Pollution Abatement in the Fruit and Vegetable Industry

BASICS OF POLLUTION CONTROL

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF TECHNOLOGY TRANSFER
WASHINGTON, D. C.

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Volume 1

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I. INTRODUCTION

> We travel together, passengers on a little spaceship,
> dependent on its vulnerable supplies of air and soil...
> preserved from annihilation only by the care, work,
> and I will say the love, we give our fragile craft.

In his inimitable eloquent address, the late Adlai E. Stevenson might readily have included reference to our vulnerable and limited natural resource of water. For of all environmental elements, man's existence on Earth is dependent foremost on the availability of fresh water.

DISTRIBUTION OF WATER

Examination of the distribution of water on this planet (Figure 1) reveals that the greatest quantity, 97.13 percent, exists in the oceans of the world. The second major quantity, 2.24 percent, 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, 0.612 percent, that is used for human consumption, exists as ground or subsurface waters. The wide-spread 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 (0.001%) of the world.

THE PRISTINE STATE

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, all of which are technically speaking, pollutants.

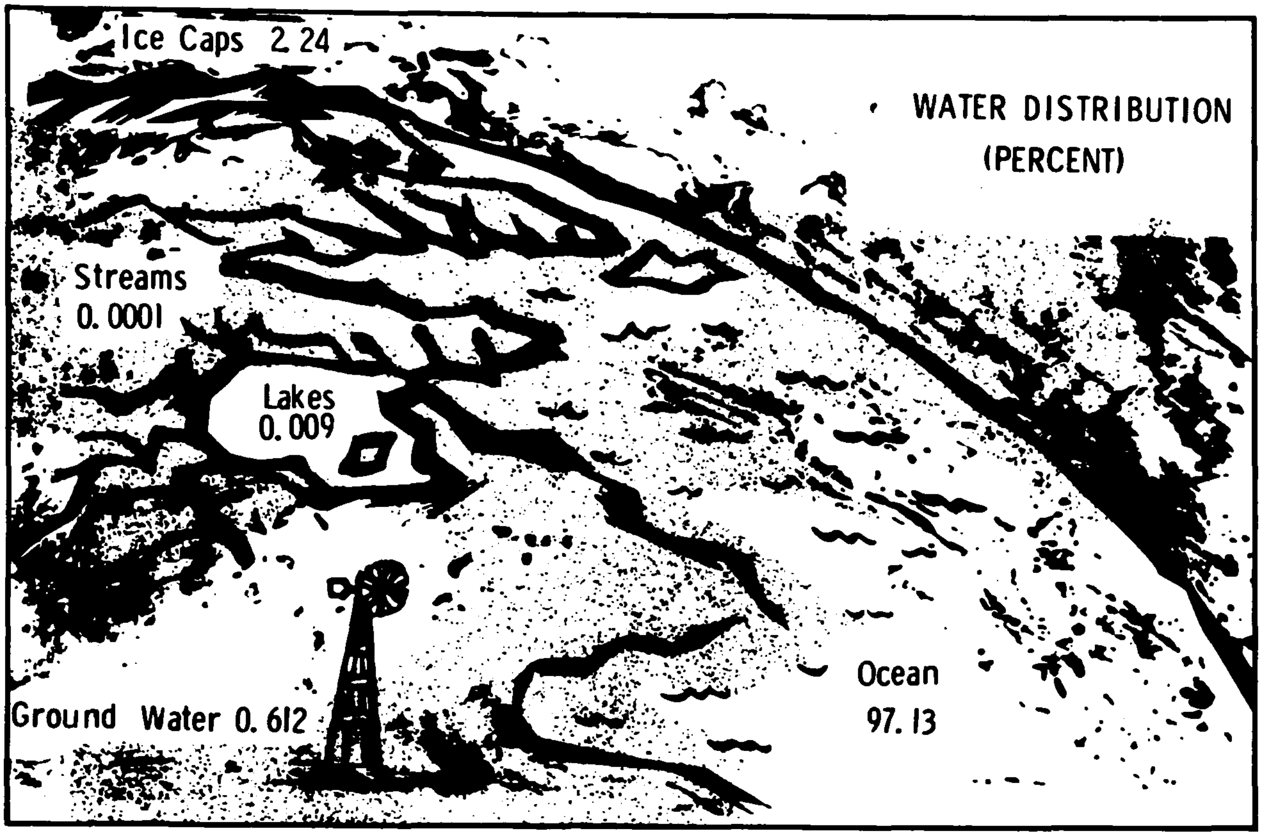

Figure 1. Distribution of water on earth.

During the discussions accompanying many recently-enacted pollution control laws, desires were expressed for returning the quality of our Nation's waters to a pristine state. When the term "pristine" is mentioned, one immediately envisions a stream of crystal-clear water flowing through pastoral meadows and lush forests. This pristine stream would support and sustain a myriad of wild creatures -- mammals, birds and fish of wide variety.

NATURAL POLLUTION AND SELF-PURIFICATION

Yet even in such a seemingly idyllic setting, pollutants are generated. 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; the 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 continuous contributions of water contaminants have been termed natural pollution.

The effect of natural pollutants on lakes is well known. Countless lakes naturally filled with detritus, eventually eutrophicating to become marshes, bogs, and stagnant ponds. In time these dried to form the very pastoral meadows, and ultimately the lush forests, through which the envisioned pristine stream flows.

However, the effect of pollutants on a stream contrasts markedly. Each stream, flowing along its course, has the capability to purify itself of various materials. In the slow-flowing stretches, suspended solids settle to the stream bed, there 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 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 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 2). Reoxygenation rates depend upon a number of factors, including

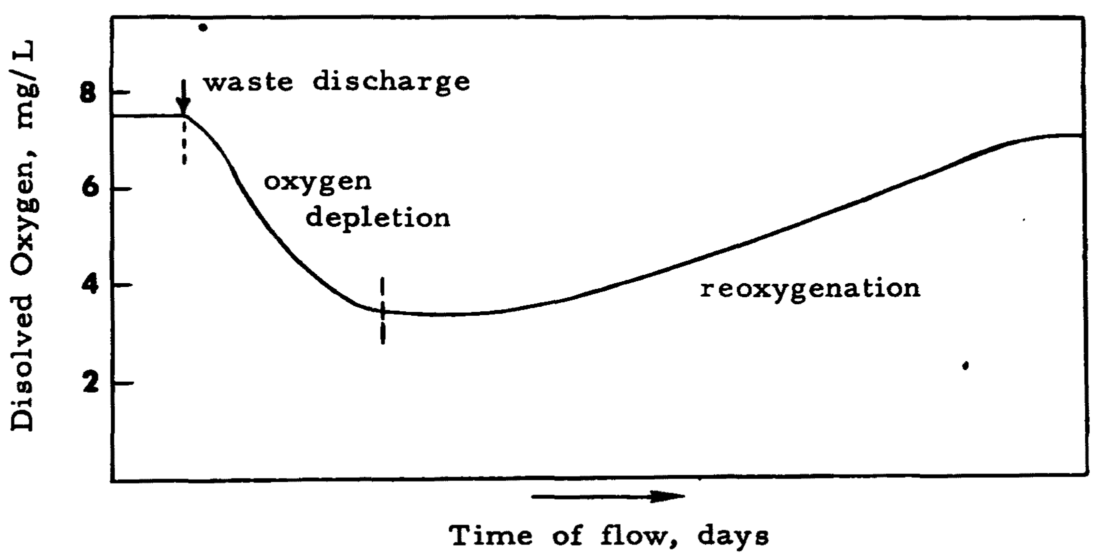

Figure 2. A hypothetical oxygen-sag curve.

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 down-stream flow (fast or slow, smooth or turbulent).

Unfortunately, waste discharges occur at numerous points along most streams, thereby 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. The increasing frequency of such occurrences in many of the Nation's lakes and rivers eventually led to the formation of environmental groups, each demanding protective legislation. Politicians immediately joined in the clamor, often using environmental issues as major platform planks. Naturally, envrionmental legislation soon followed and the Age of Ecology was born.

ENVIRONMENTAL LEGISLATION

During the late '50s and through the 60's, several important Congressional acts were passed. Although some of these were not individually effectual, they served as precursors to the most significant 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 (FWPCA). 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 FWPCA 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 Environmental Protection Agency (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 which are considered to be achievable through in-plant process changes, as well as end-of-pipe wastewater treatment.

The Act 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.

Also of direct interest to industrial wastewater dischargers, the FWPCA establishes a permit program known as the National Pollutant Discharge Elimination System (NPDES). The assure that effluent limitations are being met and that designated water quality standards are maintained, all wastewater discharges 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. (Most 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 schedule of construction of adequate wastewater treatment facilities to meet the limitations. The permits also prescribe self-monitoring procedures required of all discharges. The self-monitoring program generally consists of data collection and record keeping; reports must be periodically submitted to the appropriate regulatory agency. To meet the requirements specified in the permits, companies will generally have to expend considerable funds for pollution abatement.

