TM 5-814-8

TECHNICAL MANUAL

EVALUATION CRITERIA GUIDE FOR WATER POLLUTION PREVENTION, CONTROL, AND ABATEMENT PROGRAMS

HEADQUARTERS, DEPARTMENT OF THE ARMY

23 APRIL 1987

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Washington, DC 23 April 1987

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“This manual supersedes TM 5-814-8, dated July 1976.

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CHAPTER 1

GENERAL

1-1. Purpose

This manual provides general information, guidance, and criteria for water pollution prevention, control, and abatement programs for Department of the Army activities and installations, including contractor activities located on property under the jurisdiction of the U.S. Army. Direction is provided for formulating pollution control programs at government facilities located in the U.S. where effluent and stream requirements have been or are being established, as well as at overseas installations where guidelines for protecting water resources may not have been formalized. Program steps outlined are intended to conform to basic policy outlined in Executive Order 12088 and implemented by Ar 200-1 and AR 200-2. This directive stipulates that Federal agencies are to design, construct, manage, operate, and maintain their facilities to conform with Federal, State, interstate, and local water quality standards and effluent limitations in accordance with the Federal Water Pollution Control Act, as amended. This manual will assist field offices and commands in formulating water pollution prevention, control, and abatement programs to meet requirements established in the Executive Order which include the following:

–Assurance that all applicable water quality standards and effluent limitations are met on a continuing basis.

–Development of an abatement plan and schedule for meeting applicable standards.

–Presentation of an annual plan for funding of improvements in the design, construction, management, operation, and maintenance of existing and new facilities as may be necessary to meet applicable standards.

–Consideration of the environmental impact for each new facility or modification to an existing facility in the initial stages of planning in accordance with the National Environmental Policy Act.

—Development of cost information on alternative process considerations for new facilities or for modification of existing facilities so that budget requests for design and construction shall reflect the most cost-effective alternative for meeting applicable standards.

–Consultation, as appropriate, with Federal, State, and local regulatory agencies concerning best techniques and methods available for the prevention, control, and abatement of water pollution.

To assist users of the manual, bibliographic references are shown as numbers in parentheses throughout the text to provide in-depth coverage of the processes and treatment trains for the many wastes discussed in this manual.

1-20 Scope

This manual describes principles and procedures to be followed in formulating and conducting a water pollution prevention, control, and abatement program, and in planning facilities required for solution of water pollution problems. The manual provides guidance for selecting and applying proven technologies for wastewater treatment and for solids handling and disposal. Both capital expenditures and operating costs are outlined. While the manual is directed primarily toward handling of domestic wastewaters, system alternatives for handling special process wastes from munitions manufacture and processing, metal plating, washrack, photographic, laundry, hospital and other sources are also addressed. The manual includes technical and cost information needed for project decisions and supporting data. Authority to deviate from guidelines presented herein shall be obtained from HQDA (DAEN-ECE-B), WASH DC 20314-1000. Water pollution problems resulting from surface drainage or storm water runoff are not within the scope of this document. Guidance for pollution prevention from those sources is contained in TM 5-820-1 or TM 5-820-4. Guidance for pollution prevention from Central Vehicle Wash Facilities and from Scheduled Vehicle Maintenance Facilities is not within the scope of this document and will be contained in forthcoming guidance.

1-3. Synopsis

a. Waste water management considerations. Management of water quality at military installations requires evaluation of existing water resources, present and future uses, and existing and potential pollution problems, followed by development and implementation of a program for effective water use and pollution control. Either effluent or stream standards will dictate the treatment performance required. The raw wastewater characteristics and local site conditions are the most important factors which determine treatment requirements.

b. Nature and origin of waste waters. Wastewater can primarily be classified as domestic or industrial in nature. Industrial wastewaters can be very complex and contain a wide variety of constituents. Before a plan for treating the wastewater can be formulated, these constituents must be identified. Characterization of the waste stream by flow measurement and chemical analysis is used to identify the undesirable elements, to determine the source of these pollutants, and to implement a solution to control them to an acceptable level.

c. *Waste water discharge legislation.* Over the last decade, legislation and regulations governing the discharge and disposal of wastewater and solid wastes have had a significant impact on all aspects of wastewater management. Under the responsibility y of the U.S. Environmental Protection Agency (EPA), Federal legislation, such as the National Environmental Policy Act (NEPA) and the Resource Conservation and Recovery Act (RCRA), have been enacted to reduce or eliminate pollutant discharges and provide for safe handling and disposal of hazardous waste. Other legislation has been enacted to set standards for public drinking water, to control toxic substances, to regulate insecticides, etc. In addition to National regulations, State and local governments have established environmental regulations which in some cases are more stringent than the national counterpart.

d. Waste water management program formulation. The most critical step in effecting pollution control is the initial definition of overall program objectives and content. Without careful planning at an early stage, cost-effective pollution control systems will not be implemented. Other steps which must be taken include conducting a water and wastewater inventory, evaluating waste reduction practices, assessing the environmental impact of various control schemes, analyzing treatment alternatives, and defining specific treatment needs.

e. *Wastewater treatment processes.* Most pollution control programs at military installations will require upgrading existing wastewater treatment systems to meet more stringent criteria which have been established. Some new facilities will likely be needed in the next 10 years, but the emphasis will remain on improving performance at present sites. Treatment alternatives must be evaluated to determine the most cost-effective and environmentally acceptable systems for a particular installation. Improved treatment performance may include:

(1) Modifications or additions to preliminary treatment units which may include equalization, pH control, preaeration, or other operations which will reduce the load or improve the efficiency of subsequent facilities.

(2) Changes to primary treatment facilities either to reduce the load on secondary units or to remove specific constituents such as phosphorus.

(3) Upgrading secondary processes by providing additional "polishing" units, by changing the load on existing facilities, or by modifying the plant operations.

(4) Addition of advanced treatment processes to remove or convert nitrogen, to remove phosphorus, or to provide additional suspended solids and organics removal.

f. Solids handling processes. The methods for handling and disposal of removed wastewater residues must be evaluated along with analysis of wastewater treatment processes. Both liquid and solids treatment must be considered in cost-effective evaluations. Resource conservation and beneficial use of waste solids shall be implemented to the maximum practical extent in design and operation of sludge treatment and disposal systems.

g. *Waste water handling system alternatives.* The process of combining several technically proven unit processes and operations into a treatment system to meet specific effluent goals requires identification of the performance expected from each unit. Usually many combinations of unit processes are available to meet effluent criteria. Operational requirements shall be included in cost evaluations and effect on the environment must be weighed in evaluating alternative processes.

h. Economic considerations. It is the government's desire to implement the most efficient, cost-effective solution to polluted discharges from military facilities. Cost evaluations must consider both capital investment and operation and maintenance expenses on a life cycle basis. The impact of both schedule for start of construction and geographical location of treatment facilities must be evaluated in preparing cost estimates.

CHAPTER 2

WASTEWATER MANAGEMENT CONSIDERATIONS

2-1. Introduction

a. Technological considerations. Programs formulated to manage the discharge of wastewaters generated by domestic use and industrial operations require a broad understanding of the relationship between water sources, waste generation, and the environmental consequences of waste disposal. With very few exceptions, all problems associated with wastewater discharges have environmentally acceptable solutions. The technology for achieving any desired level of effluent quality is already developed and in most cases, well proven. The task of the environmental engineer dealing with wastewaters is to identify the problem and to apply the most appropriate technology in order to achieve the desired goal.

b. Wastewater disposal. Liquid wastes from domestic and industrial sources are ultimately disposed of into receiving water bodies or onto land. Portions of the waste products may be volatilized and discharged to the atmosphere, while part or all the water may be recycled for repeated use. When an environmentally acceptable solution to a problem is being sought, equal emphasis should be placed on all three components of the environment, i.e., land, air, and water.

2-2. Water resources and usages

a. The hydrologic cycle. The cycle of water in nature allows water to be used repeatedly. Water vapor is condensed from the atmosphere in the form of precipitation which falls to the ground and either flows as runoff to surface waters (streams, rivers, lakes and eventually oceans) or infiltrates the ground to feed groundwater aquifers. Plants draw water from surface water or groundwater sources or intercept the water as precipitation and return a portion of the water to the atmosphere through evapo-transpiration. Evaporation from surface waters contributes the majority of the water returned to the atmosphere.

b. Water uses. Water quality criteria in the U.S. are normally established to protect the water users. In foreign locations where no pertinent water quality regulations exist, downstream water uses must be recognized and pollution control steps taken to avoid interference with these uses.

(1) Water supply. Water supplies are required for domestic, industrial and agricultural uses. Domestic uses include water for drinking and food preparation, washing, waste transport, lawn sprinkling, fire fighting and commercial water uses. industrial uses include process water, cooling water and transportation of waste materials. The main agricultural water use is irrigation; others are livestock watering and waste disposal.

(2) Indirect water reuse. The indirect method of water reuse is commonly practiced when wastewater from one community is discharged to a receiving water and subsequently used as a water supply by another community. Due to the treatment provided by modern water treatment facilities and the natural assimilation of wastes by the receiving water, this type of water reuse has become acceptable. The main pollution control need for waters used for public supplies is to remove constituents that may pass through the water treatment facility or result in excessive treatment costs.

(3) Wildlife habitat. Wildlife, such as waterfowl, waterbased animals, fish, shellfish, plankton and other aquatic life, require water that is free of oil, excess solids and other toxics and that meets their needs for dissolved oxygen, temperature, etc. The successive buildup of chemicals in the flesh of predator animals has been extensively documented. Similarly, the buildup of toxic materials and flavor tainting substances have been observed in fish and shellfish.

(4) Recreation. The pollution control requirements to maintain recreational uses are related to those of wildlife habitation through hunting, fishing and other activities that utilize wildlife. Primary (complete) body contact activities such as swimming have strict water quality requirements regarding bacteria, pH and turbidity.

(5) Aesthetics. Waste treatment requirements for aesthetic reasons have become increasingly important with the emphasis on environmental concerns and protection of the complete human environment. Control of odor, color and turbidity; removal of objectionable and unsightly floating materials; and elimination of secondary effects on aquatic or stream bordering plants will usually satisfy aesthetic requirements.

2-3. Effects of discharge on the environment

Water usage generally results in production of wastewaters requiring disposal. These wastes are usually disposed of by discharge to surface waterways. Thus, water is returned to the water cycle along with a variety of contaminants incorporated in the wastewater during use. These contaminants may have detrimental effects on the environment of the receiving surface waters.

a. Waste water characteristics. In dealing with wastewaters, several typical undesirable characteristics may be identified. These are listed in table 2-1. Although an individual wastewater may not have all of these characteristics, it is important to recognize the detrimental factors which may be present and the effects they may have on the environment. The parameters used to describe the quality of wastewater are discussed in chapter 3. Examples of typical wastewater characteristics from specific sources are also presented.

b. Surface discharges. Federal, State, and local governments have placed restrictions on wastewater discharge quality in order to control the detrimental effects of contaminants as described in the last section. These restrictions may require a certain type of treatment system be used, or they may specify concentration limits on certain parameters regardless of the treatment system used. Typically, the quality of the receiving stream or body of water is taken into consideration along with the intended use of the water following the wastewater discharge. Each state has classified its major streams and bodies of water according to their own set of use classifications. The regulations involved in water quality control are discussed in the following chapter.

c. *Ocean discharges.* Domestic users and industrial plants located on the ocean coast may discharge their treated wastewater through an ocean outfall. Although the ocean offers abundant dilution water, careful attention should be given to the fate of the various constituents as they are discharged and their effects on the marine environment. Generally, most degradable organics can be safely discharged to the sea if proper discharge facilities are installed. However, inadequate design of discharge facilities may result in severe environmental nuisances including oxygen depletion, color and turbidity, algae blooms, and public health problems. Non-degradable constituents and toxic materials should generally be eliminated from wastewaters prior to discharge to the ocean. Once these materials reach the marine environment their fate is unknown and uncontrollable. Toxic materials may be passed to man through marine food chains. They may cause fish kills or sublethal effects on marine organisms.

d. Land discharges. Wastewater discharged to land should be considered on a constituent-by-constituent basis in order to make sure that no land is irreversibly removed from some other potential use. Land application of wastewater requires intimate mixing and dispersion of the waste into the upper zone of the soil-plant system with the objective being assimilation of all constituents by mechanisms such as microbial decomposition, adsorption, immobilization, and plant recovery. Adequately designed land application systems should avoid groundwater or surface water contamination from leachates, air pollution, and other aesthetic nuisances in the application area. Assimilative capacities of each wastewater constituent must be carefully established in order to make sure none are exceeded.

e. *Atmospheric discharges.* The atmospheric environment should also be considered during all phases of a wastewater management program. Although only a small portion of the wastewater constituents is intentionally discharged to the air there may be unintentional discharges of sufficient magnitude to cause environmental concern. Atmospheric pollution can be caused by gaseous materials, particulate, or aerosols. The most frequent complaint is associated with malodorous gases in the vicinity of a treatment plant. Although this is the most obvious air pollution nuisance it is not necessarily the most severe. Toxic gases and to a lesser extent pathogen-carrying aerosols may have significant public health effects. Careful attention should be given to the potential air pollution problems that may arise in any waste treatment design.

Table 2-1. Undesirable characteristics and effects of wastewater discharges and remedial approaches

Constituent	Undesirable Characteristics and Remedial Approaches
Soluble Degradable Organics	Depletion of dissolved oxygen in streams leading in severe cases to fish kills; development of anaerobic conditions; evolution of malodorous gases and an unsightly environment. Discharge within assimilative capacity of water body or by effluent standards.
Toxic Materials and Elements	Adverse effects on squatic life; accumulation of toxic materials and transfer to man via food chains; introduction of toxic materials to domestic water supply systems. Usually rigid limitation imposed on discharge of such materials.
Color and Turbidity	Aesthetically undesirable; impose increased loads on water treatment plants.
Refractory Organics	Persist in the environment for long periods; may cause aesthetic (e.g., foam) or public health (e.g., chlorinated hydrocarbons) problems.
Oil and Floating Materials	Aesthetically undesirable; may interfere with natural stream reaeration. Regulations usually require complete removal.
Nutrients (nitrogen and phosphorus)	Enhance eutrophication (i.e., blooms of algae in lakes and ponded areas); critical in recreational areas.
Suspended Solids	Create sludge deposits in streams resulting in malodorous and anaerobic conditions. Discharge limits are imposed by regulatory agencies.
Acids and Alkali	Shift the acid-base equilibria in streams; endanger aquatic life; adversely affect water quality for domestic, industrial, and navigational use. Most regulatory codes require neutralization of wastewater prior to discharge.
Heat	Thermal pollution resulting in depletion of dissolved oxygen; thermal barriers restrict movement of aquatic organisms and cause a shift in biotic composition.
Dissolved Salts	Increases the salinity of receiving fresh water i.e., brackish water; impairs reuse for water supplies.

CHAPTER 3

NATURE AND ORIGIN OF WASTEWATERS

3-1. Introduction

While domestic wastewaters can be consistently classified as to their strength and constituents, industrial wastewaters and domestic/industrial discharges may be highly variable. The latter types of wastewaters are usually a complex rather than a simple misture of constituents. Characterization of the waste stream by flow measurement and chemical analysis is used to identify the undesirable characteristics, to determine the source of these characteristics, and to implement a solution to control them to an acceptable level.

3-2. Wastewater characteristics

Wastewaters may contain any material which may be dissolved or suspended in or on water. Wastewater constituents are classified into organic, inorganic, particulate and pathogenic. Tests serve as a first step in determining the treatment requirements for a particular wastewater to preclude potential negative environmental impact.

a. Primary organic parameters. Organic materials in wastewater have traditionally been the major concern in the field of water pollution control. The decrease in dissolved oxygen due to the process of biodegradation is detrimental to the health of the receiving waterways and aquatic life. There are four major tests used to measure organic material in wastewater: the customary pollutant parameter, Biochemical Oxygen Demand (OBD); the noncustomary pollutant parameters Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), and Total Oxygen Demand (TOD).

(1) Biochemical oxygen demand (BOD). The BOD test is an indirect measurement of biodegradable organic material. The test does not measure specific organic materials but indicates the amount of oxygen required to stabilize the biodegradable organic fraction. This test was devised to simulate the impact of a particular wstewaster on the dissolved oxygen level in the receiving waters. Adequate dissolved oxygen must be provided in order to maintain aquatic life. The BOD test measures the oxygen depleted after a period of five days in a closed system which contains a mixture of wastewater and an acclimated seed of microorganisms. The test may also measure a quantity of reduced inroganic materials such as ammonia or sulfites.

(2) Chemical oxygen demand (COD). COD is another indirect measurement of organic material. COD measures the oxygen equivalent of the organic material oxidized by bichromate or permanganate during acid digestion. This parameter was developed in order to substitute for the more time-consuming BOD test.

(3) Total organic carbon (TOC). The TOC test is an indirect measurement of organic material. The test measures the quantity of carbon dioxide liberated during the combustion of the wastewater sample. Thus, TOC is the amount of carbon present in organic molecules contained in the wastewater sample.

(4) Total oxygen demand (TOD). TOD is an indirect method of measuring organic material concentration. However, it is the most direct measurement of oxygen demand. TOD is the difference in the oxygen content of a sample before and after combustion. TOD measures the amount of oxygen required to burn the contaminants in the wastewater sample.

b. Organic parameter relationships. A preliminary step in developing treatment alternatives for a specific wastewater should be an analysis of the organic parameter relationships. This analysis will provide the designer with a general idea of the treatment technologies most likely to be effective on the wastewater.

c. *Additional organic parameters.* As attention has been focused on the TOD, TOC, COD, and BOD parameters, it is necessary to recognize other important organic evaluations, such as oil and grease content, phenols, organics containing toxic functional groups, etc. Oil and phenol analyses are particularly significant when evaluating unit processes for the treatment of wastes containing petroleum distillates. Quantities of toxic organic compounds, such as pesticides, present in wastewaters entering the environment are extremely significant and require a great deal of effort to control. The need to analyze or treat these organic compounds is site specific. If a substance is used or manufactured in an industrial activity, then the possibility exists that it is present in the wastewater.

(1) Oil and grease. Oil and grease in wastewater is usually a characteristic of petroleum-

based chemical manufacturing, machining, vehicle maintenance, kitchen and restaurant wastes and, to a lesser degree, domestic wastewater. Oil and grease is an indirect measurement defined and quantified by an analytical procedure. Oil and grease is an expression of all substances extracted by the organic solvent (Freon) employed in the test procedure. Oil and grease may include hydrocarbons, fatty acids, soaps, fats, waxes, oils and any other Freon extractable substance that will not volatilize during the test procedure. Oil and grease, in large quantities, is a dangerous environmental pollutant. Oil and grease is difficult to remove by conventional treatment processes such as anaerobic or aerobic biological processes and is an interference in most physical-chemical treatment processes. Oil and grease treatment usually consists of removal by skimming or flotation and disposal by reuse, incineration, or landfilling.

(2) Phenol. Phenol is encountered most frequently in the petroleum refining and chemical processing industries, but is present where industrial activities utilize petroleum distillates. Phenol is very soluble in water, oils, carbon disulfide and numerous organic solvents. The wet chemical analysis of phenol measures directly a variety of phenolic compounds. Phenol is a toxic and mutagenic substance in high concentrations and may be absorbed through the skin. Phenols are, for the most part, biodegradable.

(3) Cyanide. Cyanide is found in metal plating, petroleum refining, plastics, and chemicals manufacturing wastewaters. The cyanide ion is highly toxic to aquatic life and humans at very low concentrations. Most cyanide appears as a chemical complex with a metallic compound. As a result, toxicity of cyanide depends upon the nature of the complex. Some cyanide compounds are harmless. Cyanide compounds are usually biodegradable and are otherwise treatable by alternate methods.

(4) Surfactants. Surfactants are found in household and industrial cleaning detergents and many industrial wastewaters. The presence of surfactants is indicated when there are large quantities of foam in the collection or treatment system.

(5) Other organic compounds of significance. Many wastewaters contain U.S. EPA identified toxic organic compounds not identifiable except by direct measurement using specialized analytical techniques such as infrared spectrophotometry, gas chromatography, gel chromatography and mass spectrometry. Other analytical methods may be required depending upon the substance.

d. Wastewater solids. Wastewater solids are present in nearly all wastewater discharges. Solids occur in wastewater as a result of stormwater runoff, sanitary discharge, chemical precipitation reactions in the waste and direct discharge of solid materials.

(1) Definitions. Waste solids are classified according to gross physical properties and chemical composition. The three basic types of solids include:

—settleable solids,
—suspended solids (TSS), and
—dissolved solids (TDS).

Settleable solids are particles which settle out of a wastewater sample during a 1 hour settling test using an Imhoff cone. Grit and most chemical sludges are settleable solids. They are denser than water and, therefore, cannot remain in suspension. Suspended solids are particles retained by filtering a wastewater sample. The suspended solids test may include settleable solids if the sample is thoroughly mixed. Dissolved solids are basically salts of organic and inorganic molecules and ions that exist in solution.

(2) Testing. Wastewater solids may be classified by direct gravimetric test methods. Suspended and dissolved solids are termed “volatile” if they are vaporized after ignition for 1 hour at 1,022 ± 122 degrees F in a furnace. In wastewater treatment, solids are said to be nonfilterable or insoluble if they are retained on the surface of a 0.45 micron filter. The filtrate is said to represent the soluble fraction of the liquid.

e. *Significant inorganic parameters.* There are many inorganic parameters which are important when assaying potential toxicity, general characterization, or process evaluation. Although special situations require the evaluation of any number of inorganic analyses, it is the intent here to discuss only the more prevalent ones.

(1) Acidity. The acidity of a wastewater is important because a neutral or near neutral water is required before biological treatment can be effective. In addition, regulatory authorities have criteria which establish strict pH limits to final discharges. Acidity is attributable to the non-ionized portions of weakly ionizing acids, hydrolyzing salts, and certain free mineral ions. Microbial systems may reduce acidity in some instances through biological degradation of organic acids, or they may increase acidity through vitrification or other biochemical processes. Acidity is expressed as mg/L $CaC0_3$.

(2) Alkalinity. Alkalinity may be considered the opposite of acidity and it is also expressed as mg/L $CaC0_3$. Alkalinity is imparted by carbonate,

bicarbonate and hydroxide components of natural water supplies. Industrial wastes often contain these species in addition to mineral and organic acids. Alkalinity determinations are useful in determining wastewater neutralization requirements.

(3) PH. pH represents the hydrogen ion (H^+) or proton concentration in waters or wastewaters. pH is an extremely important wastewater parameter as it affects the solubilities of metals, salts and organic chemicals, the oxidation-reduction tendency and direction of wastewater components, and the rate of chemical activity in wastewater solutions. Gross wastewater characteristics affected by pH include toxicity, corrosivity, taste, odor, and color. Th pH of pure water is given the value of 7. Acid solutions have a pH below 7 and alkaline or basic solutions have a pH above 7.

(4) Nitrogen. In wastewater treatment, the nitrogen forms of primary concern are:

–Total Kjeldahl nitrogen (TKN),
–Ammonia nitrogen (NH_3-N),
–Nitrate nitrogen (NO_3-N), and
–Nitrite nitrogen (NO_2-N).

(a) Total Kjeldahl nitrogen represents the organic nitrogen plus ammonia nitrogen indicated in the Kjeldahl test procedure. Following measurement and removal of the ammonia nitrogen, the organic nitrogen in the wastewater sample is converted to ammonia nitrogen by catalyzed acid digestion of the wastewater. The resulting NH_3-N is then analyzed and reported as the organic nitrogen fraction. Not all organic nitrogen compounds, however, will yield ammonia nitrogen under catalyzed acid digestion. Acrylonitrile and cyanuric acid are examples of compounds that are only partially hydrolyzed by the Kjeldahl test procedure.

(b) Ammonia nitrogen (NH_3-N) as well as organic nitrogen is present in most natural waters in relatively low concentrations. Concentrations as low as 0.5 mg/L have been reported to be toxic to some fish and concentrations as high as 1,600 mg/L have proved to be inhibitive to biological waste treatment plant microorganisms. The toxicity of ammonia is a function of pH, being highly toxic at an alkaline pH and less toxic at an acidic pH. Ammonia nitrogen is also an essential nutrient in biological waste treatment systems and a slight residual (0.5 to 1.0 mg/L) is recommended for optimum biological activity.

(c) Nitrate nitrogen (NO_3-N) may appear in wastewaters as dissociated nitric acid, HNO_3, or may result from the biological vitrification of ammonia to nitrate. Nitrate nitrogen should be restricted from drinking water supplies because it inhibits oxygen transfer in blood. Maximum NO_3-N concentrations of 10 mg/L are allowed in drinking water under National Interim Primary Drinking Water Regulations.

(d) Nitrite nitrogen (NO_2-N) is most commonly found in treated wastewaters or natural streams at very low concentrations (0.5 mg/L). Nitrite is a metabolic intermediate in the nitrification process. It is rapidly converted to NO_3-N by nitrifying organisms. Nitrite is an inhibitor to the growth of most microorganisms and for this reason is widely used as a food preservative.

(5) Phosphorus. Phosphorus occurs naturally in rivers and streams as compounds of phosphate. Elemental phosphorus does not persist naturally in aquatic systems as it is quickly oxidized by molecular oxygen to phosphate. Phosphates are commonly found in industrial and domestic wastestreams from sources including corrosion inhibitors, detergents, process chemical reagents, and sanitary wastes. Phosphorus is an essential nutrient in biochemical mechanisms. A residual of 0.5 to 1.0 mg/L total phosphorus is usually required in biological waste treatment systems to ensure efficient waste treatment. Excessive phosphorus in natural waterways, however, can be very harmful resulting in algal blooms and eutrophication.

(6) Sulfur. Sulfur occurs naturally in rivers and streams as compounds of sulfur. Elemental sulfur does not persist naturally in aquatic systems as it is oxidized by molecular oxygen to sulfate. Due to the cathartic effect of sulfate upon humans, the drinking water limit for sulfate has been placed at 250 mg/L in waters intended for human consumption.

(a) In some industrial waste streams sulfate and sulfur compounds are present in high concentrations and may be a major component of TDS and conductivity. Sulfates can cause odor and corrosion of sewer pipes under the proper conditions. The malodorous gas, hydrogen sulfide, is produced by the anaerobic biological reduction of sulfate to hydrogen sulfide. As pH is increased, the chemical equilibrium favors the ionization of sulfur and prevents the formation of hydrogen sulfate (H_2S). As pH is decreased, the formation of H_2S is favored.

(b) Crown corrosion of sewers occurs when the H_2S gas is released and rises to the crown of the sewer. At the crown, condensed water and H_2S form sulfuric acid which dissolves concrete.

(7) Chlorine. Chlorine is widely used as a disinfectant for drinking water supplies and for treated sanitary discharges. Chlorine is toxic to

all forms of life in the proper concentrations but does not persist in aquatic systems. These two qualities have helped promote the use of chlorine as a disinfectant. However, chlorine does react with other chemical compounds such as ammonia and certain hydrocarbons to form the toxic chloramines and potentially toxic or mutagenic chlorinated hydrocarbons. For this reason, chlorination is not recommended for certain industrial and combined domestic/industrial waste streams.

(8) Chlorides occur in all natural water systems and many industrial waste streams. Seawaters are very high in chlorides. Chlorides are relatively harmless to humans in low concentrations. At a concentration of 250 mg/L, drinking water is found to have an objectionable taste. In some cases, water containing concentrations of chloride up to 1,000 mg/L are consumed without ill effects. Chloride concentrations of 8,000 to 15,000 mg/L have been reported to affect adversely biological waste treatment systems.

(9) Heavy metals. Some of the heavy metals of interest are copper (Cu), chromium (Cr), cadmium (Cd), zinc (Zn), lead (Pb), nickel (Ni), and mercury (Hg). These materials may be measured directly. These elements may be inhibitive or toxic to aquatic and terrestrial organisms and the microorganisms employed in biological waste treatment systems.

(a) Copper. The primary sources of copper in industrial wastewaters are metal process pickling baths and plating baths. Copper may also be present in wastewaters from a variety of chemical manufacturing processes employing copper salts or a copper catalyst. Copper is an essential nutrient for most organisms including humans. Copper can impart a bitter taste to water in concentrations above 1 mg/L. Copper salts are used to control algae growth in reservoirs and farm ponds.

(b) Chromium. Chromium is found in metal plating and anodizing wastes, tannery wastes, and in certain textile processing wastewaters. Chromium commonly appears in the hexavalent (+6) and the trivalent (+3) valence states and also exists in less soluble complexes. Hexavalent chromium is highly toxic to microorganisms.

(c) Cadmium. Cadmium is present in wastewaters from metallurgical alloying, ceramics, electroplating, photography, pigment works, textile printing, chemical industries and lead mine drainage. Cadmium is relatively abundant in the earth's crust and the metal and its salts are highly toxic.

(d) Zinc. Zinc is present in wastewater streams from steel works, rayon manufacture, battery manufacture, sodium hydrosulfite manufacture and other chemical production. Zinc is a nutritional trace element but is toxic at higher concentrations.

(e) Lead. Lead is present in wastewaters from storage battery manufacture, drainage from lead ore mines, paint manufacture, munitions manufacture, and petroleum refining. Lead is toxic in high concentrations.

(f) Nickel. Nickel is present in wastewaters from metal processing, steel foundry, motor vehicle and aircraft, printing and chemical industries. Nickel may cause dermatitis upon exposure to the skin, and gasrointestinal distress upon ingestion.

(g) Mercury. Mercury is used in the electrical and electronics industries, photographic chemicals, and the pesticides and preservatives industries. Power generation is a large source of mercury release into the environment through the combustion of fossil fuel. Mercury in its methylated form is a highly toxic compound. In its elemental form, it is readily absorbed by inhalation, skin contact and ingestion.

f. Additional wastewater characteristics.

(1) Temperature. Temperature is a very important wastewater characteristic. The chemical equilibrium of complex wastewaters is very temperature dependent. Different reactions may be found at higher temperatures as compared to lower temperatures. Waste treatment system efficiency is affected by extremes in temperature. At low temperatures (39 degrees F), biochemical and chemical reaction rates are extremely slow, and waste treatment operations are often severely limited. At temperatures greater than 100 degrees F, many waste treatment plants experience operating difficult y. Biological processes are impaired, air and oxygen volubility becomes limited, and other physical properties such as sludge density and settling rate affect overall waste treatment.

(2) Tastes and odors. Tastes and odors in water are generally associated with dissolved inorganic salts of iron, zinc, manganese, copper, sodium, and potassium. Phenolics are a special nuisance in drinking water supplies especially after chlorination because of their very low taste and odor threshold concentration (less than 0.2 parts per billion). Petrochemical discharges and liquid wastes from the paper and synthetic rubber industries often cause taste and odor problems. Sulfides from these sources cause odors in concentrations of less than a few hundredths of a part per million. Tastes and odors may also be associated with decaying organic matter, living algae and other microorganisms containing essential oils and other odorous compounds, specific or-

ganic chemicals such as phenols and mercaptans, chlorine and its substituted compounds, and many other chemical materials.

(3) Color. Color in water and wastewaters may result from the presence of metallic ions such as chromium, platinum, iron, or manganese from humus and peat materials such as tannin and algae. Color caused by suspended matter is said to be “apparent color”. Color caused by colloidal or soluble materials is said to be “true color”. True color is the parameter by which color is evaluated. An arbitrary standard is employed to evaluate color. The color produced by 1 mg/L of cobalt-platinum reagent is taken as one color unit. Dilutions of cobalt-platinum reagent are made in the 0 to 70 unit range and placed in special comparison tubes. Water samples are then compared and matched between the cobalt-platinum standard dilutions.

(4) Radioactivity. Regulatory agencies have established standards for the maximum allowable concentrations of radioactive materials in surface waters. It is possible to differentiate between the following three types of radioactivity:

—alpha rays.

—beta rays.

—gamma rays.

(a) Alpha rays consist of a stream of particles of matter (doubly charged ions of helium with a mass of four) projected at high speed from radioactive matter. Once emitted in air at room temperature, alpha particles do not travel much more than 4 inches. These particles are stopped by an ordinary sheet of paper.

(b) Beta rays consists of a stream of electrons moving at speeds ranging from 30 to 90 percent of the speed of light, their power of penetration varying with their speed. These particles normally travel several hundred feet in air and may be stopped with aluminum sheeting a tenth of an inch thick.

(c) Gamma rays are true electromagnetic radiation which travel with the speed of light, and are similar to x-rays but have shorter wave lengths and greater penetrating power. Proper shielding from gamma rays requires an inch or more of lead or several feet of concrete. The unit of gamma radiation is the photon.

(d) Radioactive materials commonly used in tracer studies in research in biology, chemistry, and medicine are the isotopes of carbon (C^{14}) and iodine (125). In sewers and waste treatment plants certain isotopes, such as radioiodine and radiophosphorus, accumulate in biological slimes and sludges.

(5) Toxicity. Toxicity is most often related to aquatic organisms such as fish, arthropods, shellfish, and microorganisms. The toxicity bioassay test has been developed to evaluate the relative toxicities of individual wastewaters. The purpose of the test is to determine the lethal concentration of pollutant that will kill 50 percent of the test organisms (LC_{50}) in a given period of time. The LC_{50} is an indirect method of measuring toxicity.

(6) Pathogens. Wastewaters that contain pathogenic bacteria can originate from domestic wastes, hospitals, livestock production, slaughterhouses, tanneries, pharmaceutical manufacturers, and food processing industries. The major pathogens of concern include certain bacteria, viruses, and parasites.

(a) The coliform group of bacteria has been used to indicate the bacterial pollution of water and wastewater. Generally used test parameters employed as water quality indicators are total coliform and fecal coliform. The total coliform test includes organisms other than those found in the gastrointestinal tracts of mammals.

(b) The fecal coliforms are differentiated from the total coliforms by incubation at an elevated temperature in a different, growth-specific medium.

(c) Fecal Streptococci are non-coliform bacteria which are widely used as indicators of pollution. Streptococci are particularly useful in that they are commonly found in heavily polluted streams and almost always absent from non-polluted waters. Other pathogenic bacteria of concern and related diseases are listed in table 3-1.

Table 3-1. Common enteric pathogenic bacteria and related disease

Bacteria	Disease
Salmonella typhosa	Typhoid fever
Salmonella paratyphi	Paratyphoid fever
Salmonella typhimurium	Salmonellosis
Shigella sonnie, S. flexneri	Shigellosis
Vibrio chlorea	Cholera
Pseudomonas aeruginosa	Enteric infection
Klebsiella sp.	Enteric infection
Diplococcus pneumonia	Infectious pneumonia
Clostridium botulinum	Botulism
Brucella sp.	Brucellosis

(d) Viruses are submicroscopic obligate parasites which can only replicate in a host cell. However, viruses can survive for weeks, even months outside a host cell awaiting the opportunity to reinfect another host. Viruses cause a large number of diseases including the common cold, measles, poliomyelitis, mumps, hepatitis,

Table 3-2. Common parasites and related disease

Organism	Disease	Reservoir(s)	Range(s)
Protozoa			
Balantidium coli	Balantidiasis	Man, swine	Worldwide
Entamoeba histolytica	Amebiasis	Man	Worldwide
Giardia lamblia	Giardiasis	Man, animals	Worldwide
Toxoplasma gondii	Toxoplasmosis	Cat, mammals, birds	Worldwide
Nematodes (Roundworms)			
Ascaris lumbricoides	Ascariasis	Man, swine	Worldwide-Southeastern USA
Ancylostoma duodenale	Hookworm	Man	Tropical-Southern USA
Necator americanus	Hookworm	Man	Tropical-Southern USA
Ancylostoma braziliense (cat hookworm)	Cutaneous Larva Migrans	Cat	Southeastern USA
Ancylostoma caninum (dog hookworm)	Cutaneous Larva Migrans	Dog	Southeastern USA
Enterobius vermicularis (pinworm)	Enterobiasis	Man	Worldwide
Stronglyoides stercoralis (threadworm)	Strongyloidiasis	Man, dog	Tropical-Southern USA
Toxocara cati (cat roundworm)	Visceral Larva Migrans	Canivores	Probably Worldwide
Toxocara canis (dog roundworm)	Visceral Larva Migrans	Canivores	Sporadic in USA
Trichuris trichiura (whipworm)	Trichuriasis	Man	Worldwide
Cestodes (Tapeworms)			
Taenia saginata (beef tapeworm)	Taeniasis	Man	Worldwide-USA
Taenia solium (pork tapeworm)	Taeniasis	Man	Rare in USA
Hymenolepis nana (dwarf tapeworm)	Taeniasis	Man, rat	Worldwide
Echinococcus granulosus (dog tapeworm)	Hydatid Disease	Dog	Far North-Alaska
Echinococcus multilocularis	Aleveolar Hydatid Disease	Dog	Rare in USA

and distemper, to name only a few. The viruses of most concern found in wastewaters are of the Hepatitis, Coxsackie, Echo, Adeno and Arbo groups.

