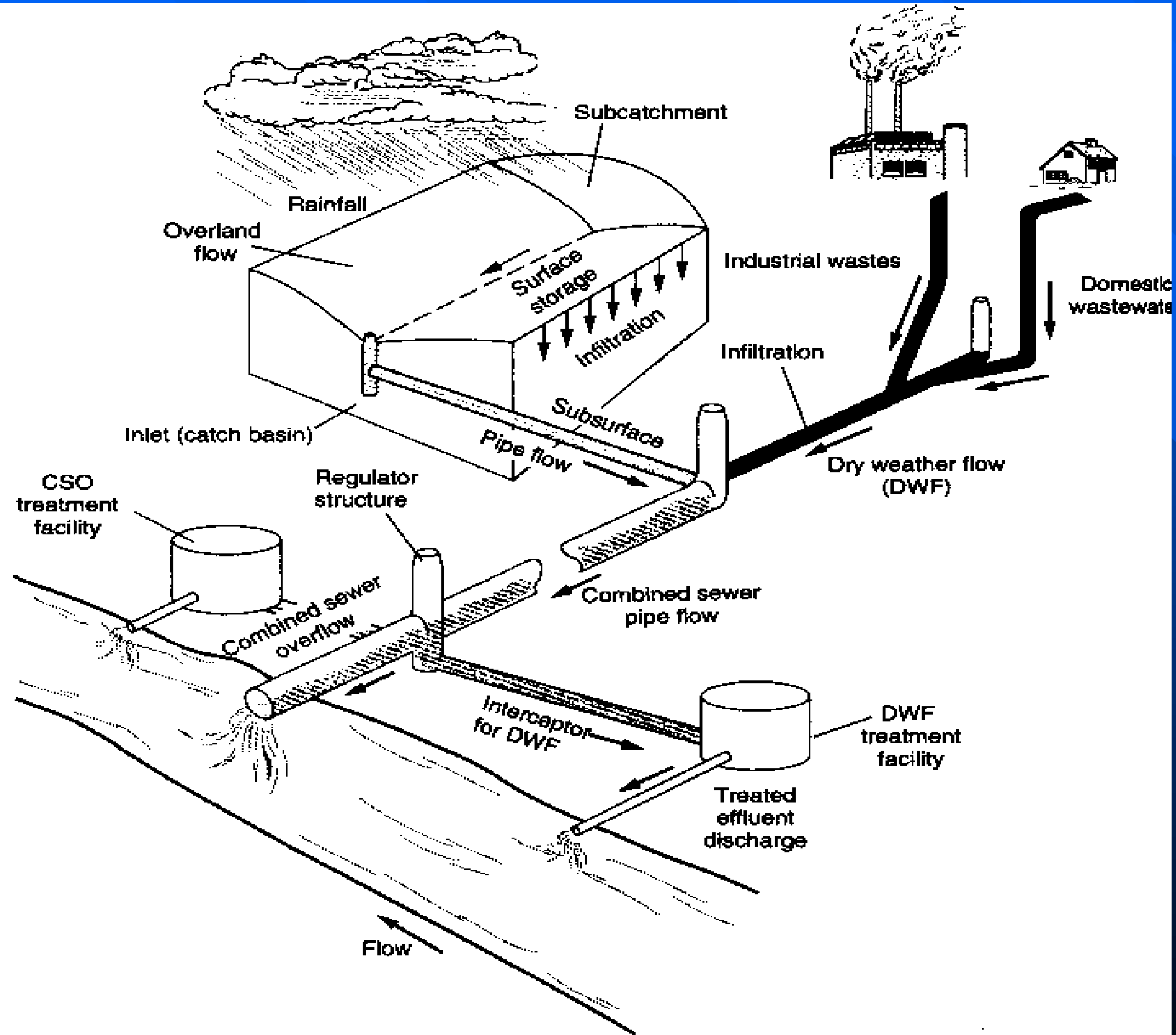
•Part I Wastewater Engineering

•1 *Wastewater Engineering: An Overview*

Fig. 1-1 Schematic diagram of a wastewater management infrastructure



1-1 Terminology

Table 1-1 Terminology commonly used in the field of wastewater engineering

1-2 Impact of Regulations on Wastewater Engineering

1-3 Health and Environmental Concerns in Wastewater Management

Fig. 1-2 Covered treatment plant facilities for the control of odor emissions

1-4 Wastewater Characteristics

Tab 1-2 Levels of wastewater treatment

Tab 1-3 Unit Operations and Processes used to Remove Constituents Found in Wastewater

1-5 Wastewater Treatment

Fig 1-3 Facilities used for chemical treatment of odors from treatment facilities

Fig. 1-4 UV lamps used for the disinfection of wastewater

1-6 Wastewater Reclamation and Reuse

1-7 Biosolids and Residuals Management

Fig. 1-5 Egg-shaped digesters used for the anaerobic treatment of biosolids

2 Constituents in Wastewater

An understanding of the nature of wastewater is essential in the design and operation of wastewater collection, treatment, and reuse facilities, and in the engineering management of environmental quality.

(1) the constituents found in wastewater,

(2) sampling and analytical procedures,

(3) physical characteristics,

(4) inorganic nonmetallic constituents,

(5) metallic constituents,

(6) aggregate organic constituents,

(7) individual organic constituents and compounds,and

(8) biological characteristics.

2-1 Wastewater Constituents

Constituents Found in Wastewater

Table 2-1 Common analyses used to assess the constituents found in wastewater

Many of the physical properties and chemical and biological characteristics are interrelated. For example, temperature, a physical property, affects both the amounts of gases dissolved in the wastewater and the biological activity in the wastewater…

Constituents of Concern in Wastewater Treatment

Tab 2-2 Principal constituents of concern in wastewater treatment

Suspended solids can lead to sludge deposition and anaerobic conditions;

Biodegradable organics composed of proteins; carbohydrates and fats ,and are measured most commonly in terms of BOD and COD;

Pathogens can transmite Communicable diseases;

Priority pollutants include carcinogenicity, metogenicity, teratogenicity or high acute toxicity;

Nutrients lead to the growth of undesirable aquatic life;

Refractory organics include surfactants, phenols, and agricultural pesticides.

2-2 Sampling and Analytical Procedures

Sampling

(1) routine operating data for accessing overall plant performance

(2) data that can be used to document the performance of a given treatment operation or process

(3) data that can be used to implement proposed new programs

(4) data needed for reporting regulatory compliance.

The data collected must be:

(1). Representative.