The provisions of the FWPCA briefly described above primarily effect direct discharges -- 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, thus 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 the 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 the total operating and maintenance costs. Thus industrial users of publicly-owned treatment works may incur significant costs for the privilege of utilizing such facilities.

II. ANATOMY OF POLLUTION CONTROLS

Food processing operations inherently require the use of water. And as long as water is used, wastewaters requiring treatment will be generated. The degree of treatment will be dictated by the quantity of pollutants, as well as discharge requirements. Several options exist by which reductions in the discharged effluent may be achieved. In almost all food processing plants, the problem of pollution abatement can be attacked in two broad areas -- inside the plant and at the "end of the pipe." Company-management will inevitably be required to decide where and how working capital can most effectively be directed to ultimately resolve a problem.

MATERIALS BALANCE

Examination of materials balance (Figure 3) may provide insight into how these areas are inter-related. Incoming materials include numerous items, but principally raw commodities (fruits/vegetables), water, energy, supplies (packaging materials and similar items), and product ingredients (sugar, salt, spices, etc.). These are utilized in various processes to produce a principal product. The processing operations utilize both energy and water, and generate residuals* which are discharged from the plant. Some residual materials may be processed into by-products; the remainder are generally considered to be "wastes". The wastes are in various forms -- gaseous (heat and steam), liquid (wastewater and dissolved product components), and solid (solid residuals and suspended solids contained in the wastewater).

Assuming that supplies and ingredients are totally utilized (if they are not, these materials will contribute to the waste load), the major inputs into the processing operation are raw commodities, water and energy. All

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*Residuals are defined as those materials from incoming items which remain after the production of all primary commodities.

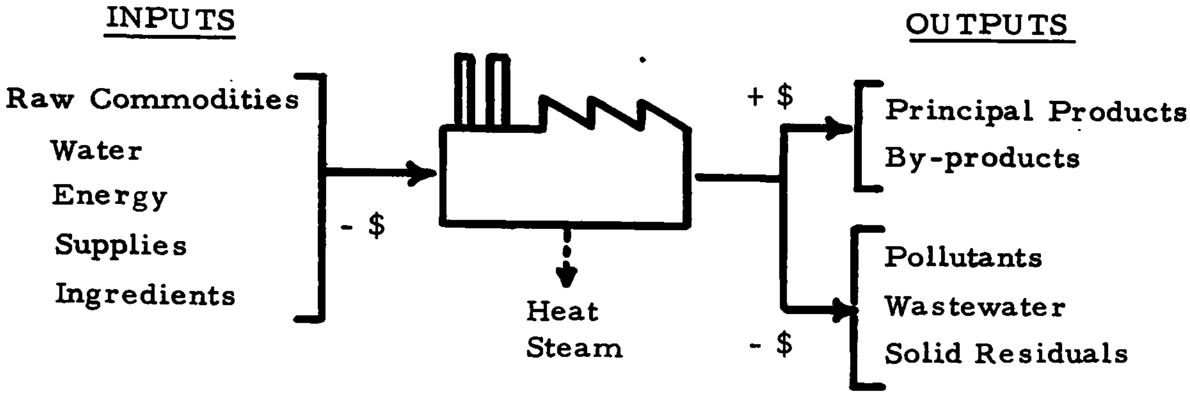


Figure 3. Balance of principal materials of a food processing plant.

of these must be purchased and, thus, represent costs to the company. There is generally little that can be done to change the cost for raw commodities; the prices are established well before the processing step. However, the costs to obtain water and energy are dictated by the quantitites consumed by the operations. Minimizing the need by optimizing operating efficiencies will result in minimizing costs.

Of the several output items, only the principal product results in an appreciable income. If by-products can be feasibly manufactured, these may also result in an income, albeit generally significantly less. The remaining outputs either do not directly affect finances, such as dissipated energy lost as heat, or else incur costs for handling and disposal. The most significant expenses are associated with the management of waste materials, namely, processing wastewaters with the pollutants contained therein and solid residuals, for which there is no current usefulness.

To appreciate the relationship between the main input and output items, one has only to realize that:

1. The total quantity of raw commodity initially purchased equals the sum of the salable products, solid residuals and discharged pollutants.
2. The volume of purchased water equals the generated wastewater volume plus the small volume of water lost as steam or used in the principal product.

By optimizing processing operations to reduce the quantity of generated wastes, the quantity of salable products must necessarily increase; by reducing water consumption, the quantity of generated wastewater requiring treatment will correspondingly be reduced.

MANAGEMENT AND POLLUTION CONTROLS

Pollution controls, whether through process modifications or end-of-pipe treatment, or a combination of the two, will require capital expenditures. Company-management's responsibilities must include:

1. Knowledge of existing operations.
2. Understanding of the problems and the available alternative solutions.
3. Decision as to where maximum benefit-cost ratios exist.
4. Dedication of resources (capital and man-power) to achieve resolution of the company's environmental problems.

To assist food processing plant owners, managers, supervisors and their engineering and operation personnel in developing an effective pollution control program, the primary pollution control parameters, the basic aspects of pollution control programs, and a brief introduction to the major treatment processes are discussed in the following sections of this manual. Details pertaining to pollution abatement through process modifications are contained in the second volume of the series, In-plant Control of Food Processing Wastewaters. Treatment alternatives are described in detail in the third volume, Wastewater Treatment in the Food Processing Industry.

III. WATER POLLUTION PARAMETERS

The potential effects of wastewater discharges, either upon a receiving stream or a treatment system, can best be evaluated by accumulating specific information with which to determine the "waste load" associated with the discharge. Waste loads are used by engineers to design appropriate wastewater treatment facilities, by regulatory authorities to specify effluent limitations, and 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 pollutional strength of the wastewater, or the quantity of pollutants contained therein. For most food processing wastes, the pollutants of major concern are 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, in addition to flow, BOD and suspended solids, which may be of concern to fruit and vegetable processors, are also briefly described below. The reader, however, is directed to References 1 and 2 for details (reagents, equipment, supplies and procedure) of the analytical methods.

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.

Numerous types of equipment or combinations of equipment are commercially available for measuring both large and small flows. These include meters, weirs, flumes, and special devices; these, as well as simple flow measuring techniques, are described in detail in the following volume (also see Ref. 3).

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 air bubbles which may be visible in water 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 4); the procedures are discussed elsewhere. Dissolved oxygen concentrations are expressed as milligrams per liter (mg/l DO), which is approximately equivalent to parts per million (ppm).

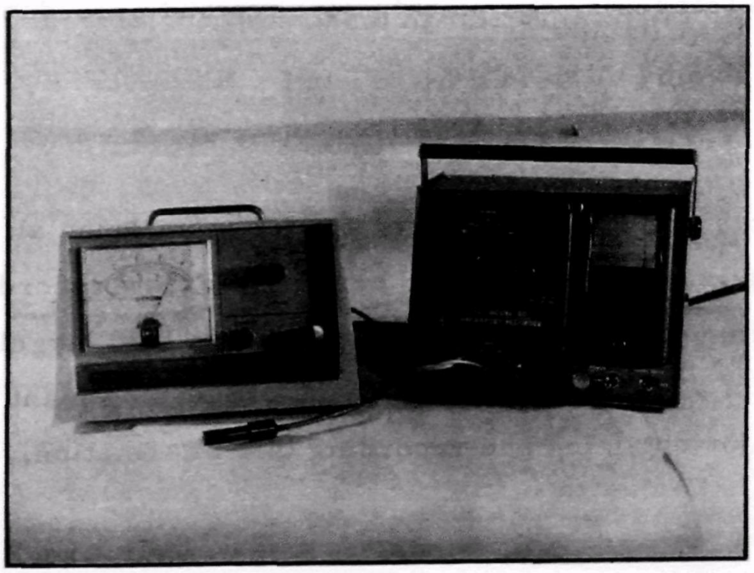


Figure 4. Dissolved oxygen meter with recorder.

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 will be the maximum maintainable DO level. Although it is possible to obtain relatively high concentrations of dissolved oxygen, a concentration of 9 mg/l DO is generally regarded to be saturation under ambient conditions. A minimum of 5 mg/l is considered to be desirable for sustaining game fish (trout, salmon, etc.).

BIOCHEMICAL OXYGEN DEMAND

For many years, investigators have attempted to measure the strength of wastewater containing dissolved 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 for stream self-purifications.