(e) Parasites and protozoa are widely found in sanitary wastewaters of the United States. Few of these organisms directly cause death but some do weaken the host and promote the possibility of contracting infectious disease. Table 3-2 lists the protozoans and multicellular parasites (nematodes and cestodes) of major concern.

3-3. Sources of industrial and sanitary wastewater

a. Industrial waste waters. Industrial wastewaters may be defined as all wastewaters other than those resulting from sanitary discharge or storm runoff. Industrial discharges include source from water treatment operations, vehicle wash racks, metal plating, motorpool and equipment maintenance shops, hospitals, laundries, x-ray and photographic and chemical laboratory operations. Discharges classified as industrial wastes often contain significant quantities of oils, soluble organic compounds, solid matter, dissolved metals, and other substances. Industrial wastes often require treatment operations not normally employed for domestic wastes are quite different from domestic wastes. This section of the manual discusses sources of sanitary and industrial wastewaters.

b. Sanitary discharges. Sanitary discharges originate from the use of restrooms, food preparation, clothes washing, and other domestic sources. When these activities are conducted on a large scale, they become an industrial source. Sanitary or domestic wastewater is commonly referred to as sewage. Table 3-3 summarizes average sanitary discharge loadings and sources from a typical domestic household of four members. Table 3-4 summarizes typical sewage volume and BOD for various services.

Table 3-3. Average pollutant loading and waste water volume from domestic household (four members) (100)

Wastewater Event	Number Per Day	Water Volume Per Use in Gallons	Total Water Use in Gallons	BOD, in Pounds Per Day	Suspended Solids, in Pounds Per Day
Toilet	16	5	80	0.208	0.272
Bath/Shower	2	25	50	0.078	0.050
Laundry	1	40	40	0.085	0.065
Dishwashing	2	7	14	0.052	0.026
Garbage disposal	3	2	6	0.272	0.384
Total			190	0.695	0.797

c. Industrial discharges. Industrial wastewaters vary considerably in strength and composition among military installations. This is due to differences in installation size and the type of site operations. Sources of industrial discharge common to many military posts are discussed below.

(1) Water treatment. Water treatment plants commonly employ chemical precipitation, sand filtration, carbon adsorption and chlorination as purifying operations. Sludges produced from the precipitation operation have high concentrations of minerals such as calcium, iron, and aluminum. These sludges vary in solids content from 2 percent to 25 percent and are most often handled in one of three manners:

–discharge to a municipal sewage treatment plant.
–discharge to an industrial waste treatment plant.
–dewater and landfill.

(2) Boiler water treatment blowdown. Boiler blowdown is required to control suspended and dissolved solids concentration. Boiler water is treated with chemicals, notably sodium and phosphate, to prevent scaling and corrosion. Boiler blowdown is typically high in pH, temperature, suspended and dissolved solids, and water treatment chemicals.

(3) Cooling water. Cooling water originates from air conditioning systems and cooling towers. Most air conditioning cooling water is once-through water which is not recovered or reused. Occasionally, air conditioning cooling water is treated with biocides to prevent slime growth in the plumbing and the condenser heat exchangers. Cooling towers are used to cool process waters and vessels, and allow reuse of utility water. Cooling towers are treated with organic and inorganic biocides to control slime growth in the tower. Severe contamination of cooling tower discharges may occur when the heat exchangers leak process chemicals into the cooling water. In general, however, non-contact cooling water is very low in chemical strength.

(4) Aircraft and vehicle wash racks.

(a) Nearly all military installations have vehicle wash racks to clean vehicles returning from field exercise and for normal maintenance. The wash waters contain grit, soil, oil and detergents.

(b) Centralized Vehicle Wash Facility (CVWF) are being constructed at Army facilities which are complete recycle systems with no discharge to wastewater facilities.

(5) Motor pools.

(a) Motor pools have a variety of waste sources. These include: engine cleaning, spilled hydraulic engine and transmission oils, battery

Table 3-4. Sewage volume and BOD for various services (126)

Type	Volume (gal/capita/day)	BOD (lb/capita/day)
Airports		
Each employee	15	0.11
Each passenger	5	0.04
Bars		
Each employee	15	0.11
Plus each customer	2	0.02
Camps and resorts		
Luxury resorts	100	0.39
Summer camps	50	0.33
Construction camps	50	0.33
Domestic sewage		
Luxury homes	100	0.44
Better subdivisions	90	0.44
Average subdivisions	80	0.39
Low-cost housing	70	0.39
Summer cottages, etc.	50	0.39
Apartment houses	75	0.29
(Note: if garbage grinders installed, multiply BOD factors by 1.5.)		
Factories (exclusive of industrial and cafeteria wastes)	15	0.11
Hospitals		
patients plus staff	150-300	0.67
Hotels, motels, trailer courts, boarding houses (not including restaurants or bars)	50	0.33
Milk plant wastes	100-225 gal/ 1,000 lb of milk	1.24 to 3.65/ 1,000 lb of milk
Offices		
Restaurants		
Each employee	15	0.13
Plus each meal served	3 (per meal)	0.07 (per meal)
If garbage grinder provided, add	1 (per meal)	0.07 (per meal)
Schools		
Day schools (each person, student or staff)		
Elementary	15	0.09
High School	20	0.11
Boarding Schools	75	0.39
Add per person if cafeteria has garbage grinder		0.02
Swimming pools		
(Employees plus customers)	10	0.07
Theaters		
Drive-in, per stall	5	0.04
Movie, per seat	5	0.04

maintenance, spray booths, radiator cleaning and floor wash. Engine cleaning is frequently performed with a decreasing agent in conjunction with steam and detergent cleaning or, in modernized facilities with high-pressure hot water, eliminating solvents and detergents. Although most spent oils are recycled, spills in engine maintenance areas are frequently sent to floor drains.

(b) Scheduled maintenance platforms (SMP) have been provided to modernize some facilities. These will be covered to minimize wastewater and will include oil removal. High-pressure hot water has replaced steam cleaning, eliminating use of solvents and detergents.

(6) Laboratories. Hospital laboratories usually incinerate pathological solid and semi-solid waste products. Liquid waste may be disinfected prior to discharge to the sanitary sewer. X-ray and photographic laboratories commonly pretreat fixing solutions to recover silver prior to discharge (DOD Div. 4160.21-M). X-ray finishing and washing solutions are discharged directly to the sewer.

(7) Laundries. Laundry washwaters are a significant source of BOD and flow. Wastewater is usually filtered through a lint screen and sometimes cooled for heat recovery prior to discharge into the sewer. Dry cleaning solvents are normally recycled but a small volume may enter the sanitary sewer system.

(8) Coal pile runoff. Coal pile runoff wastewater results from the passage of water through coal deposits where disulfides, usually pyrites, are exposed to the oxidizing action of air, water and bacteria. Coal piles exposed to air and moisture will result in sulfide oxidizing to ferrous sulfate (copperas) ($FeS0_4$) and sulfuric acid (H_2SO4). The major characteristics of this runoff flow include a high suspended solids concentration and turbidity, mainly from coal, a low pH and high H_2SO_4 and $FeSO_4$ concentrations. Major treatment and disposal methods involve settling, froth flotation and drainage control.

(9) Paint stripping. There are several paint stripping methods in use today: mechanical, chemical or molten salts. Chemical or solvent stripping uses either a hot or a cold method. Cold strippers may be further classified by material used into:

–Organic solvents.
–Emulsion type.
–Acid type.
–Combination of types.

Organic solvent stripping processes of modern paints, involving spray-on/spray-off stripping procedures, have exhibited high levels of phenolic compounds in the associated wastewater. Older paints are removed by strippers containing mostly methylene chloride and hexavalent chromium with additional surfactants, thickening and wetting agents. High levels of lead compounds can be expected when stripping lead based paints. Viable treatment alternatives for phenolic waste include hydrogen peroxide oxidation and/or carbon adsorption.

(10) Metal plating. Metal plating process wastewater is defined as all waters used for rinsing, alkaline cleaning, acid pickling, plating and other metal finishing operations; it also includes waters which result from spills, batch dumps and scrubber blowdown. The cleaning, pickling and processing solutions may contain a variety of chemical compounds, most of which at very low concentrations have a toxic potential to aquatic life. At higher concentrations, they may also be toxic to humans. The suspended solids concentration is elevated due to components such as precipitated metal hydroxides, tumbling and burnishing media, metallic chips and paint solids. Treatment methods commonly used include batch treatment for cyanide destruction, continuous flow-through treatment for cyanide and chromium contaminated rinse waters and an integrated treatment system for cyanide and chi-omit acid process solutions. Lime precipitation can be used for the removal of other metals. When clarification of the treated rinse water containing precipitated metal hydroxide is required, it normally is accomplished with settling tanks or clarifiers or filtration using pressure filters.

(11) Munitions manufacturing. Propellants and explosives are materials which, under the influence of thermal or mechanical shock, decompose rapidly and spontaneously with the evoluation of a great deal of heat and much gas. Some of the most common industrial and military propellants and explosives include gunpowder, nitrocellulose, nitroglycerin, ammonium nitrate, trinitrotoluene (TNT), picric acid, ammonium picrate, RDX, HMX, and lead azide. When these compounds are manufactured, the associated wastewater is an acidic, odorous flow sometimes containing metals, organic acids and alcohols, oils and soaps. Major treatment methods include flotation, chemical precipitation, biological treatment, aeration, chemical oxidation neutralization and adsorption.

3-4. Comparison of domestic and industrial wastewaters

a. Composition and concentration. All wastewaters differ in composition and concentration.

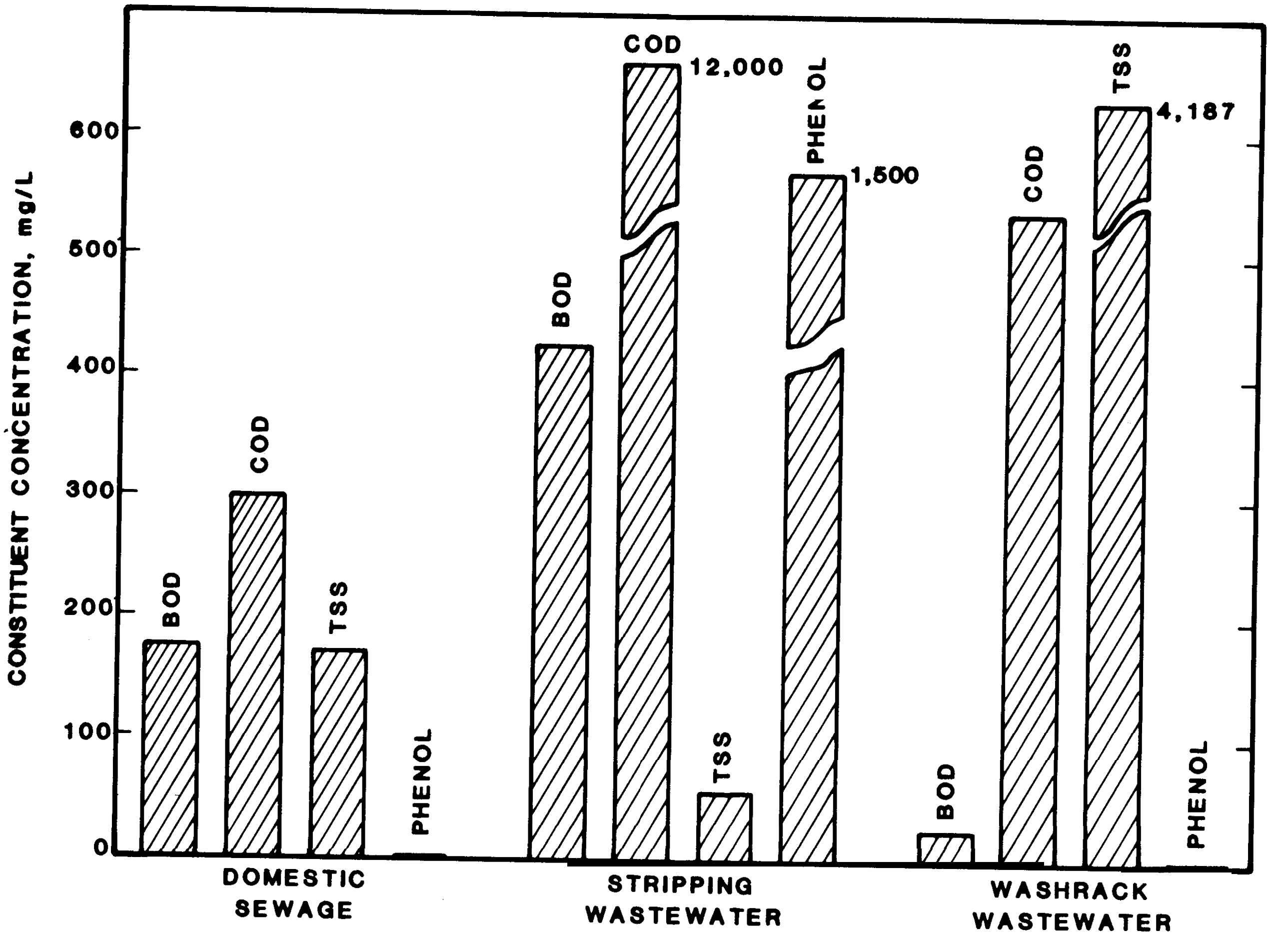


Figure 3-1. Comparison of domestic wastewater with selected military industrial wastewater.

For this reason comparison between domestic and industrial wastes is made on a case-by-case basis. However, some general conclusions may be drawn from the major differences between domestic and industrial wastes.

(1) First, a major portion of the BOD in domestic sewage is present in colloidal or suspended form while BOD in industrial wastewaters is usually soluble in character. The non-degradable COD in domestic sewage is low (usually less than 200 mg/L) while industrial wastewaters may have a non-degradable COD level in excess of 500 mg/L. Domestic sewage has a surplus of nutrients, nitrogen and phosphorus, relative to the BOD present. Many industrial wastewaters are deficient in nitrogen and phosphorus.

(2) Total dissolved solids (TDS) in domestic sewage primarily reflect the concentration of the carrier water, while many industrial activities substantially increase the TDS through the process areas. Certain industrial wastes contain parameters of special significance such as phenol or cyanide. Figure 3-1 schematically illustrates a comparison between domestic sewage and military industrial type wastewaters. Figure 3-1 and table 3-5 present a comparison between domestic sewage characteristics, aircraft stripping wastewater, and vehicle washrack discharges.

Table 3-5. Comparison of domestic waste water characteristics with selected military industrial wastewater (mg/L unless noted otherwise)

	Sanitary Wastewater	Aircraft Stripping Wastewater	Washrack Wastewater
pH (units)	6.8-7.5	6.2-7.5	7.0
BOD	75-276	375-478	10-29
COD	195-436	5,388-18,946	105-1,620
TSS	83-258	34-76	180-12,390
Phenol	Nil	71-2,220	Nil

b. Characteristics of domestic wastewaters. Domestic sewage is composed of organic matter present as soluble, colloidal, and suspended solids. The pollutant contribution in sewage is usually expressed as a per capita contribution. A study of data reported by 73 cities in 27 states in the United States (96) during the period 1958-1964 showed a sewage flow of 135 gal/capita-day and a BOD and suspended solids content of 0.20 lb/capita/day and 0.234 lb/capita/day, respectively. The average composition of domestic sewage is shown in table 3-6. It should be recognized that the presence of industrial wastes in a domestic system may radically alter these concentrations. These levels may be expected to vary by about a ratio of 3 over a 24-hour period. Flow and BOD loadings generally peak between 1400 and 1900 hours. The lowest loadings generally occur between 0300 and 0500 hours.

Table 3-6. Average characteristics of domestic sewage (mg/L unless noted otherwise)

Parameter	High	Average	Low
BOD	350	200	100
COD	800	400	200
pH (units)	7.5	7.0	6.5
Total Solids	1,200	700	400
Suspended, total	350	200	100
Fixed	100	50	25
Volatile	250	150	75
Dissolved, total	850	500	300
Fixed	500	300	200
Volatile	350	200	100
Settleable Solids (mL/liter)	20	10	5
Total Nitrogen (as N)	60	40	20
Free Ammonia (as NH_3)	30	15	10
Total Phosphorus (as P)	20	10	5
Chlorides (as Cl)	150	100	50
Sulfates (as SO.)	40	20	10
Alkalinity (as $CaCO_3$)	350	225	150
Grease	150	100	50

c. Characteristics of industrial wastewater. Industrial wastes vary widely in composition and quantity. The purpose of this section is to describe the characteristics of major industrial discharges and particularly those discharges found on military installations. The major portion of wastewaters from most military installations are domestic in nature. However, military industrial wastewaters are produced from operations such as photographic processing, metal plating, laundry, maintenance, and munitions manufacturing.

(1) Aircraft and vehicle washing.

(a) Ground equipment is routinely washed to remove any accumulated oil film, grease, metal oxides, salts and dirt. This is normally accomplished by pressure spraying with water or cleaning compounds to remove surface films, followed by scrubbing with brushes and cleaners to loosen foreign matter, and finally rinsing thoroughly with water to remove emulsified oils and dirt. An alkaline, water-based cleaner normally is used. Wastewater flows and concentrations are highly variable. This is due primarily to the type vehicle being washed, type of washing operation, amount of water used, inclusion or exclusion of storm water, variation in type of cleaning agents, and sampling procedures used. Automobile and ground vehicle washing requires 30 to 50 gal of water per vehicle. Washwater characteristics determined from ground vehicles are presented in table 3-7. Principal wastewater constituents include free and emulsified oils, suspended dirt and oxides, phosphates, detergents, and surfactants.

(b) Aircraft are routinely washed to remove foreign material from the aircraft surface. The survey results indicate significantly higher waste loads than those experienced during ground vehicle washing. BOD values ranging from less than 100 to several thousand mg/L and oil and grease levels of less than one to several thousand have been observed.

(2) Wastes from paint stripping operations. Aircraft and other vehicles are stripped of paint periodically as routine maintenance in preparation for repairs or overhaul. Aircraft are usually repainted every three or four years to prevent corrosion of metallic surfaces. The paint-stripper is brushed on and allowed to set on the painted surfaces, causing the paint to swell and blister. This loosened paint is then removed with a high pressure water spray. Modern paints are stripped with a phenolic paint remover, while the older paints are removed by strippers containing mostly methylene chloride (dichloromethane) and hexavalent chromium with additional surfactants, thickeners, and wetting agents. Flows and characteristics are highly variable. For example, approximately 3,350 gallons of paint-stripper, 715 gallons of which is phenolic paint-stripper, are used for large aircraft; while smaller aircraft may require some 300 gallons of stripper. It is estimated that from 45 to 75 gallons of water are required to rinse each gallon of paint-stripper. The principal pollutants from a phenolic aircraft paint-stripping wastewater and the ranges of concentration are presented in table 3-8.

TABLE 3-7

Summary of Wastewater Quality From Maintenance and Exterior Cleaning Activities

	Grease and Oil (mg/L)	Suspended Solids (mg/L)	Settleable Solids (mg/L)	Total Dissolved Solids (mg/L)	BOD mg/L	COD (mg/L)	Alkalinity	pH	Orthophosphate mg/L
Yakima Firing Center Maintenance Exterior	37-1,448	1.72-10,900	1-25						
Fort Stewart Exterior - Old	0.5-86.4	3.2-2,390	6.5-32		10.36	100-1,620			
Fort Polk Maintenance Exterior	174	4,780	22	1,720	340	156	82		
Fort Lewis TMP Maintenance Exterior	9-13	65-454				24-32			
Fort Lewis Maintenance - New	20- ,673	92-1,060							
Maintenance Exterior	5-110	25-1,420	.1-4.5	71-346	1.8-20	20-356		60-8.1	
Fort Lewis Maintenance - New	553-18,855	957-2,260	.25-6.2	135-160		1,020-1,800		7.5-8.0	
Fort Knox Exterior Old	.6-32.9	3,559	4.3			117.5		0.8	0.07
Fort Hood Exterior Old	1,467-16.1 (PPM)	2,864 (PPM)	60	175-230 (PPM)		336-829 (PPM)	131.0 (PPM)	8.1-8.3	

TABLE 3-7 Cent'd.

Summary of Wastewater Quality From Maintenance and Exterior Cleaning Activities

	Grease and Oil (mg/L)	Suspended Solids (mg/L)	Settleable Solids (mg/L)	Total Dissolved Solids (mg/L)	BOD (mg/L)	COD (mg/L)	Alkalinity	pH	Orthophosphate mg/L
Fort Drum Maintenance Exterior	4-22	1,500-10,000				20-1,200			
	5.9-268.5	603-1,100	1.6-4.0	15.5-43.8		110-289	65-137	7.1-7.4	0.8-2.6
Fort Carson Maintenance Exterior	.1-3,096	2-7,844			3-1,078	1-3,366			
Fort Carson Maintenance Exterior	25-3,096	30-15,700		8-1,078				7.0-8.1	

Source: U.S. Army Corps of Engineers, Construction Engineering Research Laboratory

Table 3-8. Characteristics of phenolic aircraft paint-stripping waste water (mg/L unless noted otherwise)

Parameter	Concentration
Phenols	1,000-3,000
Methylene Chloride	1,000-3,000
COD	5,000-30,000
Chromium	50-200
Suspended Solids	100-1,000
Oils	100-2,000
pH (units)	8.5-8.5

(3) Wastes from machine shops. The machining of metal parts for aircraft, ground vehicles, and large guns is an operation where the major water flows are used for cooling purposes. However, there are large amounts of both lubricating and cooling oils which eventually must be wasted. This operation is often incorporated in a large equipment rebuilding and maintenance depot but may be present in tactical posts. The major pollutants are soluble, emulsified, and free oils; and metal ions, shavings, and flakes.

(4) Wastes from vehicle mechanical maintenance. Engine maintenance on military installations can result in a number of wastewater flows. Waste sources from engine maintenance areas include: steam cleaning condensate, spilled hydraulic, engine and transmission oils, battery maintenance, radiator cleaning, and fuel tank cleaning. A major source of contamination from maintenance shops is solvents, especially petroleum distillates.

(5) Laundry wastes. Most military installations have a large central laundry facility to clean uniforms and work clothes. Wastewaters from laundries vary in composition due to the type of laundry operation, the type of detergents used, the use of dyes, and the condition of the clothing being laundered. Table 3-9 lists typical laundry waste characteristics. TM 5-842-2 indicates wastewater flows and characteristics will vary depending on the type of laundering operations used, the type of detergents used and the condition of the incoming laundry.

Table 3-9. Typical laundry waste characteristics (mg/L unless noted otherwise)

Parameter	Maximum	Average	Minimum
pH (units)	11	8	5.1
Temperature (degrees F)	140	100	50
BOD	3,810	700	45
Grease and Oil	1,410	800	150
Total Solids	3,310	1,700	120
Suspended Solids	784	160	15
Detergents (as ABS)	126	55	3
Phosphates	430	150	1
Free Ammonia	—	3	—

(6) Photographic laboratory wastes. Most military bases have one or more photographic laboratories on site. Photographic wastes normally represent a very small fraction of a facility waste load. However, separate treatment of photographic wastes is sometimes required to remove toxic materials or to recover silver.

(a) There are a number of different types of photochemical processes and each results in a different type of wastewater. Color processes produce more pollutants than black and white processes. Photographic wastes are a combination of spent process chemicals and washwater. Some spent process chemicals, notably fixing agents, are often treated separately for silver recovery. The three most common types of silver recovery processes are: metal replacement, electrodeposition, and precipitation. Metal replacement involves passing the wastewater through a fine steel wool screen. The iron in the steel wool replaces the silver in solution resulting in a settled silver-rich sludge. Electrodeposition involves plating nearly pure silver on the cathode of an electrolytic cell. Precipitation of silver is usually achieved by the addition of chlorine and sulfide to form insoluble silver chloride or sulfide.

(b) The other constituents of a typical combined photographic wastewater are listed in table 3-10. This analysis represents the combined process chemical and wash wastewaters. The toxic chemicals of concern include silver, chromium, cyanide, and boron.

Table 3-10. Analysis of photographic processing waste water discharge

Constituent	Concentration (mg/L)
COD	2,234
Dissolved Solids	5,942
Suspended Solids	70
Oils and Grease	22
Surfactants (as LAS)	13
Phenols	0
Nitrates	48
Phosphates	380
Nitrates	1,100
Sulfates	260
Cyanides	6.70
Silver	1.96
Iron	0.20
zinc	0.08
Copper	0.05
Manganese	0.05
Chromium	0.05
Lead	0.05
Cadmium	0.01

(c) Silver ion is highly toxic to aquatic organisms. However, silver in photographic wastes is largely precipitated as silver chloride or silver sulfide and in these forms represents minimal risk of toxicity.

(d) Chromium is present in the hexavalent form (Cr^{+6}) in some bleach solutions. However, hexavalent chromium is reduced to the trivalent form (Cr^{+3}) by strong reducing agents present in photographic wastewaters.

(e) Cyanide is present in bleaching solutions as potassium ferrocyanide. After chemical action by other reducing agents and by oxidation of silver, complex insoluble cyanide compounds are formed. These cyanide complexes are potentially dangerous as their degradation releases toxic cyanides.

(f) Boron is present in photographic wastes in small quantities and is usually precipitated as calcium borate.

(7) Metal plating wastes. Metals are plated onto both metallic and nonmetallic surfaces for decoration, corrosion inhibition, increased wear resistance, or improved hardness. Commonly plated metals are copper, cadmium, chromium, nickel, tin, and zinc. The surface to be plated serves as a cathode. An electrode made of the metal being deposited in most instances acts as the anode. With some metals, such as in chromium plating, an inert anode is used and the plating bath supplies the metal deposited. Nonmetallic surfaces to be plated must be made conductive by application of a conductive material such as graphite. Metal stripping, cleaning, pickling, and phosphatizing are preparation steps for the actual plating operation. Anodizing of aluminum in a chromate bath is considered a related operation since it produces a waste similar in characteristics to plating waste.

(a) A wide range of processing steps is used in the plating operation. Selection of such steps is based on the type of material receiving the plated layer, the type of metal being plated, individual plating technique preferences, and various final product requirements. A typical plating operation will include the following steps:

–Cleaning by solvent decreasing and/or alkaline cleaner.
–Rinsing.
–Acid cleaning or pickling.
–Rinsing.
–Surface preparation such as phosphatizing.
–Flash plating.
—Principal plating.
—Rinsing.
–Drying.

(b) The major waste sources are rinse water overflow; fume-scrubber water; batch-dumps of spent acid, alkali, or plating bath solutions; and spills of the concentrated solutions. Important parameters include pH, cyanides, emulsifying and wetting agents, and heavy metals. Cyanide is converted to highly toxic hydrogen cyanide gas at low pH; therefore, cyanide-plating solutions must not be mixed with acid-cleaning or acid-plating solutions.

(8) Wastes from munitions manufacture. Wastes generated from munitions manufacture originate from manufacturing areas as well as loading, assembling, and packing (LAP) areas. Wastewaters are generated from the manufacture and use of explosive chemicals such as trinitrotoluene (TNT), nitroglycerine, cyclonite (RDX), HMX, and tetryl. The amount and composition of munitions wastewaters varies with the explosive being produced.

(a) TNT ($CH_3C_6H_2(NO_2)_3$). In TNT manufacture, toluene is reacted with nitric acid in a three-step process, using fuming sulfuric acid as a catalyst and drying agent. Excess acids are washed away from the crude TNT, forming in a waste stream known as “yellow water”. Unwanted beta- and gamma-TNT isomers are selectively removed from the desired alpha-TNT in a solution of sodium sulfite (sellite). This purification step generates a dark red-colored waste known as “red water”. The purified TNT is then recrystallized, dried and flaked. TNT contains up to 0.4 percent dinitrotoluene (DNT) which also is an explosive and considered hazardous. The washdown water from processing areas contains suspended TNT and is known as “pink water”. Originally, production was a batch-type operation, however nearly all plants have been converted to continuous-type systems, as shown in figure 3-2. The continuous operations normally employ chemical recycle and result in a smaller quantity of more concentrated waste than the batch-type operations. Typical wastewater characteristics from both types of operations are presented in table 3-11.

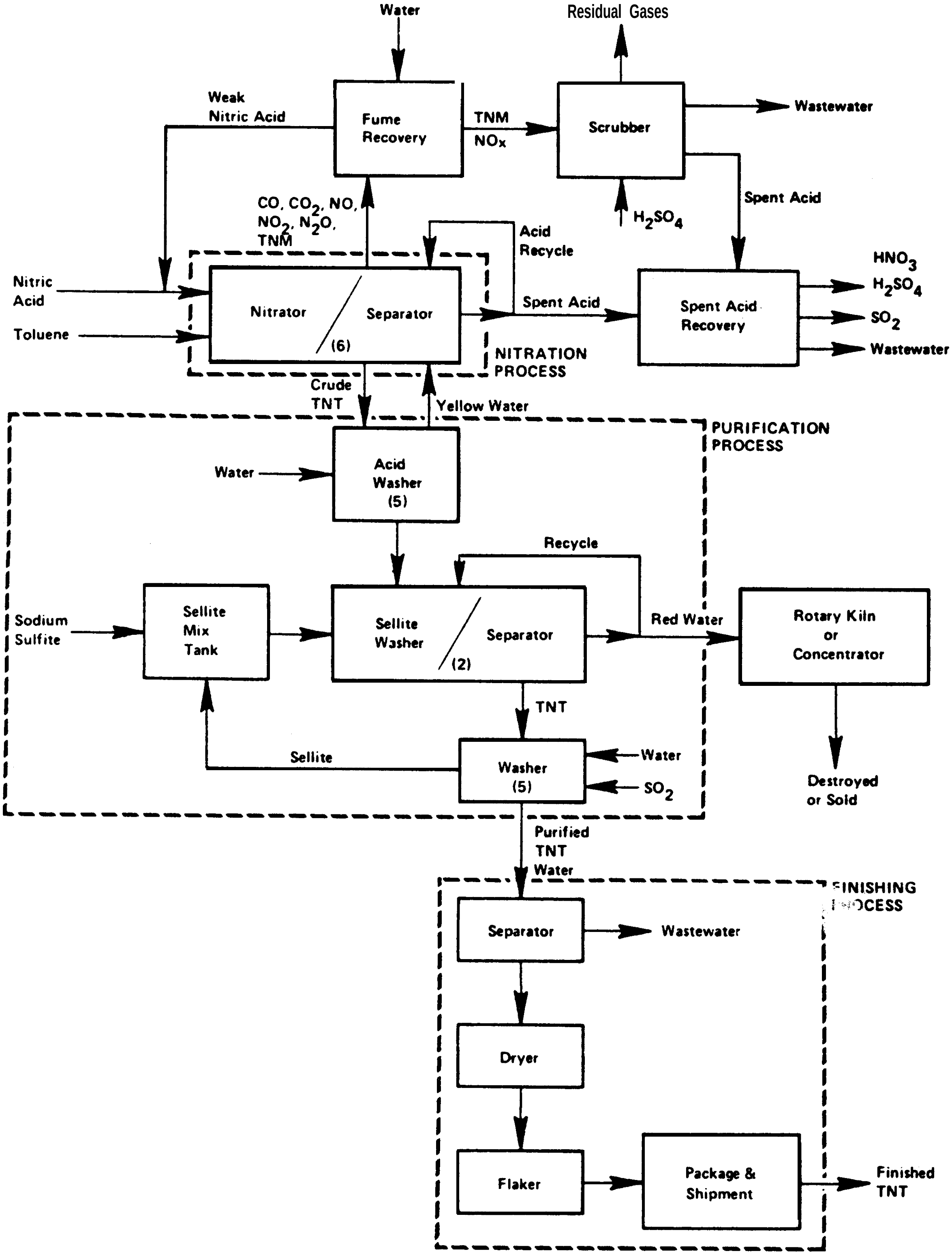


Figure 3-2. Typical TNT production process.

Table 3-11. Typical TNT waste water characteristics (mg/L unless noted otherwise)

Parameter	Continuous-Type Process 24-Hour Composite Sample	Grab Sample	Batch-Type Process
TNT	**20.3**	145	—
pH (units)	**2.5**	2.05	**2.6**
COD	**64**	274	**673**
Nitrate (as N)	**213**	53	**107**
Sulfate (as SO_4)	**1,821**	842	**638**
Color (units)	**161**	228	**6,700**
Total Solids	**2,792**	1,160	**2,048**
Volatile Solids	**1,377**	960	**850**
Suspended Solids	**619**	224	**98**
Temperature (degree F)	**95**		—
Flow (gal/lb of TNT)	—		11.2

(b) Nitroglycerine ($CHNO_3(CH_2NO_3)_2$). Nitroglycerine is produced by mixing glycerine with concentrated nitric and sulfuric acids, similar to the TNT manufacturing process. The acids are then decanted, and the nitroglycerine is washed with water and soda ash to remove any residual acids. The two principal wastewaters are the waste acid and the soda ash washwaters; and both contain nitroglycerine. Typical wastewater characteristics are presented in table 3-12.

Table 3-12. Typical nitroglycerine waste water characteristics (mg/L unless noted otherwise)

Parameter	Maximum	Minimum
Nitroglycerine	315	0
pH (units)	9.9**	1.7
COD	340	10
Nitrate (as N)	1,920	0.5
Sulfate (as SO_4)	470	15
Color (units)	80	5
Total Solids	25,000	110
Suspended Solids	40	1
Temperature (degrees F)	80	50
Flow (mgd)	0.17	0.04

**High values indicate a dump of the soda ash washing solution.

(c) HMX and RDX, HMX ($(CH_2N_2O_2)_4$) and RDX ($(CH_2N_20_2)_3$) are very similar chemical compounds and are manufactured by essentially the same process, except for different operating temperatures and raw material feed ratios. Hexamine, acetic anhydride, nitric acid, and ammonium nitrate are fed into a reactor, forming crude HMX or RDX; which is then aged, filtered, decanted, and washed with water. Wastewaters result from spillage of raw materials or product, discharge of cooling water, washwater and filtered water; and flows from equipment and floor cleanup operations. HMX and RDX wastes typically have a BOD of 900 to 2,000 mg/L and a pH ranging from 1.6 to 6.0. Analysis of wastewater must be made to determine specific treatment needs.