(2).Reproducible.The data must be reproducible by others following the same sampling and analytical protocols.

(3). Defensible. The data must have a known degree of accuracy and precision.

(4). Useful. The data can be used to meet the objectives of the monitoring plan.

There are no universal procedures for sampling. Sampling programs must be tailored individually to fit each situation.

Quality assurance project plan (QAPP) (known previously quality assurance/quality control, QA/QC).

(1).Sampling plan.

(2).Sample types and size.

(3).Sample labeling and chain of custody.

(4).Sampling methods.

(5).Sampling storage and preservation.

(6).Sample constituents.

(7).Analytical methods.

If the physical, chemical, and/or biological integrity of the samples is not maintained during interim periods between sample collection and sample analysis, a carefully performed sampling program will become worthless.

Prompt analysis is undoubtedly the most positive assurance against error due to sample deterioration.

Probable errors due to deterioration of the sample should be noted in reporting analytical data.

Methods of Analysis

The analyses used to characterize wastewater vary from precise quantitative chemical determinations to the more qualitative biological and physical determinations.

The quantitative methods of analysis are either gravimetric, volumetric, or physicochemical.

Turbidimetry, colorimetry, potentiometry, polarography, adsorption spectrometry, fluorometry, and nuclear radiation are representative of the physicochemical analyses.

Units of Measurement for Physical and Chemical Parameters

kg/m^3 ,%(by volume or by mass), pg/L, ng/L, µg/L, mg/L, g/L, ppb, ppm, mol/L, eq/L, meq/L .

The concentration of trace constituents is usually expressed as micrograms per liter (µg/L) or nanograms per liter (ng/L).

For dilute systems, one liter of sample weighs approximately one kilogram, the units of mg/L or g/m^3 are interchangeable with ppm.

"parts per billion" (ppb) and "parts per trillion"(ppt) are used interchangeably with µg/L and ng/L

2-3 Physical Characteristics

The most important physical characteristic of wastewater is its total solids content, which is composed of floating matter, settleable matter, colloidal matter, and matter in solution. Other important physical characteristics include particle size distribution,turbidity, color, transnttittance, temperature, conductivity, and density, specific gravity and specific weight. Odor, sometimes considered a physical factor, is discussed in the following section.

Solids

In the characterization of wastewater, coarse materials are usually removed before the sample is analyzed for solids.

Tab 2-3 Definitions of solids found in wastewater

Fig. 2-1 Interrelationships of solids found in water and wastewater. In much of the water quality literature, the solids passing through the filter are called dissolved solids.

A filtration step is used to separate the total suspended solids (TSS) from the total dissolved solids (TDS). Filters with nominal pore sizes varying from 0.45 μm to about 2.0 μm have been used for the TSS test.

Fig. 2-2 Size ranges of organic contaminants in wastewater and size separation and measurement techniques used for their quantification

Particle Size Distribution

Information on particle size is of importance in assessing the effectiveness of treatment processes (e.g., secondary sedimentation, effluent filtration and effluent disinfection).

The biological conversion rate of these particles is dependent on size.

The methods used most commonly to study and quantify the particles in wastewater are serial filtration, electronic particle counting, and microscopic observation .

Serial Filtration

2.0 μm as specified in Standard Methods for the TSS test.

More than 20 mg/L of additional TSS would have been measured.

Electronic Particle Size Counting

Diluted sample through a calibrated orifice . The conductivity is correlated to the size of an equivalent sphere.

Fig. 2-5 Volume fraction of particle sizes found in the effluent from two activated-sludge plants with clarifiers having different side water depths

However, the particle size data for the large particles are quite different, owing primarily to the design and operation of the secondary clarification .

Microscopic Observation

Various types of stains can be used on a routine basis, to qualitatively assess microscope slide.

Video camera attached to a microscope and transmitted to a computer are dependent on the computer software , the mean, minimum, and maximum diameter, length to width ratio, the circumference, the surface area, the volume, and the centroid . Particle imaging greatly reduces the time required but the cost of the software and equipment is often prohibitive for many small laboratories.

Turbidity

Turbidity, a measure of the light-transmitting properties of water, is another test used to indicate the quality of waste discharges and natural waters with respect to colloidal and residual suspended matter.

The results of turbidity measurements are reported as nephelometric turbidity units (NTU).

It should be noted that the presence of air bubbles in the fluid will cause erroneous turbidity readings. In general, there is no relationship between turbidity and the concentration of total suspended solids in untreated wastewater.

There is, however, a reasonable relationship between turbidity and total suspended solids for the settled and filtered secondary effluent from the activated sludge process.

The conservation factors for settled secondary effluent and for secondary effluent filtered with a granular-medium depth filter will typically vary from 2.3 to 2.4 and 1.3 to 1.6, respectively.

However, turbidity readings at a given facility can be used for process control. Some on line turbidity meters used to monitor the performance of microfiltration units are affected by the air used to clean the membranes.

Color

Condition refers to the age of the wastewater, which is determined qualitatively by its color and odor. Fresh wastewater is usually a brownish-gray color ,sequentially from gray to dark gray, and ultimately to black that is often described as septic.

In most cases, the gray, dark gray, and black color of the wastewater is due to the formation of metallic sulfides, which form as the sulfide produced under anaerobic conditions reacts with the metals in the wastewater.

Absorption/Transmittance

The absorbance measured using a spectrophotometer and a fixed path length (usually 1.0 cm) is a measure of the amount of light, of a specified wave-length,

The factors that affect the percent transmission include selected inorganic compounds (e.g., copper; iron, etc.), organic compounds (e.g., organic dyes, humic substances, and conjugated ring compounds such as benzene and toluene), and TSS.

Iron is considered to be the most important with respect to UV absorbance because dissolved iron can absorb UV light directly and because iron will adsorb onto suspended solids, bacterial clumps and other organic compounds.

The sorbed iron can prevent the UV light from penetrating the particle and inactivating organisms that may be embedded within the particle. Dosage control is extremely important when UV disinfection is to be used.

Organic constituents, are compounds with six conjugated carbons or a five- or six-member conjugated ring. The reduction in transmittance observed during storm events is often ascribed to the presence of humic substances from stormwater flows.

Fig. 2-6 Transmittance measured at various wavelengths for activated-sludge effluents and lagoon effluents

Unfiltered and filtered transmittance are mearsured in wastewater in connection with the evaluation and design of UV disinfection systems.

Temperature

The temperature of wastewater is commonly higher than that of the local water supply, because of the addition of warm water from households and industrial activities. As the specific heat of water is much greater than that of air, the observed wastewater temperatures are lower only during the hottest summer months.

