff** — 1. That portion of rainfall or melted snow which runs off the surface of a drainage area and reaches a stream or other body of water or a drain or sewer. Runoff is faster and greater during heavy rain than during protracted drizzle, on clay soils than on sandy soils, on frozen soils than on frostless soils, in treeless areas than in forests. The ratio between runoff and rainfall varies considerably with climatic conditions. 2. Total quantity of runoff water during a specified time. 3. In the general sense, that portion of the precipitation which is not absorbed by the deep strata, but finds its way into the streams after meeting the persistent demands of evapotranspiration, including interception and other losses. 4. The discharge of water in surface streams, usually expressed in inches depth on the drainage area, or as volume in such terms as cubic feet or acre-feet.

## S

**Saline water** — Water containing dissolved salts, usually from 10,000 to 33,000 mg/l.

**Sand filter** — A filter in which sand is used as a filtering medium. Also see *rapid sand filter, slow sand filter.*

**Scum baffle** — A verticle baffle dipping below the surface of wastewater in a tank to prevent the passage of floating matter. Also called *scum board.*

**Secondary wastewater treatment** – The treatment of wastewater by biological methods after primary treatment by sedimentation. Common methods of treatment include trickling filtration, activated sludge processes, and oxidation.

**Sedimentation** – The process of subsidence and deposition of suspended matter carried by water, wastewater, or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material. Also called *settling.*

**Self-cleansing velocity** – The minimum velocity in sewers necessary to keep solids in suspension, thus preventing their deposition and subsequent nuisance from stoppages and odors of decomposition.

**Self-purification** – The natural processes occurring in a stream or other body of water that result in the reduction of bacteria, satisfaction of the BOD, stabilization of organic constituents, replacement of depleted dissolved oxygen, and the return of the stream biota to normal. Also called *natural purification.*

**Settleable solids** – 1. That matter in wastewater which will not stay in suspension during a preselected settling period (such as one hour) but settles to the bottom. 2. In the Imhoff cone test, the volume of matter that settles to the bottom of the cone in one hour.

**Skimming tank** – A tank so designed that floating matter will rise and remain on the surface of the wastewater until removed, while the liquid discharges continuously under curtain walls or scum boards.

**Slimes** – Substances of viscous organic nature, usually formed from microbiological growth.

**Sloughing** – A phenomenon associated with trickling filters and contact aeration units where slimes or biological growth build up on the media and then slip off into the discharged flow.

**Slow sand filter** – A filter for the purification of water in which water without previous treatment is passed downward through a filtering medium consisting of a layer of sand or other suitable material, usually finer than for a rapid sand filter and from 24 to 40 inches thick. The filtrate is removed by an underdrainage system and the filter is cleaned by scraping off and replacing the clogged layer. It is characterized by a slow rate of filtration, commonly 3 to 6 mgd/acre of filter area.

**Sludge** – 1. The accumulated solids separated from liquids (such as water or wastewater) during processing, or deposits on bottoms of streams or other bodies of water. 2. The precipitate resulting from chemical treatment, coagulation, or sedimentation of water or wastewater.

**Sludge conditioning** – Treatment of liquid sludge before dewatering to facilitate dewatering and enhance filtering, usually by the addition of chemicals.

**Sludge density index (SDI)** – The reciprocal of the sludge volume index multiplied by 100.

**Sludge digestion** – The process by which organic or volatile matter in sludge is gasified, liquified, mineralized, or converted into more stable organic matter through the activities of either anaerobic or aerobic organisms.

**Sludge treatment** – The processing of wastewater sludges to render them innocuous. This may be done by aerobic or anaerobic digestion followed by drying on sand beds, filtering, and incineration, filtering and drying, or wet air oxidation.

**Sludge volume index (SVI)** — The ratio of the volume in milliliters of sludge settled from a 1000-ml sample in 30 minutes to the concentration of suspended solids in milligrams per liter multiplied by 1,000.