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. After a specified period the dissolved oxygen content is determined; the BOD is based on the depletion of oxygen from the sample during the

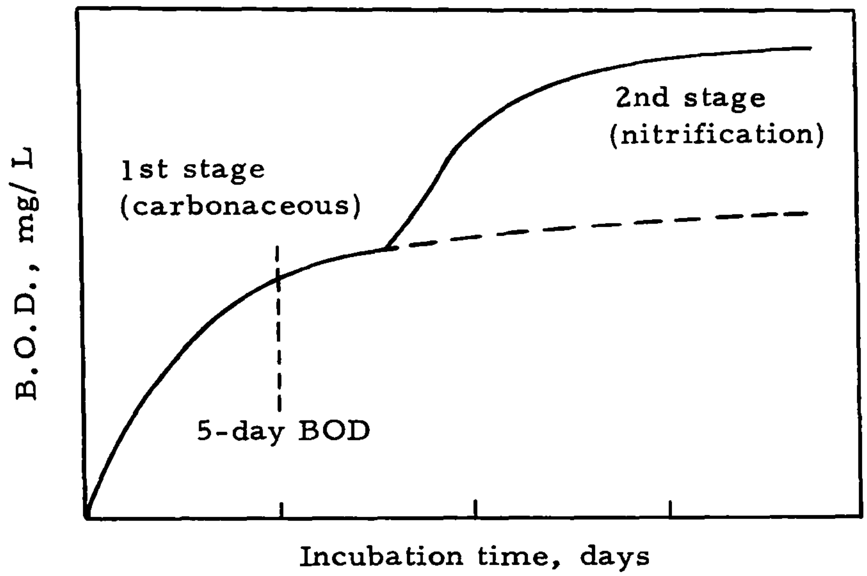


Figure 5. First and second stage BOD curve.

incubation period. Since complete stabilization of organic wastes require prolonged periods (Figure 5), 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.

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:

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

It is apparent that from this equation "dilution is no solution to pollution." 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. Instead, the BOD load can be effectively reduced only by simultaneously reducing water usage and BOD generation.

CHEMICAL OXYGEN DEMAND

Chemical oxygen demand (COD) represents 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 susceptability to interference by chloride. Thus, wastewaters containing high salt concentrations, such as sauerkraut and pickle brines, cannot be readily analyzed. However, the standard method for COD is designed to remove interferences at low chloride concentrations and can be used for analyzing 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.

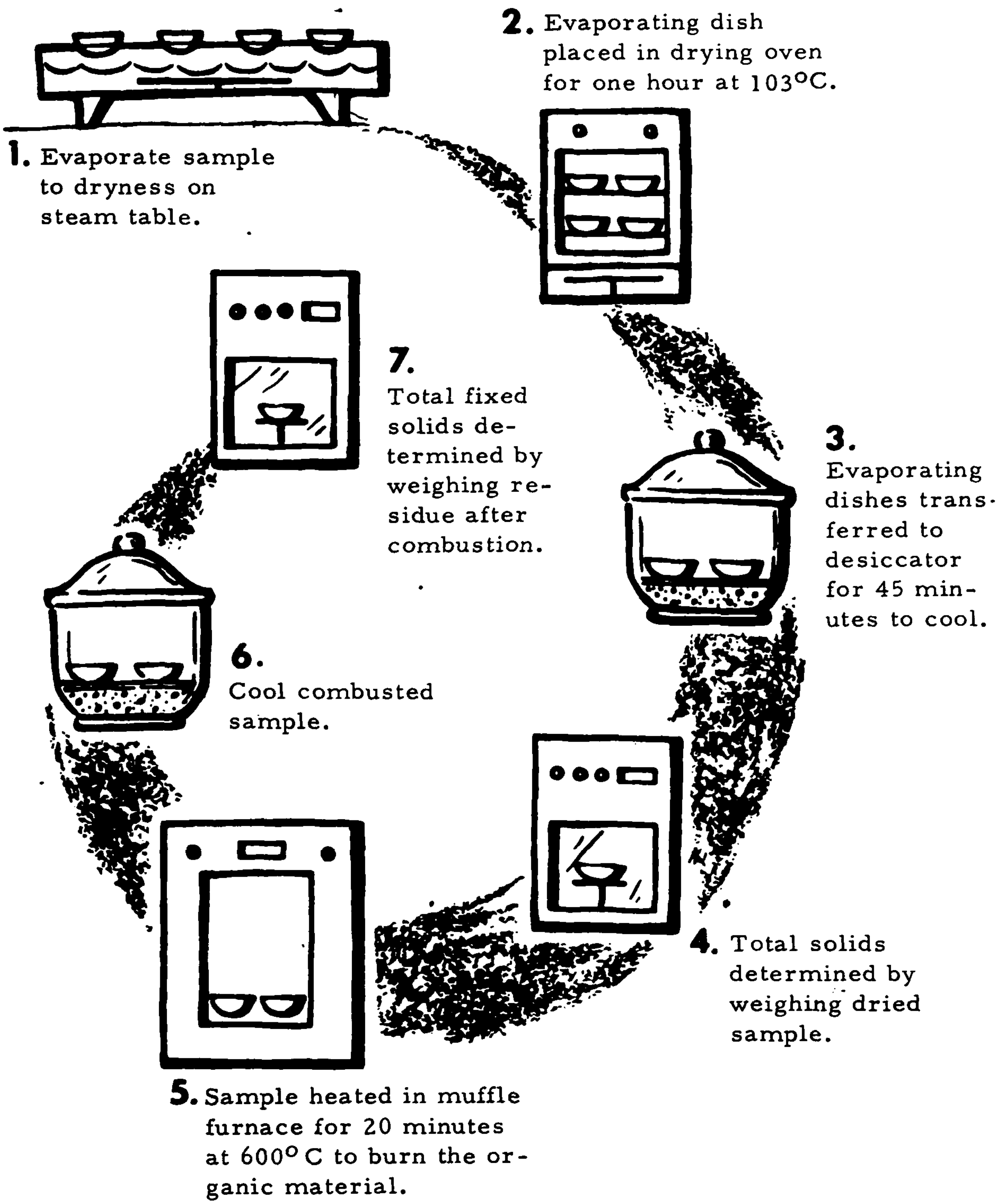
Settleable Solids

Information on the amount of settleable solids in wastewaters provides a basis with which to predict 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 measure all matter which are contained in a water or wastewater sample. Included in the determination are suspended matter, which contribute to the turbidity of water, as well as dissolved components, such as sugars and salts. Despite the fact that some volatile organic compounds may be excluded in the 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 (Figure 6).

Total solids, which is the residue remaining after evaporation of water from a sample, can be further subdivided into fixed and volatile fractions. The fixed solids, determined by weighing the residue remaining after combustion, is re-



Total Volatile Solids = Total Solids - Total Fixed Solids

Figure 6. Steps in the determination of total and fixed solids.

garded 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 test 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 filtering a wastewater sample, and 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:

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

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.

OTHER PARAMETERS

The tests discussed above constitute the parameters of major concern to fruit and vegetable processors. In specific situations, those tests which are described below may also be of importance to this industry.

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 -- that 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 mid-point, 7. 0, being neutrality (Figure 7). The 0 to 7 range is the acid scale; the 7 to 14 range, the alkaline scale. Measurements are most suitably made potentiometrically with an appropriate pH meter.

The pH of fruit and vegetable processing wastewaters may very from 3. 5 to 11. 5, depending upon the product being packed and the type of operations conducted within the plant. Natural occurring 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.