(d) Nitrocellulose ($C_6H_7O_5(NO_2)_3$). To produce nitrocellulose, purified cellulose in the form of cotton-linters or wood-cellulose is treated with a mixture of sulfuric acid, nitric acid and water. The nitrated cellulose is then purified by a combination of centrifugation, boiling, macerating, solvent extraction or washing operations. The nitrocellulose (“green powder”) is then combined with other explosive materials to be processed into various propellants. Waste materials generated include the cellulose- and nitrocellulose-contaminated acid waters from the vitrification and purification steps, alcohol and ether solvents, and other waste material from the refining and processing steps. Accidental fires caused by processing of nitrocellulose into propellants are often extinguished by automatic sprinklers, generated highly contaminated wastewater.

(e) Black powder. The industrial classification used by the Bureau of Mines defines black blasting powder as all black powder having sodium or potassium nitrate as a constituent. Black powder and similar mixtures were used in incendiary compositions and in pyrotechnic devices for amusement and for war, long before there was any thought of applying their energy usefully for the production of mechanical work. Where smoke is no objection, black powder is probably the best substance that is available for communicating fire and for producing a quick hot flame. It is for these purposes that it is now principally used in the military. (129)

(f) Nitroguanidine ($NO_2NHC(NH)NH_2$). Nitroguanidine exists in two forms. The alpha-form invariably results when guanidine nitrate is dissolved in concentrated sulfuric and the solution is poured into water. This is the form which is commonly used in the explosive industry. When alpha-nitroguanidine is decomposed by heat, a certain amount of beta-nitroguanidine is found among the products. Beta-nitroguanidine is produced in variable amounts, usually along with some of the alpha-compound. This is accomplished through nitration of the mixture of guanidine sulfate and ammonium sulfate which is formed from the hydrolysis of dicyanodiamide with sulfuric acid. Nitroguanidine on reduction is converted first into nitrosoguanidine and then into aminoguanidine (or guanylhydrazine). The latter substance is used in the explosives industry for the preparation of tetracene.

(g) Lead azide (PbN_6). Lead azide is manufactured by treating sodium azide with lead acetate or nitrate. Sodium azide is formed from sodium amide and nitrous oxide. Lead azide is used where it is desired to produce, either from flame or from impact, an initiatory shock for the detonation of a high explosive such as found in compound detonators and in the detonators of artillery fuzes. The commercial preparation of the azides is carried out either by the interaction of hydrazine with a nitrite or by the interaction of sodium amide with nitrous oxide.

(h) Lead styphnate ($PbC_6H\,0_2(N0_2)_3$). Lead styphanate is commonly prepared by adding a solution of magnesium styphnate to a well-stirred solution of lead acetate at 158 degrees F. Dilute nitric acid is added with stirring to convert the basic to the normal salt, and the stirring is continued while the temperature drops to about 86 degrees F. The product consists of reddish-brown, short, rhombic crystals. Lead styphnate is a poor initiator, but it is easily ignited by fire or by a static discharge. It is used as an ingredient of the priming layer which causes lead azide to explode from a flash. (132)

(i) Projectiles and casings. The manufacture of the lead slugs, bullet jackets, and shell casings generates wastewaters different in composition than those from explosives manufacture. Waste constituents include heavy metals, oils and grease, soaps and surfactants, solvents, and acids. Lead slugs are manufactured by extruding lead wire, then cutting and forming the lead for insertion in the bullet jacket. Alkaline cleaners, soluble oils, and cooling waters constitute the wastewater flow. Typical characteristics include high pH of about 11 and a moderate COD of 286 mg/L. Small arms bullet jackets and casings are normally brass (copper and zinc alloy), although either may be made of steel for certain applications. The larger artillery shells are generally steel. The manufacturing processes used for both brass and steel are essentially the same, consisting of stamping out plugs from metal sheets, then drawing, trimming, tapering, and shaping the plugs into either a shell, bullet jacket, or casing. Conventional metal conditioning operations, such as alkaline cleaning, pickling, phosphatizing, and metal coating occur between steps. One quality control check involves the use of a mercurous nitrate solution, creating an opportunist y for mercury pollution. Total wastes have widely fluctuating pH with heavy metals (mercury, copper, zinc, and iron), oils and surfactants. Table 3– 13 indicates typical munitions metal parts wastewater characteristics.

Table 3-13. Typical munitions metal parts waste water characteristics (mg/L unless noted otherwise)

Parameter	Maximum	Average
Temperature (degree F)	120	**65**
pH (units)	9.2	**3.3**
Alkalinity (as $CaCO_3$)	370	0
Total Solids	5,000	650
Suspended Solids	725	27
Zinc	18	7
Copper	32	0.6
Lead	less than 0.2	—
Iron	21	less than **3.0**
Oil	168	0

(j) Loading, assembling and packing (LAP). The main LAP operations are explosives receiving and melting operations, cartridge and shell-filling operations and shell-renovation. Figure 3-3 is a schematic of a typical shell-filling and renovating facility showing major waste flows. Wastewater is generated from the four following sources:

— air-scrubbing.
— shell-filling.
—shell-washout water.
—cleanup water.

Dust from the unloading operation and fumes from the molten explosives are scrubbed from the air with water. When the shells are being filled with explosives, any spillage or over-filling will contaminate the water bath unless the water is covered. The washout water from rejected or renovated shells is heavily contaminated with explosives. The metal-cleaning and metal-treating rinse waters are contaminated with alkali soaps and surfactants, as well as dissolved copper. A complete washdown of all areas and equipment which could be contaminated with explosives is usually performed at least weekly, resulting in large flows of highly contaminated water. Table 3-14 indicates typical total wastewater characteristics.

Table 3-14. Typical LAP facility industrial waste water characteristics (mg/L unless noted otherwise)

Parameter	Maximum	Average	Minimum
pH (units)	8.4	7.9	6.8
Total Solids	1,790	1,401	903
Suspended Solids	336	138	22
Total Volatile Solids	956	548	426
Total (Kjeldahl) Nitrogen	25	17	10
TNT	235	178	156
RDX	180	145	88

(k) Coal pile runoff. Large quantities of coal are used at many military facilities for power generation. The coal that is stored for this purpose is maintained in large outdoor storage piles. Rain infiltration generates a coal pile runoff

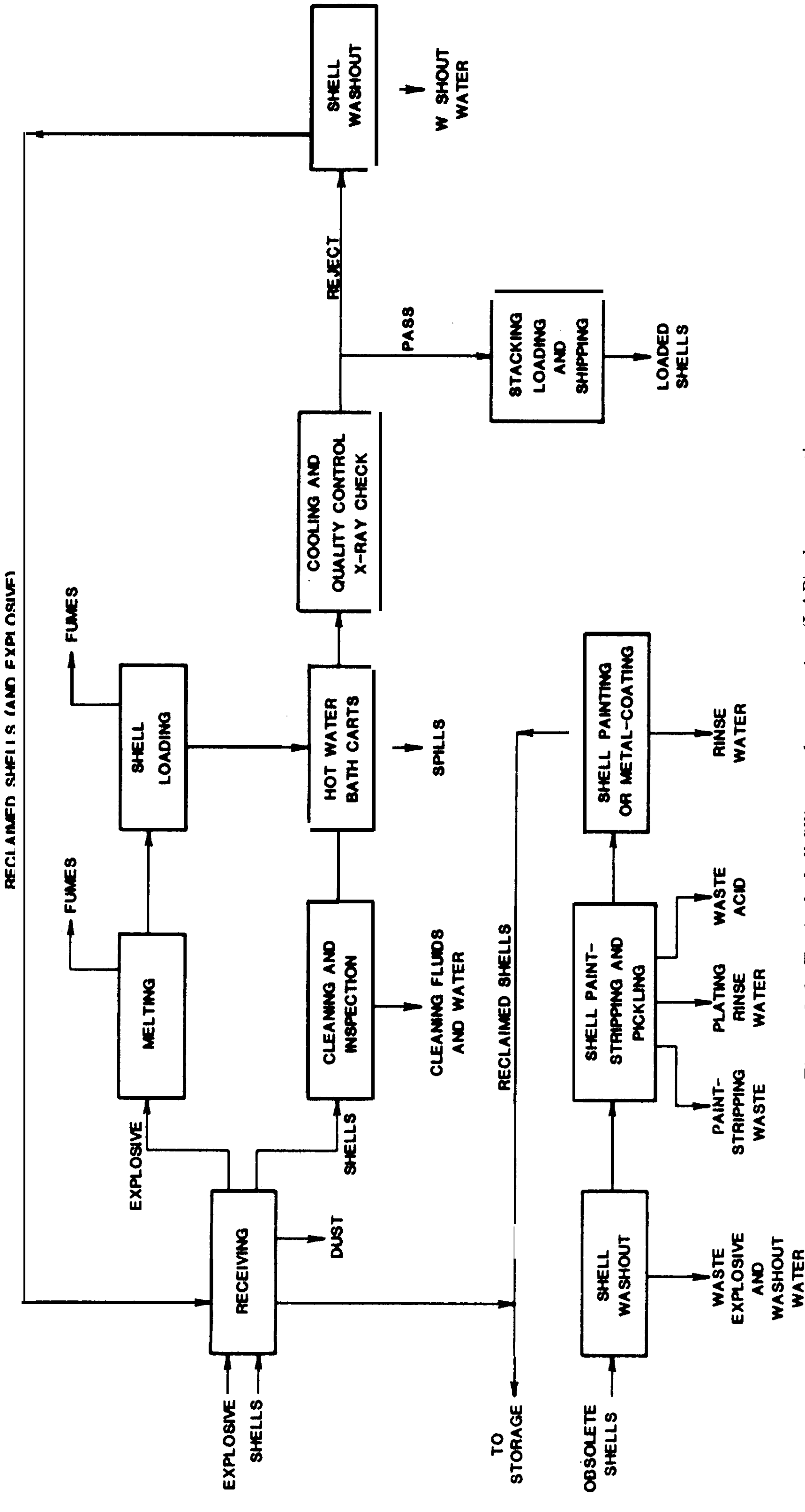


Figure 3-3. Typical shell-filling and renovating (LAP) plant operations.

flow which must be treated due to its elevated TSS and turbidity, as well as an increased $FeSO_4$ and H_2SO_4 concentration resulting from the coal oxidizing environment. Construction of a retaining curb surrounding the area of potential contamination, as well as a collection sump for short term storage, will allow for complete collection and routing of this flow to the wastewater treatment system. Construction of a coal pile cover, where applicable, would negate the need for flow collection as well as protect the coal from environmental influences and degradation.

CHAPTER 4

WASTEWATER DISCHARGE REGULATIONS

4-1. Army Regulations

The Department of the Army has prescribed general policy on environmental protection in the form of AR 200-1 and AR 200-2. The policy contained in these documents or their successors is the governing regulation for Army facilities. Any conflict between these regulations and this chapter are inadvertent. In all cases, AR 200-1 and AR 200-2 take precedence.

4-2. Legislation

a. *Historical perspective.* The decade of the 1970's saw the enactment and implementation of a variety of legislation designed to protect the environment and to regulate the disposal of waste materials. While some legislation was enacted prior to the 1970's, the statutes were generally cumbersome in the delegation of authority for enforcement of standards. In addition to the passage of several significant pieces of Federal legislation in this decade, the formation of the U.S. Environmental Protection Agency (U.S. EPA) in December, 1970, created, for the first time, a single Federal agency responsible for all aspects of environmental control including:

—air pollution.
—water pollution.
—solid and hazardous wastes.
—pesticides.
—radiation.
—noise.

This chapter will be limited to the major pieces of legislation and the resulting regulations affecting water pollution control.

b. *National Environmental Policy Act (NEPA).* The enactment of the National Environmental Policy Act (NE PA) of 1969 established protection of the environment as a national goal. Although NEPA is a short piece of legislation whose declared purpose is to establish a national policy to encourage productive and enjoyable harmony between man and the environment; the Act did contain "action-forcing" provisions for the preparation and evaluation of environmental impact statements. AR 200-2 prescribes the Department of the Army policy with regard to the implementation of NEPA.

(1) Environmental Impact Statement. A major provision of NEPA was the requirement of Environmental Impact Statements (E IS) for all major projects of Federal agencies and all State or local projects funded or regulated by a Federal agency. The E I S is required to address all the following considerations:

(a) Potential environmental impacts of the proposed action.

(b) Any unavoidable adverse environmental effects resulting from implementation of the proposed action.

(c) Alternatives to the proposed action.

(d) Irreversible and irretrievable resource commitments associated with implementation of the proposed action.

(e) Local short-term use of the environment as compared to the preservation of long-term productivity.

(2) Public participation. By requiring the publication of an EIS for public comment prior to commencement of any action on applicable projects, NEPA established the means for public participation and, therefore, promoted the field of environmental law through citizen's suits and other types of litigation. Another provision of NEPA established the Council on Environmental Quality (CEQ) to advise the President on environmental matters, to review Environmental Impact Statements, and to prepare an Environmental Quality Report assessing the status and condition of the air, aquatic, and terrestrial environments.

c. *Federal Water Pollution Control Act (FWPCA)* The Federal Water Pollution Control Act of 1972, PL 92-500, provided a comprehensive revision of prior water pollution control legislation. This Act superseded the original Federal Water Pollution Control Act passed in 1956, and its amendments prior to 1972 including the Water Quality Act of 1965, the Clean Water Restoration Act of 1966, and the Water Quality Improvement Act of 1970. The Clean Water Act of 1977 further amended PL 92–500 which subsequently is commonly referred to as the Clean Water Act.

(1) Legislative requirements. The Federal Water Pollution Control act established national goals for elimination of all pollutant discharges by 1985 and called for attainment of interim water quality standards to provide "fishable and swimmable" waters by July 1, 1983. This legislation also established requirements for:

—Establishment of a permit system to restrict discharges of pollutants from point sources.

–Development of necessary technology to eliminate the discharge of pollutants into navigable waters.

—Federal financing programs for construction of publicly owned treatment works (POTW's).

—Development of area-wide waste treatment management programs to insure pollution control in each State.

–Control of toxic pollutants.

–Federal facility compliance with Federal, State, and local requirements.

This comprehensive piece of legislation contained many other provisions relating to water pollution control. The items mentioned above will be discussed in more detail in paragraphs 4–3 and 4-4 of this chapter. Major highlights of this legislation are summarized in figure 4-1.

FEDERAL WATER POLLUTION CONTROL ACT

1972 AMENDMENTS - CLEAN WATER ACT

1. Water Quality goals established

2. Established NPDES permit system for discharges

3* Permits to be based on technology-based effluent limits

4. Federal financial assistance provided for publicly owned treatment works

5. Regional administration of Federal Policy be established

6. Major research and demonstration efforts be made to develop treatment technology

7. Federal facilities shall comply with all Federal, State, and local requirements

1977 AMENDMENTS

1. Increased emphasis on control of toxic pollutants

2. Compliance date modified

3. Best Management Practice regulations to be issued

4. Modifications to industrial pretreatment program

5. Federal facilities must investigate innovative pollution control technology

Figure 4-1. Highlights of the Federal Water Pollution Control Act,

(2) Effluent limitations. Perhaps the most significant changes in the Federal approach to water pollution control contained in the Clean Water Act included the establishment of a permitting system by which all discharges were required to meet prescribed "effluent limitations" and the appropriation of significant Federal expenditures for control of water pollution. The Act provides that all discharges to surface waterways must, as a minimum, meet certain effluent criteria. In addition, the Act requires the establishment of water quality standards for all waters and requires that all wastes must be treated to a level sufficient not to interfere with the maintenance of these water quality standards, even if this requires treatment in excess of the minimum level established by the effluent criteria.

(3) Amendments. As a result of the first five years of experience with the 1972 Amendments, Congress, in 1977, passed the 1977 Amendments to the Federal Water Pollution Control Act. The most important changes recognized by the 1977 Amendments include the following:

—Several changes in compliance dates were made allowing more time for compliance with certain regulations.

—An increased emphasis on the control of toxic pollutants was added.

—U.S. EPA was authorized to issue "best management practices" regulations for the control of toxic and hazardous pollutants contained in industrial plant site runoff, spills or leaks, and discharges from other activities ancillary to industrial operations.

—Modifications in requirements for pretreatment of industrial wastes required for discharge to municipal sewage treatment systems were made.

-Federal facilities were required to investigate innovative pollution control technology before construction of new facilities.

d. Resource Conservation and Recovery Act (RCRA) of 1976. In 1976, Congress enacted the Resource Conservation and Recovery Act (RCRA). This legislation completely revised the older Solid Waste Disposal Act. Perhaps the most significant impact of this legislation was the requirement for controlling the handling and disposal of hazardous wastes. A summary of the features of RCRA is presented in figure 4-2.

RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)

1. Established office of Solid Waste within U.S. EPA
2. Requires hazardous waste management regulations including manifest system and permit requirements
3. Requires guidelines for solid waste management
4. Provide technical and financial assistance to maximize the conservation and utilization of valuable resources
5. Developed criteria for landfill design and operation
6. Provide technical assistance to State and local governments

Figure 4-2. Features of Resource Conservation and Recovery Act (RCRA).

The significance of RCRA to wastewater treatment is that wastewater itself may be classified as a hazardous waste and the sludge generated by wastewater treatment may be hazardous.

(1) Provisions of the Act. The Act established guidelines regulating various aspects of solid waste handling practices by:

–Requiring the U.S. EPA to develop and publish guidelines and performance standards for solid waste management.

—Establishing the Office of Solid Waste within the U.S. EPA.

–Requiring the development of hazardous waste management regulations.

—Establishing minimum requirements for State or regional solid waste plans by providing technical and/or financial assistance for developing environmentally safe disposal methods which also maximize the utilization and conservation of valuable resources.

–Developing criteria for sanitary landfills, especially with respect to characteristics distinguishing sanitary landfills from open dumps and, consequently, provisions for the prevention of open dumping.

–Establishing resource and recovery panels to provide technical assistance to State and local governments.

(2) Manifesting disposal. Perhaps the single most important feature of RCRA is the establishment of a "manifest system" regulating the handling of hazardous wastes which incorporates a "cradle-to-grave" concept. Generators of hazardous wastes will be required to initiate documentation regarding the transport, handling, and disposal of these wastes. Permits will be required in each step of the handling and disposal processes and records will be kept by the waste generator identifying all persons who have responsibility for transportation and disposal of a particular waste.

e. *Safe Drinking Water Act (SD WA) of* 1974. The Safe Drinking Water Act required the establishment of national standards for all public water supplies.

(1) The National Interim Primary Drinking Water Standards were established for contaminants known to have adverse effects on human health. Compliance with the maximum contaminant levels (M CL) which comprised the primary standards is compulsory and enforceable by States having approved programs or by the U.S. EPA. Secondary standards will be established to regulate parameters such as color and odor with recommendations being made as guidelines to states for the further protection of public welfare.

(2) The major impact of the Safe Drinking Water Act on waste management is the inclusion of restrictions on underground injection of wastes. All aquifers or portions of aquifers currently serving as drinking water sources are designated for protection under these regulations. In addition, any other aquifer which is capable of yielding water containing 10,000 mg/L or less of total dissolved solids also comes under these regulations. Permits will be required for all wells which are used for the injection of wastes. Permit holders' will be responsible for maintaining injection wells in such a manner to prevent the contamination of drinking water supplies.

f. Other pertinent federal legislation.

(1) The Toxic Substances Control Act (TSCA) of 1976 requires control of chemicals which have a known adverse effect on human health. Some provisions of this Act relate specifically to the handling of polychlorinated biphenyls (PCB'S).

(2) Pesticides are specifically regulated under provisions of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as amended by the Federal Environmental Pesticide Control Act (FEPCA) of 1972 and the FIFRA Amendments of 1975. This Act is important in that it requires registration of all new pesticide products and provides for Federal control over the use of pesticides.

(3) The Marine Protection, Research and Sanctuaries Act of 1972 regulates the transportation for dumping and the dumping of material into ocean waters. This would prohibit transporting wastewater or wastewater treatment sludge to the open seas for dumping without a permit.

(4) The Comprehensive Environmental Response, Compensation and Liability Act of 1980 establishes responsibility and penalties for discharge or release of hazardous substances into the environment. This includes release into a body of water or onto land.

4-3. The NPDES Permit System

a. Legislative authorization. The Environmental Protection Agency was authorized under Section 402 of the Federal Water Pollution Control Act to establish a national permit program to control the discharge of pollutants into the nation's waterways. The National Pollutant Discharge Elimination System (NPDES) is the primary mechanism for the Federal enforcement of effluent limitations and State water quality standards. According to NPDES regulations, discharges into navigable waters from all point sources of pollution including industrial discharges, the effluent from municipal treatment plants, and large agricultural feed lots must have an NPDES permit to lawfully discharge wastewaters. Industrial discharges to municipal treatment systems are not required to have NPDES permits; however, such dischargers are required to meet certain pretreatment standards as discussed later in this chapter. Although a Federal program, it is the intent of the program that the authority and responsibility be delegated to each State, when the States enact legislation and provide adequate staff to enforce the system.

(1) Penalties for non-compliance. The NPDES permit, in essence, is a contract between a discharger and the government. Substantial penalties for failure to comply with this permit are provided by Federal law. If a discharger violates the terms of a permit or makes illegal discharges without a permit, civil penalties up to $10,000 per day may be levied by the permitting authority. Negligent violations may be punished by fines up to $50,000 per day and up to two years in prison.

(2) Permit duration. Permits are issued for periods of up to five years in duration. Holders of NPDES permits must apply for reissuance of the permit at least 180 days before expiration of the current permit. Detailed regulations and procedures regarding the NPDES system have been issued by the U.S. EPA and are listed in Title 40 of the Code of Federal Regulations.

(3) Enforcement of permit. The U.S. EPA can take enforcement action against a discharger who is in violation of his permit if the appropriate State agency fails to do so. The U.S. EPA can also revoke a State's permitting authority if the program is not administered in compliance with federal requirements.

b. *Permitting of Federal facilities.* The FWPCA requires that all U.S. Government agencies comply with Federal, State, interstate, and local water pollution control laws and regulations. This compliance will be in the same manner and to the same extent as any non-governmental entity. As such, Federal installations discharging pollutants into water bodies are covered by the NPDES permit system and, therefore, may be permitted by the U.S. EPA and/or the State in which the facility is located. Compliance with any interstate or local water pollution regulations is required, if these regulations are different from Federal or State regulations. The compliance of federal facilities was further amplified by Executive Order 12088, Federal Compliance with Pollution Control Standards, whereby each executive agency is required to obey pollution control laws and regulations.

(1) Exemptions. The Act gives the President the authority to exempt any Federal effluent source from compliance if it is in the national interest to do so. However, no exemption may be granted from new source performance standards and effluent standards for toxic pollutants, or from compliance with pretreatment standards for wastes going directly into municipal treatment systems. The President may not grant an exemption because of a lack of funds to bring a Federal facility into compliance unless he has specifically asked Congress for the funds and Congress has failed to appropriate the money. The Act also requires the President to report annually to Congress all exemptions granted with the reason for each exemption. In addition to exemptions from particular effluent limitations, the President may issue regulations exempting military operations, including weaponry, equipment, aircraft, vessels and vehicle operations from compliance with requirements pertaining to other Federal facilities. This exemption may serve to limit access to the military property by regulatory agencies. Such exemptions may also be granted for military operations due to lack of appropriation of the required funds.

(2) Cooperation with local agencies. Federal facilities, such as U.S. military installations are required to cooperate with local authorities in the development of area-wide wastewater management plans. In developing wastewater treatment facilities, Federal facilities must also consider utilizing innovative treatment processes and techniques. For new treatment works at Federal facilities, the use of innovative treatment processes and techniques must be employed unless the life-cycle cost of the innovative treatment alternative exceeds that of the most cost-effective alternative by 15 percent. The innovative treatment process and techniques shall include but not be limited to methods for materials recycle and reuse and land treatment. The U.S. EPA Administrator may waive this requirement if he determines it is in the public interest to do so.

(3) Foreign facilities. If Federal facilities are located outside the United States, they shall comply with environmental pollution control standards of general applicability in the host country or jurisdiction. In many countries, no appropriated water pollution control regulations exist. In such cases, water quality management principles discussed herein shall be considered as a general guide in establishing treatment requirements.

(4) Federal facilities coordinator. By executive order of the President, the U.S. EPA maintains a national Federal facilities coordinator and staff to work with Federal facilities in the implementation of the Clean Water Act. The coordinator and his staff work in the Office of Program and Management Operations of the U.S. EPA Office of Enforcement in Washington, D.C. In addition, a Federal facilities coordinator is located in each U.S. EPA regional office.

c. *Content of a permit.* The NPDES permit establishes specific effluent limitations which must be met by the discharger and places on the discharger the obligation to report any cases of non-compliance with these conditions to the permitting authority. The elements included in the permit include the following:

(1) Effluent limitations and monitoring requirements. This section will contain the specific constituents present or suspected to be present in the wastewater, numerical effluent limitations for each constituent, and monitoring required of the discharger. Effluent limitations are usually expressed as a "monthly average" which consists of the average over a 30-day operating period and a "daily maximum" which cannot be exceeded in the monitoring period. Effluent limitations are usually expressed in mass/time units (lb/day or kg/day), although limits for some constituents are expressed in concentration-related units.

(2) Schedule of compliance. If a permit holder cannot be in compliance with the final effluent limitations at the time the permit is issued, a schedule of compliance will be established during which time the permit holder must upgrade his water pollution control facilities.

(3) Monitoring and reporting. Instructions are given for monitoring of the waste discharge, reporting of the monitoring results, retention of records, etc.

(4) Responsibilities. The permit holder is advised of additional responsibilities regarding the right of the regulatory agency to enter the premises from which the waste is discharged, transfer ownership of the facilities, and the availability of reports submitted to the regulatory authority.

(5) Management requirements. Additional conditions regarding permit compliance are enumerated in this section. The permit holder is advised to report any changes in the nature of the discharge or non-compliance with the permit conditions to the applicable regulatory agency. Additional instructions are given regarding bypassing of facilities, modification of the permit, revisions in the permit to insure compliance with toxic pollutant discharges, civil and criminal liability, oil and hazardous substance liability, compliance with State laws, etc.

d. Permit modification suspension or revocation. The NPDES permit may be modified, suspended, or revoked if terms of the permit are violated; if the permit holder made misrepresentations to the permitting authority in obtaining the permit; or if all relevant data regarding the discharge were not disclosed at the time the permit application was made. Due to the detailed nature of permit requirements, legal advice may at times be advisable in determining compliance or non-compliance with stated permit conditions.

e. Applying for a permit. Many States now have obtained the NPDES permitting authority from the U.S. EPA. Therefore, the appropriate State or U.S. EPA regional office must be first contacted in the permit application process. The basic procedure which must be followed for issuance of a permit is as follows:

(1) The applicant must obtain and complete an NPDES Application for Permit to Discharge. Completed application forms should be filed with the appropriate U.S. EPA Regional Office.

(2) After receiving the permit application, the U.S. EPA Regional Office and/or State agency will evaluate the form, request additional information if required, and may inspect the site of the proposed discharge.

(3) The State or U.S. EPA will send a copy of the permit application to other state and/or federal agencies for comments.

(4) A draft permit will be developed which will contain all the provisions proposed by the agency for the final permit.

(5) Public notice is given of the agencies' intention to issue or deny the permit. Following the public notice, a minimum of 30 days is provided to receive comments on the draft permit. Based on comments that are received, a public hearing regarding the proposed permit may be held.

(6) The final permit is issued based on information available in the "administrative record". The administrative record includes the permit application, draft permit, supporting documents, correspondence, and other information which has been received by the agency regarding the proposed permit. This record is open to the public for inspection and copying. For a period of 30 days following issuance of the final permit, interested parties including the permit holder may contest the permit by filing a request for an evidentiary or panel hearing. Uncontested permits become effective 30 days following issuance of the final permit.

4-4. Establishment of Effluent Limitations for NPDES Permits

a. Technology based limitations. Section 301 of the Clean Water Act provides for the establishment of technology-based effluent limitations. Each industrial point source category listed in table 4-1 is to have effluent limitation guidelines established which set forth the degree of reduction of applicable pollutants that is attainable through the application of various levels of treatment technology. Many of the primary industries plus other categories at present have limitations promulgated. U.S. EPA permit writers are instructed to use "engineering judgment" in establishing similar effluent limitations for those industrial categories which have no guidelines established. For municipal dischargers, U.S. EPA has established a definition of "secondary treatment" which essentially defines a level of technology which must be applied for the treatment of these wastewaters. These effluent limitations establish a minimum level of treatment acceptable for direct discharge to waterways.

*Table 4-1. NPDES primary industry categories**

Adhesives and Sealants
Aluminum Forming
Auto and Other Laundries
Battery Manufacturing
Coal Mining
Coil Coating
Copper Forming
Electrical and Electronic Components
Electroplating
Explosives Manufacturing
Foundries
Gum and Wood Chemicals
Inorganic Chemicals Manufacturing
Iron and Steel Manufacturing
Leather Tanning and Finishing
Mechanical Products Manufacturing
Nonferrous Metals Manufacturing
Ore Mining
Organic Chemicals Manufacturing
Paint and Ink Formulation
Pesticides
Petroleum Refining
Pharmaceutical Preparations
Photographic Equipment and Supplies
Plastics Processing
Plastic and Synthetic Materials Manufacturing
Porcelain Enameling
Printing and Publishing
Pulp and Paper Mills
Rubber Processing
Soap and Detergent Manufacturing
Steam Electric Power Plants
Textile Mills
Timber Products Processing

*Effluent guidelines have been and will be established for categories in addition to the primary industries.

Source: "NPDES Permits Regulations", 40 CFR Part 122, Appendix A.

b. *Water quality limitations.* In addition to meeting the minimum level of treatment established by the technology-based effluent limitations, all discharges must, according to Section 302 of the Act, be of sufficient quality to provide for the attainment or maintenance of stream water quality to protect downstream uses as established by the State regulatory agency. Portions of streams which have insufficient assimilative capacity to accept a waste discharge treated to the level required by the technology-based effluent limitation are referred to as "water quality limited segments" and the effluent limitations determined for these discharges are referred to as water quality-based limitations.

c. *Technology-based limitations for industry.* The 1972 amendments to the Clean Water Act specified that industries must employ "best practicable control technology currently available" (BPCTCA or BPT) as a minimum level of treatment no later than July 1, 1977 and that wastes must be treated using "best available technology economically achievable" (BATEA or BAT) by July 1, 1984. The 1977 amendments to the Act substantially revised requirements for achieving treatment levels in excess of BPT. As of the time of this document publication, two bills were under consideration in Congress (HR 3282, Water Quality Renewal Act and S 431, Clean Water Act amendments) to reauthorize the Clean Water Act. The levels of treatment required according to the technology-based standards for industries and the dates by which these levels of treatment will be required are summarized below.

(1) Best practicable technology was required of all industries by July 1, 1977. U.S. EPA has defined BPT as "the average of the best existing performance by well-operated plants within each industrial category or sub-category". BPT emphasizes end-of-pipe treatment technologies, but can also include alternative in-plant modifications to reduce pollutant discharges. In determining BPT requirements, U.S. EPA was instructed to strike a balance between the total cost of treatment and the benefits of effluent reductions achieved.

(a) BPT as well as BAT regulations set effluent limitations for total toxic organics (TTO) which is defined by the regulations as the summation of all values greater than 0.01 mg/L of the toxic organics listed in table 4-2. The regulations indicate that the control authority (State or Federal) may eliminate monitoring for TTO upon certification of the discharge that concentrated toxic organics have not been dumped into the wastewater and that a solvent management plan is followed. However, to eliminate monitoring requirements, the discharger must submit a solvent management plan that specifies the toxic organic compounds used, the method of disposal used instead of dumping and the procedures employed to prevent discharge into the wastewater. If monitoring is required it would be limited to the specific compounds likely to be present.

(b) At the time this manual was written, BPT Standards were available for the following point-source discharge categories of concern.

Table 4-2. Toxic organics

Acenaphthene
Acrolein
Acrylonitrile
Benzene
Benzidine
Carbon tetrachloride (tetrachloromethane)
Chlorobenzene
1,2,4-trichlorobenzene
Hexachlorobenzene
1,2-dichloroethane
1,1,1-trichloroethane
Hexachloroethane
1,1-dichloroethane
1,1,2-trichloroethane
1,1,2,2-tetrachloroethane
Chloroethane
Bis(2-chloroethyl) ether
2-chloroethyl vinyl ether (mixed)
3-chloronaphthalene
2,4,6-trichlorophenol
Parachlorometa cresol
Chloroform (trichloromethane)
2-chlorophenol
1,2-dichlorobenzene
1,3-dichlorobenzene
1,4-dichlorobenzene
N-nitrosodi-n-propylamine
Pentachlorophenol
Phenol
Bis(2-ethylhexyl)phthalate
Butylbenzyl phthalate
Di-n-butyl phthalate
Di-n-octyl phthalate
Diethyl phthalate
Dimethyl phthalate
1,2-benzanthracene
(benzo(a)anthracene)
Benzo(a)anthracene)
3,4-Benzofluoranthene (benzo(b)fluoranthene)
11,12-benzofluoranthene (benzo(k)fluoranthene)
Chrysene
Acenaphthylene
Anthracene
1,12-benzoperylene (Benzo(ghi) perylene)
Fluorene
1,2,5,6-dibenzanthracene (dibenzo(a,h)anthracene
Indeno(1,2,3-cd)pyrene (2,3-o-phenlene pyrene)
Pyrene
Tetrachloroethylene
Toluene
Trichlorethylene
Vinyl chloride (chloroethylene)
3,3-dichlorobenzidine
1,1-dichloroethylene
1,2-trans-dichloroethylene
2,4-dichlorophenol
1,2-dichloropropane (1,3-dichloropropene)
2,4-dimethylphenol
2,4-dinitrotoluene
2,6-dinitrotoluene
1,2-diphenylhydrazine
Ethylbenzene
Fluoranthene
4-chlorophenyl phenyl ether
4-bromophenyl phenyl ether
Bis(2-chloroisopropyl)ether
Bis(2-chloroethyoxy) methane
Methylene chloride (Dichloromethane)
Methyl chloride (Chloromethane)
Methyl bromide (bromomethane)
Bromoform (tribromomethane)
Dichlorobromomethane
Chlorsibromomethane
Hexachlorobutadiene
Hexachlorocyclopentadiene
Isophorone
Naphthalene
Nitrobenzene
2-nitrophenol
4-nitrophenol
2,4-dinitrophenol
4,6-dinitro-o-cresol
N-nitrosodimethylamine
N-nitrosodimethylamine
Aldrin
Dieldrin
Chlordane (technical mixture and metabolites)
4,4-DDT
4,4-DDE (p,p-DDX)
4,4-DDD (p,p-TDE)
Alpha-endosulian
Beta-endosulfan
Endosulfan sulfate
Endrin
Endrin aldehyde
Heptachlor
Heptachlor epoxide (BHC-hexachlorocyclohexane)
Alpha-BHC
Beta-BHC
Gamma-BHC
Delta-BHC
(PCB-polychlorinated biphenyls)
PCB-1242 (Arochlor 1242)
PCB-1254 (Arochlor 1254)
PCB-1221 (Arochlor 1221)
PCB-1232 (Arochlor 1232)
PCB-1248 (Arochlor 1248)
PCB-1260 (Arochlor 1260)
PCB-1015 (Arochlor 1016)
Toxaphene
2,3,7,8-tetrachlorodibenzo-p-dioxin(T)DD)

—Hospitals (40 CFR Part 460).
—Metal finishing (40 CFR Part 433).
—Explosives manufacturing (40 CFR Part 457).
—Photographic processing (40 CFR Part 459).