Effects of Temperature

The temperature of water is a very important parameter because of its effect on chemical reactions and reaction rates, aquatic life, and the suitability of the water for beneficial uses.

Industrial establishments that use surface water for cooling water purposes are particularly concerned with the temperature of the intake water.

In addition, oxygen is less soluble in warm water than in cold water. The the rate of biochemical reactions that accompanies an increase in temperature, combined with the decrease in the quantity of oxygen present in surface waters, can often cause serious depletions in dissolved oxygen concentrations in the summer months.

A sudden change in temperature can result in a high rate of mortality of aquatic life. Moreover, abnormally high temperatures can foster the growth of undesirable water plants and wastewater fungus.

Optimum Temperatures for Biological Activity

Optimum temperatures are in the range from 25 to 35°C. Aerobic digestion and nitrification stops at50℃. At 15°C, methane-producing bacteria become quite inactive, and at about 5°C, the autotrophic-nitrifying bacteria practically cease functioning. At 2℃,even the chemoheterotrophic bacteria dormant.

Conductivity

The conductivity increases as the concentration of ions increases. In effect, the measured EC value is used as a surrogate measure of TDS concentration.

2-4 Inorganic Nonmetallic Constituents

Inorganic chemical constituents of concern include nutrients, nonmetallic constituents, metals, and gases.

Inorganic nonmetallic and metallic constituents derive from the background levels in the water supply and from the additions resulting from domestic use, from the addition of highly mineralized water from private wells and groundwater, and from industrial use.

Inorganic nonmetallic consfituents considered in this section include pH, nitrogen, phosphorus, alkalinity, chlorides, sulfur, other inorganic constituents, gases, and odors.

Chlorides

Chlorides in natural water result from the leaching of chloride-containing rocks and soils with which the water comes in contact, and in coastal areas from saltwater intrusion.

Human excreta contain about 6 g of chlorides per person per day. If hardness of water is high, home regeneration type water softeners will also add large quantities of chlorides.

Because conventional methods of waste treatment do not remove chloride to any significant extent, higher than usual chloride concentrations can be taken as an indication that a body of water is being used for waste disposal.

Alkalinity

Alkalinity in wastewater results from the presence of the hydroxides [OH^-], carbonates [CO_3^{2-}], and bicarbonates [HCO_3^-] of elements such as calcium, magnesium, sodium, potassium, and ammonia. Of these, calcium and magnesium bicarbonates are most common.

The alkalinity in wastewater helps to resist changes in pH caused by the addition of acids. Alkalinity is determined by titrating against a standard acid .

In practice, alkalinity is expressed in terms of calcium carbonate. 3 meq/L of alkalinity would be expressed as 150 mg/L as $CaCO_3$.

Nitrogen

Nitrogen is an essential building block in the synthesis of protein . Insufficient nitrogen can necessitate the addition of nitrogen to make the waste treatable.

Sources of Nitrogen

(1) plant and animal origin,

(2) sodium nitrate,

(3)atomspheric nitrogen.

Forms of Nitrogen

The chemistry of nitrogen is complex because of the several oxidation states .

The most common and important forms of nitrogen are ammonia , ammonium, nitrogen gas , nitrite ion , and nitrate ion . The oxidation state of nitrogen in most organic compounds is -III.

Tab 2-5 Definition of the various terms used to define various nitrogen species

Urea readily converted to ammonium carbonate, is seldom found in untreated municipal wastewaters. Organic nitrogen is determined analytically using the Kjeldald method.

Total Kjeldabl nitrogen is the total of the organic and ammonia nitrogen.

Ammonia nitrogen exists in aqueous solution as either the ammonium ion (NH_4^+) or ammonia gas (NH_3), depending on the pH of the solution.

Nitrite nitrogen, determined colorimetrically, is relatively unstable oxidized to the nitrate form. Nitrite can be very important in wastewater or water pollution studies because it is extremely toxic to most fish and other aquatic species . Nitrites present in wastewater effluents are oxidized by chlorine and thus increase the chlorine dosage requirements and the cost of disinfection.

The U.S. EPA primary drinking water standards limit nitrogen to 45 mg/L as NO_3^-, because of its serious and occasionally fatal effects on infants. Nitrates may vary in concentration from 0 to 20 mg/L as N in wastewater effluents.

Nitrogen Pathways in Nature

Fig. 2-7 Generalized nitrogen cycle in the aquatic and soil environment

Decomposition by bacteria readily changes the organic form to ammonia. The age of wastewater is indicated by the relative amount of ammonia that is present.

The predominance of nitrate nitrogen in wastewater indicates that the waste has been stabilized with respect to oxygen demand. Nitrates, however, can be used by plants and animals to form protein.

Phosphorus

Municipal wastewaters may contain from 4 to 16 mg/L of phosphorus as P.

The usual forms of phosphorus that are found in aqueous solutions include the orthophosphate, polyphosphate, and organic phosphate.

Polyphosphates undergo hydrolysis in aqueous solutions and revert to the orthophosphate forms; however, this hydrolysis is usually quite slow. The organically bound phosphorus can be an important constituent of industrial wastes and wastewater sludge.

The polyphosphates and organic phosphates must be converted to orthophosphates using an acid digestion step .

Sulfur

The sulfate ion occurs naturally in most water supplies and is present in wastewater as well. Sulfur is required in the synthesis of proteins and is released in their degradation.

Hydrogen sulfide gas, which will diffuse into the headspace above the wastewater sewers that are not flowing full, tends to collect at the crown of the pipe. The accumulated H_2S can then be oxidized biologically to sulfuric acid, which is corrosive to concrete sewer pipes. This corrosive effect, known as "crown rot," can seriously threatened the structural integrity of the sewer pipe .

Sulfates may upset the biological process if the sulfide concentration exceeds 200 mg/L. If burned in gas engines, the products of combustion can damage the engine.

Gases

Gases commonly found in untreated wastewater include nitrogen (N_2), oxygen (O_2), carbon dioxide (CO_2), hydrogen sulfide (H_2S), ammonia (NH_3), and methane(CH_4). The latter three are derived from the decomposition of the organic matter present in wastewater and are of concern with respect to worker health and safety.

Environmental engineer must be familiar include chlorine (Cl_2) and ozone (O_3) , and the oxides of sulfur and nitrogen .

It will be useful to review the ideal gas law and to consider the solubility of gases in water and Henry's law as applied to the gases of interest.