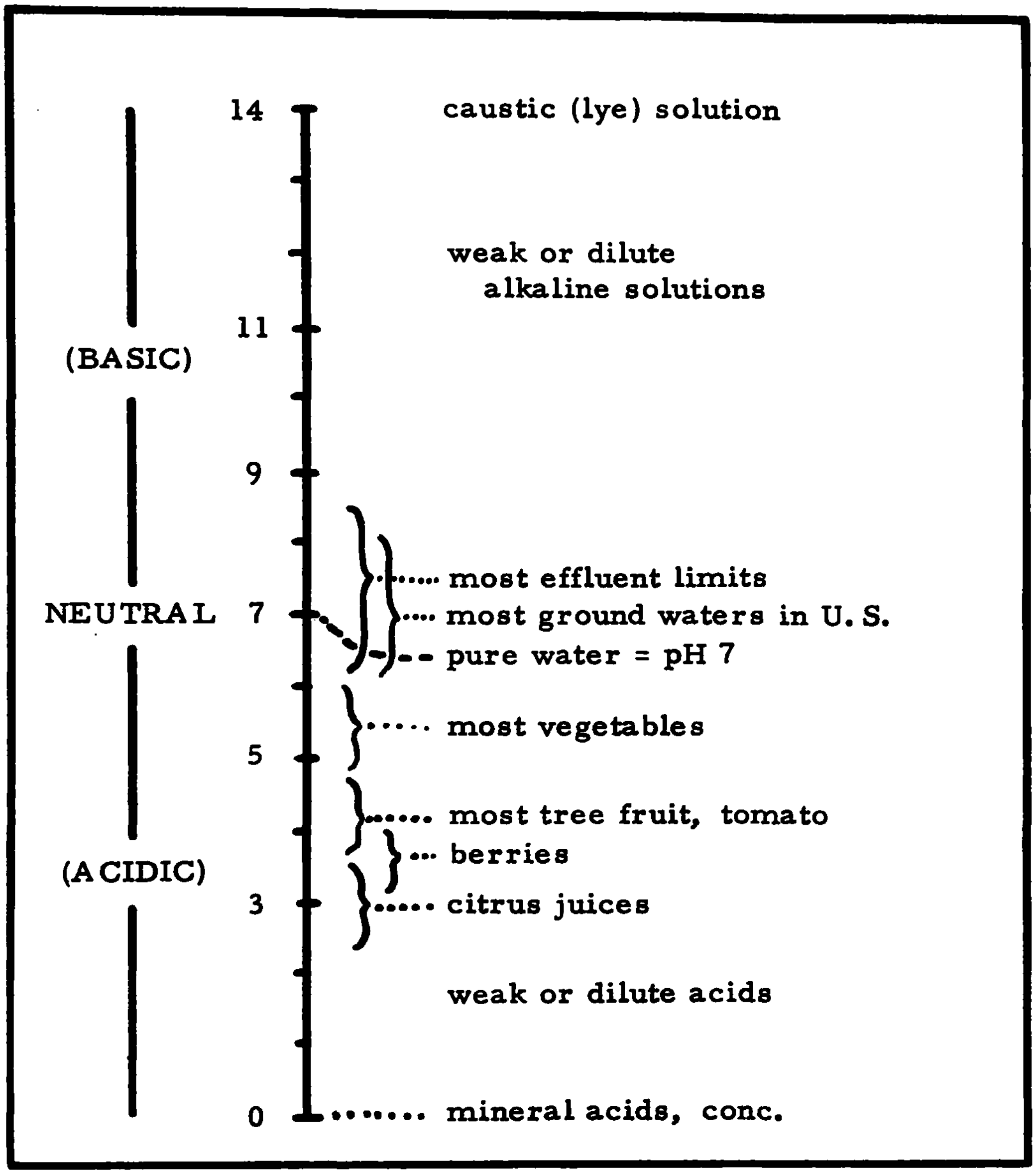


Figure 7. The pH scale, with values of some materials.

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 not 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 to the temperature and the relative flows in the plant effluent as compared to the receiving stream.

Container and compressor cooling waters and evaporator condenser effluents are the major sources of heated wastewaters in food processing plants. These streams may be discharged in several fashions. When 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 be determined by 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 vs. 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 by any one of a 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 are measured largely as BOD, nutrients of primary concern are organic nitrogen and phosphorus-containing compounds. Both of these are required for multiplication of microorganisms. Nitrogen (n) and phosphorus (P) are largely responsible for algal "blooms" which cause 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 meausred colorimetrically or by titration; results are reported as mg/l TKN.

Phosphorus occurs almost exclusively in the form of various types of phosphates (PO_4). Detergents used for product washing and plant cleanup are primary sources of phosphates in fruit and vegetable processing effluents; these phosphates are water soluble. 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 several available laboratory methods for measuring phosphate are colorimetric; results are reported as mg/l P.

IV. 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 simply 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 food 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 8). This type of information is extremely useful, not only for determining at which periods of the day the loads tend to peak, but also for calculating meaningful daily (or other period) averages. Automatic sampling equipment 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

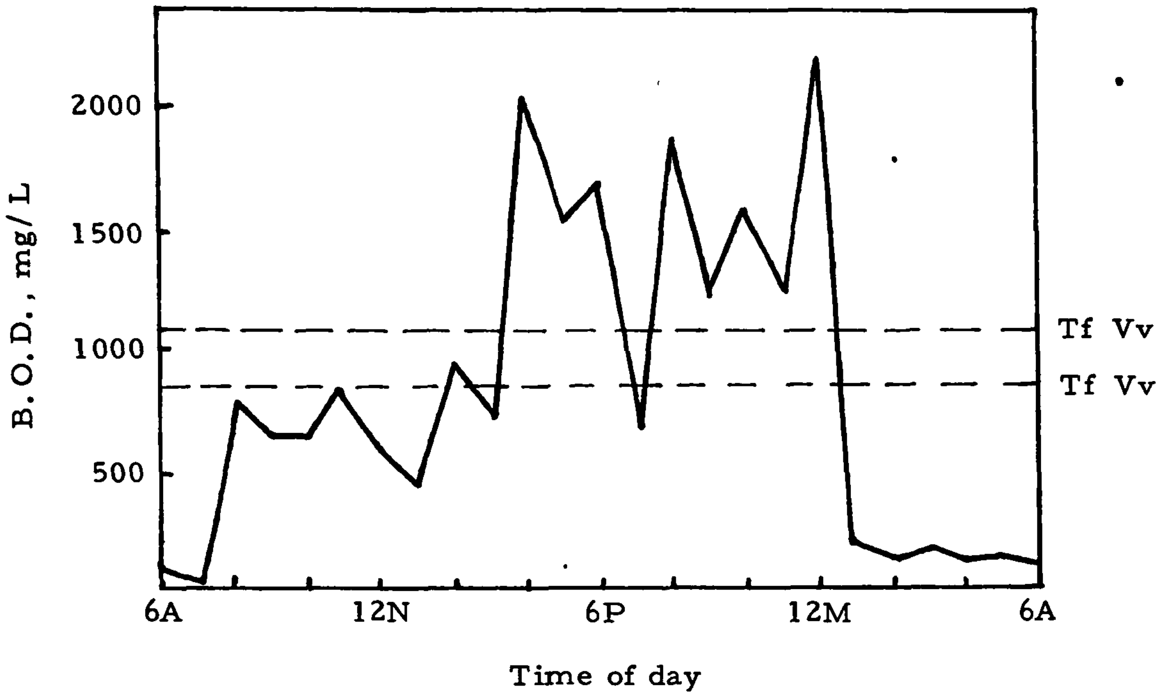


Figure 8. Temporal fluctuations in a food plant waste load.

time interval. However, this procedure for obtaining daily (or other) averages places a heavy burden on laboratory personnel. To minimize laboratory efforts which obtaining meaningful data, a single sample consisting of the combination of numerous discrete subsamples, or aliquots, may be used. 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 8).

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 twenty-four hour period, thereby resulting in a composite sample of approximately three 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 individually analyzing each aliquot. Relatively inexpensive devices are available to automatically collect $T_F V_F$ composite samples. This procedure is quite satisfactory for non-fluctuating flows.

When discharge flows fluctuate widely, a single aliquot in a $T_F V_F$ composite may seriously influence analytical accuracy of the entire composite sample. To minimize the effect of an individual aliquot, flow-proportioned aliquots should be 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 fixed time-variable volume ($T_F V_V$). This procedure, for which a few automatic sampling devices are available, will yield laboratory results in close agreement to the true average.

Best results short of continuous on-line analysis are obtained by analyzing samples composited on a "per unit flow" basis -- that 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 and in Reference 3.

V. TREATMENT METHODS

Wastewater discharge permits (NPDES permits) contain limitations on the quantity of pollutants which can be discharged into receiving streams. For food processing wastewaters, permittees are all required to reduce their raw waste loads by often extensive treatment. Industrial users of municipal treatment systems are generally also required to minimally pretreat their wastewater to the extent of removing large particulate matter. The following discussions generally describe the main treatments for food processing wastewaters. Details of each, with discussions of specific treatment processes and schemes, are contained in Volume 3 of this series.

SCREENING

The basic and primary pretreatment step for all wastewaters is the removal of large materials which are detrimental to equipment operations and to the efficiency of the remainder of the treatment system. Screens of various types are used to remove such materials. Screens may range from parallel bars (bar racks) spaced at up to two-inches (Figure 9) for removing rocks, rags and wood, to tightly woven metal or fabric cloth for removing fine particles (Figure 10).

Woven screen cloths are used in rotating cylindrical screens and in vibrating flat-bed screens utilized extensively by food processors. These cloths are sized according to mesh, the number of openings per inch. Thus, a 10-mesh cloth contains ten openings per lineal inch. However, the percent open area, which is affected by the diameter of the wire or fabric used in the weave, is not reflected by mesh designations. For fine screen cloth the size of each opening (e.g., 100μ) is used in place of mesh. For most fruit and vegetable wastewaters, 20-mesh to 40-mesh screens have proven most effective.

Figure 9. Bar rack with automatic rake.

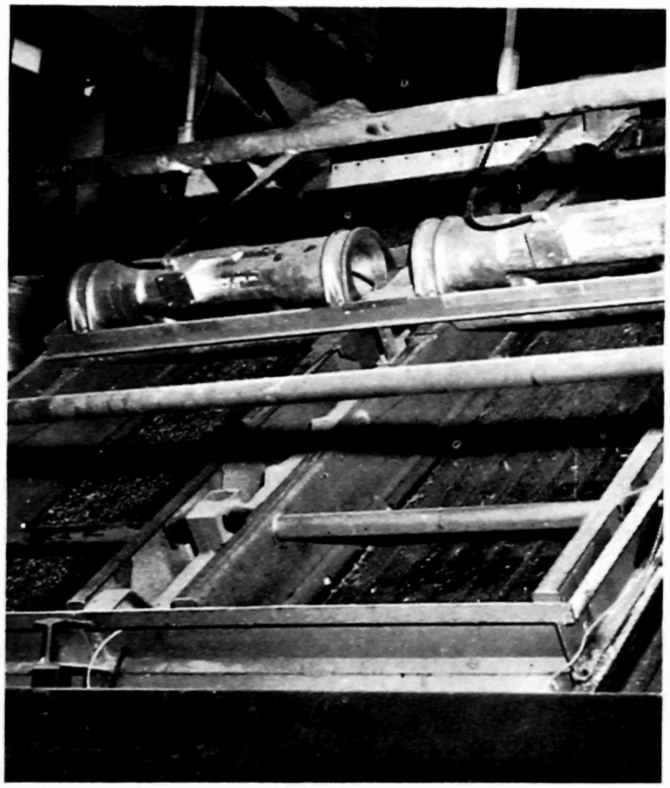


Figure 10. Vibrating screen for separation of solid particles.