**Solids-contact clarifier** — A unit in which liquid passes upward through a solids blanket and discharges at or near the surface.

**Solute** — The substance dissolved in a solution. A solution is made up of the solvent and the solute.

**Solvent** — Liquid used to dissolve a substance.

**Sparger** — An air diffuser designed to give large bubbles, used singly or in combination with mechanical aeration devices.

**Specific conductance** — A measure of a water's capacity to convey an electric current. This property is related to the total concentration of the dissolved ionized substances in the water and the temperature at which the conductance is measured.

*Spaerotilus* — A filamentous, sheath-forming bacterium, often considered the organism responsible for bulking sludge. In polluted streams, the presence of this bacterium is evidenced by fibrous growths adhering to rocks and plants along the stream bed.

**Stabilization** — 1. Maintenance at a relatively nonfluctuating level, quantity, flow, or condition. 2. In lime-soda water softening, any process that will minimize or eliminate scale-forming tendencies. 3. In waste treatment, a process used to equalize wastewater flow composition prior to regulated discharge. 4. In erosion control, treatment of dikes or shorelines with riprap, sod, penetrations, or similar protective devices. 5. In corrosion control, pH adjustment of water to maintain carbonate equilibrium at the saturation point.

**Stage aeration** — Division of activated sludge treatment into stages with intermediate settling tanks and return of sludge in each stage.

**Standard methods** — Unless otherwise specified, it refers to the latest edition of *Methods for the Examination of Water and Wastewater* published jointly by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation.

**Step aeration** — A procedure for adding increments of settled wastewater along the line of flow in the aeration tanks of an activated sludge plant.

**Substrate** — 1. The substances used by organisms in liquid suspension. 2. The liquor in which activated sludge or other matter is kept in suspension.

**Supernatant liquor** — 1. The liquor overlying deposited solids. 2. The liquid in a sludge-digestion tank that lies between sludge at the bottom and floating scum at the top.

**Suspended solids (SS)** — Those inorganic and organic particles which exist in suspension in a liquid and which may be partially removed by gravity settling and completely removed by filtration.

## T

**Tapered aeration** — The method of supplying varying amounts of air into the different parts of an aeration tank.

**Tertiary treatment** – Treatment beyond normal or conventional secondary methods for the purpose of increasing water reuse potential.

**Thermal pollution** – Impairment of water through temperature change due to geothermal, industrial, or other causes.

**Thermophilic range** – That temperature range most conducive to maintenance of optimum digestion by thermophilic bacteria, generally accepted as between 120° and 135° F.

**Totalizer** – A device for indicating the total quantity of flow through a measuring device. Also called *integrator.*

**Total organic carbon (TOC)** – A test expressing wastewater contaminant concentration in terms of the organic carbon content.

**Total solids** – A measure of both suspended and dissolved solids.

**Toxic substance** – A substance that either directly poisons living things or alters their environment so that they die.

**Transpiration** – The process by which water vapor is lost to the atmosphere from living plants.

**Trickling filter** – A structure containing an artificial bed of coarse material, such as broken stone, clinkers, slate, slats, or plastic materials, over which wastewater is distributed, giving opportunity for the formation of zoogleal slimes which clarify and oxidize the wastewater through biological oxidation.

**Turbidity** – The presence of suspended matter, resulting in the scattering and absorption of light rays.

**Turnover** – A phenomenon usually occurring in spring and fall because of the increase in density of water above and below the temperature of maximum density. In the spring, as the surface of the water warms above the freezing point, the water increases in density, becomes heavier, and tends to sink, producing vertical currents, while in the fall, as the surface water becomes cooler and therefore heavier, it also tends to sink. Also called *overturning.* It is of particular importance to the operation of ponds and lagoons.

## U

**Ultimate biochemical oxygen demand** – 1. Commonly, the total quantity of oxygen required to satisfy completely the first-stage biochemical oxygen demand. 2. More strictly, the quantity of oxygen required to satisfy completely both the first-stage and the second-stage biochemical oxygen demands.