Solubility of Gases in Water

The actual quantity of a gas that can be present in solution is governed by :

(1) the solubility of the gas as defined by Henry's law,

(2) the partial pressure of the gas in the atmosphere,

(3) the temperature, and

(4) the concentration of the impurities in the water (e.g., salinity, suspended solids, etc.).

The Ideal Gas Law

Boyle's law (volume of a gas is inversely proportional to pressure at constant temperature)

Charles' law (volume of a gas is directly proportional to temperature at constant pressure)

Dissolved Oxygen

Oxygen is only slightly soluble in water. Dissolved oxygen levels tend to be more critical in the summer months. The presence of dissolved oxygen in wastewater is desirable because it prevents the formation of noxious odors.

Hydrogen Sulfide

Hydrogen sulfide is formed from the reduction of mineral sulfites and sulfates . This gas is a colorless, inflammable compound having the characteristic odor of rotten eggs. The loss of smell can lead to a false sense of security that is very dangerous. The blackening of wastewater and sludge usually results from the formation of hydrogen sulfide .Various other metallic sulfides are also formed.

Methane

Methane is a colorless, odorless, combustible hydrocarbon of high fuel value.

Because methane is highly combustible and the expolosion hazard is high, access ports (manholes) and sewer junctions or junction chambers where there is an opportunity for gas to collect should be ventilated with a portable blower during and before the time required for operating personnel to work in them for inspection renewals, or repairs.

Odors

Odors in domestic wastewater usually are caused by gases produced by the decomposition of organic matter or by substances added to the wastewater.

Industrial wastewater may contain either odorous compounds or compounds that produce odors during the process of wastewater treatment.

Odors have been rated as the foremost concern of the public relative to the implementation of wastewater treatment facilities.

Within the past few years, the control of odors has become a major consideration in the design and operation of wastewater collection, treatment, and disposal facilities, especially with respect to the public acceptance of these facilities.

In many areas, projects have been rejected because of the concern over the potential for odors.

Effects of Odors

Effects of odors is related primarily to the psychological stress rather than to the harm they do to the body.

Offensive odors can cause poor appetite for food, lowered water consumption, impaired respiration, nausea and vomiting, and mental perturbation,and can lead to the deterioration of personal and community pride, interfere with human relations, discourage capital investment, lower socioeconomic status, and deter growth.

These problems can result in a decline in market and rental property values, tax revenues, payrolls, and sales.

Detection of Odors

One of the difficulties in developing a universal theory has been the inadequate explanation of why compounds with similar structures may have different odors and why compounds with very different structures may have similar odors.

Tab 2-7 Major categories of odorous compounds associated with untreated wastewater

Odor Characterization and Measurement

It has been suggested that four independent factors are required for the complete characterization of all odor: intensity, character, hedonics, and detectability.

Odor can be measured by sensory methods, and specific odorant concentrations can be measured by instrumental methods .

MDTOC ----minimum detectable threshold odor concentration

The ED_{50} value represents the number of times all odorous air sample must be diluted before the average person(50 percentile) can barely detect an odor in the diluted sample.

TON---- threshold odor number

2-5 Metallic Constituents

Many of these metals are also classified as priority pollutants.

The presence of any of these metals in excessive quantities will interfere with many beneficial uses of the water because of their toxicity; therefore, it is frequently desirable to measure and control the concentrations of these substances.

Importance of Metals

All living organisms require varying amounts (macro and micro) of metallic elements, such as iron, chromium, copper,zinc,and cobalt,for proper growth,but the same metals can be toxic when present in elevated concentrations.

Where composted sludge is applied in agricultural applications, arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc must be determined.

Sources of Metals

These are found particularly in metal-plating wastes and should be removed by pretreatment at the site of the industry rather than be mixed with the municipal wastewater. Fluoride, a toxic anion, is found commonly in wastewater from electronics manufacturing facilities.

Tab 2-9 Typical waste compounds produced by commercial, industrial, and agricultural activities that have been classified as priority pollutants

Sampling and Methods of Analysis

Metals are determined typically by flame atomic absorption, electrothermal atomic absorption, inductively coupled plasma, or IPC/mass spectrometry.

2-6 Aggregate Organic Constituents

The organic matter in wastewater typically consists of proteins (40 to 60 percent), carbohydrates (25 to 50 per cent), and oils and fats (8 to 12 percent). Because urea decomposes rapidly it is seldom found in other than very fresh wastewater.

In general, the analyses may be classified into those used to measure aggregate organic matter comprising a number of organic constituents with similar characteristics that cannot be distinguished separately.

Measurement of Organic Content

Gross concentrations of organic matter are greater than about 1.0 mg/L and trace concentrations are in the range of 10^{-12} to 10^{0} mg/L.

Laboratory methods include:

(1) biochemical oxygen demand(BOD),

(2) chemical oxygen demand (COD),

(3) total organic carbon (TOC).

Complementing these laboratory tests is the theoretical oxygen demand (ThOD), which is determined from the chemical formula of the organic matter.

Trace organics in the range of 10^{-12} to 10^{-13} mg/L are determined using instrumental methods including gas chromotography and mass spectroscopy.

Biochemical Oxygen Demand (BOD)

Despite the widespread use of the BOD test, it has a number of limitations. BOD test results are now used

(1) to determine the approximate quantity of oxygen that will be required to biologically stabilize the organic matter present,

(2) to determine the size of waste treatment facilities,

(3) to measure the efficiency of some treatment processes,

(4) to determine compliance with wastewater discharge permits.

Basis for BOD Test

The term COHNS(which represents the elements carbon, oxygen, hydrogen, nitrogen, and sulfur) represent the organic waste and the term $C_5H_7NO_2$ (first proposed by Hoover and Porges) to represent cell tissue.

If only the oxidation of the organic carbon , The oxygen demand is known as the ultimate carbonaceous or first-stage BOD, and is usually denoted as UBOD.

BOD Test Procedure

To ensure that meaningful results are obtained, the samples must be suitably diluted with a specially prepared dilution water so that adequate nutrients and oxygen will be available during the incubation period. Normally, several dilutions are prepared to cover the complete range of possible values.

Tab 10 Measurable of BOD using various dilutions of samples

The BOD of the sample is the difference in the dissolved oxygen concentration values, expressed in milligrams per liter, divided by the decimal fraction of sample used.

When testing waters with low concentrations of microorganisms, a seeded BOD test is conducted .