The existing regulations are summarized in table 4-3.

(c) Laundries have been exempted by the U.S. EPA from both BPT, and BAT guidelines and no national standards will be forthcoming. However, in the absence of categorical standards U.S. EPA expects to provide a guidance document.

(2) Best conventional pollutant control technology (BCT) was to be required of all industries by July 1, 1984. BCT will include levels of treatment for "conventional pollutants," usually in excess of the BPT requirements. Conventional pollutants include BOD, total suspended solids, fecal coliforms, pH, and oil and grease. The proposed Water Quality Renewal Act would change this deadline to July 1, 1987.

(3) Industries were to provide BAT treatment for the control of "toxic pollutants" no later than July 1, 1984. The list of toxic pollutants is presented in table 4-4. For these substances U.S. EPA must promulgate effluent limitations consistent with best available treatment technology. In the future, U.S. EPA may add to or delete from this list. Information relating to such additions is published in the Federal Register. In January, 1980 U.S. EPA made a proposal to add ammonia to this list. At the time this manual was written, no final decision had been made regarding the status of ammonia as a toxic pollutant. Best available technology has been defined as the highest degree of technology and treatment measures capable of being designed for plant-scale operation. BAT requirements may be developed around in-plant process changes to achieve specified effluent limitations in addition to end-of-pipe treatment.

(a) BAT Standards for hospitals had been reserved with U.S. EPA concentrating resources on more significant categories of industrial discharge with no activity foreseen in the near future.

(b) Explosives manufacturing and photographic processing have been exempted from BAT Regulations, with U.S. EPA prefering not to publish national guidelines. Such facilities or operations will be regulated on a site specific case-by-case basis. However, in the absence of categorical standards, U.S. EPA does expect to publish guidance documents for these industries.

(c) BAT Standards for the metal finishing point source category (40 CFR Part 433) are given in table 4-5. The regulations are inclusive of electroplating operations addressed separately under 40 CFR Part 413 which deals only with pretreatment standards.

(4) Compliance with BAT limitations for "non-conventional pollutants" must be accomplished within three years of promulgation, but no later than July, 1987. Non-conventional pollutants are defined as all other pollutants which are not specifically identified as conventional or toxic.

(5) New industrial facilities classified as "new sources" must meet New Source Performance Standards (NSPS) from the time the facility is placed into operation. NSPS limitations are based upon "best available demonstrated technology" (BADT). A "new source" for regulatory purposes is defined as an industrial category for which new source performance standards were issued prior to the initiation of construction of the facility. These limitations apply to grass roots facilities, significant modifications to existing facilities, and additions of new facilities at existing plant sites which function independently of an existing plant.

d. Best management practices. The 1977 amendments authorized the U.S. EPA to require best management practices (BMP) of industries to control discharges of toxic or hazardous wastes from ancillary industrial activities. U.S. EPA may prescribe regulations to control plant site runoff, leaks and spills, sludge and waste disposal practices, and drainage from raw material storage areas which are associated with industrial manufacturing or treatment operations. BMP regulations were proposed in August, 1978 and final regulations were promulgated as Subpart K of the final NPDES regulations. However, implementation of these regulations has been delayed due to a court challenge. U.S. EPA has prepared a BMP guidance document to assist in the preparation of BMP requirements for NPDES permits. As of the writing of this manual, U.S. EPA intends to withdraw the BMP regulations.

e. *Secondary treatment standards for municipal dischargers.* Municipal dischargers were required to achieve secondary treatment levels by July 1, 1977. U.S. EPA has defined secondary treatment as shown in table 4-6. Exceptions to these requirements may be granted for facilities which discharge to the ocean. All municipal treatment facilities were to meet best practicable treatment technology by July 1, 1983. At the time this manual was written, U.S. EPA had not defined applicable BPT requirements for municipal treatment systems.

Table 4-3. Existing BPT effluent guidelines for point sources

Point Source Discharge	Regulation	Effluent Characteristic	Limitation: Daily Maximum, Metric Units	Limitation: Daily Maximum, English Units	Limitation: 30 Consecutive Day Average, Metric Units	Limitation: 30 Consecutive Day Average, English Units
Metal Finishing	40 CFR 433	Cd(T)[a]	0.69		0.26	
		Cr(T)	2.77		1.71	
		Cu(T)	3.38		2.07	
		Pb(T)	0.69		0.43	
		Ni(T)	3.98		2.38	
		Ag(T)	0.43		0.24	
		Zn(T)	2.61		1.48	
		CN(T)	1.20		0.65	
		TTO[b]	2.13		--	
		Oil & Grease	42		26	
		TSS	60		31	
		pH	6.0-9.0		6.0-9.0	
Units - mg/L except pH [a](T) - Total [b](T) - Total Toxic Organics						
Explosives Manufacturing Plants	40 CFR Part 457	COD	7.77	7.77	2.59	2.59
		BOD_5	0.72	0.72	0.24	0.24
		TSS	0.25	0.25	0.084	0.084
		pH	6.0-9.0	6.0-9.0	--	--
Load, Assemble, Pack Plants		Oil & Grease	0.11	0.11	0.035	0.035
		TSS	0.26	0.26	0.088	0.088
		pH	6.0-9.0	6.0-9.0	--	--
Metric Units = Kilograms/1,000 kg of product English Units = Pounds/1,000 lb of product						
Photographic Processing	50 CFR Part 459	Ag	0.14	0.030	0.07	0.015
		CN	0.18	0.038	0.09	0.019
		pH	6.0-9.0	6.0-9.0	--	--
Regulations do not apply to facilities processing 1,600 sq ft of film/day or less Metric Units = kg/1,000 sq m of product English Units = lb/1,000 sq ft of product						
Hospitals	40 CFR Part 460	BOD_5	41.0	90.4	33.6	74.0
		TSS	55.6	122.4	33.8	74.5
		pH	6.0-9.0	6.0-9.0	--	--
Metric Units = Kilograms/1,000 occupied beds English Units = Pounds/1,000 occupied beds						

Table 4-4. Toxic pollutants

Acenaphthene
Acrolein
Acrylonitrile
Aldrin Dieldrin
Antimony and compounds*
Arsenic and compounds
Asbestos
Benzene
Benzidine
Beryllium and compounds
Cadmium and compounds
Carbon tetrachloride
Chlordane (technical mixture and metabolites)
Chlorinated benzenes (other than dichlorobenzenes)
Chlorinated ethanes(including 1,2-dichloroethane, 1,1,1-trichloroethane, and hexachloroethane)
Chloroalkyl ethers (chloromethyl, chloroethyl, and mixed ethers)
Chlorinated naphthalene
Chlorinated phenols (other than those listed elsewhere; includes trichlorophenols and chlorinated cresols)
Chloroform
2-chlorophenol
Chromium and compounds
Copper and compounds
Cyanides
DDT and metabolites
Dichlorobenzenes (1,2-, 1,3-, and 1,4-dichlorobenzenes)
Dichlorobenzidine
Dichloroethylenes (1,1- and 1,2-dichloroethylene)
2,4-dichlorophenol
Dichloropropane and dichloropropene
2,4-dimethylphenol
Dinitrotoluene
Diphenylhydrazine
Endosulfan and metabolites
Endrin and metabolites
Ethylbenzene
Fluoranthene
Haloethers (other than those listed elsewhere includes chlorophenylphenyl ethers, bromophenylphenyl ether, bis(dischloroisopropyl) ether, bis-(chloroethoxy) methane and polychlorinated diphenyl ethers)
Halomethanes (other than those listed elsewhere includes methylenechloridmethylchloride, methylbromide, bromoform, dichlorobromomethane,trichlorofluoromethane,dichlorodifluoromethane)
Heptachlor and metabolites
Hexachlorobutadiene
Hexachlorocyclohexane (all isomers)
Hexachlorocyclopentiadiene
Isophorone
Lead and compounds
Mercury and compounds
Naphthalene
Nickel and comounds
Nitrobenzene
Nitrophenols (Including 2,4-dinitrophenol) dinitrocresol)
Nitrosamines
Pentachlorophenol
Phenol
Phthalate esters
Polychlorinated biphenyls (PCSs)
Polynuclear aromatic hydrocarbons (including benzanthracenes, benzopyrenes.benzofluoranthene, chrysenes, dibenzanthracenes, and indenopyrenes)
Selenium and compounds
Silver and compounds
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)
Tetrachloroethylene
Thallium and compounds
Toluene
Toxaphene
Trichloroethylene
Vinyl chloride
Zinc and compounds

Table 4-5. BPT and BAT standards for metals finishing (mg/L)

Parameter	BPT Daily Maximum	BPT 30 Day Average	BAT Daily Maximum	BAT 30 Day Average
Cadmium (T)[a]	0.69	0.26	0.69	0.26
Chromium (T)	2.77	1.71	2.77	1.71
Copper (T)	3.38	2.07	3.38	2.07
Lead (T)	0.69	0.43	0.69	0.43
Nickel (T)	3.98	2.38	3.96	2.38
Silver (T)	0.43	0.24	0.43	0.24
Zinc (T)	2.61	1.48	2.61	1.48
Cyanide (T)	1.20	0.65	1.20	0.65 “
TTO[b]	2.13		2.13	--
Oil and Grease	52	26	--	--
TSS	60	31	--	--
pH				
Cyanide (A)[d]	0:86	0:32	0.86	0.32

All values in mg/L except pH.

[a] (T) = Total

[b] TTO = Total Toxic Organics, which is the summation of all value greater than 0.1 mg/L for toxic organics.

[c] Within 6.0 to 9.0 standard units.

[d] A means amenable to alkaline chlorination. This value is an alternative cyanide value for industrial facilities with cyanide treatment.

Source: 40 CFR Part 433.

Table 4-6. U.S. EPA secondary treatment standards for municipal dischargers

Parameter	Effluent Concentration Monthly Average	Effluent Concentration Weekly Average	Minimum Removal (%)
BOD (mg/L)	30	45	85
TSS (mg/L)	30	45	85
Fecal Coliforms (organisms/100 mL)	200	400	—
pH	Value must be between 6.0 and 9.O at all times.		

f. Water quality determined effluent limitations. The Clean Water Act contains specific provisions for the establishment of efflulent limitations more stringent than technology-based guidelines where necessary for the maintenance of water quality standards in a stream. The Act also required the attainment of “fishable-swimmable” water quality across the nation by 1985. Treatment facilities located either in areas where the number and quantity of discharges is large compared to the flow in the stream or along waterways where very stringent quality standards have been established may be required to provide a level of treatment considerably higher than that required by technology-based standards or by the U.S. EPA secondary treatment criteria. Present criteria for the establishment of these water quality determined effluent limitations are contained in *Quality Criteria for Water.* Typically, establishment of water quality determined limitations requires mathematical modeling of the stream to establish the allowable discharge at low flow conditions. Water quality modeling is not an exact science and significant room for negotiation usually exists in establishing effluent limitations which are compatible with the required stream water quality.

4-5. Pretreatment of industrial wastes discharged to municipal treatment systems

a. Pretreatment programs. The Clean Water Act authorizes the U.S. EPA to establish pretreatment standards for industries discharging wastewaters to municipal treatment systems. Municipalities receiving industrial wastes must develop local pretreatment programs which are described in the U.S. EPA pretreatment regulations.

(1) Photographic processing, explosives manufacturing, laundries, and hospitals. Photographic processing, explosives manufacturing, and laundries having been exempted from BAT Standards were also exempted from national guidelines for pretreatment standards. In addition, no pretreatment standards are expected for hospitals. The U.S. EPA expects that these standards will be set by state and local requirements.

(2) Electroplating and metal finishing. Pretreatment standards for electroplating (40 CFR Part 413) and metal finishing (40 CFR Part 433) are in effect and include regulation of TTO as discussed above. The standards applicable to electroplating are presented in tables 4-7 and 4-8. The regulations indicate that after October 12, 1982, no user introducing wastewater to a POTW may change the use of process wastewater or dilute the wastewater as a partial or total substitute for adequate treatment to achieve compliance with the standard. The pretreatment standards for metal finishing are summarized in table 4-9. These standards cover both existing and new sources. Note that the only difference between the existing and new source category is the stricter limitation proposed for cadmium.

Table 4-7. Pretreatment standards for electroplating point source category, existing sources, all subcategories, discharge of 10,000 gpd or less

	Basic Standard (mg/L)		
Parameter	Daily Maximum	4 Day Average	30 Day[a] Average
CN, A[b]	500	2.7	1.5
Pb	0.6	0.4	0.3
Cd	1.2	0.7	0.5
TTO[c]	4.57		

Applicable only with consent of the controlling authority, in the absence of strong chelating agents, after reduction of hexavalent chrome, and after neutralization using calcium oxide or hydroxide.

applicable to discharges combined with regulated discharges that have 30-day average standards.

[b] CN, A = Cyanide Amendable to Chlorination

[c] TTO = Total Toxic Organics, standards reported are proposed.

Source: 40 CFR Part 413

Table 4-8. Pretreatment standards for electroplating point source category, existing sources, all subcategories, discharges of 10,000 gpd or more

	Basic Standard (mg/L)			Mass Based Standard (mg/sq m - operation)[b]			Optional Standard[a] (mg/L)		
Parameter	Daily Maximum	4 Day Average	0 Day[b] Average	Daily Maximum	4 Day Average	30 Day[b] Average	Daily Maximum	4 Day Average	30 Day Average
CN, T[c]	1.9	1.0	0.55	74	39	21	1.9	1.0	0.55
Pb	0.6	0.4	0.3	23	16	12	0.6	0.4	0.3
Cd	1.2	0.7	0.5	47	29	20	1.2	0.7	0.5
Cu	4.5	2.7	1.8	176	105	70			
Ni	4.1	2.6	1.8	160	100	70			
Cr	7.0	4.0	2.5	273	156	98			
Zn	4.2	2.6	1.8	164	102	70			
Ag[d]	1.2	0.7	0.5	47	29	20			
Total Metals[e]	10.5	6.8	5	410	267	195			
pH								7.5-10.0	
TTO[f]	2.13						2.13		
TSS							20.0	13.4	10

applicable only with consent of the controlling authority, in the absence of strong chelating agents, after reduction of hexavalent chrome and after neutralization using calcium oxide or hydroxide.

[b] Applicable to discharges combined with regulated discharges that have 30-day average standards.

[c] CN, T = Total Cyanide

[d] Applicable to precious metals subcategory only.

[e] Total Metals = Sum of the concentration or mass of Cu, Ni, Cr(T) and Zn.

[f] TTO = Total Toxic Organics, standards reported are proposed.

Source: 40 CFR Part 413

Table 4-9. Pretreatment standards metal finishing

	Existing Sources (mg/L)		New Sources (mg/L)	
Parameter	Daily Maximum	30 Day Average	Daily Maximum	30 Day Average
Cd (T)[a]	0.69	0.26	0.11	0.07
Cr (T)	2.77	1.71	2.77	1.71
Cu (T)	3.38	2.07	3.38	2.07
Pb (T)	0.69	0.43	0.69	0.43
Ni (T)	3.98	2.38	3.98	2.38
Ag (T)	0.43	0.24	0.43	0.24
Zn (T)	2.61	1.48	2.61	1.48
CN (T)	1.20	0.65	1.20	0.65
TTO (T)[b]	2.13	--	2.13	
CN, A[c]	0.86	0.32	0.86	0.32

[a] (T) Means total

[b] TTO = Total Toxic Organics

[c] CN, A means amenableto alkaline chlorination. This limit may apply in place of Cyanide (T) for industrial facilities with cyanide treatment.

Source: 40 CFR Part 433

b. Non-compliance pollutants. The U.S. EPA regulations prohibit or control certain discharges to municipal systems. Prohibited industrial discharges which apply to all industrial users of publicly owned treatment works (POTW's) are listed in table 4-10. Categorical standards are being developed by U.S. EPA and will specify maximum quantities of non-compatible pollutants which can be discharged to municipal systems. These limitations will be equal to or greater than best available treatment limitations for specified substances. Incompatible pollutants are defined as those substances which will require pretreatment to prevent interference with the operation of the POTW, contamination of sludge, or objectionable pass-through of the substance to a receiving stream or to the atmosphere. Exceptions to categorical pretreatment standards may be granted under certain conditions if the POTW has the capacity to handle adequately the non-compatible pollutant. The U.S. EPA has been directed to prepare categorical standards for industries which are listed in table 4-11.

Table 4-10. Prohibited industrial discharges to publicly owned treatment works (POTW'S)

1. Pollutants that create a fire or explosion hazard, such as fuels, solvents, etc.
2. Pollutants that cause corrosive structural damage, such as acids, bases, solvents, etc.
3. Any discharge with a pH less than 5 unless the POTW is specifically designed for same.
4. Pollutants in amounts that create obstructions to flow in rivers or to the operation of the POTW.
5. Any pollutant discharged in an amount or strength that interferes with the POTW.
6. Heat in an amount that interferes with the POTW.
7. Heat which causes the influent temperature to rise above 40°C.

Table 4-11. Industries for which initial categorical pretreatment standards are being written

- Auto and Other Laundries*
- Coal Mining
- Inorganic Chemicals*
- Iron and Steel*
- Leather Tanning and Finishing*
- Machinery and Mechanical Products
  - Battery Manufacturing*
  - Plastics Processing
  - Foundries*
  - Coil Coating
  - Porcelain Enameling
  - Aluminum Forming
  - Copper Products
  - Electric & Electronic*
  - Ship Building Metal Fabrication
  - Electroplating*
- Miscellaneous Chemical Mfg.
  - Pesticide Manufacturing
  - Photographic Products
  - Gum and Wood Chemicals*
  - Pharmaceutical
  - Explosives*
  - Adhesives and Sealants
  - Carbon Black
- Nonferrous Metals*
- Ore Mining and Dressing
- Organic Chemicals
- Paint and Ink Formulation and Printing*
- Paving and Roofing Materials*
- Petroleum Refining
- Plastic and Synthetic Materials
- Printing and Publishing
- Pulp & Paper Products*
- Rubber Processing*
- Soap and Detergents
- Steam Electric Power Plants
- Textile Mills*
- Timber Products*

*Certain subcategories of industrial categories are exempt from regulation pursuant to paragraph 8 of the NRDC v. Costle consent decree.

CHAPTER 5

WASTEWATER MANAGEMENT PROGRAM FORMULATION

5-1. Introduction

a. General requirements. Developing a wastewater management program requires the evaluation of the quantity, quality, and location of wastes produced; the sizing and configuration of collection systems; and a determination of the degree of treatment required to comply with discharge or stream standards. This chapter describes the approach and principles used to define and meet specific system requirements. The major portion of wastes will be domestic, although most military systems contain at least some industrial wastes. Specific information on industrial wastes which may require special consideration is presented in chapter 6. Wastewater characteristics are discussed in chapter 3. There are some differences in approach used in assessing the need for modifying or upgrading an existing system compared with that used for establishing the requirements of new facilities. At most military installations, a wastewater management program will require upgrading treatment as opposed to construction of completely new facilities.

b. Planning cycle. As discussed in chapter 4, numerous regulations are imposed on the discharge of both domestic and industrial wastewaters and the safe disposal of solids generated in waste treatment. Since all such discharges are regulated by law, program formulation and solution development can be seen as problem-solving cycle beginning and ending with specific regulatory requirements. The planning cycle is presented schematically in figure 5-1 and discussed briefly below.

(1) Regulatory requirements. At both the beginning and end of the planning cycle, regulatory requirements in themselves define the ultimate objectives of any wastewater management program. The cycle may be triggered for one or a combination of the following reasons:

—Permit violations with existing systems requiring upgrading and/or new construction.

—New limitations requiring increased levels of treatment.

—The imposition of discharge limitations on non-conventional pollutants such as ammonia or chemical oxygen demand requiring the extension of existing or construction of new facilities.

—The imposition of discharge limitations on toxic pollutants not previously regulated and requiring a re-evaluation of existing processes and/or treatment methods.

—Limitations on the handling and disposal of hazardous wastes not previously identified but requiring immediate attention.

Once the program is in motion, it must be coordinated as applicable with local, State, interstate, and Federal agencies. The Federal Facilities Coordinator of the Regional U.S. EPA office having jurisdiction should be utilized as the point of contact for obtaining all applicable effluent requirements, for approval of treatment processes selected, and for securing of the required discharge or disposal permits.

(2) Problem identification/definition. The initial steps in identifying and defining a problem involve setting specific objectives, reviewing available data, and developing a program outline.

(a) Objectives. Program objectives, based on the previous step, are developed to establish general constraints on work to be performed. Such objectives should include, but may not be limited to identifying the following:

—Area or facilities to be served.

–Source, configuration, and location of waste sources in question.

—System components to be included such as lateral sewers, trunk sewers, and existing treatment facilities.

—Provision for future facilities.

–Process waste to be handled.

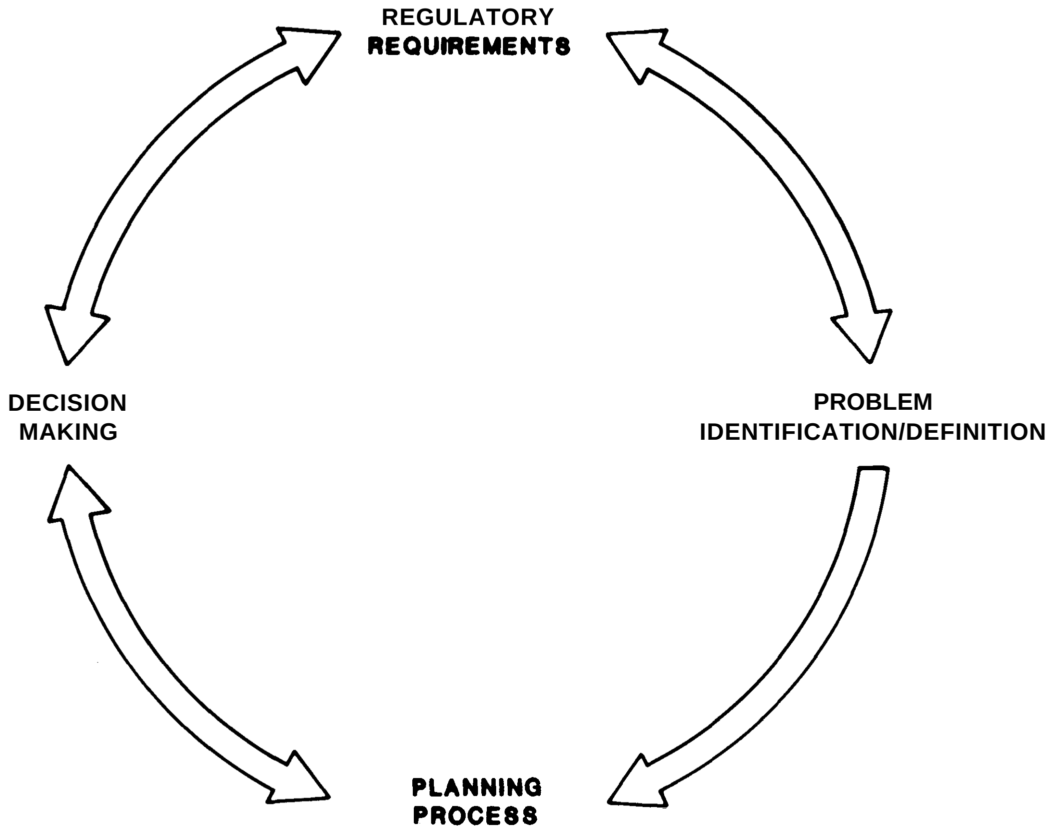
—Location of treated wastewater disposal.

–Location of treatment process residuals disposal.

–Specific modifications that may be required for existing systems.

—Any special considerations resulting from regulations and/or safety in handling specific process wastes (e.g., explosives, etc.).

(b) Data review. All available data should be reviewed. Specific information for new facilities may be limited to reports and preliminary plans of proposed construction plus quantitative data on the function and staffing of the installation. For modification, expansion, or upgrading of



DOUBLE HEADED ARROWS INDICATE FEED" BACK

REGULATORY REQUIREMENTS

PERMIT VISITATIONS
INCREASED LEVELS OF TREATMENT
LIMITS ON NONCONVENTIONAL POLLUTANTS
LIMITS ON TOXIC POLLUTANTS
LIMITS ON HAZARDOUS WASTE DISPOSAL
SPECIFIC TREATMENT NEEDS

PLANNING PROCESS

SOLUTION DEVELOPMENT
ALTERNATIVES DEVELOPMENT
COSTS DEVELOPMENT

PROBLEM iDENTIFICATION/DEFINITION

DEFINITION OF OBJECTIVES
DATA REVIEW
PROGRAM OUTLINE

DECISION MAKING

ALTERNATIVE REVIEW
NEGOTIATIONS
PROCESS SELECTION
FINANCIAL DECISIONS PROCUREMENT
IMPLEMENTATION

Figure 5-1. Program formulation problem solving cycle

existing facilities, additional data such as detailed system plans, design criteria, and operating records are generally required. Reference should be made to applicable planning guides and technical manuals (TM 5-803-1, TM 5-803–3, and TM 5-814-3), which stipulate requirements for sewerage and wastewater treatment at military installations. Military installations of a similar nature should be contacted to determine how similar problems have been addressed. The review should be conducted with a secondary purpose of defining and obtaining missing data or information.

(c) Program outline. After objectives have been developed and a review of available data and definition of missing information has been completed, a preliminary plan for implementing the wastewater management program should be formulated. The program outline prepared can be expected to vary depending on the types of facilities required. Typical types of facilities include the following:

—Upgrading existing wastewater management systems to correct deficiencies and/or modification to achieve a higher level of treatment.

— Wastewater management programs for completely new installations including facilities to meet mission requirements, personnel housing, and supporting service and recreational facilities.

—Treatment facilities to serve an addition of personnel housing with support facilities.

—Treatment and disposal facilities to serve an addition of a functional facility such as a major equipment maintenance center at a storage depot.

—Modification of an existing wastewater system for an installation where a change in mission of the facility changes the waste quality or quantity.

The above is not a complete list of facilities; however, it does illustrate the need for differences in the approach to program development.

(3) Planning process. Having clearly defined the program objectives and set general constraints on the work required, the planning process may begin. The typical course of the planning process is presented schematically in figure 5-2 with work elements proceeding in order from left to right. The specific work elements are aimed at problem solution, alternatives, and cost development.

(4) Decision making. As the project progresses, information is generally fed forward to decision makers controlling financial decisions, procurement, and project implementation. Feedback from decision makers based on initial reviews of alternatives and additional negotiations with regulatory agencies serves to direct the work in progress and ensure that ultimate objectives are met. The decision making process feeds forward to the original objectives and with implementation and procurement represents the final step in the process.

5-2. Water and wastewater inventory

a. Introduction. The water and wastewater inventory is an important part of any environmental control program. It provides a data base from which solutions to wastewater management problems can be developed. In any type of inventory, various waste streams are characterized for flow rate, concentration of pollutants and source. This information is essential in developing a treatment or abatement strategy and is required by Federal ‘Law for inclusion in an NPDES permit application. Military installations desiring to discharge into municipal sewage systems often must present the municipality with a complete wastewater characterization before connection will be considered.

(1) Inventory objectives. Due to the importance of such inventories, accurate, complete, and reliable survey information is essential. For this reason, the planner and the survey team should always keep in mind the major objectives of an industrial waste survey. These objectives are:

(a) To locate and inventory the waste sources.

(b) To quantify the waste sources in terms of pollutant concentrations, flows, and mass loadings.

(c) To classify the waste stream as: low strength, i.e., suitable for reuse or untreated discharge; incompatible or hazardous; valuable for recovery; amenable to or requiring treatment; or complex and/or high strength.

(d) To identify problem areas.

(e) To develop preliminary control philosophies and alternatives.

(2) Loadings and variability. The inventory of waste streams is necessary as a matter of record and to ensure that all waste streams have been considered. Quantifying each of the waste streams provides the basic waste load information required for selection of alternatives and design of treatment systems. Particular attention should be given to the variability of the waste stream quantities.

(3) Reviewing alternatives. In developing the survey data, the characteristics of each waste stream should be closely examined to determine potential alternatives for handling the stream. The first step in this process is to classify the waste stream. Low strength wastewaters “may be suitable for reuse elsewhere or for discharge without treatment. Incompatible waste streams may be hazardous, extremely difficult to treat when mixed with water or other wastes, or very easy to treat when not mixed with other wastes.

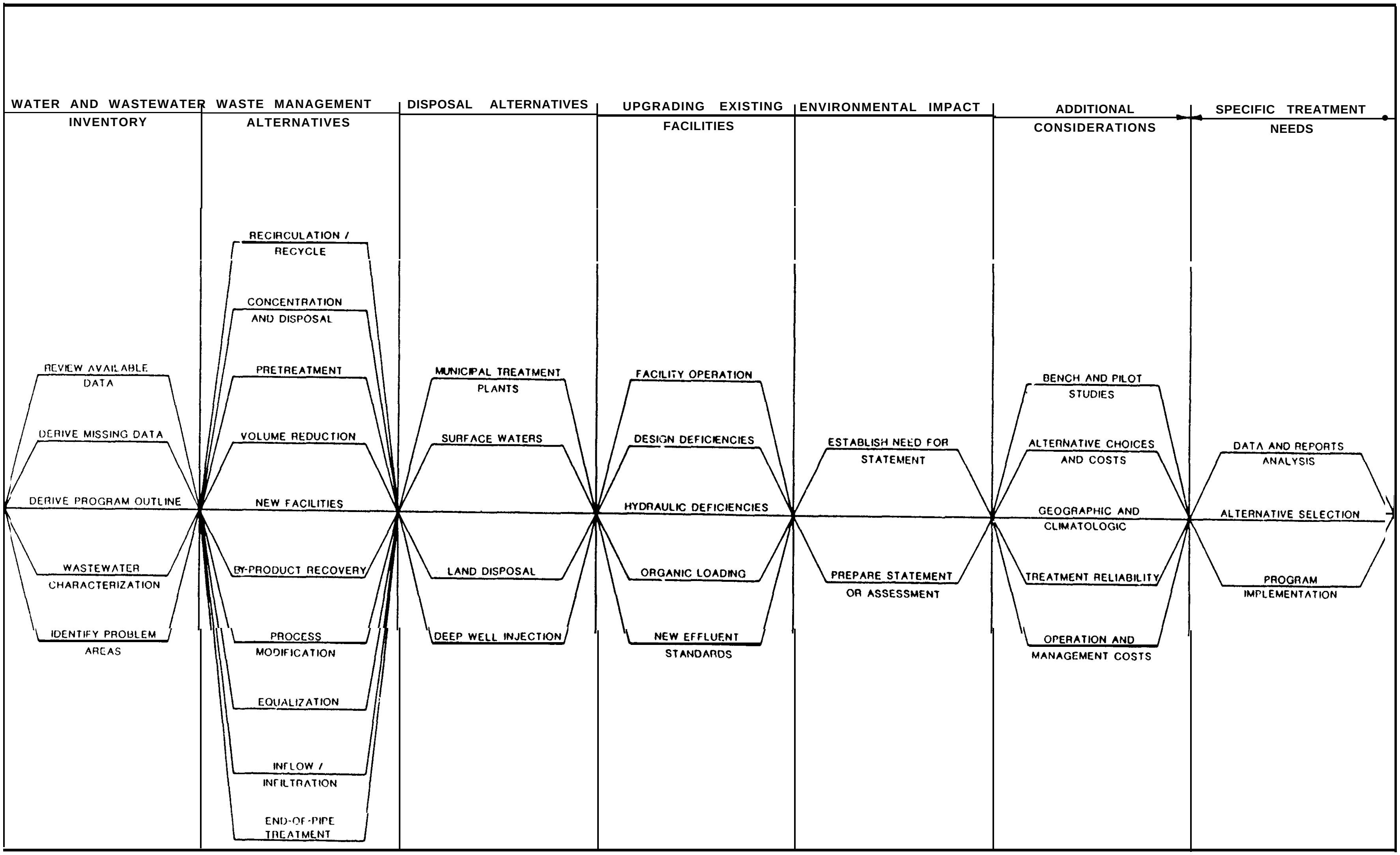


Figure 5-2. Factors to be considered in a wastewater management program.

Some wastewaters may contain valuable metals, oil, or other materials suitable for recovery. Waste streams amenable to or requiring treatment are moderate in strength and probably require no special consideration. High strength wastewaters may be a very complex mixture of substances or a highly concentrated source of a few constituents. In either case, the wastewater requires special consideration when it is included in a collection system where it will be diluted and probably more difficult to treat. Once problem areas have been identified, alternative control schemes should be assembled on a preliminary basis. This provides the starting point for an evaluation of the alternatives which will result in developing a solution to the problems.

b. Domestic waste. Domestic or sanitary wastewaters at military installations are derived from barracks, households, schools, hospitals, administrative buildings, and any other sources related to the general population served. Typical parameters required to define the size of domestic waste collection and treatment facilities include flow, BOD, suspended solids, phosphorus, and nitrogen content. Average daily per capita contributions are defined in TM 5-814-1 and TM 5-814-3. Data for BOD and suspended solids are tabulated in TM 5-814-3. Similarly, flow data are shown in TM 5–814-1. Combining per capita use, population and the capacity factor, sewage treatment facilities can be sized. Hydraulic characteristics of all facilities must be based on peak flows. The relationship between peaking factor and population is shown in TM 5-814-1. Most domestic water sources can discharge directly to the sewer system without pretreatment. However, some sources of domestic waste, such as food preparation facilities, may require preliminary treatment units such as grease removal or coarse screens to minimize problems in the sewers or at the treatment plant.

c. *Industrial waste.* Industrial or process wastes at military installations are produced by metal finishing operations, vehicle repair depots, photographic processing, munitions plants, laundries, and other similar facilities. Industrial chemicals and the by-products from these facilities contribute to the process wastewater. Reference should be made to chapter 3 in this manual for characteristics of wastes from these sources. In some instances, process wastes can be routed directly to sewers handling sanitary wastes without pretreatment. If the process waste contains a toxic compound, a hazardous compound, or excessive quantities of such materials as oil and grease, separate pretreatment is required. Wastes which cause sewer plugging, interfere with the treatment system, or pass through the system and cause contamination of the receiving stream should be kept out of the sanitary sewer until the interfering effect is eliminated. Flow and quality characteristics of process wastes which combine with sanitary waste must be included to yield total system capacity requirements. In some cases, process wastes are collected and treated in a separate system which discharges directly to the receiving stream.

d. Wastewater characterization. The use of published standard data for determining the magnitude of parameters for flow and waste constituents is normal practice; often no other data are available at new facilities. An adequate allowance is included in published standards to provide a factor of safety in system sizing. However, it is prudent to supplement this approach by also considering characterization of wastes from any similar existing facilities or installations. This latter approach can be implemented by examining laboratory records, data logs, and reports. Waste flows can also be determined by correlation with water use after adjustment for lawn watering, cooling losses, and other uses wherein water is not returned to the sewer. Wastewater characterization can also be accomplished by examining the industrial chemicals used in the processes contributing to the waste stream. To determine the constituents of the industrial chemicals, the appropriate Military Specification (MIL SPEC) should be examined and the quantity of each constituent verified.