**Undigested sludge** – Settled sludge promptly removed from sedimentation tanks before decomposition has much advanced. Also called *raw sludge.*

**Unloading** – The periodic or continuous sloughing of the biological film from the medium on which it has been growing.

**Upflow contact clarifier** – A unit in which water enters the bottom and is discharged at or near the surface. See *solids contact clarifier.*

## V

**Vacuum filter** — A filter consisting of a cylindrical drum mounted on a horizontal axis, covered with filtering material made of wool, felt, cotton, saran, nylon, dacron, polyethylene or similar substance, by stainless steel coil springs or metal screen, revolving with a partial submergence in the liquid. A vacuum is maintained under the filter medium for the larger part of a revolution to extract moisture. The cake is scraped off continuously.

**Venturi meter** - A differential meter for measuring flow of water or other fluid through closed conduits or pipes, consisting of a venturi tube and one of several proprietary forms of flow-registering devices. The difference in velocity heads between the entrance and the contracted throat is an indication of the rate of flow.

**Volatile acids** – Fatty acids containing six or less carbon atoms, which are soluble in water and which can be steam-distilled at atmospheric pressure. Volatile acids are commonly reported as equivalent to acetic acid.

**Volatile solids** — Organic solids which are combustible at 600° C.

## W

**Watercourse** — A channel in which the flow of water occurs, with some degree of regularity, in a definite direction.

**Water cycle** — The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration. Also called *hydrologic cycle.*

**Water quality standards** — Limits set by authority on the basis of water quality criteria required for beneficial uses. Limits are imposed on the physical and chemical characteristics required for specific beneficial use.

**Water softening** — The process of removing from water, in whole or in part, those cations which produce hardness.

**Weir** — A diversion dam with an edge or notch sometimes arranged to measure flow.

**Wet oxidation process** — A method of sludge disposal that involves the oxidation of sludge solids in water suspension and under increased pressure and temperature.

## Z

**Zeolite** — A group of hydrated aluminum complex silicates, either natural or synthetic, with cation-exchange properties.

**Zeolite process** — The process of softening water by passing it through a natural ion exchange substance known as zeolite.

**Zooglea** — A jelly-like matrix developed by bacteria. A major part of activated sludge floc and of trickling filter slimes.

# METRIC CONVERSION TABLES

*Recommended Units*

| Description | Unit | Symbol | Comments | Customary Equivalents* |
|---|---|---|---|---|
| Length | meter | m | *Basic SI unit* | 39.37 m = 3.281 ft = 1.094 yd |
| | kilometer | km | | 0.6214 mi |
| | millimeter | mm | | 0.03937 in |
| | micrometer or micron | μm or μ | | $3.937 \times 10^{-5}$ in = $1 \times 10^4$ Å |
| Area | square meter | $m^2$ | | 10.76 sq ft = 1.196 sq yd |
| | square kilometer | $km^2$ | | 0.3861 sq mi = 247.1 acres |
| | square millimeter | $mm^2$ | | 0.001550 sq in |
| | hectare | ha | The hectare (10,000 $m^2$) is a recognized multiple unit and will remain in international use. | 2.471 acres |
| Volume | cubic meter | $m^3$ | | 35.31 cu ft = 1.308 cu yd |
| | litre | l | | 1.057 qt = 0.2642 gal = $0.8107 \times 10^{-4}$ acre ft |
| Mass | kilogram | kg | *Basic SI unit* | 2.205 lb |
| | gram | g | | 0.03527 oz = 15.43 gr |
| | milligram | mg | | 0.01543 gr |
| | tonne | t | 1 tonne = 1,000 kg | 0.9842 ton (long) = 1.102 ton (short) |
| Force | newton | N | The newton is that force that produces an acceleration of 1 $m/s^2$ in a mass of 1 kg. | 0.2248 lb = 7.233 poundals |
| Moment or torque | newton meter | N-m | The meter is measured perpendicular to the line of action of the force N. Not a joule. | 0.7375 lb-ft 23.73 poundal-ft |
| Flow (volumetric) | cubic meter per second | $m^3/s$ | | 15.850 gpm = 2,119 cfm |
| | liter per second | l/s | | 15.85 gpm |