Fig. 2-8 Procedure for settling up BOD test bottles: (a)with unseeded dilution water and (b) with seeded dilution water

The organisms contained in the effluent from primary sedimentation facilities are used commonly as the seed for the BOD test. Seed organisms can also be obtained commercially. When the sample contains a large population of microorganisms (e.g., untreated wastewater), seeding is not necessary.

Longer time periods (typically 7 days), which correspond to work schedules, are often used, especially in small plants where the laboratory staff is not available on the weekends.

The 20℃ temperature used is an average value for slow-moving streams in temperate climates and is easily duplicated in an incubator.

After incubation, the dissolved oxygen of the sample is measured and the BOD is calculated using the following Eq.:

$$BOD, mg/L = (D_1 - D_2)/P$$

When diluted water is seeded:

$$BOD, mg/L = [(D_1 - D_2) - (B_1 - B_2)]f/P$$

Within a 20-day period, the oxidation of the carbonaceous organic matter is about 95 to 99 percent complete, and in the 5-day period used for the BOD test, oxidation is from 60 to 70 percent complete.

Effect of particle size on BOD Reaction Rates

The observed BOD reaction rate coefficients are affected significantly by the size of the particles in wastewater.

Limitations in the BOD test

The limitations of the BOD test are as followings

(1)a high concentration of active, acclimated seed bacteria is required;

(2)pretreatment is needed when dealing with toxic wastes, and the effects of nitrifying organisms must be reduced;

(3)only the biodegradable organics are measured;

(4)the relatively long period of time required to obtain test results.

Of the above, perhaps the most serious limitation is that the 5-day period may or may not correspond to the point where the soluble organic matter that is present has been used.

Total and soluble chemical oxygen demand(COD and SCOD)

The COD test is used to measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically using dichromate in an acid solution.

$$C_nH_aO_bN_c + dCr_2O_7^{2-} + (8d+c)H^+ \rightarrow NCO_2 + [(a+8d-3c)/2] H_2O + cNH_4^+ + 2dCr_3^+$$

Some of the reasons for the observed difference are as follows:(1)many organic substances which are difficult to oxidize biologically, such as lignin,can be oxidized chemically,(2)inorganic substances that are oxidized by the dichromate increase the apparent organic content of the sample,(3)certain organic substances may be toxic to the microorganisms used in the BOD test

One of the main advantages of the COD test is that it can be completed in about 2.5 h, To reduce the time further, a rapid COD test that takes only about 15 min has been developed.

The principal fractions are particulate and soluble COD.

Fractions that have been used include:

(1)readily biodegradable soluble COD,

(2)slowly biodegradable colloidal and particulate COD, (3)nonbiodegradable soluble COD,and

(4)nonbiodegradable colloidal and particulate COD. The readily biodegradable soluble COD is often fractionated further into complex COD that can be fermented to volatile fatty acids(VFAs) and short chain VFAs. Unfortunately, as noted previous

Oil and Grease

The term oil and grease, as commonly used, includes the fats, oils, waxes, and other related constituents found in wastewater .

The oil and grease content of a wastewater is determined by extraction of the waste sample with trichlorotrifluoroethane

Other extractable substances include mineral oils. such as kerosene and lubricating and road oils. Oil and grease are quite similar chemically; they are compounds (esters) of alcohol or glycerol(glycerin) with fatty acids. The glycerides of fatty acids that are liquid at ordinary temperatures are called oils, and those that are solids are called grease (or fats).

If grease is not removed before discharge of treated wastewater, it can interfere with the biological life in the surface waters and create films.

The low solubility of fats and oils reduces their rate of microbial degradation. Mineral acids attack them, however, resulting in formation of glycerin and fatty acid. In the presence of alkalis, such as sodium hydroxide, glycerin is liberated, and alkali salts of the fatty acids are formed. These alkali salts are known as soaps.

They are soluble in water, but in the presence of hardness constituents,the sodium salts are changed to calcium and magnesium salts of the fatty acids, or so-called mineral soaps. These are insoluble and are precipitated.

Kerosene, lubricating, and road oils are derived from petroleum and coal tars and contain essentially carbon and hydrogen. These oils sometimes reach the sewers in considerable volume from shops, garages, and streets.

To an even greater extent than fats, oils, and soaps, the mineral oils tend to coat surfaces. The particles interfere with biological action and cause maintenance problems.

Surfactants

Surfactants, or surface-active agents cause foaming in wastewater treatment plants and in the surface waters into which the waste effluent is discharged. Surfactants are most commonly composed of a strongly hydrophobic group combined with a strongly hydrophilic group.

In the United States, ionic surfactants amount to about two-thirds of the total surfactants .

Surfactants tend to collect at the air-water interface with the hydrophilic in the water and the hydrophobic group in the air

During aeration of wastewater, these compounds collect on the surface of the air bubbles and thus create a very stable foam.

ABS was especially troublesome because it resisted breakdown by biological means.As a result of legislation in 1965, ABS has been replaced in detergents by lineax-alkyl-sulfonate (LAS), which is biodegradable . So-called "hard" synthetic detergents axe still used extensively in many foreign countries.

Two tests are now used to determine the presence of surfactants in water and wastewater. The MBAS (methylene blue active substances) test is used for anionic surfactans. Nonionic surfactants are measured using the CTAS (cobalt thiocyanate active substances) test.

2-7 Individual Organic Compounds

Individual organic compounds are determined to assess the presence of priority pollutants identified by the U.S. Environmental Protection Agency (U.S. EPA) and a number of new emerging compounds of concern.

Priority pollutants (both inorganic and organic) have been and are continuing to be selected on the basis of their known or suspected carcinogenicity, mutagenicity, teratogenicity, or high acute toxicity.

Priority Pollutants

The Environmental Protection Agency has identified approximately 129 priority pollutants in 65 classes to be regulated by categorical discharge standards.

Two types of standard are used to control pollutant discharges to publicly owned treatment works (POTWs).

One is prohibited discharge standards,the other is Categorical standards

Disinfection Byproducts

It has been found that when chlorine is added to water containing organic matter a variety of organic compounds containing chlorine are formed. Collectively, these compounds, along with others, are known as disinfection byproducts (DBPs). Although general present in low concentrations, they are of concern because many of them are known as suspected potential human carcinogens. Typical classes of compounds include trihalomethanes (THMs), haloacetic acids (HAAs), trichlorophenol, and aldehydes.

More recently, N-nitrosodimethylamine (NDMA) has been found in the effluent from wastewater-treatment plants.