5-3. Solution methodology

a. Alternative approaches. In order to solve a wastewater management problem, it is first necessary to define an approach to the problem. The approaches commonly employed are end-of-pipe control and in-plant control. End-of-pipe control usually involves collecting all the waste sources into one waste stream and designing treatment processes to remove the undesirable constituents. In-plant control involves handling wastes at their source either by modifying the source or by removing undesirable constituents while they are still concentrated. Often, the most attractive solution to a waste problem will be a combination of both abatement philosophies.

b. In-plant/source control. Control techniques for in-plant pollution abatement are usually oriented toward a single source. In developing such controls it is necessary to consider the means by which the waste is generated. In general, in-plant control consists of one or more of the following:

—Segregation.
—Recirculation and recycling.
—Disposal of concentrated residuals.
—Pretreatment.
—Reduction in volume or waste load.
—Process modification.

(1) Segregation. Segregation means isolating the waste streams originating from various sources or types of sources from others. Segregation usually involves controlling the manner in which wastes are collected. Often, segregation of waste streams is the key to implementing in-plant control because each source may require individual consideration. Segregation may be necessary before any of the other in-plant controls can be exercised. For example, in order to reclaim waste oils, it is necessary to collect used oil before it enters the sewer. Thus, segregation is the key to oil reclamation. Potential undesirable effects of segregation should also be considered. These arise whenever two streams which are complimentary in some respect are segregated. When an acidic stream is segregated from a basic stream pH adjustment problems may intensify. Similarly, warm and cold streams are sometimes better treated when combined due to temperature effects on treatment efficiency. A nutrient containing waste stream is desirable in a mixture of predominantly carbonaceous waste and should, therefore, not be segregated. All these and similar factors should be considered whenever segregation is contemplated.

(2) Water recirculation and recycling. In-plant control by recirculation and recycling refers to the reuse of wastewaters from some operation either within that operation or within another operation. Recirculation and recycling may require some form of local treatment in order to render the wastewater recyclable. An example of a case where treatment is not necessary would be heat recovery from laundry wastewater to preheat boiler water. An example of a waste that requires treatment before reuse would be the filtering of water in a wet spray booth scrubber before recycling. These operations will result primarily in reduced hydraulic loading of the treatment plant.

(3) Disposal of concentrated residuals. In some instances, wastes can be collected in a semi-dry or otherwise concentrated state and recovered for reuse or separate disposal. Potential benefits of special disposal are enhancement of end-of-pipe treatment due to a reduction in pollutional load or by elimination of toxic or otherwise hazardous material which may be detrimental to end-of-pipe treatment. Income can also be generated by the marketing of reclaimable substances such as oils or solvents.

(4) Pretreatment. Isolated waste streams may be treated locally for removal of specific constituents before discharge to the main collection system. Such pretreatment is possible in a vehicle maintenance area by installation of an oil/water separator on the sewer which collects floor washings. A number of treatment processes may be used for pretreatment as illustrated in table 5-1.

(5) Reduction in volume or waste load by better housekeeping. A close examination of most processes will reveal a number of operations which result in unnecessary dumping to the sewer. Needless flushing of spilled materials, emptying of old or used containers, running of unused hoses, and leaking of worn equipment are all examples where reduction can be effective. In many cases, good housekeeping practices, proper management, adequate supervision and everyday common sense can be applied to reduce waste discharges.

(6) Process modification. In considering the in-plant controls, a frequently overlooked method is modification of the operation which generates the waste. Modification can occur by either changing or replacing the equipment or materials employed in the operation. Equipment modification could involve repair, renovation or replacement of existing process machinery. An example of this would be to replace a wet scrubber with a cyclone or fabric filter to remove cinders from a waste paper incinerator. The replacement of chemicals and materials used with ones having less pollutional impact can also have a significant in-plant control.

(7) Combined sewers. Many sewer systems have served as combined sewers handling both sanitary and storm flows. In some instances, this was purposely planned to eliminate the need for two separate systems. However, this practice was implemented prior to the time when any significant waste treatment was required. Today, combined sewers do not exist to a significant extent on military installations and are prohibited in new construction. If a combined sewer is encountered during modification of an existing facility, the stormwater flow should be separated from the process flow.

(8) Cooling water. Water used for indirect cooling purposes (such as shell and tube heat exchangers) normally contains essentially no BOD or suspended solids. Once-through cooling waters can be diverted from the sanitary sewer system. For recirculating evaporative cooling systems,

Table 5-1. Example of waste load reductions by in-plant control

In-plant Control Method	Description of Modification	Flow Reduction		BOD Load Reduction	
		MGD	Percent	lb/day	Percent
Segregation and special disposal	Incineration of high strength organic streams	0.04	0.4	6,510	11.7
	Wet scrubber replaced with afterburner	0.30	2.7	560	1.0
Process modification	Repair and replacement of process equipment	1.60	14.4	4,650	8.3
	Unit shutdowns due to the age of the process or product*	0.25	2.2	1,860	3.3
Substitution	Use of raw materials with less pollutant load	0	0	560	1.0
Recycling	Reprocessing of specific wastestreams to recover more product and concentrate waste	0.01	0.1	560	1.0
Reduction	A number of small, varied projects	0.60	5.4	3,900	7.0
	Totals	2.8	25.2	18,600	33.3

*These were not caused by environmental considerations but they were a factor.

dissolved solids may be high and diversion may not be possible.

(9) Infiltration/inflow. Entry of storm flow and groundwater into the sewer system through faulty sewer lines or illicit connections can be a major contribution to sewer flows. Infiltration is particularly serious for the several days following a major storm event or other periods when groundwater levels are high. Inflow impacts the sewer flow during and immediately following the storm event when roof drain or storm sewer connections contribute. Infiltration/inflow can create undesirable environmental conditions and health hazards by sewer overflows and by requiring bypassing of treatment facilities when hydraulic capacity is exceeded. To produce needed environmental protection with minimum costs, infiltration/inflow must be effectively controlled either by corrective action to the sewer system, provision of equalization/surge basins or by provision of increased treatment capacity.

(10) By-product recovery. By-product recovery, applied to process waste, is another means of waste reduction wherein materials from a waste stream are recovered for further use. It is quite often not economically feasible, but it should be considered and evaluated.

(11) Equalization. An indirect means of waste reduction before treatment can be accomplished by equalization of wastes. This involves various methods for smoothing out the wastewater loads reaching a treatment facility, and is especially applicable to the treatment of wastes from industrial or process operations.

(12) Examples. The use of centralized vehicle wash facilities (CVWF) provides an excellent example of exercising in-plant control techniques. The centralized wash facility is designed to be used for exterior washing after tactical operations and employs water conservation by treatment and recycle of wash water. Segregation is accomplished by isolating the wash water for exterior washing from the wastewater generated by vehicle maintenance activities and any other wastewater source. Recycling ,and treatment are accomplished by collecting wash water, removing settleable solids and floating oils, passing it through an intermittent sand filter and storing it for reuse. The volume of wash water can be minimized by using baths for soaking and loosening the dirt from vehicles and by using automatic shut-off nozzles on all wash hoses. Detergents, solvents or other cleaning aids are not allowed because they are not necessary for exterior washing, and they complicate the waste strem. Another example of using an in-plant control approach to pollution abatement is presented in table 5-1. In this case, a chemical plant was faced with implementing a comprehensive control program employing both in-plant and end-of-pipe technologies. The total reduction in BOD waste load was 33 percent and the flow reduction was 25 percent due to in-plant control. Table 5-1 illustrates how this reduction was achieved. Process modification and segregation for special disposal played key roles in attaining the reduction. The in-plant controls resulted in a corresponding decrease in the size of end-of-pipe treatment facility required.

c. End-of-pipe control. Pollution control using and end-of-pipe abatement philosophy means treating the waste discharges from a number of operations after these wastes have been combined in a common sewer. End-of-pipe control usually addresses removal of a large variety of wastewater constituents. There are many treatment processes which can be employed in a treatment sequence to obtain an acceptable discharge quality. This approach is generally more attractive than in-plant control because all wastewater treatment operations are carried out in a single, central location. Technologically, the end-of-pipe alternative may pose severe treatment problems due to the variety of pollutants in the wastewater and the variability of wastewater characteristics to be handled by a single facility.

5-4. Disposal alternatives

A major factor in developing a solution for wastewater management is the method of ultimate disposal of the treated wastewater. Very often there is more than one disposal alternative and it is the planner's task to select the one which is most suitable for the specific waste. There are four general wastewater disposal alternatives:

–Discharge to a domestic wastewater treatment plant.
—Dilution in surface waters.
–Land disposal.
—Deep well injection.

The following is a brief discussion of each of these disposal alternatives as related to wastewaters from military installations.

a. Discharge to a domestic waste water treatment plant. Military installations may be located within or near a civilian community which owns a treatment plant, or they may have a treatment system for their own domestic wastes. In both cases the industrial and new domestic wastewater may be discharged to the existing plant for treatment in combination with the existing wastewaters. Before proceeding with combined treatment of industrial and domestic wastes, several factors should be considered.

(1.) Verification of waste compatibility. Non-compatible industrial discharges can be identified based upon physical and chemical wastewater parameters which could damage or make inoperative the sewage treatment facilities. Industrial discharges can reduce the biochemical reaction rates or decrease the sludge settling velocity for biological treatment systems. Sludge handling problems commonly result from poor settleability and dewaterability of combined industrial/municipal sludges. Additionally, toxic compounds, such as heavy metals, may render the municipal plant's sludge unacceptable for common disposal methods.

(2) Loading variations. The contaminant concentrations of industrial wastes are usually much more variable than that of domestic wastes. Variations in the amount or type of the waste generated can significantly impact the municipal plant operation and performance. Batch processes or changes in production methods result in organic, hydraulic, and toxic loading variations which domestic systems have difficulty anticipating and responding to.

(3) Pretreatment technologies. The applicable pretreatment technologies can only be defined after a comprehensive assessment of the waste characteristics, discharge limitations and consideration of alternative generation and treatment techniques. Occasionally, non-compatible waste components can be eliminated by process changes. Frequently, production or maintenance schedules can be adjusted to minimize discharges or reduce the impact on municipal plants during switching to new products or operations. Examples of in-plant and end-of-pipe techniques are presented in table 5-2 for removal of potentially non-compatible materials in industrial discharges.

(a) Selection of the pretreatment technology should also include consideration of reducing the amount and concentration of compatible pollutants. Such consideration can frequently result in a substantial reduction in the sewer use for industrial discharges. Installation of aerated lagoons or anaerobic pretreatment systems can also result in significant savings. Biological systems can be used to reduce waste loads discharged to a physical-chemical treatment system.

(b) The most commonly used physical/chemical pretreatment methods are screening, emulsion breaking, oil/water separation, sedimentation, equalization, and neutralization. Biological pretreatment methods which are most commonly used are aerated lagoons, rough trickling filters, and rotating biological contactors. Examples of pretreatment methods employed at military installations before discharge to municipal sewers are:

—Screens used for lint collection in laundries.
—Removal of oil and grease from wash rack wastes.
—Sedimentation of solids from wash rack wastes.
—Gravity separation of oils and wastes from motor pool maintenance facilities.

b. Dilution in surface waterways. Discharge of wastewaters to surface waterways is the most common ultimate disposal method. Both the location of discharge point and the type of dispersion mechanism are important for protecting water quality. A properly designed subsurface dispersion system will allow maximum utilization of the receiving water assimilative capacity.

(1) Federal, State and local governments have placed restrictions on wastewater discharge quality in order to control the detrimental effects of contaminants as described in chapter 2. These restrictions may require a certain type of treatment system be used, or they may specify concentration limits on certain parameters regardless of the treatment system used to obtain these. Typically, the quality of the receiving stream or body of water is taken into consideration along with the intended use of the water following the wastewater discharge. Each state has classified its major streams and bodies of water according to their own set of use classifications. Table 5-3 lists some typical classifications and the associated quality criteria and required treatment methods for each one. The regulations involved in water quality control are discussed in chapter 4.

(2) Of the various pollutants discharged to surface waterways, oxygen-depleting compounds have received the most attention. These compounds are primarily soluble organics, the discharge of which may be extremely damaging to the health of the receiving stream. Soluble organics are used as food by microorganisms. Microorganisms exist almost everywhere in our world and most microorganisms utilize oxygen for respiration. Discharge of large quantities of organic material results in increased microorganism growth and oxygen consumption. Thus, the increased organism activity resulting from discharge of soluble organics exerts a "biochemical oxygen demand (BOD) on the receiving strewn. This natural phenomenon may deplete dissolved

Table 5-2. Potential non-compliance materials and example control measures*

Component	In-plant Control	End-of-Pipe Control
Physical Constituents		
1. Suspended Solids	Clarifier	Primary clarifier
2. Floating Material	Separators	Separators
3. Fiber	Screen	Screens, primary clarifier
4. Temperature	Cooling tower	Combine w/other wastes
5. Oily material	Separator, segregation	Separator
Chemical Constituents		
1. Organics		
a. Complex	Activated carbon, ozone	Activated carbon
b. Toxic	Activated carbon, special disposal	Activated carbon
c. Surfactants	Activated carbon, special disposal, process substitution	--
d. Colored waste	Activated carbon	--
e. pH	Neutralization	Neutralization
2. Inorganic		
a. Total dissolved fixed solids	Special disposal	Ion exchange
b. Heavy metals	Precipitation	Precipitation

*The waste generation rate must also be considered in terms of the diurnal discharge of domestic wastewater into the POTW.

Table 5-3. Stream classification for water quality criteria[a]

Class		Quality Criteria	Required Treatment
A[b]	Water supply, recreation	Coliform bacteria, color, turbidity, pH, dissolved oxygen, toxic materials, taste- and odor-producing chemicals, temperature	Secondary (tertiary in some cases to meet criteria) plus disinfection
B[b]	Bathing, fish life, recreation	Coliform bacteria, pH dissolved oxygen, toxic materials, color and turbidity (at high levels), temperature	Secondary plus disinfection
C	Industrial, agricultural navigation, fish life	Dissolved oxygen, pH, floating and settleable solids, temperature	Primary and, in some cases, secondary
D	Navigation, cooling water	Nuisance-free conditions, floating material, pH	Primary

[a] Based upon data from (3) and (4)

[b] May require nutrient (nitrogen and phosphorus) removal

oxygen in a stream to a point where other aquatic life cannot, exist.

(3) Toxic materials and heavy metals such as cadmium, lead, mercury and zinc may severely inhibit or kill organisms in the receiving waters. Many of these substances may concentrate in aquatic organisms. Small concentrations in the stream can be stored up in aquatic animals (bioaccumulation) to extremely high levels which may eventually be passed to man through the food chain. Occurrence of this type of toxic migration has been documented for several toxic compounds such as polychlorinated biphenyls (PCB's).

(4) The major problem associated with additions of color and turbidity to natural waters is that these parameters reduce light penetration into the water. This, in turn, decreases the rate of photosynthesis and causes a decrease in the stream population of algae and aquatic plants. The food supply for animals feeding on algae and aquatic plants is then reduced, possibly resulting in growth inhibition or death of the higher forms of life.

(5) Nutrients, although necessary to aquatic life, may, when present at too high a concentration, cause algal blooms (where algae reproduce extremely quickly, covering water surfaces in large floating colonies). Although algae produce oxygen in sunlight by photosynthesis, at night they utilize oxygen in much the same manner as other microorganisms do. When they reach a harmful level, the lake or reservoir is considered eutrophic. This is offensive in recreational facilities and may inhibit future uses of impounded waters unless treatment is provided.

(6) Refractory materials, such as some synthetic detergents, may cause foaming which is aesthetically displeasing.

(7) Oil and floating materials are aesthetically undesirable, typically high in BOD, and may suffocate aquatic life by blanketing gills, leaves and other oxygen transfer surfaces. Floating substances may also have a capping effect on the stream decreasing or destroying the natural stream reaeration abilities.

(8) Acids and alkalis may shock (rapid or localized change in conditions which is detrimental to aquatic life) receiving streams if the pH of the waste is sufficiently different from the existing pH in the stream. Most localities require that discharges to natural waters be neutralized to within a pH range of 6.0 to 9.0. Some restrictions are even more stringent,

(9) Substances resulting in atmospheric odors, such as sulfides, are aesthetically unappealing and should be eliminated before discharge.

(10) Suspended solids produce a variety of detrimental effects. Turbidity and its associated problems are increased by suspended solids addition to a stream. The high organic content of some suspended solids exerts a high BOD on the water and creates oxygen depletion problems. Sedimentation of suspended solids results in an accumulation of solids on the bottom of the receiving body of water. This sludge bank may alter the habitat of the bottom dwelling (benthic) organisms sufficiently to decrease or eliminate some species populations. Additionally, biological activity within the sludge bank may produce gases which lift masses of decomposing sludge to the surface creating an unsightly and malodorous situation.

(11) Discharge of wastewaters having temperatures significantly higher than the receiving stream may elevate the temperature of the stream. This will subsequently decrease the dissolved oxygen content, since oxygen is less soluble in water at higher temperatures. Increased biological activity resulting from higher temperatures further accelerates oxygen depletion. Thermal pollution can therefore result in suffocation of aquatic life.

c. *Ocean disposal.* Within environmental constraints either barge transport or an outfall pipe can be used for ocean disposal of industrial wastes. The former is primarily used for the disposal of low volume concentrated wastewater whereas the latter is more suitable for large volumes of diluted wastewater.

(1) Developing an ocean outfall solution for a particular waste should include the following steps:

—Define the beneficial uses of the marine waters at the disposal site and its vicinity. Beneficial uses may include commercial fishing, marine recreation, navigation, fishery propagation and migration, and industrial use.

—Define the water quality criteria pertinent to the relevant beneficial uses. Areas of concern include public health, aesthetic nuisances, toxicity to marine biota, stimulation of planktonic blooms, and oxygen depletion.

—Define the oceanographic characteristics of the disposal site. This includes water circulation patterns, currents and dispersion, density and temperature profiles, and submarine topography.

–Design wastewater disposal system to meet required quality criteria.

(2) The main objective in the design of an ocean outfall is the enhancement of dilution of wastewater in marine waters. This is achieved by installing a multiple port diffuser through which wastewater is discharged. This dilution, referred to as "initial dilution", is primarily dependent on the depth of sea at the point of discharge.

(3) The wastewater plume which forms at the sea surface above the diffuser is subject to ocean currents, turbulent mixing, and wave and wind effects. This results in further dilution referred to as "turbulent dilution." The intensity of this dilution depends mainly on the natural turbulence in the ocean.

(4) Ocean dumping of industrial waste is closely regulated by the U.S. EPA. Before permits are issued several studies have to be conducted including biological and oceanographic investigations. Therefore, this approach should be taken only as a last resort when inland treatment and disposal are not feasible.

d. Land application. Land application of wastewater is a treatment approach in which the characteristics of the wastewater are altered by microbial stabilization, adsorption, immobilization and crop recovery. Industrial wastes are applied to the land at rates that are low enough not to exceed the assimilative capacity of the soil. Pretreatment processes are almost always necessary to reduce toxic or pollutant species which increase land requirements, and thus, improve the overall economics of the total system. Land application has not been widely used for industrial wastes due to the complexity of the wastewaters and the lack of proven design criteria. However, it is now believed that an environmentally acceptable rate of application can be determined for any and all domestic and industrial waste constituents with the exception of radioactive materials.

(1) Land application design. A rational approach to developing a land application solution should proceed in the following sequence:

—Determine the controlling parameter in the wastewater based on the assimilative capacity of the plant-soil system and the waste load on a constituent-by-constituent basis. The controlling parameter is that constituent which requires the greatest land area.

—Economically evaluate all components required for the land application system under various levels of the land-limiting constituents (LLC).

—Economically evaluate pretreatment or in-plant modifications for reducing the concentration of the land-limiting constituent.

—Select the most cost-effective combination of pretreatment and land application systems.

(2) Land application design has a highly site-specific character and requires careful development of the individual solution. Failures of existing systems have been most frequently attributed to not considering the site-specific nature of this disposal method.

(3) Determination of the land application rate for any industrial waste constituent is based on a calculation of the mass balance of this constituent in the soil system. The result of these calculations is the application rate, expressed in lb/acre-yr, that will not exceed the environmentally accepted levels of pollutant in any part of the system. There are no standard application rates for all types of soils and each case should be treated individually.

e. Deep well injection. Deep well injection is a disposal method in which industrial wastes are stored in subsurface strata of proper characteristics. The technology of deep well injection was described in detail by Warner (165).

(1) Deep well applications.

(a) Deep wells have been used extensively for many years in oil producing regions to return large quantities of saline water underground. However, due to the uncertainties involved and the regulatory constraints, they have not been used extensively for industrial waste disposal.

(b) The approval of a new injection well for industrial waste disposal requires investigation of alternative methods which concludes that an injection well is the most environmentally satisfactory option. Drilling of a preinjection test well, monitoring provisions, contingency plans and provisions for capping of wells after shutdown are also required. Even though this method may not be of widespread application, for a specific waste, it may be the most environmentally accepted practice available.

(2) Considerations for design.

(a) The most important consideration in developing deep well injection concerns the protection of underground water resources from being contaminated by the industrial wastes. This means that the wastes must remain confined in a specified zone and not diffuse into strata which were not designated for wastewater storage. The well area and its casing must be designed and constructed to avoid upward migration of fluid from the injection well. A comprehensive monitor-

ing program has to be established for the injection area.

(b) Compatibility of the wastewater with the water in the injection zone must be studied carefully. The reaction between wastewater constituents and salinity of the groundwater may result in precipitation of mineral salts or formation of gases both of which could render the strata impermeable. Organic material in the wastewater may result in extensive biological growth and rapid plugging of the aquifer pores.

5-5. Upgrading of existing facilities

Upgrading existing wastewater treatment systems refers to a variety of design and operational techniques intended to improve plant performance or increase plant capacity. Upgrading of existing plants may be desirable for one or several of the following reasons:

- –To improve performance of facilities with operational deficiencies, i.e., those facilities which have poor performance due to difficulties in operation of the systems.
- –To improve performance of facilities with design deficiencies, i.e., facilities displaying poor performance due to inadequacy of design.
- —To increase hydraulic capacity to alleviate hydraulic overloads from infiltration and expansion of services.
- —To increase organic capacity compensating for organic overload due to the number of connections or high strength contributions.
- –To provide compliance with more stringent standards.

a. Plant performance. A national survey was conducted by the U.S. EPA in 103 wastewater treatment plants to identify and rank the major causes of poor plant performance. The survey excluded plants with hydraulic or organic overloading problems. Table 5-4 lists the top 10 ranked problem areas and provides a short explanation of each. The survey results indicate that operation and design are often the two most important areas to consider when upgrading an existing system.

b. Upgrading techniques. Methods or techniques used in upgrading are entirely dependent upon the problems to be solved by the upgrading. Often, several problems are involved; therefore, several techniques must be employed in a manner to provide the level of performance required. For simplicity of discussion, the various approaches will be addressed separately with the understanding that combined use is encouraged where necessary.

(1) Upgrading of poorly operated facilities. One of the most common reasons for poor plant performance is poor operation. The operating techniques applied in a plant should always be considered as the first step in upgrading a system. In order to verify performance, optimization of operations should be completed before any other upgrading technique is applied. Specific operating problems are listed and briefly discussed in the U.S. EPA survey quoted in paragraph 5-5a. These and other problems may be categorized into the three basic problem areas listed below:

–Improper application of process control methods.

–Inadequate training or guidance of plant operators.

–Improper testing and data analyses.

(2) Upgrading poorly designed facilities. Many plants have sizing or process design deficiencies relating to hydraulic or organic overloading problems. Many design problems also result in poor performance. These were listed in the U.S. EPA survey for five of the top 10 ranked plant problems. Major design deficiencies include:

- —Insufficient flexibility in pumping rates, preventing proper control of plant processes in times of high or low flow.
- –Inadequate by-passes for repair and maintenance of equipment, resulting in entire processes being taken out of service unnecessarily.
- –Lack of standby equipment, causing possible loss of process operation while replacements are ordered.
- —Poor hydraulic and solids distribution to parallel units resulting in over or underloading of different portions of the system.
- –Lack of flexibility in process instrumentation and equipment resulting in poor low flow or low load operation.
- —Poor accessibility of equipment for repair and maintenance often resulting in repair problems and negligent maintenance practices. The remedies for most of these problems are obvious. Correction of these deficiencies may result in sufficient improvement of plant performance to eliminate the need for further upgrading.

(3) Upgrading to provide increased hydraulic capacity. Although units based on flow rates are operable when hydraulically overloaded, the removal efficiencies are greatly reduced. Some of the units most adversely affected by hydraulic overload are equalization basins, primary clarifi-

Table 5-4. Ten top ranked causes of poor plant performance

The 10 major causes of poor plant performance are described as follows:

1. Operator Application of Concepts and Testing to Process Control -This factor was ranked as the most severe deficiency and leading cause of poor performance at 23 facilities and was a high-ranked factor at a total of 89 out of the 103 plants evaluated. It occurs when a trained operator in a satisfactorily designed plant permits less than optimum performance. This factor was ranked when incorrect control adjustment or incorrect control test interpretation occurred, or when the use of existing inadequate design features continued when seemingly obvious operations alternatives or minor plant modifications could have been implemented to improve performance. The lack of testing and control were not necessarily the result of inadequate training or comprehension in these areas, but simply the lack of or inability to apply learned techniques.

2. Process Control Testing Procedures - Inadequate process control testing involves the absence or wrong type of sampling or testing for process monitoring and operational control. This deficiency leads to making inappropriate decisions. Standard unit process tests such as mixed liquor suspended solids, mixed liquor dissolved oxygen, mixed liquor settleable solids, and return sludge suspended solids for activated sludge processes were seldom or never conducted. Also, important operating parameters such as sludge volume index, F/M ratio and mean cell retention time in suspended growth systems or recirculation rates in trickling filter plants were usually not determined. This factor adversely impacted performance at 67 of the 103 plants evaluated.

3. Infiltration/Inflow - The results of this widespread problem are manifested by severe fluctuations in flow rates, periods of severe hydraulic overloading, and dilution of the influent wastewater so that both suspended and fixed biological systems are loaded to less than optimal values. The extreme result is the “washout” of suspended growth systems as a result of the loss of solids from the final clarification stage during high flow periods. This factor was ranked first at 56 of the 103 plants evaluated.

Table 5-4 Cont'd)

4. Inadequate Understanding of Wastewater Treatment - This factor is distinguished from Factor #1 in that it is defined as a deficiency in the level of knowledge that individual staffs at various facilities exhibit concerning wastewater treatment fundamentals. On occasion, an operator's primary concern is simply to keep the equipment functional rather than to learn how the equipment relates to the processes and their control. This factor adversely affected performance at 50 plants and was the leading cause of poor performance at nine facilities.

5. Technical Guidance - Improper technical guidance includes misinformation from authoritative sources including design engineers, state and Federal regulatory agency personnel, equipment suppliers, operator training staff and other plant operators. At any one plant, improper technical guidance was observed to come from more than one source. This factor was ranked as the most severe deficiency at seven plants, and was an adverse factor at 47 facilities.

6. Sludge Wasting Capability- This factor was ranked as the leading cause of poor performance at nine facilities and was a factor at 43 plants studied. This factor includes inadequate sludge handling facilities and the inability to measure and control the volume of waste sludge. Either one or both of these conditions was noted as having a major impact on performance at several plants.

7. Process Controllability - The lack of controllability was evident in the inability to adequately measure and control flow streams such as return sludge flow and trickling filter recirculation rates. While measurement and control of return activated sludge flow were the most frequent reasons for rating this factor, process controllability was not a major cause of poor performance. It prevented an operator from "tuning" his treatment system to the varying demands which were placed on it by hydraulic and organic loading fluctuations. This factor occurred at 55 plants and was the leading factor at three facilities.

Table 5-4 Cent'd

8. Process Flexibility - Lack of flexibility refers to the unavailability of valves, piping and other appurtenances required to operate in various modes or to include or exclude existing processes as necessary to optimize performance. Poor flexibility precludes the ability to operate an activated sludge plant in the contact stabilization, step loading or conventional modes and the ability to bypass polishing ponds or other downstream processes to discharge high quality secondary clarifier effluent. Either the lack of or inadequate process flexibility was noted as the leading cause of poor performance at three plants and was a factor at 37 facilities.

9. Ineffective O&M Manual Instruction - This situation, existing at 40 plants, was judged serious although the adverse effect was moderate. The poor quality of most plants' O&M manuals undoubtedly has contributed to operators' general lack of understanding of the importance of process control and the inability to practice it, but a competent staff could use other available information sources.

10. Aerator Design - Deficiencies in aerator design were the major cause of poor performance at six facilities and were less significant factors at an additional 21 plants. Deficiencies were noted in the type, size, shape, capacity, and location of the unit and were of such a nature as to hinder adequate treatment of the waste flow and loading and stable operation.

ers, dissolved or induced air flotation system, filtration units, and oil/water separators.

(a) Reducing volumes. Hydraulic overloading may be caused by peak flows in excess of plant design or by average flows exceeding plant design capacity. Peak flows may be remedied by installing equalization basins which will dampen the peaks to acceptable average flow levels. Average loading in excess of hydraulic capacity may be remedied in many cases by elimination of infiltration and inflow. Decreased industrial water use or water recycle may also help to eliminate hydraulic overloading.

(b) Process modifications. Process modifications may be used to increase the hydraulic capacity of an existing system. The addition of chemical coagulant greatly enhances the efficiency of most hydraulic based units. Equipment has been developed to increase hydraulic capacity in some units, such as, tube settlers in clarifiers and corrugated plate interceptors in oil/water separators. If none of these methods provide sufficient increases, construction of parallel units may be necessary.

(4) Upgrading to provide increased organic loading capactiy. Biological units are most affected by organic overloading. Specifically, waste stabilization ponds, activated sludge systems, trickling filters, and rotary biological contractors are among the more easily affected systems. In these systems, organic overloading often results in poor sludge settleability, sludge bulking and odor problems. Increased secondary sludge production caused by overloading could result in problems with sludge thickeners, digesters, dewatering and disposal facilities. When overloaded, many biological systems not only exhibit decreased removal efficiencies, but in severe organic overloading situations they may fail completely. Aerobic systems may become anaerobic and/or the organisms may become completely unsettleable due to filamentous bulking. In activated sludge systems, organic overloading may sometimes result from inadequate mixing which leads to sludge settling in the aeration basin thus reducing the effective biomass in the system. This problem can be solved by increasing the

mixing level through the addition of mixing equipment, draft tubes or hydraulic modifications.

(a) Reducing organic loading. As with hydraulic overloading, organic overloads may be caused by either peak loads or excessive average loads. Peak loads may be dampened by equalization at the source or at the treatment plant. If the average load still represents an organic overload, other correctional methods must be used. In activated sludge systems with low dissolved oxygen concentrations, increasing aeration capacity may provide the oxygen required by the bacteria to assimilate excessive quantities of organic matter. Additionally, enrichment with pure oxygen may also provide the necessary oxygen. If the problem is not insufficient oxygen, increasing the aeration tank mixed liquor volatile suspended solids (MLVSS) level would provide a larger biological population which could subsequently oxidize more organic matter. This line of action is contingent upon the capability of the secondary clarifiers to accommodate higher solids loadings. A similar effect can be achieved by increasing the volume of the aeration basin.

(b) Temperature. One important factor in all biological treatment systems is operation at low temperatures. Since biological reactions slow down as temperature drops, many plants experience operational difficulties under winter conditions. Upgrading methods for winter operation and associated problems are directed toward better heat conservation within the treatment plant. Among the possible winter upgrading methods are reduced mixing in equalization basins, complete or partial bypass around equalization basins, covering equalization basins, and shift from surf ace to diffused aeration.

(c) Capital expansion. Finally, the addition of supplementary organic load reduction units such as roughing trickling filters before biological systems or polishing filters following biological systems, may be necessary to properly upgrade the treatment plant.

(5) Upgrading to meet more stringent standards. Many plants are facing the prospect of having to meet more stringent standards than those for which the plant was designed. Optimization of all operational and design aspects of the existing system may be insufficient to meet the new, more strict standards. Compliance may require construction of additional units depending on the parameters which must be met. Three parameter commonly subject to increasing strict standards are TSS, BOD, and NH_3. Suspended solids removal may be increased by addition of filters, clarifiers, or air flotation systems. BOD removal may be increased by aeration devices, increased aeration tank volumes, roughing units or polishing filters. Ammonia standards may require the addition of biological vitrification units, in-plant control, or the operation of existing biological systems to provide vitrification.

5-6. Environmental impact

The environmental impact statement (E IS) and the environmental assessment are documents which present the results of a study of all the potential effects of a proposed or existing facility or activity on its environment. A discussion of the requirements and preparation of the EIS is included in chapter 4 of this manual. Detailed instructions on the preparation of environmental impact statements are set forth in AR 200-2. Additional guidance is available in the DA Pamphlet 200-1.

5-7. Other considerations

In many instances, establishing a pollution control program involves consideration of factors different from those experienced at similar installations and can be evaluated only at the prospective site. Such factors may include the treatment needs of a new type of process waste; integration with an existing waste system; the effect of system performance under different climatic constraints; and peculiar needs such as architecture, landscaping, and materials of construction. A site visit should be conducted to establish the mission of the installation and to determine any unusual site conditions which may dictate certain pollution control plans.

a. Bench and pilot studies. A basic consideration during wastewater treatment investigations is evaluation of the need for bench (laboratory) and pilot scale studies. There are usually two objectives of such studies. The first is to determine whether the waste is amenable to treatment by the proposed unit operations or processes. The second is to obtain sufficient data to effectively design the full scale facility. Laboratory tests should be conducted before proceeding to pilot scale studies. For existing plants, full scale plant testing may be substituted for pilot studies under some circumstances.

(1) Factors considered. Generally, consideration of the need for bench (laboratory) and pilot scale studies is encountered with treatment of process or industrial wastes. Requirements may be to treat a waste stream or streams for which a suitable treatment method has not previously been established. These studies can also be used to determine if a particular process waste can be

combined and treated with normal sanitary waste. In these instances, laboratory studies are quite often conducted to determine treatability by the system. If it is treatable, then pilot scale studies may be initiated to yield data required for full scale design. Among commonly employed bench and/or pilot scale studies on industrial or combined domestic-industrial wastes are unit processes such as activated sludge, carbon adsorpotion, and dissolved air flotation.

(2) Application to domestic waste. In situations where wastewater requiring treatment originates from sanitary or domestic sources, the need for bench or pilot scale facilities is normally unnecessary. However, it may be desirable or even necessary to conduct such studies to assess the impact of severe climates on some processes; to confirm design criteria; or to determine the most cost-effective process selection.

b. Alternative treatment choices.

(1) Connection to municipal systems. When upgrading existing facilities to meet a higher level of treatment or selecting a wastewater treatment facility for a new installation, consideration shall be given to discharging either raw or partially treated wastewater to a municipal system if such a facility is within a practical and economical distance. When the municipality can provide the necessary increment of treatment capacity, such practice eliminates facility duplication and removes the operational and staffing problems from the military installation. It can also reduce costs. Combined or joint treatment is the preferred method outlined in the 1972 Amendments to the Federal Water Pollution Control Act.

(2) Expanding existing treatment facilities. When an existing facility is expanded to handle more waste or upgraded to provide a higher level of treatment, consideration must be given to integration of additional treatment facilities. Studies must be made to determine the types of processes to be added, timing to avoid service interruption, and provisions for any future facility expansion.

c. Geographic and climatologic. In the selection of a cost-effective treatment scheme, geographic and climatologic conditions must be carefully analyzed. In cold climates, the rate of biological degradation of waste materials decreases with decreasing temperature to a point where it may virtually cease during the winter months. Other treatment schemes, such as physical-chemical treatment, need to be explored in such situations. Extreme cold may cause operating problems due to freezing of mechanical components. Construction is more difficult in cold climates also. Extreme warm weather areas have few unusual treatment problems, because biological systems are aided by higher ambient temperatures.