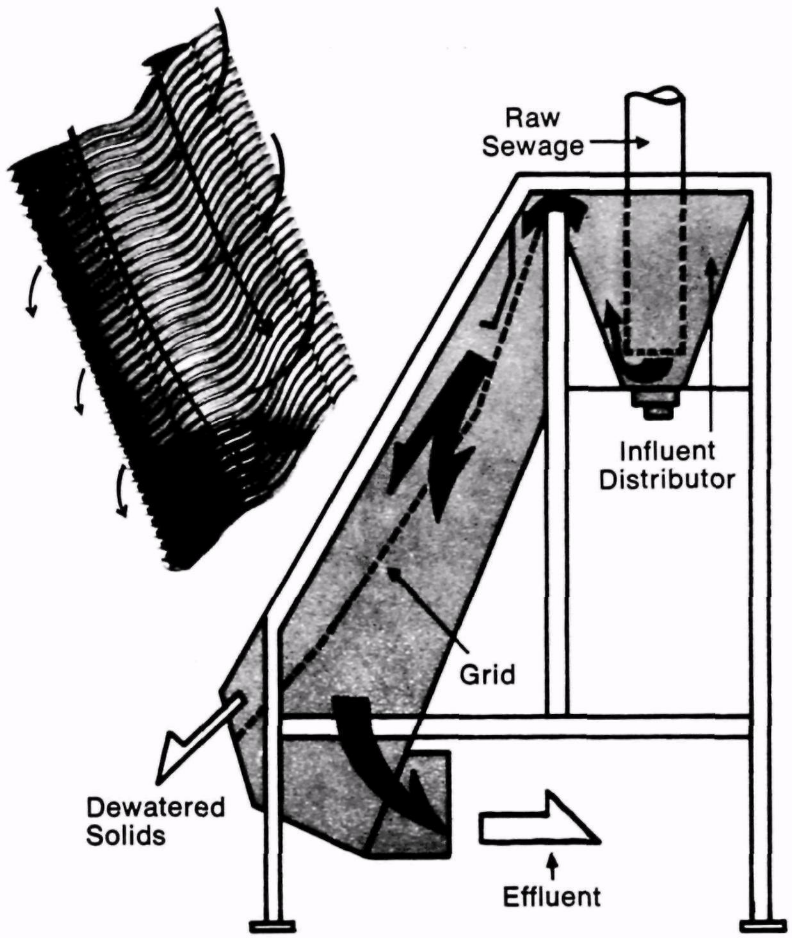


Figure 11. Parabolic or tengential screen.

A design gaining in popularity is the parabolic or tangential screen (Figure 11). The screening surface consists of a curved steel sheet containing slits through which water can pass but on which solids are retained. By introducing wastewater tangentially to the top of the curved slope, the retained solids are gravitationally forced to the bottom discharge. Dewatering of solids is facilitated by the deceleration of retained materials at the bottom of the slope. Size designation is by mesh-equivalent or by the measurement of the slit width.

PRIMARY TREATMENT

Primary treatment refers to removal of floatable and readily settleable materials. This is always a necessary initial step in the treatment of domestic sewage. Settling tanks and clarifiers (Figure 12) are designed to reduce influent flow rates so that floatable and settleable materials will be naturally separated from the wastewater. Mechanical devices are incorporated to continuously remove scum and sediment from the units.

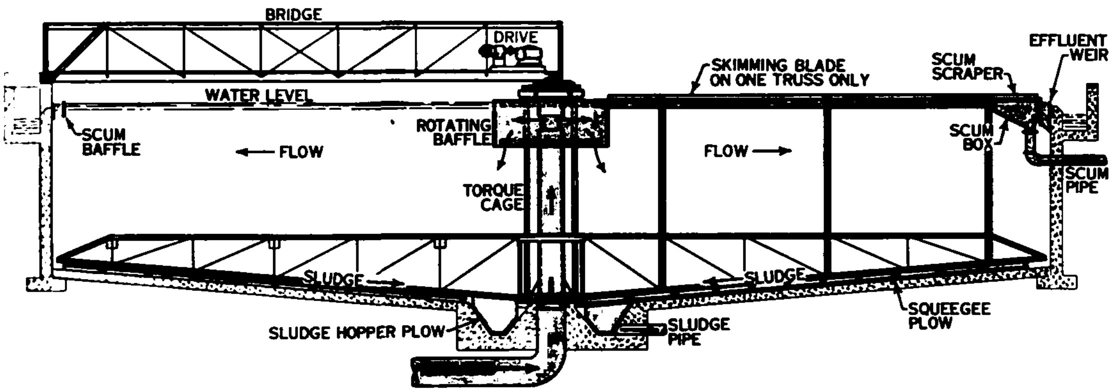


Figure 12. Sectional diagram of a circular clarifier.

Wastewater from washing certain commodities, such as root vegetables and mechanically-harvested tomatoes, contains high concentrations of soil. Under these circumstances, primary treatment may be required to prevent sedimentation of soils in subsequent treatment works. However, primary treatment will have little effect in reducing the BOD loads associated with fruit and vegetable processing wastewaters. Generally, screening is all that will be required for solids removal.

SECONDARY TREATMENT

Secondary wastewater treatment systems are designed to reduce organic loads. Under practical situations, BOD and suspended solids removals of 85 to 90 percent are achieved. Effluent limitations generally require the minimum of secondary treatment for all discharges into receiving streams. The numerous types of systems which are available for this purpose are classified into two broad categories -- biological and physical-chemical.

Biological Treatment

Biological systems are so named because microorganisms are depended upon to reduce organic loads. System designs attempt to optimize environmental conditions for the support and growth of suitable micro-fauna. The simplest of biological systems is a lagoon or stabilization pond, usually four to six feet deep. Lagoons are sized to retain waste flows for long periods (as much as 30 days or more), during which time organic materials are degraded. Aerated lagoons are equipped with mechanical devices (Figure 13) to increase the dissolved oxygen concentration in lagoon water, thereby increasing the efficiency of treatment and reducing required retention times. Both stabilization ponds and aerated lagoons are used widely by food processors.

Figure 13. Aeration basin with floating surface aerators.

The activated sludge process, with its many variations, is the most sophisticated biological treatment procedure. An activated sludge system basically consists of an aeration tank followed by a clarifier. Wastewater is continuously introduced into the aeration tank; nutrient balances are maintained to optimize the growth of microorganisms within the tank. The organisms are removed from the system effluent by the clarifier; the clarified treated wastewater is discharged and the recovered organisms (activated sludge) are mixed with the influent wastewater to achieve maximum degradation rates. Retention times required by this process are relatively short (a few hours for weak wastes to a few days for stronger wastes).

The operating principle of trickling filters (Figure 14) is unique among biological processes. Instead of providing an environment in which microorganisms are suspended within a liquid, trickling filters are vertical tanks containing rock, plastic or wood media which provide large surface areas upon which microorganisms form a film, or zoogleal slime. The media is arranged within the system to provide a high percentage of void spaces, thereby assuring maintenance of aerobic conditions. Wastewater is applied slowly over the top of the packing and allowed to slowly trickle down through the media. Organic matter contained in the wastewater is adsorbed on the slime and degraded by the microorganisms. The BOD of the effluent collected at the bottom of the unit is thus considerably reduced.

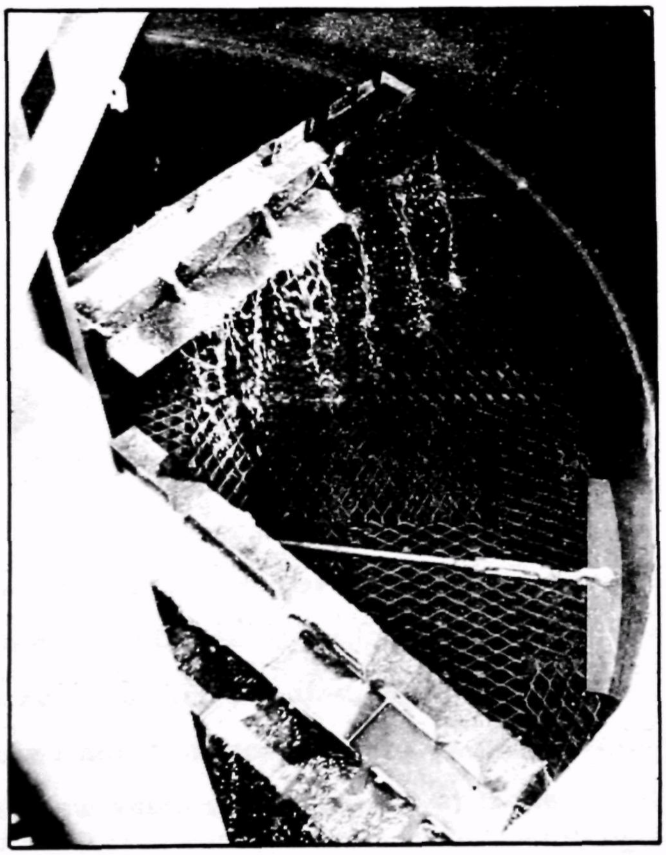


Figure 14. Top view of trickling filter packed with plastic media.