Nitrosamines are among the most powerful carcinogens known. The U.S. EPA action limit for NDMA is 2 parts per trillion. NDMA appears to be formed during the chlorination process, in treated effluent, the nitrite ion can react with hydrochloric acid.

Dimethylamine is also part of polymers used for water treatment and for ion-exchange resins.

Considerable attention has been focused over the past five years on the use of ultraviolet disinfection as a possible replacement for chlorine.

2-8 Biological Characteristics

The biological characteristics of wastewater are of fundamental importance in the control of diseases caused by pathogenic organisms of human origin, and because of the extensive and fundamental role played by bacteria and other microorganisms in the decomposition and stabilization of organic matter, both in nature and in wastewater treatment plants.

Microorganisms Found in Surface Waters and Wastewater

Organisms found in surface water and wastewater include bacteria, fungi, algae, protozoa, plants and animals, and viruses.

Living single-cell microorganisms that can only be seen with a microscope are responsible for the activity in biological wastewater treatment.

The prokaryotes have the simplest cell structure and include bacteria, blue green algae (cyanobacter), and archaea.

Many archaea are bacteria that can grow under extreme conditions of temperature and salinity, and also include methanogethc methane-producing bacteria, important in anaerobic treatment processes.

The absence of a nuclear membrane to contain the cell DNA is also a distinguishing feature of the prokaryota organisms.

Viruses are obligate intracellular parasites that require the machinery of a host cell to support their growth. Although viruses contain the genetic information (either DNA or RNA) needed to replicate themselves, they are unable to reproduce outside of a host cell. Viruses are classified separately according to the host infected. Bacteriophage, as the name implies, are viruses that infect bacteria.

3 Analysis and Selection of Wastewater Flowrates and Constituent Loadings

Reliable data for existing and projected flowrates affect the hydraulic characteristics, sizing, and operational considerations of the treatment system components.

Constituent mass 1oading, the product of constituent concentration and flowrate, is necessary to determine capacity and operational characteristics of the treatment facilities and ancillary equipment to ensure that treatment objectives are met.

3-1 Components of Wastewater Flows

1. Domestic (also called sanitary) wastewater.
2. Industrial wastewater.
3. Infiltration/inflow (I/I)
4. Stormwater. Infiltration is extraneous water that enters the collection system through leaking joints, cracks and breaks, or porous walls.

Wastewater flows in sanitary collection systems consist of three major components:

(1) domestic wastewater,

(2) industrial wastewater, and

(3) infiltration/inflow.

3-2 Wastewater Sources and Flowrates

Domestic Wastewater Sources and Flowrates

The principal sources of domestic wastewater in a community are the residential areas and commercial districts. Other important sources include institutional and recreational facilities.

For areas now served with collection systems, wastewater flowrates are commonly determined from existing records or by direct field measurements.

For new developments, wastewater flowrates are derived from an analysis of population data and estimates of per capita wastewater flowrates from similar communities.

on the average about 60 to 90 percent of the per capita water consumption becomes wastewater.

The higher percentages(90%) apply to the northern states during cold weather; the lower percentages(60%) are applicable to the semiarid region of the southwestern United States where landscape irrigation is used extensively.

Residential Areas

Wastewater flowrates can vary depending on various situations such as economic, social, and other characteristics of the community.

Tab 3-1 Typical wastewater flowrates from urban residential sources in the U.S.

Reduced household water use changes not only the quantity of wastewater generated but also the characteristics of wastewater as well.

Commercial Districts

Depending on the function and activity, unit flowrates for commercial facilities can vary widely. Because of the wide variations that have been observed, every effort should be made to obtain records from actual or similar facilities.

Unit----passenger, bedroom, vehicle serviced, employee, seat, guest.

Flowrates were generally expressed in terms of quantity of flow per unit area.

Institutional Facilities

Tab 3-2 Typical wastewater flowrates from institutional sources in the U.S.

Recreational Facilities

Wastewater flowrates from many recreational facilities are highly subject to seasonal variations.

Tab 3-3 Typical wastewater flowrates from recreational facilities in the U.S.

Strategies for Reducing Interior Water Use and Wastewater Flowrates

Tab 3-4 Typical rates of water use for various devices and appliances in the U.S.

Tab 3-5 Flow-reduction devices and appliances in the U.S.

Water Use in Developing Countries

Water use and, consequently, wastewater-generation rates in developing countries, however, are significantly lower. In some cases, the water supply is only available for limited periods of the day.

Sources and Rates of Industrial (Nondomestic) Wastewater Flows

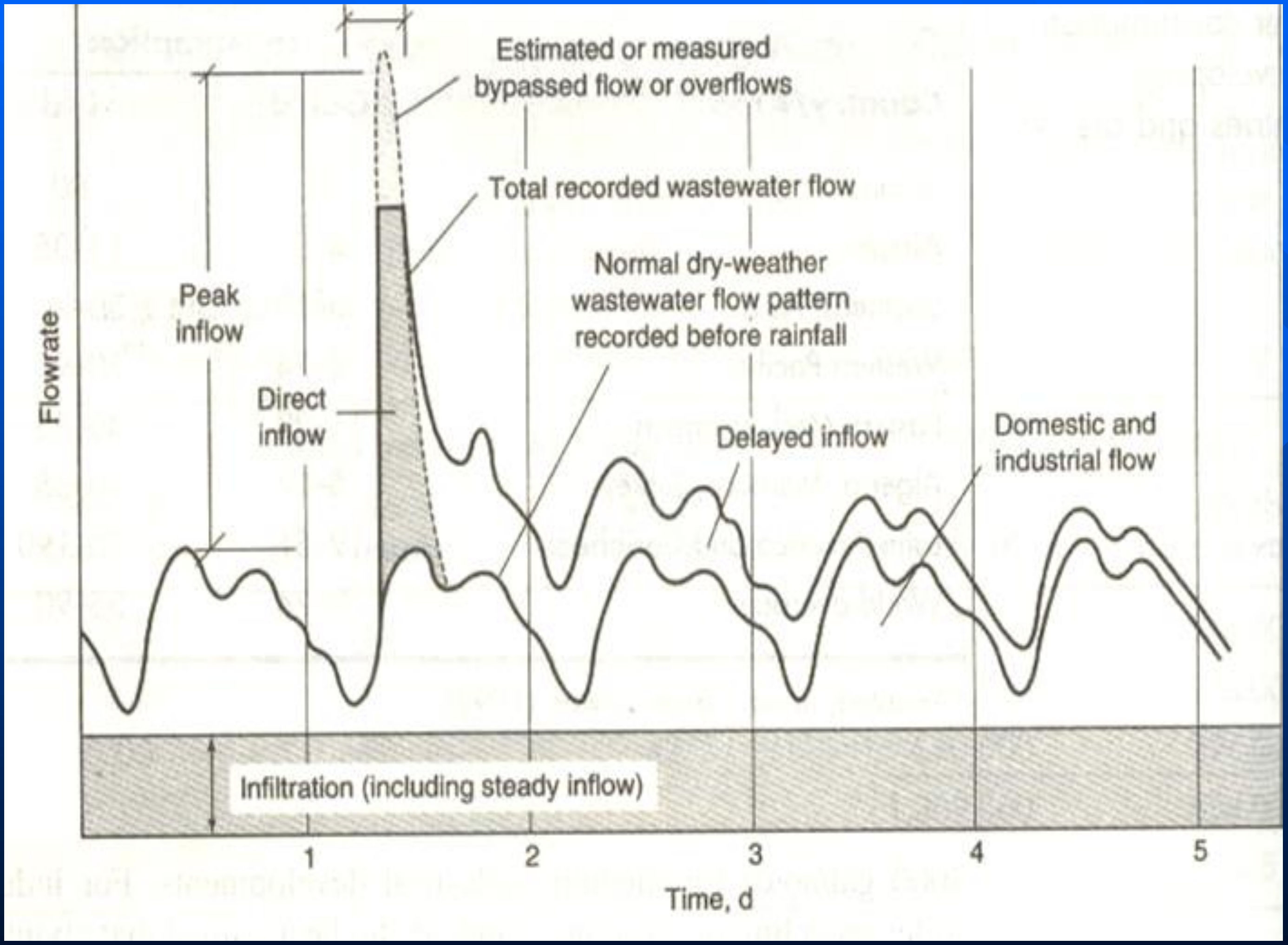
Extremely high peak flowrates may be reduced by the use of onsite detention tanks and equalization basins.