(1) Cold region treatment systems. The U.S. Army Cold Regions Research and Engineering Laboratory, P. O. Box 282, Hanover, NH 03755, should always be contacted when exploring waste treatment alternatives for facilities located in regions where the ambient temperature is below 32 degrees F for significant periods of the year.

(2) Treatment processes for other areas. Installations located in arid and water-short areas often require the direct and indirect reuse of water due to limited supply. A high degree of treatment is often required for wastewaters prior to discharge due to the very low dilution provided by small stream flows in these areas. In wildlife refuges, fish spawning waters, and wetland areas, wastewater discharges must have low pollutant concentrations to preserve the delicate environmental balance. This is particularly true with regard to toxics, oxygen demanding material, nutrients, and temperature.

d. Treatment reliability. Components of the treatment process must be selected to ensure a high degree of reliability. Duplicate units shall always be provided for high maintenance units, treatment processes requiring frequent cleaning, and units which are essential for proper operational efficiency. Some examples of these are pumps, screens, filters, and chlorination equipment.

(1) Toxic waste. When treating toxic substances such as strong solutions of heavy metal salts and cyanides, sufficient testing after treatment is required to ensure acceptable quality before release. Redundant or duplicate processing steps may also be warranted. Automatic controls should be arranged for fail-safe operation.

(2) Domestic waste. For treatment plants primarily handling sanitary wastes, treatment system reliability is generally geared to established water quality standards.

(3) Establishing reliability requirements. In areas where effluent or stream standards are established, coordination with the Regional U.S. EPA Federal Facilities Coordinator should be employed to determine treatment requirements and reliability y necessary to meet all conditions. The U.S. EPA has set forth certain design guidelines to be used to ensure reliability of treatment processes dependent upon the type of receiving watercourse. Equipment and facilities to meet these requirements shall be incorporated

into the system during the planning and feasibility study analysis.

e. Operation and management. The selection of a wastewater treatment process shall include consideration of the operational expertise and management required. When the geographical location and installation size permit use of treatment ponds, operating needs will be much less than other treatment systems. For other treatment processes, operational capability becomes more of a factor in equipment selection. The increased emphasis on more stringent effluent quality standards and the resulting increase in the degree of treatment complexity, make it mandatory that operators have adequate training and experience. One major responsibility of the operating staff will be to perform all necessary tests to ensure that the effluent meets requirements. When process wastes are involved, more detailed surveillance and testing will be required. Operator capability and management needs are not usually the determining factor in process selection, but should be evaluated and properly weighted in life cycle cost consideration when making process selection.

5-8. Specific treatment needs

After all prior elements of the program are complete, selection of wastewater treatment system components can be made by evaluating all factors.

a. Data analysis. Analyses of all data will begin with the wastewater characteristics establishing the following:

–Average waste flow.
–Total system peak flow as well as peak flows in tributary sections of the system.
–Concentration of pollutants for which parameters (BOD, suspended solids, nutrients, etc.) have been established or can be estimated.
–Sources and type of process wastes.
–-Concentration of process chemicals and any potentially toxic materials.

(1) Waste reduction. The next step will be to factor into these data the effect of any waste reduction practices. The output from the procedure will establish system raw waste loads.

(2) Environmental consideration. The environmental impact statement or environmental assessment will document the required treated wastewater quality and establish the performance level required from treatment facilities. The required performance will serve as the basis for treatment process selection.

b. Selection of pollution control alternatives. If bench and/or pilot scale studies have been conducted on wastewaters to be treated, the results will provide guidance in the selection of process alternatives. With data obtained from the studies, design criteria can be established for feasible alternatives. Cost comparison and operational relationships can be established in selecting a cost-effective system. Pertinent economic considerations should be investigated. If bench or pilot scale studies have not been conducted, then process selection must involve preliminary and detailed screening of available unit processes to meet treatment requirements. Unit treatment processes and their ranges of applicability y, combined with economic criteria, all as discussed herein, will allow the selection of the most cost-effective solution.

c. *Program implementation.* After treatment methods have been established, discussions should be held with the Regional U.S. EPA Federal Facilities Coordinator to review environmental aspects, dates for implementation of the project, and such other information as may be necessary to satisfy regulatory agency requirements. One or more written reports are prepared during the course of the pollution control program investigations. The number and types of reports will depend on the complexity and time span of the project. The final report shall outline the investigations conducted, and summarize the findings and recommendations for implementation of the program. Often it is desirable to assign priority items for implementation of the program on a staged basis. These reports will form the basis for subsequent preliminary and/or final design reports and justification for the project.

CHAPTER 6

WASTEWATER TREATMENT PROCESSES

6-1. Preliminary and Primary Wastewater Treatment Processes

a. Introduction. Preliminary treatment of wastewater generally includes those processes that remove debris and coarse biodegradable material from the waste stream and/or stabilize the wastewater by equalization or chemical addition. Primary treatment generally refers to a sedimentation process ahead of the main system or secondary treatment. In domestic wastewater treatment, preliminary and primary processes will remove approximately 25 percent of the organic load and virtually all of the nonorganic solids. In industrial waste treatment, preliminary or primary treatment may include flow equalization, pH adjustment or chemical addition that is extremely important to the overall treatment process. Table 6-1 liss the typical effluent levels by degree of treatment. This section of the manual will discuss the various types of preliminary and primary treatment processes available.

b. Preliminary treatment. An important part of any wastewater treatment plant is the equipment and facilities used to remove items such as rags, grit, sticks, other debris, and foreign objects. These interfere with the operation of the facility and often cause severe problems. Methods of removing these materials prior to primary and subsequent treatment are part of a pretreatment or preliminary treatment. While a summary discussion of the commonly employed unit operations follows, a more complete description of design criteria which must be used is contained in TM 5-814-3.

(1) Screening and comminution. Screening and comminution are preliminary treatment processes utilized to protect mechanical equipment in the treatment works, to aid downstream treatment processes by intercepting unacceptable solids, and to alter the physical form of solids so they are acceptable for treatment. Screening or comminution shall always be used for military domestic wastewaters.

(a) Screening. Screening devices remove materials which would damage equipment or interefere with a process or piece of equipment. Screening devices have varied applications at wastewater treatment facilities, but most often are employed as a preliminary treatment step. Screens are classified as fine or coarse and then further classified as manually or mechanically cleaned. Coarse screens are used in preliminary treatment, while fine screens are used in lieu of sedimentation preceding secondary treatment or as a step in advanced wastewater treatment. Fine screens as a preliminary or primary treatment are more applicable to process or industrial wastes. TM 5-814-3 provides detailed descriptions of these units and design considerations.

(b) Comminution. A comminutor acts as both a cutter and a screen. Its purpose is not to remove but to shred (comminute) the solids. Solids must be accounted for in subsequent sludge handling facilities. Comminutors, like most screens, are mounted in a channel and the wastewater flows through them. The rags and other debris are shredded by cutting teeth until they can pass through the openings. Some units require specially shaped channels for proper hydraulic conditions, resulting in more expensive construction. Treatment. plant design manuals, textbooks, and manufacturer's bulletins provide detailed information on these units. A bypass channel is required for all comminutors to permit maintenance of equipment.

(2) Grit removal. Grit represents the heavier inert matter in wastewater which will not decompose in treatment processes. It is identified with matter having a specific gravity of about 2.65, and design of grit chambers is based on the removal of all particles of about 0.011 inch or larger (65 mesh). For some sludge handling processes, it may be necessary to remove, as a minimum, grit of 0.007 inch or larger (100 mesh). Grit removal, compared to other unit treatment processes, is quite economical and employed to achieve the following results:

- Prevent excessive abrasive wear of equipment such as pumps and sludge scrapers.
- Prevent deposition and subsequent operating problems in channels, pipes, and basins.
- Prevent reduction of capacity in sludge handling facilities.

Grit removal facilities shall be used for combined sewer systems or separate sanitary systems which may have excessive inert material. Grit removal equipment should be located after bar screens and comminutors and ahead of raw sewage pumps. Sometimes it is not practical to locate

Table 6-1. Typical effluent levels of principal domestic wastewater characteristics by degree of treatment (mg/L unless noted otherwise)

		Wastewater Treatment				
				Advanced[a]		
Parameter	Average Raw Wastewater	(1) Primary	(2) Secondary	3 (l)+(2)+NR[b]	(4) (3)+PR[c]	(5) — (4)+SSOR[d]
BOD	300	195	30[e]	15	5	1
COD	600	400	150	100	45	12
Suspended Solids	300	120	30[e]	20	10	1
Amnonia (as N)	25	25	28	3	3	3
Phosphate (as P)	20	18	14	13	2	1
pH (units)	7	6-9	6-9[e]	6-9	6-9	6-9
Fecal Coliform (no. /100 mL)	1,000,000	15,000	200[e]	200	200	100

[a] Reasonable levels but not necessarily minimum for all constituents.

[b] NR = Nitrogen Removal or Conversion

[c] PR = Phosphorus Removal

[d] SSOR = Suspended Solids and Organics Removal

[e] Environmental Protection Agency, Secondary Treatment Information, 40 CFR, Part 133, Federal Register, Monday, 30 April 1973.

the grit removal system ahead of the raw sewage pumps because of the depth of the influent line. Therefore, it may be required to pump the wastewater containing grit. If this mode is selected, pumps capable of handling grit should be employed.

(a) Horizontal flow grit chambers. This type of grit chamber is designed to allow wastewater to pass through channels or tanks at a horizontal velocity of about one foot per second. This velocity will allow grit to settle in the channel or tank bottom, while keeping the lighter organic solids in suspension. Velocity control and other design features are covered in TM 5-814-3.

(b) Detritus tanks. A grit chamber can be designed with a lower velocity to allow organic matter to settle with the grit. This grit-organic matter mixture is referred to as detritus and the removal devices are known as detritus tanks. When detritus tanks are employed, the organic matter is separated from the grit by either gentle aeration or washing the removal detritus to re-suspend the organic matter. Several proprietary systems are available to accomplish this, and the advantage over other types is that the configuration of the tank is simple and the system allows for continuous removal of grit.

(c) Aerated grit chambers. As the name implies, diffused air can be used to separate grit from other matter. A secondary benefit to the aeration method is that is also freshens the wastewater prior to further treatment; quite often it is used in conjunction with a preaeration facility. The different types of grit removal facilities employed are described in TM 5-814-3.

(3) Preaeration. Methods of introducing supplemental oxygen to the raw wastewater are sometimes used in preliminary treatment. This process is known as preaeration and the objectives are to:

—Improve wastewater treatability.
—Provide grease separation, odor control, and flocculation.
—Promote uniform distribution of suspended and floating solids to treatment units.
—Increase BOD removals in primary sedimentation.

This is generally provided by either separate aeration or increased detention time in an aerated grit chamber. Provisions for grit removal are provided in only the first portion of the tank (125).

(4) Equalization. Equalization has limited application for domestic wastes, but should be employed for many industrial discharges including some of those from military industrial manufacturing processes as discussed later in this chapter. Equalization reduces fluctuations of the influent to levels compatible with subsequent biological or physical-chemical processes. A properly designed facility dampens the wide swings of flow, pH, BOD, and other parameters to levels such that downstream systems operate more efficiently and economically, and can be constructed at a reduced capital investment. Proper equalization will also minimize system upsets and more consistently provide a better quality effluent. A graphical example of how an equalization facility can stabilize a wastewater having significant cyclic pH variations is illustrated in figure 6-1. While there are definite primary benefits for equalization, a facility can also be designed to yield secondary benefits by taking advantage of physical, chemical, and biological reactions which might occur during retention in the equalization basin. For example, supplemental means of aeration are often employed with an equalization basin to provide:

—Better mixing.
—Chemical oxidation of reduced compounds.
—Some degree of biological oxidation.
—Agitation to prevent suspended solids from settling.

If aeration is not provided, baffles or mechanical mixers must be provided to avoid stratification and short circuiting in equalization basins. The size and shape of an equalization facility will vary with the quantity of waste and the patterns of waste discharge. Basins should be designed to provide adequate capacity to accommodate the total volume of periodic variation from the wastewater source (125) (130).

(5) pH control. Similarly to equalization, the use of pH control as a preliminary treatment step is usually limited to treatment of industrial process wastes. It is necessary to regulate pH since treatment processes can be harmed by excessively acidic or basic wastes. Regulation of this parameter may be necessary to meet effluent levels specified for secondary treatment. Control of the pH at elevated levels is usually required to precipitate certain heavy metals and/or alleviate an odor producing potential.

(6) Flotation. In preliminary treatment, flotation is sometimes used for wastes which have heavy loads of grease and finely divided suspended solids. These are mainly systems having large industrial discharges and may apply to military installations with significant oil and grease quantities from manufacturing or laundry

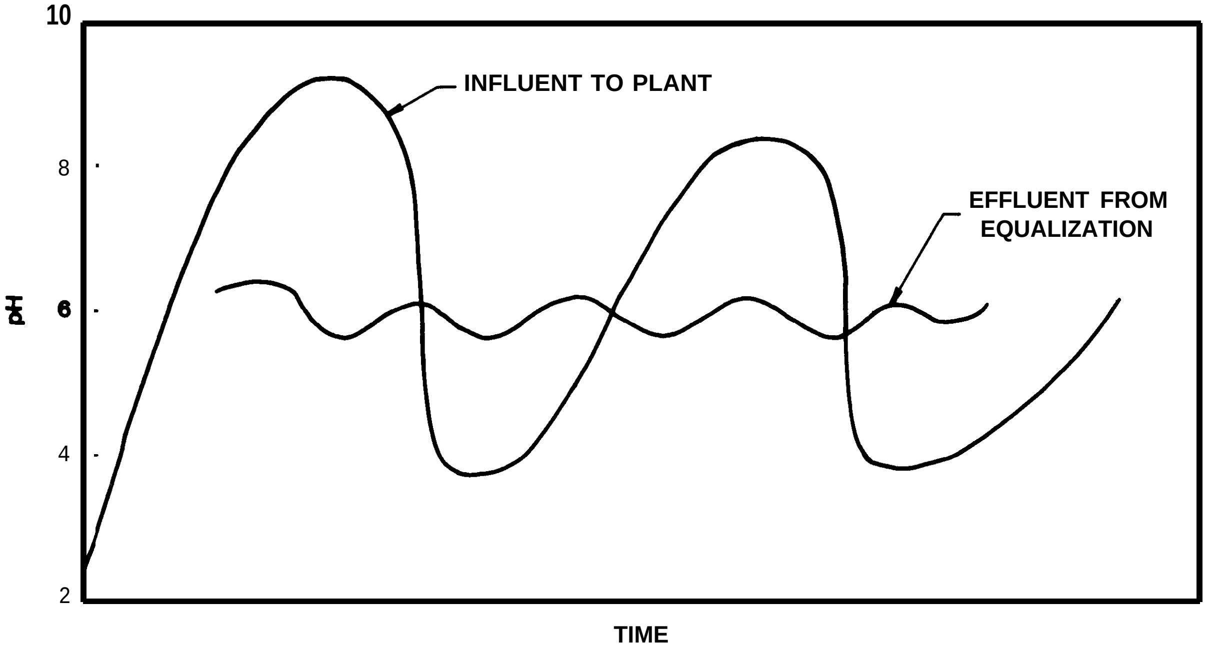


Figure 6-1. The effect of equalization on a wastewater with variable pH.

operations. Domestic waste may also contain large quantities of grease from food preparation. Use of air to float materials may relieve scum handling in a sedimentation tank and lower the grease load to subsequent treatment units. Grit removal is often incorporated with a flotation unit providing sludge-removal equipment. Flotation design guidelines are available, but bench testing is desirable to finalize the criteria and expected performance.

(7) Other methods. Other preliminary treatment steps include coagulation and chlorination. Coagulation is a part of sedimentation as presented later in this chapter. Chlorine additions are often made to the plant influent for odor control (120). Two other operations which usually precede any treatment process include pumping and flow measurement. Wastewater bypasses must also be provided.

(a) Pumping. Pumping facilities may be employed to gain sufficient head for the wastewater to flow through the treatment works to the point of final disposal. Pumping is also generally required for recirculation of all or part of the flow around certain units within the plant. Pumping facilities are classified as influent, effluent, or recirculation stations and perform a critical function. Provisions shall be made for reliability to ensure the facility is operable at all times. This means the largest pump has a standby duplicate so that pumping capacity is available to meet peak flows. It also means duplicate sources of power and/or standby power must be provided. U.S. EPA requires this flexibility for municipal facilities. Guidelines for pumping facilities are available in TM 5–814-3.

(b) Flow Measurement. Metering and instrumentation devices in numerous sections of a wastewater treatment facility are necessary for adequate plant control and operating flexibility. Proper monitoring of effluent characteristics is required to comply with NPDES permits. Use of devices such as Venturi meters, weirs, and Parshall flumes predominate. Parshall flumes are the preferred flow measuring method for military installations. TM 5-814-3 provides a description of sizing and design considerations. The need for other meters and instrumentation throughout the treatment facility will be dictated by the size of the facility, complexity, and need for recordkeeping and operator control of the process. In small installations, where maintenance and availability of spare parts may be difficult, metering can be a problem. Reference should be made to publications (120) for guidelines on types of measurement systems available, limitations, and preliminary design criteria. Also standard textbooks and literature from equipment manufacturers should be investigated thoroughly prior to selection of type and degree of plant measurement and instrumentation.

(c) Wastewater bypasses. Piping arrangements and duplicate treatment units may be provided to the maximum practical extent so that an inoperative unit, such as a clarifier, may be bypassed without reducing the overall treatment

efficiency of the plant. Bypassing of the entire wastewater treatment plant through an emergency overflow structure during periods of extraordinarily high flow must be provided. In all cases, this diverted flow shall be disinfected and screened, and the quantity of flow measured and recorded. The appropriate regulatory agency shall be notified of every bypass occurrence. When the wastewater is discharged to a waterway which could be permanently or unacceptably damaged by the quantity of bypassed wastewater, such as shellfish waters, drinking water reservoirs, or areas used for water contact sports, provision shall be made to intercept the bypassed flow in a holding basin. The intercepted flow shall then be routed back through the treatment facility as soon as possible. Bypasses for diversion of flow around treatment plants will be locked in a closed position. The bypass must be controlled by supervisory personnel.

c. Primary treatment. Primary treatment for the purposes of this manual will be limited to sedimentation with and without chemical addition. Other unit processes are usually combined with sedimentation as a part of “primary treatment”, including some degree of preliminary treatment, sludge treatment and disposal, and chlorination as a disinfection step. For many years, water quality criteria specified only the use of primary treatment for domestic wastewaters. Primary treatment is no longer acceptable as the total wastewater treatment step prior to discharge to a receiving body of water and secondary treatment must now be employed to meet regulatory criteria. Therefore, the discussion presented herein on primary treatment shall be utilized by military personnel concerned with:

—Alternatives that must be considered for existing treatment facilities which are to be upgraded to meet effluent limitations and water quality criteria.

—Design factors and alternatives that must be considered when planning a new wastewater treatment facility.

(1) Plain sedimentation. Wastewater, after preliminary treatment, undergoes sedimentation by gravity in a basin or tank sized to produce near quiescent conditions. In this facility, settleable solids and most suspended solids settle to the bottom of the basin. Mechanical collectors should be provided to continuously sweep the sludge to a sump where it is removed for further treatment and disposal. Skimming equipment should be provided to remove those floatable substances such as scum, oils, and greases which accumulate at the liquid surface. These skimmings are combined with sludge for disposal. Removals from domestic wastewaters undergoing plain sedimentation will range from about 30 to 40 percent for BOD and in the range of 40 to 70 percent for suspended solids. With optimum design conditions for sedimentation, BOD and suspended solids removal efficiency is dependent upon wastewater characteristics and the proportion of organics present in the solids. One of the most important design parameters if the overflow rate, usually expressed in gal/day/sq ft, which is equal to the flow in gal/day divided by the settling surface area of the basin in square feet. Usually average daily flow rates are used for sizing facilities. The flow rates, detention time, and other factors which shall be employed for design purposes are documented in TM 5-814-3.

(a) Secondary treatment sedimentation facilities. It should be recognized that design principles of secondary sedimentation tanks are significantly different than those for primary tanks, the fundamental difference being in the amount and nature of solids to be removed. Primary sedimentation facilities are basically designed on overflow rate alone; secondary units must be designed for solids loading as well as overflow rate. Reference should be made to TM 5–8 14–3 for design criteria.

(b) High-rate settlers. In recent years, the development of high-rate settlers has proven quite promising for both primary and secondary sedimentation applications. These have been used primarily to improve performance and to increase treatment capacity of existing plants and should receive attention for upgrading military facilities. The theory is that sedimentation basin performance can be improved by introducing a number of trays or tubes in existing facilities, since efficiency is independent of depth and detention time. Until recent years, use of trays or tubes was unsuitable on a practical basis because of difficult sludge collection and removal. These problems have been largely overcome although slime growths may cause flow restrictions and require periodic cleaning. The principal advantage of the settlers is their compactness which reduces material costs and land requirements. For most military installations, the land savings is not critical but cost reductions will be important. Settlers do not improve the efficiency of primary sedimentation facilities that are already achieving reasonably high removals of suspended solids. Available data indicate that where the settlers have been installed in existing units, it has been possible to increase the surface overflow rate of both primary and final sedimentation systems

from 2 to 5 times the conventional rate while still maintaining about the same suspended solids effluent level. Manufacturer's bulletins and U.S. EPA Technology Transfer series documents provide data on design criteria.

(2) Sedimentation with chemical coagulation. Sedimentation using chemical coagulation has been implied mainly to pretreatment of industrial or process wastewaters and removal of phosphorus from domestic wastewaters. Chemical usage as a pretreatment step for industrial wastes and phosphorus removal is discussed later. The use of chemical coagulating agents to enhance the removal of BOD and suspended solids has not been used extensively on domestic wastewaters, since it is not usually economical or operationally desirable. However, special applications may exist at some installations. Advantages of increased solids separation in primary sedimentation facilities are:

–A decrease in organic loading to secondary treatment process units.

–A decrease in quantity of secondary sludge produced.

–An increase in quantity of primary sludge produced which can be thickened and dewatered more readily than secondary sludge.

Chemicals commonly used, either singularly or in combination, are the salts of iron and aluminum, lime, and synthetic organic polyelectrolytes. It is desirable to run jar studies to determine the optimal chemicals and dosage levels. The use of a given chemical(s) and effluent quality must be carefully balanced against the amount of additional sludge produced in the sedimentation facility. Design information and guidance is contained in the U.S. EPA Technology Transfer series documents.

(3) Other methods. For some industrial wastes which contain large amounts of floatable and finely suspended matter, flotation may be used in lieu of sedimentation as a cost-effective means of primary treatment. Some wastewater treatment alternatives, including ponds and extended aeration, do not require primary treatment as a distinct process step. Other secondary treatment processes could operate without primary treatment but it is cost-effective to remove the suspended organics physically rather than biologically.

6-2. Biological Wastewater Treatment Processes

a. Introduction. Biological treatment processes are those that use microorganisms to coagulate and remove the nonsettleable colloidal solids and to stabilize the organic matter. There are many alternative systems in use and each uses biological activity in different manners to accomplish treatment. Biological processes are classified by the oxygen dependence of the primary microorganism responsible for waste treatment (125). In aerobic processes, waste is stabilized by aerobic and facultative microorganisms; in anaerobic processes, anaerobic and facultative microorganisms are present. The discussion of biological treatment processes has been further divided into the following two categories:

—Suspended growth processes.

—Fixed growth processes.

(1) Suspended growth processes refer to treatment systems where microorganisms and wastewaters are contained in a reactor. Oxygen is introduced to the reactor allowing the bilogical activity to take place. Examples of suspended growth processes include ponds, lagoons and activated sludge systems.

(2) Fixed growth processes refer to systems where a biological mass is allowed to grow on a medium. Wastewater is sprayed on the medium or put into contact in other manners. The biological mass stabilizes the wastewater as it passes over it. Examples of fixed growth processes include trickling filters and rotating biological contractors.

b. Suspended growth processes.

(1) Ponds. Ponds have found wide-spread usage in the U.S. In 1968, 34.7 percent of the nearly 10,000 secondary treatment systems operating in the U.S. were in the category of stabilization ponds (49). Waste treatment ponds can be divided into three general classifications: aerobic ponds, aerobic-anaerobic (facultative) ponds, and anaerobic ponds. Ponds are sized on an average BOD loading or detention time basis and are quite sensitive to climate and seasonal variations.

(a) Aerobic ponds. Photosynthetic ponds are 6 to 18 inches deep with BOD loadings ranging from 100 to 200 lb per acre per day and detention times of 2 to 6 days. These are usually mixed intermittently, generally by mechanical means, to maximize light penetration and algae production. A very high percent of the original influent BOD is removed, but due to algae growth and release to the effluent, overall removals are in the 80 to 95 percent range. Suspended solids in the effluent are also mainly due to algae. Lower efficiencies occur during warmer periods of the year due to algal growths, and during extremely cold periods due to decreased biological activity and freezing. Aerated aerobic ponds uti-

lize oxygen mixed with the wastewater either from diffused air or mechanical means, with photosynthetic oxygen generation not playing a major role in the process. These ponds are 6 to 20 feet deep with BOD loadings ranging from 100 to 300 lb per acre per day and detention times of 2 to 7 days. BOD and suspended solids removals in the range of 80 to 95 percent are obtained if a quiescent cell is provided to effect solids removal after aeration. Aerated aerobic ponds may be considered for military applications where flow is variable or land is precious. Without the aerators operating, the system might function as an aerobic-anaerobic (facultative) pond during low loads.

(b) Aerobic-anaerobic (facultative) ponds. These ponds consist of three zones: a surface zone of algae and aerobic bacteria in a symbiotic association; an intermediate zone populated with facultative bacteria (aerobic or anaerobic); and an anaerobic bottom zone where settled organic solids are decomposed by anaerobic bacteria. The ponds, operated in natural aeration mode, are 3 to 8 feet deep with BOD loadings ranging from 10 to 100 lb per acre per day and detention time of 10 days to 1 year. BOD removals of 80 to 95 percent are obtained with proper operation and loadings, but suspended solids removals vary because of algal carryover. These ponds may also be partially mixed using mechanical or diffused aerators to supply some oxygen. Mechanically mixed ponds normally have BOD loadings ranging from 30 to 100 lb per acre per day; detention times of 7 to 20 days; operational depths of 3 to 8 feet; and, BOD removals of 90 to 95 percent.

(c) Anaerobic ponds. These ponds have BOD loadings in the range of 10 to 700 lb per acre per day and can provide removals of 50 to 80 percent. Detention times range from 30 days to 6 months and operational depths range from 8 to 15 feet. Anaerobic ponds have been used principally in industrial waste applications and particularly in meat packing wastes. Due to the nature of the pond environment, these treatment units generally produce severely offensive odors. They are normally not used by themselves and in order to produce a higher quality effluent, must be followed by an aerobic pond. Anaerobic ponds should not be utilized for military wastewaters except under special circumstances.

(d) Other considerations. In treatment of principally domestic wastes, there are additional factors to consider (44)(154). Aside from not meeting effluent criteria, operating problems include odors, colored effluent, high effluent suspended solids, mosquito and insect problems and weeds. A study (154) indicated that of 21 different pond installations studied, none would consistently meet the secondary treatment effluent requirement of 30 mg/L BOD. Similarly, of 15 installations reporting effluent suspended solids values, none would consistently meet the 30 mg/L effluent limit. New wastewater treatment pond designs and existing installations being upgraded must recognize and provide methods which will achieve required effluent levels. Definitive design criteria for all situations are beyond the scope of this manual. EPA Technology Transfer series documents and similar publications should be consulted when planning a new wastewater treatment pond facility or when assessing alternatives for upgrading an existing pond system. Locally applicable design criteria considering the effect of climate should be used when planning new or upgrading existing facilities. Wide variations in criteria are followed in the U.S. in terms of loading rates, detention times, depths and number of cells required. While most States in the midwest relate to a BOD design loading criteria in pounds BOD per acre per day, the principal design factor in northern states is retention time, primarily because of the extreme winter temperatures. In terms of organic loading, pounds of BOD per acre per day, State design criteria range from less than 20 in the northern states to as high as 75 in the southern, southwestern or western states, reflecting temperature effects on performance.

(2) Activated sludge. Activated sludge is an efficient process capable of meeting secondary treatment effluent limits. In recent years, this process has undergone significant changes and improvements from the conventional activated sludge process. For further information on the process itself or its modifications, reference should be made to TM 5-814-3. The principal factors which control the design and operation of activated sludge processes are:

—Detention time.

—BOD volumetric loading.

—Food to microorganism (F/M) ratio.

—Sludge age or solids retention time (SRT).

While all of these parameters have been used to size facilities, the most commonly used are the F/M ratio and the SRT. Reference should be made to textbooks or TM 5-814-3 for further explanation and limitations to be considered when dealing with these parameters. Secondary sedimentation is particularly important for activated sludge systems. The design of these units is based on overflow rate and solids loading. Design criteria for various size plants and process modifications are available (152). A number of variations of the conventional activated sludge process were developed to achieve greater treatability, to minimize capital and/or operating costs or to correct a problem. While not all of the variations are mentioned herein, the following should be evaluated when considering a new facility, or upgrading an existing primary or secondary facility:

–Completely-mixed.
—Step aeration.
—Contact stabilization.
—Extended aeration.
—Pure oxygen system.

Summary characteristics on design criteria, removal efficiencies and basic applications of the modifications are described in table 6-2. Based on the overall BOD removal efficiency reported, most variations are able to achieve a high degree of treatment. The extended aeration system is a flexible system, but is more cost-effective for small populations. Extended aeration and contact stabilization are most applicable as package plants and are described under that heading. Activated sludge systems are commonly designed to accomplish two or more of the operating modes to accommodate flexible operational requirements. An example is the completely-mixed and step aeration systems. From the data in table 6-2, it can be seen that depending upon volumetric loading, F/M or detention time, selection of one variation over another can result in significant differences in the size of the aeration basins. The information presented in table 6-2 covers the range which has been experienced.

(*a*) Conventional. The conventional activated sludge process employs long rectangular aeration tanks which approximate plug-flow although some longitudinal mixing occurs. This process is primarily employed for the treatment of domestic wastewater. Return sludge is mixed with the wastewater prior to discharge into the aeration tank. The mixed liquor flows through the aeration tank during which removal of organics occurs. The oxygen utilization rate is high at the entrance to the tank and decreases toward the discharge end. The oxygen utilization rate will approach the endogenous level toward the end of the tank. Principle disadvantages of conventional activated sludge treatment in industrial application are:

—The oxygen utilization rate varies with tank length and requires irregular spacing of the aeration equipment or a modulated air supply.
—Load variation may have a deleterious effect on the activated sludge when it is mixed at the head end of the aeration tanks.
—The sludge is susceptible to slugs or spills of acidic, caustic or toxic materials.

(*b*) Completely mixed. In the completely mixed process, influent wastewater and recycled sludge are introduced uniformly throughout the aeration tank. This flow distribution results in a uniform oxygen demand throughout the aeration tank which adds some operational stability. This process may be loaded to levels comparable to those of the step aeration and contact stabilization processes with only slight reductions compared to the removal efficiencies of those processes. The reduced efficiency occurs because there is a small amount of short circuiting in the completely mixed aeration tank.

(c) Step aeration. The step aeration process is a modification of the conventional activated sludge process in which influent wastewater is introduced at several points in the aeration tank to equalize the F/M, thus lowering the peak oxygen demand. The typical step aeration system would have return activated sludge entering the tank at the head end. A portion of the influent also enters near the front. The influent piping is arranged so that an increment of wastewater is introduced into the aeration tank at locations down the length of the basin. Flexibilityof operation is one of the important features of this system (125). In addition, the multiple-point introduction of wastewater maintains an activated sludge with high absorptive properties. This allows the soluble organics to be removed within a shorter period of time. Higher BOD loadings are therefore possible per 1000 cu ft of aeration tank volume.

(*d*) Contact stabilization. The contact stabilization process is applicable to wastewaters containing a high proportion of the BOD in suspended or colloidal form. Since bio-adsorption and flocculation of colloids and suspended solids occur very rapidly, only short retention periods (15-30 minutes) are generally required. After the contact period the activated sludge is separated in a clarifier. A sludge reaeration or stabilization period is required to stabilize the organics removed in the contact tank. The retention period in the stabilization tank is dependent on the time required to assimilate the soluble and colloidal material removed from the wastewater in the contact tank. Effective removal in the contact period requires sufficient activated sludge to remove the colloidal and suspended matter and a portion of the soluble organics. The retention

Table 6-2. Summary characteristics of the activated sludge process variations

Process Variation	Volume Loading lb BOD/1,000 cu ft/day	Food/Micro-organism Ratio (F/M) lb BOD/lb MLVSS/day	Mixed Liquor Suspended Solids (MLSS) mg/L	Detention Time, hr	Overall BOD Removal Efficiency, percent	Comments
Conventional (plug flow)	20-40	0.2-0.5	1,000-3,000	4-8	85-95	Applicable to low-strength domestic waste, susceptible to shock loads.
Completely-Mixed	50-120	0.2-0.6	3,000-6,000	3-6	85-95	General application, resistant to shock loads.
Step Aeration	50-60	0.2-0.4	2,000-3,500	3-6	85-95	Applicable to wide range of wastes.
Contact Stabilization	60-75	0.2-0.6	1,000-3,000; 4,000-8,000	0.2-1.5[a] 3-6[b]	80-90	Flexible system; expansion of existing systems or package plants.
Extended Aeration	10-25	0.05-0.2	3,000-6,000	18-36	75-90	Applicable to small communities and package plants, flexible.
Pure Oxygen System	100-250	0.3-1.0	4,000-8,000	1-10	85-95	General application but more so for high-strength wastes.

[a] Contact Unit.

[b] Stabilization unit.

time in the stabilization tank must be sufficient to stabilize these organics. If it is insufficient, unoxidized organics are carried back to the contact tank and the removal efficiency is decreased. If the stabilization period is too long, the sludge undergoes excessive auto-oxidation and loses some of its initial high removal capacity. Increasing retention period in the contact tanks increases the amount of soluble organics removed and decreases required stabilization time.

(e) Extended aeration. The extended aeration process operates in the endogenous respiration phase of the growth curve, which necessitates a relatively low organic loading and long aeration time. Thus it is generally applicable only to small treatment plants of less than 1 mgd capacity (125). This process is used extensively for prefabricated package plants. Although separate sludge wasting generally is not provided, it may be added where the discharge of the excess solids is objectionable.

(f) Pure oxygen system. The variations set forth in table 6-2, with the exception of the pure oxygen system, represent flow models which are based on plug flow or completely mixed systems. Some systems use a diffused air system, others are more applicable to mechanical aeration, and some variations are adaptable to either aeration system. All of the systems, with the exception of the pure oxygen system, use air as the source of oxygen. The principal distinguishing features of the pure oxygen system are that it utilizes high-purity oxygen as a source of oxygen and employs a covered, staged aeration basin for the contact of the gas and mixed liquor (49). To date, the system has demonstrated its greatest applicability and cost-effectiveness for treatment of high strength industrial wastes and for large plants treating domestic wastes. Thus, pure oxygen systems for military wastewaters have limited application.