Physical-Chemical Treatment

Physical and/or chemical processes may provide effective secondary treatment when a high percentage of the organic load is attributable to solids contained in the wastewater. For most fruit and vegetable processing wastes, most of the BOD is due to dissolved organic matter. Therefore, biological systems will generally be required. However, physical-chemical processes may be required in conjunction with biological treatment in situations where extremely stringent discharge requirements must be met.

Colloidal particles -- suspended solids which are extremely fine and tend to remain suspended in water -- are most problematic. Chemical flocculation has been demonstrated to effectively facilitate their removal. When certain chemicals are mixed with wastewater, the particles are physically encouraged to agglomerate, thereby forming larger particles (floc) which can then be readily separated. Effective chemicals include ferric chloride, alum, and a wide variety of synthesized polyelectrolytes.

When flocculated materials are relatively heavier than water, separation can be most readily achieved by sedimentation. However, some flocs can remain close to the density of the water and will not readily settle. In such cases, air flotation has proven quite effective (Figure 15). In this process minute bubbles of air are introduced into a tank of wastewater. As the bubbles rise to the surface, they become attached to floc particles, thus encouraging the particles to float. The floc can be removed from the system with skimmers.

Suspended solids may also be removed by various filtration techniques. Vacuum filters, widely used by potato processors for dewatering settleable

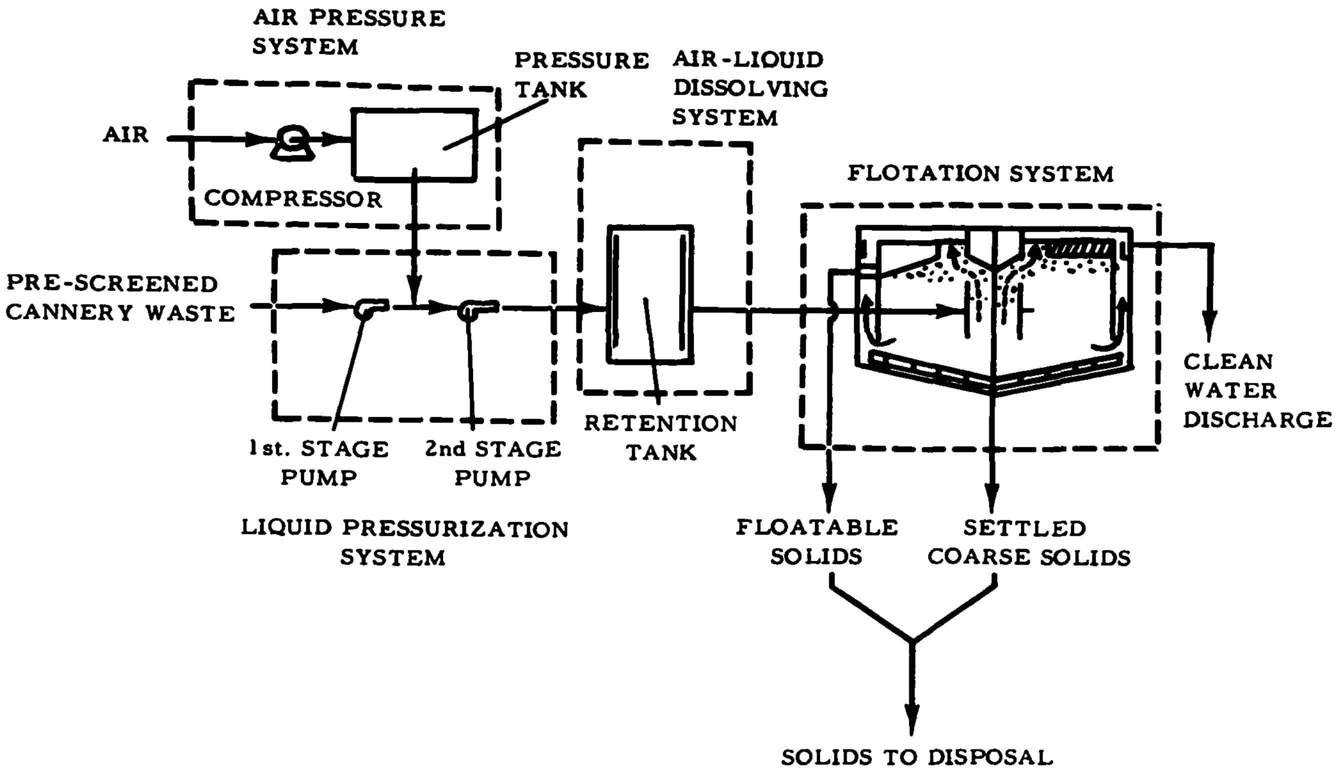


Figure 15. Schematic of a full flow pressurization floatation system.

solids, employ rotating drums covered with extremely fine-mesh filter cloths. The drums are partially vacuated and immersed partly in wastewater. The water phase is drawn through the fabric cover; the suspended solids are retained as a coating on the outer surface. The solids are removed by scraping the exposed drum surface and collecting the dislodged solids. Fine suspended solids may be removed by sand filtration. By passing wastewater through a bed of fine sand, suspended materials are retained within the bed while water passes through. The bed must be periodically cleaned by backwashing, thus dislodging trapped solids which are collected in a concentrated stream. When a filter bed consists of a mixture of size-graded materials, such as sand, garnet and anthracite, the process is named mixed-media filtration. Filtration rates are greatly improved by use of mixed-media.

Refractory compounds -- that is, materials which are difficult to remove by conventional processes -- can often be removed by carbon adsorption. Activated carbon has the unique property of being able to "hold onto" a wide variety of compounds. Refractory compound concentrations contained in wastewater will be significantly reduced by passage through columns of activated carbon. When the adsorptive capacity of a column is reached, the carbon must be regenerated, typically by incineration to combust the adhering pollutants. The carbon can then be reused to treat additional volumes of wastewater.

LAND DISPOSAL

The EPA generally considers land disposal (with no associated run-off) as satisfying the WPCA goal of "zero discharge". Effluent limitations for several industrial categories, such as beet sugar processing, specify zero discharge through land disposal. Under practical conditions, land disposal of large volumes of wastewater is limited to either flood or spray irrigation, both techniques are widely used by fruit and vegetable processors.

Flood irrigation, as the term implies involves spreading wastewater over designated fields. Disposal is accomplished by percolation of wastewater into the soil and by evaporation. In check irrigation, the field is divided into diked sections or "checks". Wastewater is applied by flooding the checks on a rotational schedule; each check is allowed to dry before further wastewater applications are made. In ridge-and-furrow irrigation, the field is prepared by creating parallel furrows or ditches. Wastewater is applied by flooding the furrows; the ridges facilitate disposal by absorbing water from the furrows. Crops may be planted on the ridges to further facilitate disposal through evapotranspiration.

Spray irrigation involves application of wastewater through impulse sprinkler heads (Figure 16). As in flood irrigation, spray fields are normally divided into sections and wastewater applications are made on a rotational schedule. Disposal is accomplished by evaporation and percolation. Cover crops, generally a mixture of water-tolerant grasses, are planted to facilitate disposal through evapotranspiration. Percolative spray irrigation systems are designed for complete disposal -- that is, all applied wastewaters are disposed of through percolation and evaporation, thereby resulting in zero run-off.

Overland flow systems, which are gaining in popularity, are intentionally designed for excessive application with resultant runoffs. These systems are engineered to utilize soil bacteria for degradation of organic matter contained in the wastewater. The quantity and pollutant content of the collected runoff is thus considerably reduced. In principle, this system is a combination percolative spray irrigation and biofilter (trickling filter).

Figure 16. Spray irrigation disposal of food processing wastewater.