*Recommended Units*

| Description | Unit | Symbol | Comments | Customary Equivalents* |
|---|---|---|---|---|
| Velocity linear | meter per second | m/s | | 3.281 fps |
| | millimeter per second | mm/s | | 0.003281 fps |
| | kilometers per second | km/s | | 2,237 mph |
| angular | radians per second | rad/s | | 9.549 rpm |
| Viscosity | pascal second | Pa-s | | 0.6722 poundal(s)/sq ft |
| | centipoise | Z | | $1.450 \times 10^{-7}$ Reyn (μ) |
| Pressure or stress | newton per square meter or pascal | $N/m^2$ or Pa | | 0.0001450 lb/sq in |
| | kilonewton per square meter or kilopascal | $kN/m^2$ or kPa | | 0.14507 lb/sq in |
| | bar | bar | | 14.50 lb/sq in |
| Temperature | Celsius (centigrade) | °C | | (°F−32)/1.8 |
| | Kelvin (abs.) | °K | | °C + 273.2 |
| Work, energy, quantity of heat | joule | J | 1 joule = 1 N-m where meters are measured along the line of action of force N. | $2.778 \times 10^{-7}$ kw-hr = $3.725 \times 10^{-7}$ hp-hr = 0.7376 ft-lb = $9.478 \times 10^{-4}$ Btu |
| | kilojoule | kJ | | $2.778 \times 10^{-4}$ kw-hr |
| Power | watt | W | 1 watt = 1 J/s | 44.25 ft-lbs/min |
| | kilowatt | kW | | 1.341 hp |
| | joule per second | J/s | | 3.412 Btu/hr |

*Application of Units*

| Description | Unit | Symbol | Comments | Customary Equivalents* |
|---|---|---|---|---|
| Precipitation, run-off, evaporation | millimeter | mm | For meteorological purposes, it may be convenient to measure precipitation in terms of mass/unit area ($kg/m^2$). 1 mm of rain = 1 $kg/m^2$ | |
| Flow | cubic meter per second | $m^3/s$ | | 35.31 cfs |
| | liter per second | l/s | | 15.85 gpm |
| Discharges or abstractions, yields | cubic meter per day | $m^3/d$ | 1 l/s = 86.4 $m^3/d$ | 0.1835 gpm |
| | cubic meter per year | $m^3$/year | | 264.2 gal/year |
| Usage of water | liter per person per day | l/person/day | | 0.2642 gcpd |

*Application of Units*

| Description | Unit | Symbol | Comments | Customary Equivalents* |
|---|---|---|---|---|
| Density | kilogram per cubic meter | $kg/m^3$ | The density of water under standard conditions is 1,000 $kg/m^3$ or 1,000 g/l or 1 g/ml. | 0.06242 lb/cu ft |
| Concentration | milligram per liter (water) | mg/l | | 1 ppm |
| BOD loading | kilogram per cubic meter per day | $kg/m^3/d$ | | 0.06242 lb/cu ft/day |
| Hydraulic load per unit area, e.g., filtration rates | cubic meter per square meter per day | $m^3/m^2/d$ | If this is converted to a velocity, it should be expressed in mm/s (1mm/s = 86.4 $m^3/m^2$/day). | 3.281 cu ft/sq ft/day |
| Air supply | cubic meter or liter of free air per second | $m^3/s$ l/s | | |
| Optical units | lumen per square meter | lumen/$m^2$ | | 0.09294 ft candle/sq ft |

*Miles are U.S. statute, qt and gal are U.S. liquid, and oz and lb are avoirdupois.

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