(g) Continuous loop reactors. The continuous loop reactor (CLR) is best described as an extended aeration activated sludge process. The process uses a continuously recirculating closed loop channel(s) as an aeration basin. The reactor is sized based upon the wastewater influent and effluent characteristics with emphasis given to the hydraulic considerations imposed by the basin geometry. hydraulic detention times range from 10 to 30 hours and the mixed liquor concentration in the basin is typically 4,000 to 5,000 mg/L. To provide the necessary oxygen to the system and impart a horizontal velocity, several pieces of equipment are available. These include:

—Brush aerators.
—Low speed surface aerator as used in the Carrousel system.
—Jet aeration.
—Diffused aeration with slow speed mixers.

Clarification can be accomplished using a conventional clarifier or by using an integral clarifier as with the Burns and McDonnell system (159). Advantages of the CLR process include:

–The ability for the system to handle upset loading conditions.
–Produces low sludge quantities.
–Can provide for vitrification and denitrification.
–Typically produces very good and stable effluent characteristics.
–Simplicity of operation.

The major disadvantages include the potential washout of the system by excessive hydraulic flows and the large land area and basin sizes that are required due to the typically high detention times.

(h) Nitrification. The kinetics and design criteria for this system are already well defined. Two important considerations are maintenance of a proper pH and temperature. Nitrification is a very temperature-sensitive system and the efficiency is significantly suppressed as the temperature decreases. For example, the rate of vitrification at pH of 8.5 and 50 degrees F is only about 25 percent of the rate at 86 degrees F. Treatment facilities located in northern climates must be sized at the appropriate loading rate to accomplish the desired effluent level if required to provide year-round vitrification. The loading rate significantly affects the capital costs for construction of the nitrification tanks. The optimum pH has been determined to range between 8.4 and 8.6. However, for those wastewaters where it would be necessary to provide chemical-feeding facilities for pH adjustment, the cost-effective alternative may be to provide additional tankage to allow for the reduced biological activity when the pH is not optimum.

(i) Biological denitrification. As with nitrification, denitrification is a process which involves further removal of the nitrogen by conversion of the nitrate to nitrogen gas. This represents a process for the ultimate removal of nitrogen from wastewater. As with vitrification, there are a number of system configurations that have been developed for denitrification. The most promising system alternatives include suspended growth and columnar systems (46). While there are advantages and disadvantages to either alternative, the more feasible system for military installations

will depend somewhat on effluent criteria. Where suspended solids are critical, a columnar unit may also serve as a filter. In other instances, the suspended growth system will usually be most appropriate.

c. Fixed film processes.

(1) Trickling filters. This type of treatment method has proven very popular over numerous years in the U.S. In 1968, more than 3,700 trickling filter installations existed in this country. In the past, the use of the trickling filter has been considered as the ideal method for populations of 2,500 to 10,000. The principal reasons for its past popularity have been cost, economics and operational simplicity as compared to the activated sludge process.

(a) Types. The trickling filter process is well documented in TM 5-814-3 and will not be repeated herein. The types of trickling filters used and their basic design criteria are set forth in table 6-3. BOD and hydraulic loadings are based on average influent values. Filters at military installations have either been low or high rate single stage facilities. One advantage of most low rate filters is that the longer solids retention time (SRT) in the unit allows for production of a highly nitrified effluent, provided the climatic conditions are favorable. By comparison, intermediate and high rate filters, which are loaded at higher organic and hydraulic loadings, do not achieve as good an overall BOD removal efficiency and preclude the development of vitrifying bacteria. The other classification of filters are those termed as super rate. These employ synthetic media and have been shown to be able to sustain much higher loadings than a stone medium unit. As a result, the super rate filters, in addition to normal applications for domestic and industrial wastewaters, have found applications as roughing filters prior to subsequent treatment facilities. The large surface area per unit volume (specific surface area) and high percent voids of synthetic media allow higher organic and hydraulic loadings. The greater surface area permits a larger mass of biological slimes per unit volume. The increased void space allows for higher hydraulic loadings and enhanced oxygen transfer due to increased air flow.

(b) Performance. Most existing trickling filter installations must be upgraded to meet the new secondary treatment requirements. Decreasing hydraulic or organic loading at existing facilities will not produce a significant increase in BOD removal above original design values; instead, additional treatment operations will be needed to achieve greater BOD removals. Performance of trickling filters is dependent upon several other factors including: wastewater characteristics, filter depth, recirculation, hydraulic and organic loading, ventilation and temperature. While all of these factors are important, wastewater temperature is the one which is most responsible for secondary effluent criteria not being met during winter operating conditions. Based on data from several high rate filters in Michigan, filter performance was observed to vary 21 percent between summer and winter months. Covering trickling filters or providing an additional stage should be considered for improving and maintaining performance.

(2) Rotating biological contractors. Another type of biological secondary treatment system is the rotating biological contactor. This system has been used in Europe, particularly West Germany, France and Switzerland. Manufacturers indicate 1000 installations in Europe treat wastewaters ranging in size from single residences to 100,000 population equivalent. Domestic, industrial and mixtures of domestic and industrial wastewaters have been treated. In the process, the large diameter corrugated plastic discs are mounted on a horizontal shaft and placed in a tank. The medium is slowly rotated with about 40 percent of the surface area always submerged in the flowing wastewater. The process is similar in function to trickling filters since both operate as fixed film biological reactors. One difference is that the biomass is passed through the wastewater in the biological contactor system rather than the wastewater over the biomass as in a trickling filter unit. No sludge or effluent recycle is employed. The system has several advantages, including:

–Low energy requirements compared with activated sludge.

–Small land area requirement compared with trickling filters.

–A high degree of vitrification can be achieved.

—A more constant efficiency can be achieved during cold weather than with trickling filters since the units are easily covered. The covers allow sufficient ventilation, but minimize the effect of low ambient air temperatures.

While the system has achieved high BOD removal efficiencies on domestic wastewaters in the U. S., pilot testing should be performed for any industrial application. A recent U.S. EPA study (42) on an industrial waste showed the biological contractors could not perform at the anticipated loading rate and achieve required removal efficien-

Table 6-3. General trickling filter design criteria

Filter Type	Organic Loading lb BOD/1000 cu ft/day		Hydraulic Loading mgad	Depth, ft	
	Literature	TM 5-814-3 Design Criteria		Literature	TM 5-814-3 Design Criteria
Low Rate (Standard)	10-20	up to 14	2-4	5-7	6
Intermediate	15-30	--	4-10	--	--
High Rate	up to 90	up to 70	10-30	3-6	3-6
Super Rate (Synthetic Media)	--	--	Less Than 50	--	--

ties. It also demonstrated that the activated sludge process was better able to handle shock loads. Although the system may not be applicable for certain industrial waste applications unless pretreatment is provided, it should be considered for upgrading existing military treatment plants treating primarily domestic wastewater. The process has potential as a second stage unit with existing trickling filters to improve performance and also as a vitrification unit. The rotating biological contractor can be considered as an option, however, the use may be limited to add-on or advanced wastewater treatment capacity for nitrogen removal until the RBC equipment reliability and economics have been improved.

(3) Activated biological filter. An activated biofilter (ABF) is a tower of packed redwood or other media which supports the growth of attached microorganisms. Influent wastewater is mixed with recycled solids from the clarifier and returned mixed liquor. The mixture is sprayed over the media and flows through the tower. Oxidation occurs in both the falling liquid film and in the attached growth. Less sludge is produced from ABF treatment, diminishing the size of the final clarifier. Reduced life-cycle and land costs, compensate for high capital cost. ABF treatment achieves the same degree of effluent quality as activated sludge process (39). Biological towers can be designed and operated with the same parameters as activated sludge systems. ABF's are used for both domestic and industrial applications.

(4) Anaerobic denitrification filter. Denitrification in attached growth anaerobic reactors has been accomplished in a variety of column configurations using various media to support the growth of denitrifying bacteria. In the denitrification column, the influent wastewater is evenly distributed over the top of the medium and flows in a thin film through the medium on which the organisms grow. These organisms maintain a balance so that an active biological film develops. The balance is maintained by sloughing of the biomass from the medium, either by death, hydraulic erosions or both. Sufficient voids are present in the medium to prevent clogging or pending. The denitrification column must be followed by a clarification step to remove sloughed solids. The various types of denitrification columns currently available are summarized below:

–Packed bed, nitrogen gas void space, high porosity media.

–Packed bed, liquid voids, high porosity media.

–Packed bed, liquid void, low porosity media.

–Fluidized bed, liquid void, high porosity fine media (sand, activated carbon).

Most denitrification work has been conducted on submerged columns wherein the voids are filled with the fluid being denitrified. The submerged columns can be further subdivided into packed bed and fluidized bed operations. Recently, a new type of column has been developed in which the voids are filled with nitrogen gas, a product of denitrification.

d. Miscellaneous Biological Systems.

(1) Package plants. A number of so called "package plants" have been developed to serve the wastewater treatment needs of small installations. Many of these units are available from a number of manufacturers. The small ones are all factory fabricated and shipped as nearly complete units except for electrical connections and other minor installation requirements. These will serve a maximum population of 300 to 400. Larger sized package plants are partially constructed in the factory and then field erected. These types of facilities generally will serve larger installations, up to about 1 mgd. Package plants are available as biological treatment facilities and some new units have been developed for physical-chemical treatment applications. Nearly all of the biological units use the activated sludge process, principally extended aeration and contact stabilization modifications. The small physical-chemical package plants have been developed mainly as "add on" units to existing biological facilities to provide additional removal of organic and inorganic constituents. Physical-chemical package units are available for multi-media filtration, phosphorus removal, nutrient removal and activated carbon operations. For widely varying flows at small installations, a battery of physical-chemical units might be employed. The on-off operation of these installations would not be satisfactory for biological units.

(2) Batch activated sludge. A batch activated sludge system utilizes a single tank reactor. The typical treatment cycle consists of:

—fill, in which the wastewater is received.

—react, which allows treatment reactions to be completed.

— settle, which separates the sludge from the effluent.

–draw, in which the effluent is discharged.

—idle, the time period between discharge and refill.

A batch activated sludge system combines the reactor and clarifier into a single unit. Sludge wastage can take place at either the end of the react cycle or after the settling cycle, prior to draw off of the effluent. If required, a higher wastage concentration can be obtained through draw off of the settled solids. Effluent quality can be considered essentially equal to conventional treatment, with its benefits being seen mainly with smaller sytems requiring a relatively low flow of wastewater for treatment.

(3) Sequencing batch reactors. The sequencing batch reactor system (SBR) uses two or more tanks with various functions operating in a sequence. The typical treatment cycle consists of the same steps as a single batch activated sludge treatment system, fill, react, settle, draw, and idle. The tanks fill in sequence in a multiple tank system, allowing for a joint reactor-clarifier unit. As with the batch activated sludge system, sludge wastage can occur from each reactor during either the react or settle mode. Vitrification and dentrification are possible through system modifications. The SBR system is capable of meeting effluent requirements, with operational and maintenance cost roughly equal to, and initial cost less than or equal to conventional systems (74).

(4) Septic system with recirculating sand filters. A septic system with a recirculating sand filter utilizes a conventional septic or Imhoff tank with a sand filter instead of a tile field (166). The system also includes a recirculation tank which receives effluent from the septic system as well as underflow from the sand filter. Effluent from the recirculator tank is pumped to the filter on a time basis. Float controls may also be required to keep the recirculation tank from overflowing. The purpose of the recirculation tank is to keep the sand filter wetted at all times. This system eliminates the odor problem common with intermittent filters. This system is applicable for small domestic facilities, recreational areas, etc.

(5) Overland flow. This technique is the controlled discharge, by spraying or other means, of effluent onto the land with a large portion of the wastewater appearing as run-off. Soils suited to overland flow are clays and clay silts with limited drainability. The land for an overland flow treatment site should have a moderate slope.

e. *Biological system comparisons.* Table 6–4 provides a comparison of the key wastewater treatment processes which must be considered for pollution control programs at military installations. These comparisons include major equipment required, preliminary treatment steps, removal efficiency, resource consumption, economics and several other factors which must be considered.

6-3. Physical and Chemical Wastewater Treatment Processes

a. Introduction. Physical and chemical processes may be categorized as treatment for the removal pollutants not readily removable or unremovable by conventional biological treatment processes. These pollutants may include suspended solids, BOD (usually less than 10 to 15 mg/L), refractory organics, heavy metals and inorganic salts. In domestic wastewater treatment, a physical-chemical process may be required as tertiary treatment to meet stringent permit applications. In industrial applications, physical-chemical treatment is frequently used as a pretreatment process in addition to its use as a tertiary process. The primary physical-chemical processes included in this manual are:

—Activated carbon adsorption.

–Chemical oxidation.

–Solids removal (clarification, precipitation).

Each of the treatment alternatives above, as well as, other less common physical chemical processes are discussed in this section.

b. Activated carbon adsorption.

(1) Description. Carbon adsorption removes many soluble organic materials. However, some organics are biodegradable, but not adsorbable. These will remain in the effluent from physical-chemical systems. While carbon adsorption is used in physical-chemical secondary treatment systems, its most significant application is as part of an advanced wastewater treatment system employing numerous schemes for additional constituent removal or as part of a system treating an industrial wastewater stream.

(2) Applications. Carbon adsorption has been adequately demonstrated in numerous pilot and full scale facilities as a system which can achieve a high degree of organic removal to satisfy water quality standards. The carbon adsorption process can be readily controlled and designed to achieve various degrees of organic removal efficiency. This feature makes it unique as an advanced wastewater treatment step. The activated carbon system is utilized to treat certain industrial process wastewaters from military installations including munitions wastes.

(3) Design considerations. Both the powdered and granular forms of activated carbon can be used. However, powdered carbon currently cannot be justified economically due to problems associated with regeneration of the material; thus, the present state-of-the-art in activated carbon

Table 6.4. Summary of primary and biological wastewater treatment processes

Unit Process	Purpose	Major Treatment Equipment. Required	Preliminary Treatment Steps	Application
A. Primary Sedimentation	Remove settleable suspended inorganic and organic solids.	Primary sedimentation tank with sludge collecting mechanism and skimming device.	Screening and usually grit removal .	Almost all domestic wastewaters. Must precede trickling filter. Does not have to precede activated sludge, but usually most economical method of reducing BOD and suspended solids.
B. Trickling Filter Systems	Biologically convert dissolved and nonsettleable organic material and remove by sedimentation.	Trickling filter, settling tank and sludge collector, recirculation pumps (high rate units), and piping.	Must have primary treatment.	Removal of carbonaceous BOO. Under certain environmental conditions may achieve considerable nitrification.
C. Activated Sludge System	Biologically convert dissolved and unsettleable suspended organic material and remove by sedimentation.	Aeration tank, aeration equipment, settling tank, sludge collector, sludge return pumps, and piping.	Usually primary treatment although not necessary.	Removal of carbonaceous BOO. Usually little nitrification unless designed for long solids retention time.
D. Ponds	Combines the purposes of primary and secondary biological treatment as well as sludge treatment and disposal into one unit process.	Earthen pond with inlet and outlet structures.	None.	Small facilities where adequate land area is available. Good for intermittent wastewater discharge, but will not meet U.S. EPA-defined secondary treatment standards.
E. Vitrification (Nitrogen Conversion)	Biologically oxidize ammonia to nitrates.	1. Suspended Growth System - vitrification tank, aeration equipment, settling tank and sludge collector. sludge return pumps, and piping. 2. Trickling Filter System - low-rate filter, settling tank and sludge collector. 3. Rotating Biological Contactor System - several RBC stages, settling tank and sludge collector.	Usually secondary treatment; although in many cases with proper design and operation, nitrification can be part of secondary treatment.	Where ammonia conversion or nitrogen removal is required.
F. Denitrification	Biological removal of nitrogen by reduction from nitrates to nitrogen gas.	1. Suspended Growth system - denitrification tank with mixing equipment, final settling tank with sludge collection equipment, return sludge pumps and piping, chemical feed system, and possibly small aerated basin for release of nitrogen gas. 2. Columnar System - structure containing media similar to deep bed filter (gravity or pressure system), backwash and chemical feed equipment.	Most be preceded by vitrification step.	Where complete nitrogen removal is required and vitrification facilities are installed. Potential for combining with filtration step is good.

wastewater treatment is limited to granular carbon. Both upflow and downflow carbon contractors can be used. Upflow units more efficiently utilize carbon since counter-current operation is closely approached. Downflow contractors are used for both adsorption and some suspended solids filtration. Dual-purpose downflow contractors offset capital cost at the expense of higher operating costs. The following basic factors should be considered when evaluating an activated carbon system (l)(127):

—To avoid clogging, the influent total suspended solids concentration to the activated carbon unit should be less than 50 mg/L.

–Hydraulic loadings and bed depth are important design parameters, but contact time is the most important factor in carbon systems.

–For some domestic and certainly all industrial applications, treatability studies, (laboratory and pilot scale) must be conducted. This is essential since the carbon removes the dissolved trace organics from wastewaters by a combination of adsorption, filtration and biological degradation. Treatability studies will assist in evaluating these factors to optimize design criteria for the particular wastewater under consideration.

c. *Chemical oxidation.*

Table 6-4 (Cont'd). Summary of primary and biological wastewater treatment processes

	Removal Efficiency	Economics	Resource Consumption	Operation	Side Streams	Aesthetic Problems
A.	Removes 40 to 60% of suspended solids and 30 to 40% of BOO.	Capital costs are generally lower than secondary treatment. O&M costs are low.	Very small power consumption for sludge collection mechanism.	Simple to operate and maintain. Most operational labor associated with sludge removal.	Sludge-solids content 3 to 6%.	Severe odor problems if sludge is not removed periodically.
B.	Overall BOD removal (including primary sedimentation) about 85%. Effluent suspended solids 30 to 50 mg/L. Unless covered, removals drop off considerably In winter.	O&M costs are quite low.	Minimal power costs.	Relatively simple and stable operation. Not as easily upset as activated sludge systems. Tends to pass rather than treat shock loads.	Sludge - humus that sloughs off filter medium is generally returned to primary sedimentation.	Filter flies that breed in filter medium. Potential odors if overloaded or improperly maintained.
C.	Generally can remove 90+% of carbonaceous BOD. Effluent suspended solids usually are less than 30 mg/L.	O&M costs are considerably higher than trickling filter system.	High electrical power consumption to operate aeration equipment.	Requires more skilled operation than trickling filter. Subject to upsets with widely varying organic load, but can handle and treat shock loads.	Sludge - considerably more than trickling filter system. Low solids content (0.5 to 1.0%).	None if properly operated. Potential odors if improperly operated.
D.	Removes 99+% of original BOD, but algae in effluent may result in suspended solids (100 mg/L) and BOD (30 mg/L). High vitrification during warm weather. Must provide winter storage; no treatment during ice cover.	Relatively low construction cost and very low O&M costs.	None except land.	Minimal operation. Close effluent lines during ice cover and retain all wastewater until spring thaw.	None.	Odor problems during spring thaw as pond is turning from anaerobic to aerobic conditions.
E.	Greatly dependent on environmental factors such as temperature and pH. Can reach effluent ammonia Concentrations down to 1 to 2 mg/L. Also removes much of the carbonaceous BOD remaininq from secondary treatment.	Costs similar to the appropriate secondary treatment system (activated sludge, trickling filter, RBC).	High power consumption in suspended growth system.	Generally requires supervision equivalent to the appropriate secondary treatment process.	Almost negligible sludge production.	None if properly operated.
F.	Nitrates (as nitrogen) can be reduced to below 1 mg/L. Columnar system with fine grain media also can double as filter with appropriate suspended solids removal.	High construction costs. O&M costs relatively high due to carbon source such as methanol that usually is added to system.	Chemical use such as methanol; miminal power consumption.	Requires skilled operation, careful control of methanol feed, and system monitoring.	A relatively small amount of waste sludges are generated in suspended growth system and coarse grain columnar system. Backwash water in fine grain columnar system.	None apparent at time.

(1) Chlorination. Chlorine is the principal chemical utilized for disinfection in the U.S. Chlorine dosages vary, but for secondary treatment effluents the normal range is from 5 to 15 mg/L with requirements for a chlorine residual of not less than 0.2 to 1.0 mg/L after a 15 minute detention time at maximum flow rate (108). Regulatory requirements may differ in various States and consultation with the appropriate agency is recommended. Disinfection must meet the U.S. EPA fecal coliform level of 200/100 mL. General practice is to provide the chlorine feed either as gaseous chlorine, normally vaporized from liquid storage, or from a calcium hypochlorite solution feeder. Other than for extremely small plants, the gaseous chlorines more economical. However, many of the large metropolitan areas, such as New York and Chicago, have converted to the use of hypochlorite solutions due to the potential hazards involved in transporting chlorine through populated areas. Where treatment facilities are remotely located, such as many military installations, gaseous chlorine will be acceptable provided suitable safety precautions are taken with shipping and handling. Possible disadvantages of chlorine disinfection are the toxicity of the chlorine residual to aquatic life and the potential of the chlorine combining with organic material in the effluent or the receiving stream to form cancer-causing compounds. Some States and the U.S. EPA have proposed limitations on the residual chlorine concentration in both effluent and streams. Thus, for some chlorination systems additional detention time, addition of a reducing agent (sodium bisulfite or sulfur dioxide), or passage through activated

carbon may be required to reduce chlorine residuals prior to discharge.

(2) Alkaline chlorination. Use of breakpoint chlorination to oxidize ammonia to nitrogen gas, which is released to the atmosphere, has been used in water treatment for numerous years. the process requires large chlorine dosages (8 to 10 mg/L chlorine for each mg/L of ammonia oxidized) resulting in high operating costs. Adjustment of pH is often required and formation of complex organic-nitrogen-chlorine compounds have been harmful environmental effects. Application will be limited to removal of trace ammonia after some other ammonia removal process.

(3) Ozonation. An alternative to chlorine is use of another disinfectant such as ozone. Manufacturer's literature indicate over 500 water treatment plants in Europe use ozone for disinfection. Chlorine, however, remains the predominant disinfectant for portable water in the U.S. Although ozone has had limited application in wastewater treatment, equipment manufacturers and other literature report many pilot studies have been and are currently being conducted. Results indicate ozone is an effective disinfectant for wastewater effluents. Use of ozone avoids the problems with aquatic life and disinfects at a faster rate than chlorine. Ozone, however, is 10 to 15 times as expensive as chlorine and on-site generation is necessary (80).

(4) Hydrogen peroxide oxidation. Hydrogen peroxide (H_20_2) is a strong oxidizer but has only limited application in the disinfection of wastewater. This is primarily because three to four hours of contact time is required to accomplish disinfection and it tends to leave a distinctive taste. The primary use of hydrogen peroxides is in industrial applications where it is extremely effective in oxidizing a wide variety of pollutants. Uses include destruction of cyanide which is generated from electroplating and destruction of organic chemicals including chlorinated and sulfur containing compounds and phenols. Hydrogen peroxide is clear, colorless, water like in appearance and has a distinctive pungent odor. Hydrogen peroxide is not a hazardous substance and is considerably safer to handle and store than chlorine gas.

(5) Ultraviolet radiation. Ultraviolet radiation is a very effective alternative to chemical oxidation. This method consists of exposure of a film of water up to several inches thick to quartz mercury-vapor arc lamps emitting germicidal ultraviolet radiation. This technique has been reported to have been used on small systems in Europe for over 100 years. Although this alternative is receiving attention as an alternate, it remains unattractive due to high capital and operating costs for other than very small systems.

(6) Ionizing radiation. Application of ionizing radiation as an alternative to chlorine or ozone for disinfecting wastewater and as an alternative to heat for disinfecting sludge is now in the development and demonstration stage in the U.S. and in Europe. Both gamma rays and high energy electrons are being evaluated. The technical feasibility has been established but data to assess the cost-effectiveness are not yet available. Experience to date with ionizing radiation indicates that applications will be characterized by relatively high capital costs and moderate-to-low operating costs. In addition to destroying microorganisms in wastewater and sludge, ionizing radiation has shown capabilities of reducing concentrations of phenol and surfactants, increasing settling rates and destroying chlorine in wastewater, and improving physical characteristics of sludge. Engineers concerned with either upgrading existing wastewater treating facilities or designing new facilities should be aware of this developing area of potentially applicable technology. Reference to available literature or contact with HQDA (DAEN-ECE-G) WASH DC 20314, is suggested, Authority to apply this emerging technology in any waste treatment process must be obtained from DAEN-ECE-G.

d. Solids removal.

(1) Chemical precipitation phosphorus removal.

(a) Description. Phosphorus removal is needed because it is a major nutrient for algae and other aquatic vegetation. The sources of phosphorus in a typical domestic wastewater for a military facility are associated with human excretions, waste foods and laundry products. While conventional wastewater treatment techniques, i.e., primary sedimentation and secondary treatment, will remove about 10 to 40 percent of influent phosphorus, it often becomes necessary to provide for additional removal to meet effluent or water quality criteria. Numerous States in the U.S. have developed water quality criteria and/or effluent standards for phosphorus. Typical limitations are 1 to 2 mg/L. However, recent standards being considered by regulatory agencies indicate levels for given situations may become more stringent. The U.S. EPA should be contacted for requirements when wastewater treatment facilities alternatives include phosphorus removal.

(b) Application. Some biological techniques for removing phosphorus have been identified,

but no large scale or long term demonstrations of the process have been undertaken. The common method of removal is by chemical treatment usually employing alkaline precipitation with lime or precipitation using minerals (iron or aluminum salts). The process can be accomplished in numerous ways either in the primary system, secondary system or as a separate system. The particular method to employ at a given installation is a matter of numerous constraints. The two predominant methods are mineral addition to the primary clarifier and lime clarification after secondary treatment, although addition of minerals or lime to the final clarifier of trickling filter systems has been successful. Mineral additions to the primary or secondary clarifier will not usually provide quite as low a phosphorus level as lime precipitation. All precipitation processes increase sludge quantities which must be handled. Recalcination of lime will not be economical at most military facilities. Design considerations for the various phosphorus removal alternatives are presented in TM 5-814-3 and the U.S. EPA Process Design Manual for Phosphorus Removal.

(2) Sedimentation.

(a) Process description. Sedimentation is the separation of suspended particles that are heavier than water from water by gravitational means. It is one of the most widely used unit operations in wastewater treatment. This operation is used for grit removal; particulate-matter removal in the primary settling basin; biological-floc removal in the activated sludge settling basin; chemical-floe removal when the chemical coagulation process is used; and for solids concentration in sludge thickeners. Although in most cases the primary purpose is to produce a clarified effluent, it is also necessary to produce sludge with a solids concentration that can be easily handled and treated. In other processes, such as sludge thickening, the primary purpose is to produce a concentrated sludge that can be treated more economically. In the design of sedimentation basins, due consideration should be given to production of both a clarified effluent and a concentrated sludge (125).

(b) Clarifier design. Clarifiers may either be rectangular or circular. In most rectangular clarifiers, scraper flights extending the width of the tank move the settled sludge toward the inlet end of the tank at a speed of about 1 ft/min. Some designs move the sludge toward the effluent end of the tank, corresponding to the direction of flow of the density current. Circular clarifiers may employ either a center feed well or a peripheral inlet. The tank can be designed for center sludge withdrawal or vacuum withdrawal over the entire tank bottom. Circular clarifiers are of three general types. With the center feed type, the waste is fed into a center well and the effluent is pulled off at the weir along the outside. With a peripheral feed tank, the effluent is pulled off at the tank center. With a rim-flow clarifier, the peripheral feed and effluent discharge are also along the clarifier rim, but this type is usually used for larger clarifiers. The circular clarifier usually gives the optimal performance. Rectangular tanks may be desired where construction space is limited. The circular clarifier can be designed for center sludge withdrawal or vacuum withdrawal over the entire tank bottom. Center sludge withdrawal requires a minimum bottom slope of 1 in/ft. The flow of sludge to the center well is largely hydraulically motivated by the collection mechanism, which serves to overcome inertia and avoid sludge adherence to the tank bottom. The vacuum drawoff is particularly adaptable to secondary clarification and thickening of activated sludge. The mechanisms can be of the plow type or the rotary-hoe type. The plow-type mechanism employs staggered plows attached to two opposing arms that move about 10 ft/min. The rotary-hoe mechanism consists of a series of short scrapers suspended from a rotating supporting bridge on endless chains that make contact with the tank bottom at the periphery and move to the center of the tank.

(3) Microscreening. The use of microscreening or microstraining in advanced wastewater treatment is chiefly as a polishing step for removal of additional suspended solids (and associated BOD) from secondary effluents. The system consists of a rotating drum with a peripheral screen. Influent wastewater enters the drum internally and passes radially outward through the screen, with deposition of solids on the inner surface of the drum screen. The deposited solids are removed by pressure jets located at the top of the drum. The backwash water is then collected and returned to the plant. The screen openings range from about 23 to 60 microns depending upon manufacturer type and material. However, the small openings themselves do not account for the removal efficiency of the unit. Performance is dependent on the mat of previously trapped solids which provide the fine filtration. Thus an important factor in design is the nature of the solids applied to the system. The strong biological floes are better for microscreening; weak chemical floe particles are not efficiently removed. Depending upon the influent wastewater characteristics and the microfabric, suspended solids removals have

ranged from about 50 percent to as high as 90 percent. Maintenance of the units can be costly, since they require periodic cleaning. For further information, the U.S. EPA "Process Design Manual for Suspended Solids Removal", and "Process Design Manual for Upgrading Wastewater Treatment Plants".

(4) Filtration. Secondary effluents normally contain minerals which range from the easily visible insoluble solids to colloids. Filtration is one means of removing the suspended solids (and the BOD associated with the suspended solids) remaining after secondary sedimentation to a level which will meet effluent or water quality criteria. Filtration methods most applicable to military facilities are the multimedia filter and the diatomaceous earth system. For information on design criteria and operating considerations, the U.S. EPA Process Design Manual for Suspended Solids Removal should be consulted.

(a) Multi-media. Recently, dual-media, mixed-media and multi-media filtration units have basically replaced the conventional single medium filter otherwise known as the "rapid-sand filter" for wastewater applications. These filters, widely utilized in advanced wastewater treatment, are sometimes referred to as "deep-bed" filters. Single medium filters have a fine-to-coarse gradation in the direction of flow which results from hydraulic gradation during backwash. This gradation is not efficient, since virtually all solids removal must take place in the upper few inches of the filter with a consequent rapid increase in headloss. A coarse-to-fine gradation, as used by multi-media units, is more efficient since it provides for greater utilization of filter depth, and uses the fine media only to remove the finer fraction of suspended solids. The multi-media filter is capable of producing effluents with suspended solids of less than 10 mg/L from typical feed concentrations of 20 to 50 mg/L. This also reduces the BOD since about one-half of the BOD of a secondary effluent is normally associated with the suspended solids. The feed concentration must be kept below 100 mg/L of suspended solids for practical backwash cycles. A typical multi-media system consists of three or more materials, normally anthracite (coal), sand and garnet, with carefully selected specific gravities. Dual-media filters usually utilize anthracite and sand. The filtering system is supported by a few feet of gravel or other support means. Addition of small amounts of coagulant chemicals such as alum or polymer enhances filtration. Multi-media filtration is a process normally associated either with physical-chemical wastewater treatment or as a polishing step after biological treatment. It is particularly applicable for removal of the weaker chemical floe particles while surface straining devices such as rapid-sand filters and microstrainers work well with the stronger biological floes. Use of the filters for the dual purpose of solids removal and as a fixed media for denitrification should also be considered where both processes are necessary. A summary of information on effluent suspended solids to be expected from a multi-media filtration system is indicated in table 6-5.

*Table 6-5. Expected effluent suspended solids from multi-media filtration of secondary effluent**

Effluent Type	Effluent Suspended Solids, mg/L
High-Rate Trickling Filter	10-20
Two-Stage Trickling Filter	6-15
Contact Stabilization	6-15
Conventional Activated Sludge	3-10
Extended Aeration	1--5

*Adapted from the U.S. EPA "Process Design Manual for Suspended Solids Removal".

(b) Diatomaceous earth. Filtration by diatomaceous earth consists of mechanically separating suspended solids from the wastewater influent by means of a layer of powdered filter aid or diatomaceous earth, applied to a support medium. The use of the system for clarification of domestic secondary treatment effluent has been demonstrated only at pilot scale facilities. Multi-media filters are more cost–effective for domestic wastewaters from military installations. However, the diatomaceous earth system is applicable and currently being used as part of a treatment step in munitions wastewater treatment.

e. *Membrane processes.* Other feasible methods of advanced wastewater treatment consist of what are generally known as the membrane processes, and include electrodialysis, ultrafiltration and reverse osmosis. These processes can remove over 90 percent of the dissolved inorganic material to produce a high quality product suitable for discharge or reuse. Considerable pretreatment is required. Use of these membrane processes in the field of wastewater treatment is at the present time limited because the costs are very high and applications will be to small flows at best. For example, a possible application is the treatment for reuse of small process discharges at military field installations. Three different reverse osmosis units were evaluated at a field location by the U.S. Army Environmental Hygiene Agency (1). This study was initiated to determine the feasibility of treating and reusing wastewater from field laundries, showers and kitchens. Where it may be necessary to consider the application of a membrane process for reuse or discharge, reference should be made to appropriate design manuals or manufacturer's literature for information on design criteria.

f. Physical and chemical process comparisons. Table 6-6 provides a comparison of the key wastewater treatment processes which must be considered for pollution control programs at military installations. These comparisons include major equipment required, preliminary treatment steps, removal efficiency, resource consumption, economics and several other factors which must be considered.

6-4. Industrial process wastewater treatment

a. Introduction. Except at those facilities where the principal function is manufacturing, processing or equipment maintenance, the major portion of wastewater produced at a military installation will be domestic waste similar in characteristics to that produced in a residential area. However, for those installations with industrial facilities, certain process wastes produced on-site require separate consideration. The following are examples of these waste producing processes:

–Munitions manufacturing, loading, assembling and packing.
–Metal plating.
–Washing, paint-stripping and machining operations.
–Photographic processing.
–Laundry.

Other process waste sources include hospitals and blowdown from cooling towers, boilers and gas-scrubber systems. Chapter 3 of this manual describes typical industrial waste producing pro

Table 6-6. Summary of physical and chemical wastewater treatment processes

	Unit Process	Purpose	Major Treatment Equipment Required	Preliminary Treatment Steps	Application
A.	Breakpoint Chlorination for Ammonia Removal	Removes nitrogen by chemitally concerting to nitrogen gas. Process also serves as disinfection step.	Chlorine contact basins and chlorination equipment may require carbon adsorption step to remove potentially toxic chloro-organic compounds formed.	At least secondary treatment. Nitrogen must be in ammonia form. The higher the degree of treatment, the less chlorine required to reach breakpoint.	Nitrogen removal . Hiqh chemical costs and side effects make process most attractive as a back-up system in case of failure of primary nitrogen removal process and for removal of remaining trace ammonia concentrations.
B.	Lime Clarification	Primary purpose is to chemically precipitate phosphorus. Secondary purpose is to remove suspended solids and associated BOO.	Clarifier, usually solids contact up-flow type, with sludge collection equipment; chemical feed equipment; and recarbonation facilities. Low alkalinity wastewaters may require two-stage system with two clarifiers. Lime recalcining furnance and related equipment may be used for large facilities.	Usually secondary treatment although lime clarification of raw wastewater is practiced in physical-chemical plants.	Where standards require over 90% phosphorus removal, or phosphorus concentrate ions below 0.5 mg/L, or as an additional step for suspended solids removal. Recalcination of lime sludge generally uneconomical in plants under 10 mgd capacity.
C,	Mineral Addition to Primary Sedimentation	Primary purpose is to chemically precipitate phosphorus. Secondary purposes are increased suspended solids and BOO removal in primary sedimentation, thereby decreasing the load on secondary treatment facilities.	Chemical feed equipment, mixing and flocculating basins for existing primary sedimental ion basins.	Screening and usually grit removal.	Where standards require 80 to 90% phosphorus removal. Phosphorus removals over 90% usually cannot be achieved by this process. Upgrading existing treatment plants where secondary treatment facilities are overloaded.
D.	Multi-Media Filtration	Suspended solids removal.	Filters and backwash equipment.	Generally at least secdary treatment.	Where a high degree of suspended solids removal is required. Particularly applicable following chemical clarification because of "in depth" filtration characteristics.
E.	Microscreening	Suspended solids removal.	Microscreens and tanks.	Seconary treatment.	Removal of suspended solids from secondary effluents. Works best with strong biological floc particles. Not used for chemically clarified effluents because weak chemical floc particles will break through screen.
F.	Granular Carbon Adsorption	1. AWT-remove non-biodegradable dissolved organics following secondary treatment 2. PCT - remove organic material instead of by biological treatment.	Carbon contractors, carbon regeneration furnance, and carbon storage facilities	1. AWT - secondary treatment followed by filtration for down-flow contractors. Filtration not necessary for up-flow contractors. 2. PCT - chemical coagulation of raw wastewater.	1. AWT - to remove trace organic and produce high quality effluent. 2. PCT - remove carbonaceous BOD as in secondary biological treatment.