Typical design values are 7.5 to 14 m^3/ha·d for light industrial developments and 14 to 28 m^3/ha·d for medium industrial developments. For industries without internal water recycling or reuse programs, it can be assumed that about 85 to 95 percent of the water used in the various operations and processes will become wastewater.

Average domestic (sanitary) wastewater contributed from industrial facilities may vary from 30 to 95 L/capita·d.

Infiltration/Inflow

Fig. 3-1 Graphic identification of infiltration/inflow



Infiltration. Water entering a collection system from a variety of entry points including service connections and from the ground through such means as defective pipes, pipe joints, connections, or access port (manhole) walls.

Steady inflow. Water discharged from cellar and foundation drains, cooling-water discharges, and drains from springs and swampy areas. This type of inflow is steady and is identified and measured along with infiltration.

Direct inflow. Those types of inflow that have a direct stormwater runoff' connection to the sanitary collection system and cause an almost immediate increase in wastewater flowrates. Possible sources are roof leaders, yard and areaway drains, access port covers, cross connections from storm drains and catch basins, and combined systems.

Infiltration into Collection Systems

The proportion of the rainfall that percolates into the ground depends on the character of the surface and soil formation and on the rate and distribution of the precipitation. Any reduction in permeability, such as that due to buildings, pavements, or frost, decreases the opportunity for precipitation to become groundwater and increases the surface runoff correspondingly,

The presence of high groundwater results in leakage into the collection systems and in an increase in the quantity of wastewater and the expense of disposing of it.

Infiltration/inflow is a variable part of the wastewater, depending on the quality of the material and workmanship in constructing the collection systems and building connections, the character of the maintenance, and the elevation of the groundwater compared with that of the collection system.

The rate and quantity of infiltration depend on the length of the collection system, the area served, the soil and topographic conditions, and, to a certain extent, the population density (which affects the number and total length of house connections).

The use of high quality pipe with dense walls, pre-cast access port sections, and joints sealed with rubber or synthetic gaskets is standard practice in modern collection-system design to reduce infiltration.

Exfiltration from Collection Systems

Collection systems that have high infiltration rates and are in need of rehabilitation also may exhibit high exfiltration.

If the piping and joints are in poor condition, significant quantities of wastewater may seep into the ground, travel through the gravel bedding of the piping system, or even surface in extreme cases.

Combined System Flowrates

During a rainfall event, the amount of storm flow is normally much larger than the dry-weather wastewater flow, and the observed flows during wet weather can mask completely the dry weather flow patterns.

When the collection system capacity is exceeded, a portion of the flow may be discharged directly into a receiving body through overflows(maybe intentionally most of times), or routed to a special combined sewer overflow (CSO) treatment facility.

In some cases where the combined system is undersized, flooding or surcharging may occur at various upstream locations within the system.

In contrast, the hydrograph at the treatment plant shows less distinct flow peaks and a lag time of several hours for flows to return to normal dry-weather levels following rainfall cessation.

The peak flowrates and accompanying mass loadings, however, must be accounted for in the hydraulic design of the treatment plant and in the selection of appropriate unit operations and processes.

3-3 Analysis of Wastewater Flowrate Data

In cases where only flowrate data in the collection system is available, it must be recognized that the flowrates may differ somewhat from the flowrate entering the treatment plant because of the flow-dampening effect of the sewer system.

Peak hourly flowrates may also be attenuated by the available storage capacity in the sewer system.

Definition of Terms

***Tab 3-6** Terminology used to quantify observed variations in flowrate and constituent concentrations*

Wastewater flowrates vary during the time of day, day of the week, season of the year, or depending upon the nature of the dischargers to the collection system.

Short-Term Variations

***Fig. 3-3** Typical hourly variations in domestic wastewater flowrates*

Minimum flows occur during the early morning hours when water consumption is lowest and when the base flow consists of infiltration and small quantities of sanitary wastewater.

A second peak flow generally occurs in the early evening between 7 and 9 P.M. The time of occurrence and the amplitude of the peak flowrates vary with the size of the community and the length of the collection system.

As the community size increases, the variations between the high and low flows decrease due to (1) the increased storage in the collection system of large communities that tends to equalize flowrates and (2) changes in the economic and social makeup of the community. When extraneous flows are minimal, wastewater discharge curves resemble water consumption curves, but with a lag of several hours.

Seasonal Variations

Seasonal variations in domestic wastewater flows are commonly observed at resort areas, in small communities with college campuses, and in communities that have seasonal commercial and industrial activities.

Industrial Variations

Industrial wastewater discharges are difficult to predict. Many manufacturing facilities generate relatively constant flowrates during production, but the flowrates change markedly during cleanup and shutdown.