REFERENCES

1. U.S. Environmental Protection Agency. Methods for Chemical Analysis of Water and Wastes (Document Number EPA-625-/6-74-003), EPA Office of Technology Transfer, Washington, D.C. (1974)

2. Standard Methods for the Examination of Water and Wastewater, (13th ed.), American Public Health Association, N.Y. (1971)

3. U.S. Environmental Protection Agency. Handbook for Monitoring Industrial Wastewater, EPA Office of Technology Transfer, Washington, D.C. (1973)

GLOSSARY OF TERMS

Definition of Selected Terms
used in
Water and Waste Management

A

acidity -- The quantitative capacity of aqueous solutions to react with hydroxyl ions. It is measured by titration with a standard solution of a base to a specific end point. Usually expressed as milligrams per liter of calcium carbonate.

activated carbon -- Carbon particles usually obtained by carbonization of cellulosic material in the absence of air and possessing a high adsorptive capacity.

activated sludge -- Sludge floc produced in raw or settled wastewater by the growth of zoogleal bacteria and other organisms in the presence of dissolved 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 wasted or returned to the process as needed. The treated wastewater overflows the weir of the settling tank in which separation from the sludge takes place.

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 90-99% oxygen demand and organic solids removal of secondary treatment. May include nitrogen, phosphorous, 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 -- (1) A condition characterized by an excess of dissolved oxygen in the aquatic environment. (2) Living or taking place only in the presence of molecular oxygen.

alkalinity -- The capacity of water to neutralize acids, a property imparted by the water's content of carbonates, bicarbonates, hydroxides, and occasionally borates, silicates, and phosphates. It is expressed in milligrams per liter or equivalent calcium carbonate. Natural waters are generally neutral or slightly alkaline. The alkalinity of water may range from a few milligrams per liter to several hundred. Domestic sewage is usually slightly more alkaline than the water from which it is derived.

alum -- A chemical substance (usually potassium aluminum sulfate), gelatinous when wet, used in water-treatment plants for settling out small particles of foreign matter.

anaerobic -- (1) A condition in which dissolved oxygen is undetectable in the aquatic environment. Usually characterized by formation of reduced sulfur compounds such as sulfides in a putrefaction activity. (2) Living or taking place in the absence of molecular oxygen.

anaerobic digestion -- The degradation of organic matter brought about through the action of microorganisms in the absence of elemental oxygen.

assimilative capacity -- The capacity of a natural body of water to receive: (a) wastewaters, without deleterious effects; (b) toxic materials, without damage to aquatic life or humans who consume the water; (c) BOD, within prescribed dissolved oxygen limits.

available chlorine -- A measure of the total oxidizing power of chlorinated lime and hypochlorites.

biochemical oxygen demand (BOD) -- The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. (2) A standard test used in assessing wastewater strength.

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 -- The ratio based upon analysis of wastewater passing into a waste treatment system, of the BOD to total nitrogen to 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 a mineral content in the general range between fresh water and seawater. Water containing from 1,000 to 10,000 mg/l of dissolved solids.

breakpoint chlorination -- Addition of chlorine to water or wastewater until the chlorine demand has been satisfied and further additions result in a residual that is directly proportional to the amount added beyond the breakpoint.

buffer action -- The action exhibited by certain chemicals that resist a change in the effective acidity or hydrated H+ ion content of a solution. In surface water the primary buffer action is related to carbon dioxide, bicarbonate and carbonate equilibria.

bulking sludge -- An activated sludge that settles poorly because of a floc of low density.

C

chemical oxygen demand (COD) -- A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specific test. It does not differentiate between stable and unstable organic matter and thus does not necessarily correlate with biochemical oxygen demand. Also known as OC and DOC, oxygen consumed and dichromate oxygen consumed, respectively.

chloramines -- Compounds of organic or inorganic nitrogen and chlorine.

chlorine demand -- The difference between applied chlorine and residual available chlorine in aqueous media under specified conditions and contact time. Chlorine demand varies with dosage, time, temperature and nature of the water impurities.

clarification -- Any process or combination of processes the primary purpose of which is to reduce the concentration of suspended matter in a liquid.

C/N ratio -- The weight ratio of carbon to nitrogen.

coagulation -- The process of modifying chemical, physical or biological conditions to cause flocculation or agglomeration of particles.

coliform group -- A group of bacteria predominantly inhabiting the intestines of man or animal, but also occasionally found elsewhere. It includes all aerobic and facultative anaerobic, Gram-negative, non-spore forming bacilli that ferment lactose with production of gas. Also included are all bacteria that produce a dark, purplish-green colony with metallic sheen by the membrane-filter technique used for coliform identification. The two groups are not always identical, but they are generally of equal sanitary significance. Their presence in water is presumptive evidence of contamination by fecal material.

colloids -- (1) Finely divided solids which will not settle but may be removed by coagulation or biochemical action or membrane filtration; they are intermediate between true solutions and suspensions. (2) In soil physics, discrete mineral particles less than two microns in diameter. (3) Finely divided dispersions of one material, called the dispersed phase with another, called the dispersion medium. (4) In general, particles of colloidal dimensions are approximately 10 A to 1μ in size. Colloidal particles are distinguished from ordinary molecules by their inability to diffuse through membranes that allow ordinary molecules and ions to pass freely.

combined available chlorine -- The concentration of chlorine which is combined with ammonia as chloramine or as other chloro derivitives, yet is still available to oxidize organic matter.

composite wastewater sample -- A combination of individual samples of water or wastewater taken at selected intervals, generally hourly for some specified period, to minimize the effect of the variability of the individual sample. Individual samples may have equal volume or may be roughly proportioned to flow at time of sampling.

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 60 min, to obtain BOD 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 conversion of oxidized nitrogen (nitrate and nitrite-N) to nitrogen gas by contact with septic wastewater solids or other reducing chemicals. (2) A reduction process with respect to oxidized nitrogen.

detritus -- (1) The coarse debris carried by wastewater. (2) The heavier mineral debris moved by natural watercourses, usually in bed-load form.

diatomaceous earth, diatomite -- A fine, siliceous earth consisting mainly of the skeletal remains of diatoms (unicellular organisms).

diffuser -- A porous plate, tube, or other device through which air is forced and divided into minute bubbles for diffusion in liquids. Commonly made of carborundum, alundum, metal, or plastic materials.

digested sludge -- Sludge digested under either aerobic or anaerobic conditions until the volatile content has been reduced to the point at which the solids are relatively nonputrescible and inoffensive.

dispersed growth -- Non-flocculating micro-organisms whose presence in treated wastewater results in a turbid effluent.

dissolved oxygen (DO) -- The oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter, parts per million, or percent of saturation. Abbreviated DO. In unpolluted water, oxygen is usually present in amounts of up to 10 ppm. Adequate dissolved oxygen is necessary for the life of fish and other aquatic organisms. About 3-5 ppm is the lowest limit for support of fish life over a long period of time.

dissolved-oxygen sag curve -- A curve that represents the profile of dissolved oxygen content along the course of a stream resulting 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 soilds -- The total amount of dissolved material, organic and inorganic, contained in water or wastes. Excessive dissolved solids can make water unsuitable for industrial uses, unpalatable for drinking, and even cathartic. Potable water supplies may have dissolved solid content from 20 to 1000 mg/l, but sources which have more than 500 mg/l are not recommended by the U.S. Public Health Service.

drinking water standards -- (1) Standards prescribed by the U.S. 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, ground-water or bottled-water sources.

E

E. coli -- Abbreviation of Escherichia coli, a species of bacteria in the coliform group and normal inhabitants of the intestine of man and animals. Its presence of considered indicative of fresh fecal contamination.

effluent -- (1) A liquid which flows out of a containing space. (2) Waste-water or other liquid, partially or completely treated, or in its natural state, flowing out of a reservoir, basin, treatment plant, or part thereof. (3) An outflowing branch of a main stream or lake.

estuary -- The mouth of a river, where tidal effects are evident and where fresh water and sea water mix.

eutrophication -- The normally slow aging process by which a lake evolves into marsh and ultimately becomes completely filled with detritus and disappears. In the course of this process the lake becomes overly rich in dissolved nutrients (for example, nitrogen and phosphorus), so that an excessive development of algae results. First the water becomes murky, the noxious odors and unsightly scums appear. In the lower layers dissolved oxygen levels become depressed, and bottom-dwelling fauna change from clean-water forms to pollution-tolerant forms.

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. The concept envisages the stabilization of organic matter under aerobic conditions and disposal of the end products into the air as gases and with the plant effluent as finely divided suspended matter and soluble matter.

F

facultative bacteria -- Bacteria that can adapt themselves to growth and metabolism under aerobic or anaerobic conditions. Many organisms of interest in wastewater stabilization are among this group.

fats -- Triglyceride esters of fatty acids. Naturally occuring compounds functioning as storage products in the living organism. Generally semi-solid or oily at normal temperatures. Erroneously used as synonymous with grease.

filter -- A device or structure for removing solid or colloidal material, usually of a type that cannot be removed by sedimentation, from water, wastewater, or other liquid. The liquid is passed through a filtering medium, usually a granular material but sometimes finely waven cloth, unglazed porcelain, or specially prepared paper. There are many types of filters used in water or wastewater treatment. See trickling filter filtration.