Industrial discharges are most troublesome in smaller wastewater-treatment plants where there is limited capacity to absorb shock loadings.

Wastewater Flowrate Factors

Peaking factors can be developed based on maximum hour, maximum day, maximum month, or other time periods,and are applied most frequently to determine the peak hourly flowrate.

The most common method of determining the peaking factor is from the analysis of flowrate data.

3-5 Analysis of Constituent Mass Loading Data

From the standpoint of treatment processes, one of the most serious deficiencies results when the design of a treatment plant is based on average flowrates and average BOD and TSS loadings, with little or no recognition of peak conditions.

In many communities, peak influent flowrates and BOD and TSS loadings can reach two or more times average values, it must also be emphasized that, in nearly all cases, peak flowrates and BOD and TSS mass-loading rates do not occur at the same time.

Wastewater Constituent Concentrations

Composite samples made up of portions of samples collected at regular intervals during a day are used.

Quantity of Waste Discharged by Individuals in the United States.

Tab. 3-7 Quantity of waste discharged by individual on a dry weight basis

If one or more members of a family are ill and shedding pathogens, the number of measured organisms can increase by several orders of magnitude.

Composition of Wastewater in Collection Systems

Tab. 3-8 Typical composition of untreated domestic wastewater

Because there is no "typical" wastewater, it must be emphasized that the typical data presented in Table 3-8 should only be used as a guide.

Mineral Increase Resulting from Water Use

Tab. 3-9 Typical mineral increase from domestic water use

Increases in the mineral content of wastewater may be due in part to addition of highly mineralized water from private wells and groundwater and from industrial use. Domestic and industrial water softeners also contribute significantly to the increase in mineral content.

Variations in Constituent Concentrations

Short-Term Variation in Constituent Values

Fig. 3-4 Typical hourly variations in flow and strength of domestic wastewater

The BOD variation generally follows the flow. The peak BOD (organic matter) concentration often occurs in the evening.

Seasonal Variation in Constituent Values.

Variations in Industrial Wastewater

In some cases, flow values and water quality measurements may vary by several orders of magnitude over a period of a year.

For example, the BOD and TSS concentrations contributed from vegetable-processing facilities during the noon wash-up period may far exceed those contributed during working hours. Problems with high short-term loadings most commonly occur in small treatment plants that have limited reserve capacity to handle "shock loadings." The seasonal impact of industrial wastes such as canneries can cause both the flow and BOD loadings to increase from two to five times average conditions.

If industrial wastes are to be discharged to the collection system for treatment in a municipal wastewater facility, it will be necessary to characterize the wastes adequately to identify the ranges in constituent concentrations and mass loadings. Such characterization is also needed to determine if pretreatment is required before the waste is permitted to be discharged into the collection system.

With sufficient characterization of the wastewater from industrial discharges, suitable pretreatment facilities can be provided and plant upsets can be avoided.

Variations in Constituent Values in Combined Collection Systems.

Tab. 3-10 Typical factors influencing the characteristics of combined wastewater

Fig. 3-5 Typical variations of flowrate, BOD, TSS, and fecal coliform in a combined collection system during a storm event

As shown, the BOD and fecal coliform bacteria concentrations are low during the storm when runoff flows are high. After the storm, when runoff subsides and the flow consists primarily of wastewater, concentrations rise significantly.

Unlike BOD and fecal coliform bacteria, TSS concentrations rise slightly during the storm, and remain unchanged after the storm.

The slight rise in the TSS concentration during the peak flow may be due to a phenomenon common to many combined sewer systems known as the "first flush”.

Much of the accumulated surface contaminants are washed into the combined system. In combined collection systems, the increased flows may be capable of resuspending material deposited previously during low-flow periods.

Factors known to contribute to the magnitude and frequency of the first-flush effect include combined sewer slopes; street and catch basin cleaning frequency and design; rainfall intensity and duration; and surface buildup of debris and contaminants.

Wastewater from combined collection systems usually contains more inorganic matter than wastewater from sanitary collection systems because of the larger quantities of storm drainage that enter the combined sewer system.

Effect of Mass Loading Variability on Treatment Plant Performance

Fig. 3-6 Illustration of diurnal Wastewater flow,BOD and Mass loading variability

The variations are more pronounced in small collection systems where the collection system storage capacity does not provide a significant dampening effect. The impact of these load variations is seen most dramatically in the effects on biological treatment operating conditions.

Fig. 3-7 Example variations of TSS and BOD concentrations and mass loadings over a monthly period

3-6 Selection of Design Flowrates and Mass Loadings

The rated capacity of wastewater-treatment plants is normally based on the average annual daily flowrate at the design year plus an allowance for future growth.

Conditions that must be considered include peak and minimum hydraulic flowrates and the maximum, minimum and sustained process constituent mass loading rates. Additionally, periods of initial operation and low flows and loads must be taken into consideration in design.

Tab. 3-11 Typical flowrates and mass loading factors used for the design and operation of wastewater-treatment facilities

The overall objective of wastewater treatment is to provide a wastewater-treatment system that is capable of coping with a wide range of probable wastewater conditions while complying with the overall performance requirements.

Design Flowrates

Flowrates need to be developed both for the initial period of operation and for the future (design) period.

Consideration of the flowrates during the early years of operation is often overlooked, and oversizing of equipment and inefficient operation can result.

Rationale for the Selection of Flowrates

The process units and hydraulic conduits must be sized to accommodate the anticipated peak flowrates . Provisions have to be made to ensure bypassing of wastewater does not occur either in the collection system or at the treatment plant.

Forecasting Flowrates

A yardstick by which total dry-weather base flow can be measured is 460 L/capita·d, established by the U.S. EPA as a historical average where infiltration is not excessive.

Minimum Flowrate

In cases where very low nighttime flow is expected, provisions for recycling treated effluent may have to be included to sustain the process.

In the absence of measured flowrate data, minimum daily flowrates may be assumed to range from 30 to 70 percent of average flowrates for medium- to large size communities, respectively.

Peak Flowrate Factors

Tab. 3-11 Typical flowrates and mass loading factors used for the design and operation of wastewater-treatment facilities

Peak hourly flowrates are used to size the hydraulic conveyance system and other facilities such as sedimentation tanks and chlorine contact tanks where little volume is available for flow dampening.

Other peaking factors such as maximum week or maximum month may be used for treatment facilities such as pond systems that have long detention times or for sizing solids and biosolids processing facilities that also have long detention times or ample storage.