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 influent liquid by a physical straining action. The trickling filter process used in wastewater treatment is a method of contacting dissolved and suspended organic matter with biologically active aerobic slime growths, and hence is not a true filtration process.

five-day BOD -- The part of oxygen demand associated with biochemical oxidation of carbonaceous, as distinct from nitrogenous, material. It is determined by allowing biochemical oxidation to proceed, under conditions specified in standard methods, for 5 days.

fixed solids -- The residue remaining after ignition of suspended or dissolved matter according to standard methods.

floc -- Gelatinous or amorphous solids formed by chemical, biological, or physical agglomeration of fine materials into large masses that are more readily separated from the liquid.

flocculation -- In water and wastewater treatment, the agglomeration of colloidal and finely divided suspended matter after coagulation by gentle stirring by either mechanical or hydraulic means. In biological wastewater treatment where coagulation is not used, agglomeration may be accomplished biologically.

flotation -- The raising of suspended matter to the surface of the liquid in a tank as scum -- by aeration, the evolution of gas, chemicals, electrolysis, heat, or bacterial decomposition -- and the subsequent removal of the scum by skimming.

F/M ratio -- Food to microorgamsism ratio: the weight ratio of BOD (food) in wastewater to suspended solids (microorganisms) within an activated sludge treatment system. This value is used as an operational control criterion for activated sludge processes.

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 available chlorine -- Generally includes that chlorine existing in water as the hypochlorous acid. Characterized by rapid color formation with orthotolidine, can be titrated in a neutral solution with phenyl arsene oxide and produces a rapid organism kill in low concentrations.

free residual chlorination -- The application of chlorine or chlorine compounds to water or wastewater to produce a free available chlorine residual directly or through the destruction of ammonia or certain organic nitrogenous compounds.

grease -- In wastewater, 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, cinders.

hardness -- A characteristic of water, imparted by salts of calcium, magnesium, and iron such as bicarbonates, carbonates, sulfates, chlorides and nitrates, that causes curdling of soap and increased consumption of soap, deposition of scale in boilers, damage in some industrial processes, and sometimes objectionable taste. It may be determined by a standard laboratory procedure or computed from the amounts of calcium and magnesium as well as iron, aluminun, manganese, barium, strontium, and zinc, and is expressed as equivalent calcium carbonate. Soft water is that with less than 60 ppm of salts, temporary water, 60 to 120 ppm, permanent water, in excess of 120 ppm.

hydrolysis -- (1) The reaction of a solute with water in aqueous solution. (2) A change in the chemical composition of matter produced by combination with water. Sometimes loosely applied in wastewater practice to the liquefaction of solid matter in a tank as a result of biochemical activity.

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 land-fill 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.

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).

mgd -- Abbreviation for million gallons per day.

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 commonly, 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, the quantity of solids contained in the mixed liquor of an activated sludge treatment system which is lost on ignition of the dry solids at 600°C. This value is an index of the active biological mass within the treatment system.

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 consituents, 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 treatment.

nitrogenous wastes -- Wastes of animal or plant origin that contain a significant concentration of nitrogen.

nutrient -- A chemical substance (an element or a chemical compound) absorbed by living organisms and used in organic synthesis. The major nutrients include carbon, hydrogen, oxygen, nitrogen, sulfur, and phosphorus. Nitrogen and phosphorus are of major concern because they tend to recycle and are difficult to remove from water due to their solubility.

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.

overturning -- The phenomenon of vertical circulation which occurs in large bodies of water. It is due to the increase in density of water above and below 39.2^{o}F, 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 colder and therefore heavier, it also tends to sink. Wind may also create such vertical currents.

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 -- (1) The quanitty of oxygen utilized in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. See BOD.

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

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, 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.

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 reciprocal of the 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 -- A means of expressing the strength of organic material in wastewater. Domestic wastewater consumes, on an average, 0.17 lb of oxygen per capita per day, as measured by the standard BOD test. This figure has been used to measure the strength of organic industrial waste in terms of an equivalent number of persons. For example, if an industry discharges 1,000 pounds of BOD per day, its waste is equivalent to the domestic wastewater from 6,000 persons (1,000 ÷ 0.17 = 6,000).

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 -- (1) The first major (sometimes the only treatment in a wastewater treatment works. Commonly considered to include bar racks, grit chambers, comminution, sedimentation and sludge digestion treatment operations, may include flocculation or disinfection. (2) The removal of a substantial amount of suspended matter but little or no colloidal and dissolved matter.

process water -- Water (liquid or vapor) that comes in contact with an end product or with materials incorporated in an end product.

proportional composite sample -- A combination of individual samples of water or wastewater taken at selected intervals, generally hourly for some specified period, to minimize the effect of the variability of the individual sample. Prior to combination, each individual sample is roughly proportioned to the flow at time of sampling.

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 24-30 in. 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 supplementing 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 two to three 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 occuring 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 either settles to the bottom or floats to the top. (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 build up to a varying degree 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 in. 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 3-6 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 bulking -- A phenomenon that occurs in activated sludge plants whereby the sludge occupies excessive volumes and will not concentrate readily.

sludge conditioning -- Treatment of liquid sludge before dewatering to facilitate dewatering and enhance drainability, usually by the addition of chemicals.

sludge density index -- 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 1,000-ml sample in 30 min. to the concentration of mixed liquor 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 -- Measure of a water's capacity to convey an electric current. This property is related to the total concentration of the ionized substances in the water and the temperature of the water. Most inorganic acids, which dissociate readily in aqueous solution, will conduct an electric current well, while organic compounds (such as sucrose and benzene), which do not dissociate in aqueous solution will conduct a current poorly if at all.

Sphaerotilus -- 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 -- (1) 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. (2) Methods published by professional organizations and agencies covering specific fields. These include, among others: American Public Health Association, American Public Works Association, American Society of Civil Engineers, American Society of Mechanical Engineers, American Society for Testing and Materials, American Water Works Association, United States Bureau of Standards, United States of America Standards Institute (formerly American Standards Association), United States Public Health Service, 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) -- (1) Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering. (2) The quantity of material removed from wastewater in a laboratory test, as prescribed in "Standard Methods for the Examination of Water and Wastewater" and referred to as nonfilterable residue.

T

tapered aeration -- The method of supplying varying amounts of air into the different parts of an aeration tank in the activated sludge process, more at the inlet, less near the outlet, in approximate proportion to the oxygen demand of the mixed liquor under aeration.

tertiary treatment -- Treatment beyond normal or conventional secondary methods for the purpose of increasing water re-use 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.

total dissolved solids (TDS) -- See dissolved solids.

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 (TS) -- Refers to the solids contained in dissolved and suspended form in water. Commonly determined on a weight basis by evaporation to dryness and expressed as milligrams per liter (mg/l).

toxic substance -- A substance that either directly poisons living things or alters their environment so that they die. Examples are cyanides found in plating and steel mill wastes, phenols from coke and chemical operations, pesticides and herbicides, and heavy metal salts. Another broad group includes oxygen-consuming substances that upset the balance of nature, such as organic matter from food plants, pulp and paper mills, chemical plants, and textile plants. Still another group are sulfides, produced by oil refineries, smelters, and chemical plants.

transpiration -- (1) The process by which water vapor is lost to the atmosphere from living plants. (2) The quantity of water thus dissipated.

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 or applied in drops, films, or spray from troughs, drippers, moving distributors, or fixed nozzles, and through which the wastewater trickles to the underdrains, giving opportunity for the formation of zoogleal slimes which clarify and oxidize the wastewater. See filter filtration.

turbidity -- (1) A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light rays. (2) A measure of fine suspended matter in liquids. (3) An analytical quantity usually reported in arbitrary turbidity units determined by measurements of light diffraction.

turnover -- A phenomenon usually occuring 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 colder and therefore heavier, it also tends to sink. Also see overturning.

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.

USPHS drinking water standards -- Standards prescribed by the U.S. Public Health Service for the quality of drinking water supplied to interstate carriers and prescribed as standards by most state and local jurisdictions for all public water supplies.

V

vacuum filter -- A filter consisting of a cylindrical drum mounted on a horizontal axis, covered with a filter cloth, and revolving with a partial submergence in liquid. A vacuum is maintained under the cloth 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 -- Apparent loss of matter from a residue ignited at 550° C for a period of time sufficient to reach constant weight of residue, usually 10-15 min.

W

watercourse -- (1) A natural or artificial channel for passage of water. (2) A running stream of water. (3) A natural stream fed from permanent or natural sources, including rivers, creeks, runs, and rivulets. There must be a stream, usually flowing in a particular direction (though it need not flow continuously) in a definite channel, having a bed or banks and usually discharging into some other stream or body of water.

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 -- (1) A diversion dam. (2) A device that has a crest and some side containment of known geometric shape, such as a V, a trapezoid, or rectangle, and is used to measure flow of liquid. The liquid surface is exposed to the atmosphere. Flow is related to upstream height of water above the crest, to position of crest with respect to downstream water surface, and to geometry of the weir opening.

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. Also see ion exchange, zeolite process.

zeolite process -- The process of softening water by passing it through a substance known in general as a zeolite, which exchanges sodium ions for hardness constituents in the water.

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

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