Table 6-6 (Cont'd). Summary of physical and chemical wastewater treatment processes

	Removal Efficiency	Economics	Resource Consumption	Operation	Side Streams	Aesthetic Problems
A.	Can essentially remove 99+% of ammonia.	Low capital and high O&M cost.	Chlorine. Large quantities needed (from 8 to 10 mg/L for each mg/L of ammonia oxidized).	Requires careful or automatic monitoring to control dose and PH. May require addition of chemicals to control PH.	None.	Adds considerable amount of chlorides to wastewater.
B.	On secondary effluents can remove 99+% of the total phosphorus. Suspended solids levels will be in the 10 to 20 mg/L range.	Construction costs are moderate, but O&M costs are high due to chemical (lime) addition. Disposal of lime sludge must be included in costs.	Lime quantities depend on wastewater alkalinity but generally are high. If recalcination is practiced, fuel consumption will be high but lime is recovered. Power consumption is minimal.	Careful attention to chemical dosage and sludge blankets in clarifiers. Recalcination requires skilled operation.	Lime sludge. Large quantities which, if recalcined, will result in ash for disposal. If not recalcined, must be dewatered for disposal.	None with operation of clarifiers. Potential air pollution problem with recalcining furnace.
C.	Approximately 80% phosphorus removal in primary sedimentation. Overall phosphorus removal after secondary treatment will range from 85 to 95%. Increase suspended solids removal to 60 to 75% and BOD removal to 40 to 50% in primary sedimentation.	With existing primary sedimentation tank capital cost is small compared to lime clarification of secondary effluent. O&M costs are high becasue of chemicals-usually alum or an iron salt. Must consider increased quantities of primary sludge in costs	Chemicals, either alum or iron salt.	Similar to primary sedimentation except for close attention to chemical feed and flocculation.	Increased quantity of primary sludge including chemical precipitates. It may be necessary to enlarge existing sludge handling facilities. Increased primary sludge offset somewhat by reduced secondary biological sludges.	Potential sludge odor problems if improperly handled.
D.	Filter effluents with suspended solids from 0 to 2 mg/L can be obtained with chemically clarified secondary effluents. Removals for secondary effluents depend on degree of bio-flocculation, but range from 3 to 10 mg/L for activated sludge plants to 10 to 20 mg/L for trickling filter plants. Also removes BOD and phosphorus associated with suspended material.	Construction costs are high and O&M costs are moderate.	More power use than microscreening.	Reliable. Can handle shock loads. Relatively easy to operate and maintain.	Backwash water.	None
E.	With secondary effluents suspended solids removals will vary from 50 to 80% and BOD removals from 40 to 70% depending on size of screen openings.	Costs generally less than multi-media filtration.	Minimal power use.	Some slime growth problems on screen. Flow through screen very sensitive to solids loading.	Screen backwash water.	None.
F.	1. AWT - with biological pretreatment can get COD 10 mg/L and BOD 1 mg/L. 2. PCT - cannot remove COD and BOD to levels in AWT due to nonadsorbable biodegradable organic (sugars and alcohols).	High capital and O&M costs. One of the most expensive wastewater treatment processes.	High fuel consumption. for carbon regeneration. Power use is relatively small.	Monitoring carbon column break through and carbon regeneration requires skilled operation.	Considerable waste activated carbon without regeneration; very small-amounts with regeneration.	Regeneration furnace potential air pollution problem.

cesses, waste characteristics. This section describes waste reduction and treatment methodology applicable to military installations.

(1) Considerations. The need to consider industrial process wastes separately is based on the following potential effects:

—Degradation of the sewer lines by corrosion or chemical attack and/or production of an environment dangerous to maintenance and operating personnel.

–Interference with normal treatment plant processes.

–Inability of treatment plant processes to reduce a process waste constituent to a level required by regulatory constraints or other environmental considerations.

(2) Limitations. Brief descriptions of processes are included in chapter 3 to serve as a basis for consideration of the effect of such wastes on facility planning. Typical analyses of

some process wastes are also provided. The quantity and quality of process wastes produced often vary in similar installations; therefore, data presented are descriptive only. To establish basic design criteria, more detail is required. The applicability of the wastewater treatment and sludge disposal processes presented elsewhere is discussed for each special process in this section.

b. Munitions wastes. Wastes generated from the munitions industry originate from both manufacturing (MFG) plants as well as loading, assembling and packing (LAP) facilities.

(1) Explosives and propellants. The major explosive product produced is trinitrotoluene (TNT). Other explosive chemicals that are generated in military installations include:

—nitroglycerine.
—HMX and RDX.
—tetryl.
—nitrocellulose.
—black powder.
—nitroguanidine.
—lead azide.
—lead styphnate.

A description of the manufacturing process utilized for each explosive, as well as typical wastewater characteristics are included in chapter 3.

(a) Waste reduction. Process changes to include increased chemical recovery/reuse and good housekeeping are important waste reduction practices in the manufacture of explosives and propellants. For examples, as indicated in chapter 3, changing from batch-type to continuous TNT manufacturing resulted in lower chemical and water usage and reduced waste volumes (20)(23)(116). High pressure water sprays also may result in decreased cleanup water usage. Batch-dumping of process wastes and acids must be discouraged. Whenever cooling water is reasonably uncontaminated, it should be segregated from the contaminated water streams, thereby reducing the volume of waste to be treated.

(b) Sampling and gaging. Care must be taken in establishing a sampling program for explosives manufacturing wastes which will accurately represent the waste flow and characteristics. This is necessary because of the difference in waste characteristics from different manufacturing plants, even if they are making the same product. Batch dumping, periodic cleanup operations and changes in production levels all contribute to wide variations in flows and concentrations. Such variations can result in the need for added treatment capacity and/or provision for equalization storage. Cost-effective design and operation of treatment equipment depend on accurate assessment and management of waste flow and quality.

(c) Environmental impact. The blood-red color from red water produced in TNT manufacture and fish kills resulting from high acid concentrations are the most readily visible environmental impacts of improperly treated explosive wastes. High oxygen demand, excessive nitrate compounds, elevated temperature and high suspended solids also contribute to the gradual degradation of the receiving body of water.

(d) Treatability. Explosives manufacturing wastes are sometimes toxic to conventional biological treatment plants, but may be treated by physical and chemical methods and by specifically adapted biological means. Waste acids may be neutralized with lime or other alkaline material using conventional pH control methods. Activated carbon adsorption has been successful for removing color-causing TNT compounds as well as HMX and RDX (20)(116)(130). The acidic wastes must not be neutralized with lime until after carbon treatment, because color removal efficiency is greater at low pH, and precipitates formed by lime addition will encrust and clog the carbon column. Color may also be removed by ion exchange, although problems exist with resin regeneration. Wastewater from an acid plant in a TNT manufacturing complex has been successfully treated by lime precipitation followed by ion exchange (11 5). Biodegradable explosives wastes, including dynamite, nitrocellulose, HMX and RDX and TNT to some extent, may be treated by biological methods such as land irrigation or activated sludge after process proof by bench and pilot scale studies (77)(106)(107). Lead resulting from the production of lead azide and lead styphnate may be removed by chemical precipitation using sodium sulfhydrate.

(e) Red water treatment. Red water is currently one of the most difficult disposal problems. Red water has been sold to kraft paper mills when transportation costs make this economically feasible. In other cases, it has been burned in an incinerator. Where land permits, evaporation ponds have been used; care must be taken to effectively line the pond to prevent ground water contamination from leaching. Fluidized bed incineration and recycle of the resultant ash are being studied (87).

(2) Projectiles and casings. The manufacture of the lead slugs, bullet jackets and shell casings generates wastewater different in composition than from explosives manufacture. Waste constituents include heavy metals, oil and grease, soaps and surfactants, solvents and acids.

(a) Waste reduction. Waste reduction practices which should be evaluated include use of counter-current flow of successive rinse waters, separation and reuse of lightly contaminated water (such as cooling water), elimination of batch-dumping of processing solutions, recovery and reuse of metals and pickling liquor, and provisions to divert highly contaminated spills to holding tanks for individual treatment.

(b) Gaging and sampling. Due to the extreme variations in flows and characteristics encountered, careful sampling and gaging procedures must be employed in order to characterize the waste and identify peak values. Identification of peak values is helpful in tracing batch dumping and is essential to cost-effective design of treatment facilities.

(c) Environmental impact. The environmental impact of metal working wastes can be acute. Heavy metals, acids, surfactants and oils are all highly toxic to aquatic life. Serious stream degradation results from the direct discharge of insufficiently treated metal wastes.

(d) Treatability. Toxic materials present in the wastewaters from munitions metal parts manufacturing can interfere with biological treatment. Treatment methods available include neutralization with lime, heavy metal removal and recovery by precipitation or cementation, and oil removal by gravity separation. Suitably pretreated wastes will be cost-effectively treated along with domestic wastes in biological facilities (21).

(3) Loading, assembling and packing wastes. The main LAP operations are explosives receiving, drying and blending operations, cartridge and shell-filling operations and shell-renovation. The main waste sources are spillage, cleanup water, dust and fume scrubber water and waste flows from renovation operations.

(a) Waste reduction. Waste reduction which should be considered in a pollution control program can be accomplished by reuse of lightly contaminated water for air-scrubbing and shell-washout. In the shell-loading operation, the use of covered hot water baths and shell-loading funnels can reduce or eliminate explosives contamination of the water baths. High-pressure water sprays can reduce the amount of water used for cleanup. Recovery of waste explosives from shell-washout operations reduces the waste load and is an economic incentive. Proper wastewater gaging and sampling practices can be quite helpful in identifying the source of any unauthorized batch-dumps and lead to waste reduction practices.

(b) Environmental impact. The environmental impacts of LAP wastes include red coloration from TNT-containing wastewater, heavy metal toxicity, oxygen depletion and toxicity and bitter tastes from excess nitrates (11)(20).

(c) Treatability. LAP plant wastes have been treated successfully by diatomaceous earth filtration followed by activated carbon adsorption. Effluents of less than 5 mg/L of TNT are readily attainable. Suspended solids removals by the diatomaceous earth filters have, in some instances, been much less than expected. Presence of suspended solids in waste entering the activated carbon filter greatly reduces the effective life of the carbon unit due to clogging. Normally, the spent carbon is burned, although experimental work is being performed to determine the feasibility of regeneration in fluidized beds. Carbon usage varies from 2 to 7.5 lb carbon/1000 gal (11)(20). Plating wastes from renovation operations are treated in the manner described in chapter 3.

c. *Metal plating.* The major waste sources are rinse water overflow, fume-scrubber water, batch-dumps of spent acid, alkali, or plating bath solutions, and spills of the concentrated solutions.

(1) Plating waste separation. Processing solutions are often replaced on an intermittent basis; consequently, dumps of spent solutions impose a heavy short term load on treatment facilities. Therefore, separate collection of waste process solutions and rinse waters should be evaluated. Separation as to type of waste is also desirable to facilitate later treatment and to avoid the production of the toxic hydrogen cyanide gas at low pH levels. Categories for waste separation are as follows:

—Oil bearing wastes from cleaning operations.
—Acid wastes including waste pickling liquor, acid-plating solutions, and anodizing solutions.
—Alkaline wastes including cyanide-plating solutions.

(2) Waste reduction practices. There are a number of waste reduction practices which can be effective and should be considered for plating operations including: dragout reduction, process/chemical changes, and good housekeeping (35)(41)(111).

(a) Plating waste dragout reduction. Reducing the dragout from chemical baths not only reduces the contamination of successive rinse water, but it also prolongs the life of the chemical bath. Some dragout reduction practices which should be evaluated are:

—Design special drip pans, high-pressure fog-sprays, air knives and shaking mechanisms.

— Improve racking procedures and minimize overcrowding on the rack to facilitate drainage of process chemicals back into the chemical tank.

—Increase drainage time over the process tank or install an empty tank upstream from the rinse operation in which the process solution can be drained and returned to the process tank.

–Reduce the viscosity of plating agents with either water or heat.

—Add wetting agents to process solutions to reduce surface tension and facilitate drainage.

(b) Plating process changes. Changes in process or chemicals used can result in a reduced waste volume, reduced waste strength or a waste which is more readily treatable. Process/chemical changes include the following and should be considered in pollution control evaluations:

—Eliminate use of breakable containers for concentrated solutions.

—Employ a recovery step for metals from the waste stream. This adds an economic incentive to cleanup the effluent.

—Recirculate the water used in the fume-scrubber systems.

—Separate cyanide wastes from chromium bearing and other acid wastes to avoid production of lethal hydrocyanic acid fumes.

—Substitute high-concentration plating solutions for low-concentration solutions, reducing the volume of waste to be treated.

—Replace cyanide salt plating solutions with low cyanide or cyanide-free solutions.

—Use counter-current rinse flows rather than using fresh water in all rinses.

(c) Plating waste reduction by other means. Good housekeeping steps are important waste reduction practices which should be employed for all industrial operations; those particularly important to plating include the following:

—Curb areas which have chronic spillage or leakage problems and divert spills to a holding tank for treatment.

— Increase inspection and maintenance of pipes, valves and fittings to prevent leaks and spills.

(3) Gaging and sampling. Because of the concentrated processing solutions used and their highly variable characteristics, proper wastewater gaging and sampling is essential in determining the characteristics and sources of batch-dumps and the resultant peaks. Sampling of effluents from the individual waste sources can be an important supplement to end-of-pipe data.

(4) Environmental impact. The extremes of pH and the high concentrations of heavy metals and cyanides are extremely toxic to all forms of life. Fish kills and even fatalities to livestock have been reported when plating wastes were fed directly to a body of water (34). The accumulation of heavy metals in sediment causes long term pollution. In addition, toxicity to micro-organisms retards the self-purification abilities of the receiving stream.

(5) Treatability. Plating wastes may be treated by conventional municipal biological processes if sufficient dilution is provided. Otherwise, the extreme toxicity of the waste will seriously interfere with the biological processes. Just as heavy metals become concentrated in stream sediments, they also accumulate in treatment plant sludge and can interfere with subsequent biological treatment processes and disposal procedures. Pretreatment of industrial wastes to reduce constituents to levels which will be compatible with biological treatment is required. Pretreatment requirements for plating wastewater to ensure successful subsequent treatment with domestic waste may require pilot scale studies (34)(76)(78). The pH control, cyanide destruction and heavy metal removal/recovery methods discussed in chapter 3 are capable of providing the required pretreatment for discharge to a biological treatment system or directly to a receiving body of water. Such treatment may also permit recycling and reuse of the water for some process needs. In many cases, it is desirable to integrate the treatment operations into the overall plating scheme (33)(109).

d. Washing, paint-stripping and machining. Washing and paint stripping of aircraft and land vehicles is performed as routine maintenance or in preparation for repairing, overhauling and machining of a part or component of the aircraft or vehicle.

(1) Waste reduction practices. The volume of washrack and paint-stripping wastewater to be treated can be reduced considerably by excluding storm water and by employing practices to reduce the amount of water used. It is reported that some U.S. commercial airlines have used hot, rather than cold, water sprays in the paint-

stripping operation, resulting in a water usage of only four gallons per gallon of stripper. Also, squeegees are used to remove the paint-stripper and paint skins onto plastic sheets which are disposed of at a sanitary landfill (29).

(2) Gaging and sampling. Care must be taken when sampling wastewaters with high oil contents, such as washrack and paint-stripping wastes, to ensure that a representative sample is obtained (15 1). The precaution is required due to the tendency of oil to float on the water surface.

(3) Environmental impact. Washrack and paint-stripping wastewaters containing high concentrations of phenols, organic solvents, chromium, oils and surfactants are extremely toxic to aquatic life. Failure to properly contain and treat these wastes can result in fish kills, stream purification inhibition and odors. All of these are unacceptable by any water quality standards (26)(29)(1 13). Oils from machining operations can be toxic and may impose a high oxygen demand on the receiving body of water.

(4) Treatment. Unless highly diluted, the raw wastewaters from machining and paint-stripping operations and washracks utilizing solvents are highly toxic to the microorganisms of biological treatment plants, interfering with both aeration and sludge digestion processes. Paint-stripping wastes are particularly toxic. A typical pretreatment system for a major facility would include the following steps:

- –Gravity separation tank equipped to remove floating oils and settleable solids.
- –Detention tanks with mixing to provide equalization of flow and waste strength as well as to permit evaporation of volatile solvents.
- –Chemical addition in a rapid mix tank followed by slow mixing in a separate tank to promote flocculation, break emulsions and agglomerate solids.
- –Final treatment in an air flotation unit to remove flocculated particles.

For smaller facilities, where washrack wastes are only a small part of the total waste flow, an alternate approach can be used. A storage tank, arranged to receive this waste and equipped with air mixing and adequate air emission controls, would provide for evaporation of a part of the volatile solvents and permit pumping to the main sewer at a controlled rate. At the main treatment plant, the primary settling tank preceding biological treatment will have adequate oil and solids removal capacity.

e. *Photographic processing.* Because of the widespread use of photography in military operations, the military services operate many photoprocessing facilities. The size of such facilities varies greatly, with waste flows of 10,000 to 1,000,000 gallons per month. Liquid wastes originate from the discharge of spent processing solutions and associated rinse or washwaters. Approximately 90 percent of the liquid waste produced is from the rinse operations.

(1) Waste reduction practices. Waste reduction practices include recovery of silver, regeneration of ferrocyanide and other chemicals, chemical bath reuse and the use of squeegees to reduce the carryover, or dragout, of chemicals from one step to another.

(a) Silver recovery. Because of the high market value of silver, it can be economically recovered from the spent bleach and fixer solutions as well as from the final washwater. Such recovery reduces the impact of silver as a pollutant and in some cases allows the fixer solution to be reused, reducing chemical replacement costs. Silver recovery is most often accomplished by passing the waste effluent through a proprietary steel-wool-filled canister where silver is exchanged for iron. Silver can also be removed by precipitation with sodium sulfide or by electrolysis.

(b) Bleach regeneration. The bleach solution may also be reused by regenerating ferrocyanide from the spent ferrocyanide using oxidizing agents such as persulfate and ozone. One manufacturer offers a packaged bleach regenerator material (123). Regeneration provides a cost savings as well as pollutant reduction. Methods of complete cyanide destruction are discussed later in this chapter.

(c) Equalization. Equalization is very important if photographic wastes are treated biologically, particularly when the photographic processing operation occurs during only part of the day. Daily variations in flow and concentration can cause serious operating difficulties at the treatment plant.

(2) Gaging and sampling. To define wastewater quality and quantity for a new installation, sampling and gaging data from a similar operating facility is valuable. The presence of a large amount of free silver metal will inhibit biological action and yield unreliable BOD test data. Large amounts of thiosulfates from the fixing bath will exert an oxygen demand. Care must be taken to prepare appropriate waste dilutions to avoid these interferences with the BOD tests.

(3) Environmental impact. The environmental impact of discharging improperly treated photographic waste can be severe due to high concen-

trations of toxics. Heavy metals such as silver are toxic to aquatic life and can accumulate in sediments. Cyanides, strong reducing agents and constituents with high oxygen demands are all capable of seriously degrading water quality.

(4) Compatibility with domestic wastewater treatment. Experimental work has shown that photographic processing wastewater is treatable by biological means. One survey (30) indicated that almost 80 percent of Air Force base photographic facilities discharge all or part of their wastes to sanitary sewers. The Air Force Environmental Health Laboratory at Kelly AFB recommended disposal of desilvered photographic wastewater in trickling filter or activated sludge plants in proportions not exceeding 0.05 percent of the total waste influent. It is further specified that the plant should discharge to a stream providing a dilution of at least ten to one hundred times, to account for the conversion of ferrocyanide to toxic cyanides. Mohanro, et al., (75) chemically treated photographic wastes with alum to reduce the COD by 40 percent, then polished the effluent in activated sludge units. With roughly a two to one ratio of domestic sewage to chemically treated photographic waste, 90 percent BOD reductions were obtained. Dagon (70) reported on a 20,000 gal/day package activated sludge plant operating totally on raw photographic wastewater and obtaining as much as 85 percent BOD reduction. However, problems were experienced with poor sludge settling. Therefore, it is generally recommended that photographic wastes be treated witih domestic sewage in a biological plant after providing silver recovery and bleach regeneration; the photographic waste portion should be kept to less than 20 percent of the total. Bench scale or pilot plant testing may be required to define the treatment approach in some instances.

f Laundries. Central laundering facilities are provided at most military facilities. At facilities engaged in industrial-type operations, additional pollution problems may result from the laundering of the employees' work clothes.

(1) Waste reduction practices. In recent years a variety of different synthetic laundry detergents have been used. Biodegradable detergents have replaced "hard" detergents. In some areas, low phosphate or non-phosphate detergents have replaced the established high phosphate compounds. The type of detergents used does warrant some consideration because of treatment requirements to meet regulations covering effluent characteristics.

(2) Gaging and sampling. Gaging and sampling of laundry wastewaters present no particular problems. However, due to the differing characteristics of the various laundering processes and wash cycles within a process, some care must be taken in order to obtain representative wastewater samples.

(3) Environmental impact. The older "hard" synthetic detergents such as alkyl benzene sulfonates (ABS) were resistant to degradation by biological means. Thus, they were discharged untreated to bodies of water, causing foaming problems. Currently used biodegradable detergents such as linear alkylbenzene sulfonate (LAS) have eliminated this problem. These detergents are biodegradable and exert a BOD in addition to that of the soil, grease, starch and other materials washed from the soiled garments.

(a) Phosphate. There has been a great amount of controversy about the contribution of detergent phosphate compounds toward the eutrophication of lakes and rivers. Some states and cities have banned the use of phosphate-containing or high-phosphate detergents. The environmental effects of phosphates or the elimination thereof are still unresolved.

(b) Explosives. In explosives manufacturing or LAP facilities, the laundering of employees' work clothes can create "pink water" conlamination of the laundry effluent, with the resultant toxic effects and undesirable aesthetic conditions.

(4) Treatability. Laundry wastewaters may generally be treated with domestic sewage by conventional biological systems. Due to the high levels of emulsified grease, BOD and phosphates, special primary treatment, or pretreatment at the laundry, may be required depending on the relative proportion of laundry flow to total plant flow. Chemical precipitation and flotation have been used successfully as pretreatment (103)(130). Because surfactants (ABS and LAS) interfere with oxygen transfer, special care should be taken to ensure that biological processes are receiving a sufficient oxygen supply. When phosphorus removal is required, chemical precipitation processes should be employed.

(a) Unacceptable treatment. Laundry wastewaters should not be treated anaerobically, as in a septic tank-drainage field system. The synthetic detergents are not broken down and are therefore more likely to enter water supplies. There is evidence that the detergents may also facilitate the movement of coliform bacteria through the soil (25).

(b) Treatment and recycle. Laundry wastewaters may be treated in commercially available physical-chemical units with the possibility of recycling the effluent. One system involves chemical precipitation with alum, followed by sand filtration, carbon adsorption and ion exchange. Another system consists of chemical precipitation and diatomaceous earth filtration. About 94 percent phosphate removal, 90 to 98 percent ABS removal, 60 to 80 percent COD reduction and 60 to 70 percent BOD reduction can be obtained (35).

g. *Other generators.* Other wastewaters typical of some military facilities include hospitals discharges, boiler water blowdown, cooling water system blowdown, blowdown from boiler flue gas-scrubber systems and vehicle washing facilities.

(1) Hospitals. Hospital wastewaters require special attention because of several factors. The diurnal peaks and minimums of both flow and concentration may be different from those normally associated with domestic wastewaters due to the unique hospital patterns of activity. Pathogenic organisms will probably be present in higher than normal concentrations; however, modern biological or physical-chemical secondary treatment plants with post-chlorination should eliminate excess pathogens in the effluent. Conservative design of chlorination facilities is encouraged. Operating personnel must exercise special care to reduce the possibility of infection. Ample design and maintenance of screening equipment should be exercised to eliminate most problems caused by excessive quantities of gauze, rags and bandages in the wastewater. Average sewage flows from hospitals are estimated at about 100 gallons per resident per day in TM 5-814-1, while other sources estimate as high as 200 gallons per bed per day. These values are quite similar to those for normal domestic sewage. Resident population includes patients and full time employees.

(2) Boilers. This waste is normally hot, up to 210 degrees F, and contain phosphates (30 to 60 mg/L), sulfite (30 to 60 mg/L), organic matter and some suspended material. Normally, blending this water with other wastes reduces various constituents to a level which will not inhibit subsequent biological treatment. Direct discharge of blowdown to a receiving stream would require treatment to reduce phosphate and sulfite concentrations. In addition, cooling would be required for direct discharge.

(3) Cooling water systems. Cooling water systems can be classified in these general categories:

–Once-through systems.
–Closed systems.
—Evaporative recirculating systems.

(a) In once-through systems, the cooling water is obtained from a lake or stream and returned to the same stream with little or no treatment. Periodic additions of biocides are sometimes required to prevent fouling of the cooling water equipment. Chlorine is the most commonly used biocide. In some instances, the water may require de-chlorination prior to return to the stream.

(b) Closed cooling systems are used where the composition of the cooling water is critical, such as in the cooling of high temperature surfaces. The cooling water rejects heat to an air-cooled radiator or through a heat exchanger to a once-through or evaporative recirculating system. Blowdown or other losses from a closed system are small but contaminated. Corrosion inhibitors sometimes contain chromate, zinc, sodium nitrate, and borax which must be removed prior to biological treatment or stream disposal.

(c) The evaporative recirculating system uses a cooling tower or spray pond to dissipate heat by evaporation of a part of the flow. Although limited by blowdown, this results in an increase in the concentration of dissolved solids to a level of 3 to 5 times that found in the makeup water. To avoid corrosion, scale and biological problems, acid, inhibitors and biocides are added to the system. Treatment of the blowdown is sometimes necessary for removal of any chromate, zinc compounds or other materials used as an inhibitor.

(4) Scrubber systems. Scrubbers are used to avoid air pollution. Airborne wastes, accumulated by the recirculating liquid, require that the liquid be periodically or continuously treated for removal of wastewater constituents. In scrubbing of boiler stack gases, fine ash and sulfur oxides must be removed or neutralized. Other scrubbing systems have similar treatment requirements.

h. *Treatment methods.* Special treatment processes are required for some industrial wastewater constituents. These processes may be employed to provide for pretreatment prior to mixing with other wastes for complete wastewater treatment and discharge, or for recovery of special constituents.

(1) pH control. For discharging wastewater to a biological treatment process or directly to a receiving stream, pH must generally be maintained in the range of 6.0 to 9.0; although limits may be much closer in certain instances. Treatment processes to destroy cyanides, to reduce hexavalent chromium and to precipitate heavy metals also require pH control.

(a) Acid waste neutralization. Neutralization of an acid waste (low pH) can be accomplished by adding alkaline materials such as crushed limestone, lime, soda ash or sodium hydroxide to the acidic waste. Limestone ($CaCO_3$) neutralization of a waste containing sulfuric acid forms a salt of limited volubility ($CaS0_4$) which cn cause adherent deposits on equipment surfaces and piping. Hydrated lime ($Ca(OH)_2$) or quicklime (CaO) are more commonly used, since these materials have more neutralizing capacity per pound than limestone. However, lime may also form calcium sulfate sludges. Strong bases such as soda ash (Na_2C0_3) or sodium hydroxide ($NaOH$) quickly neutralize strong acids, forming soluble salts and virtually eliminating the sludge problem, although increasing the dissolved solids content of the water. Strong bases require special equipment and handling and are four to eight times as expensive as lime or limestone.

(b) Alkaline waste neutralization. Neutralization of an alkaline or basic wastewater (high pH) can be accomplished by adding acidic materials such as carbon dioxide (CO_2) or sulfuric acid (H_2S0_4). Carbon dioxide may be added by passing boiler flue gas or bottled CO_2 gas through the alkaline waste, forming carbonic acid (H_2CO_3) which then neutralizes the base. Sulfuric acid readily neutralizes bases, although it is highly corrosive and requires special equipment and handling. Other strong acids, such as hydrochloric acid ($HC1$), can be used depending on acid costs.

(2) Heavy metal removal and recovery. Heavy metals which are of most concern are silver (Ag), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), lead (Pb), nickel (Ni), tin (Sri), and zinc (Zn) because of their toxicity and/or high market value (86). Military sources of heavy metals include munitions production, metal plating, aircraft and motor vehicle washing, paint-stripping and metal-working, photographic processing and cooling water system blowdown. The most commonly used heavy metal removal techniques are chemical precipitation, metallic replacement, electrodeposition, ion exchange, evaporation, and reverse osmosis, although solvent extraction, activated carbon adsorption and ion flotation are being developed and are applicable in some situations (32)(33)(39)(86).

(a) Chemical precipitation. the most commonly used removal method, particularly when metal recovery is not a consideration, is precipitation. This process is based on the fact that most metal hydroxides are only slightly soluble and that some metal carbonates and sulfides are also only sparingly water soluble. The typical precipitation process using sodium hydroxide or lime as a reactant is generally applicable to copper, zinc, iron or nickel removal with no special modifications.

–Chromium exists in wastewater in both the highly toxic hexavalent and the less toxic trivalent forms. To precipitate chromium, the hexavalent form must first be reduced to the trivalent form using reducing agents such as sulfur dioxide, ferrous sulfate, metallic iron, or sodium bisulfite. The reaction is best performed in an acidic solution with a pH of 2.0 to 3.0. The trivalent chromium is precipitated as chromium hydroxide by raising the pH with lime or sodium hydroxide (34)(39)(86).

–Cadmium hydroxide precipitation by lime occurs at high pH. If cyanide is also present (as inplating waste), it must be eliminated first by adding sodium sulfide. The proprietary "Kastone" process is a hydrogen peroxide oxidation-precipitation system which simultaneously oxidizes and precipitates cadmium as cadmium oxide which can be recycled to some process solutions (130).

–Lead may be precipitated by substituting soda ash for lime in the conventional lime precipitation scheme. Both mercury and silver as well as lead may be precipitated as sulfides with the addition of combinations of sodium sulfide, sodium thiosulfate or sodium hydroxide (21)(86). The precipitated sulfide sludge may be sold to a refinery for recovery (130).

(b) Metallic replacement. The metallic replacement or displacement process is used when metal recovery is desirable, such as silver recovery from photographic wastes and copper recovery from brass-working wastes. In this process, a metal which is more active than the metal to be recovered is placed into the waste solution. The more active metal goes into solution, replacing the less active metal which precipitates (or plates) out and is recovered. Zinc or iron, in the form of either dust or finely-spun wool, is often used to recover silver or copper (30)(86). A proprietary spun-iron cartridge is used to recover silver from waste photographic fixing solutions in normally a continuous operation (111). The treated fixing solution may still contain at least 1,000 mg/L of silver as well as the ionized iron and cannot be

reused because the iron is a contaminant in the fixing process. The high residual concentration of potentially toxic metal also requires that bench and/or pilot scale studies be used to establish the treatability of the waste by conventional biological systems.

(c) Electrodeposition. Like metallic replacement, electrolytic recovery is used to recover valuable metals such as silver or copper from photographic processing, brass pickling or copper-plating wastes. When a direct electrical current of the proper density is passed through the wastewater solution, the metal in solution plates out in a pure form on the cathode. The electrolytic method may be operated continuously or batch-wise, is effective over a range of 1000 to 100,000 mg/L of influent metal and may produce an effluent as low as 500 mg/L of metal. However, close supervision is required in order to maintain proper current density (30)(86)(130). Again, the residual metal concentrations are high enough to limit biological treatment of the waste.

(d) Ion exchange. Ion exchange technology has been developed for treating chromium wastes from plating processing to include chromium detoxification or recovery, water reuse and heat recovery from hot rinses. This is normally a continuous flow process rather than a batch-type operation. Mixed wastes of chromium and cyanides can be treated first by a cation exchanger to remove metals from complex metal cyanides generating hydrogen cyanide, and then by an anion exchanger to remove the liberated cyanide. The concentrated solution formed by regenerating the exchange resins can be a source of recoverable product in many cases (34). Ion exchange is also being investigated for the recovery of silver from photographic processing wastes, chromate from cooling water system blowdown (115) and cadmium from plating solutions.

(e) Evaporation. Evaporation is used to recover heavy metals particularly chromate from some plating solutions. Evaporation by applying heat or vacuum to the solution may be employed. The distilled water from evaporation is reused as process rinse water (129). Rinsing with high purity water results in low rinse water use.

(f) Reverse osmosis and ultrafiltration. Reverse osmosis and ultrafiltration processes have been rapidly improved in recent years, and are used in several cases to treat plating rinse waters. Use of membrane processes for treatment of cooling water blowdown for dissolved solids and chromate removal has also been reported (45)(50)(92).

(3) Cyanide destruction. Cyanides are found principally in metal plating wastes (including those wastes from metal-renovation operations) and photographic processing wastewaters. The most toxic form of cyanide is hydrogen cyanide (HCN), while the complex iron cyanides $(Fe(CN_6)^{-4}$ and $(Fe(CN)_6)^{-3}$ and the cyanate $(CNO)^-$ are less toxic by several orders of magnitude. The most widely used cyanide destruction process is alkaline chlorination. Other treatment processes which have been used in actual practice include oxidation using hydrogen peroxide (including the proprietary “Kastone” process), and ion exhange (32)(33)(34).

(a) Alkaline chlorination. Alkaline chlorination involves oxidation of the cyanide to carbon dioxide and nitrogen gas using chlorine in a high pH solution. This is normally a single-step reaction requiring about 4 hours with a solution pH of 11. A two-step operation consists of cyanide conversion to cyanate at pH of 11, requiring about 30 minutes, followed by complete destruction of cyanate to carbon dioxide and nitrogen gas at pH of 8, requiring another 30 minutes. About 5 mg/l of excess chlorine is maintained (129). Vigorous agitation is required, especially when metal-cyanide complexes are present, to prevent precipitation of untreated cyanide salts (34)(130). Generally, flows smaller than 20,000 gallons per day use batch treatment in two tanks, in which one tank of waste is treated while the other is filling. A continuous treatment scheme requires instrumentation to control the chemical additions, and is normally uneconomical for small flows. Either chlorine gas or hypochlorites may be used as the chlorine source, depending on economics and particular preference. Either sodium hydroxide or lime is used to raise the pH (34)(109).

(b) Hydrogen peroxide oxidation. Cyanides may be oxidized to cyanate by hydrogen peroxide. This process is used in Europe and has the advantage of not introducing an additional pollutant (residual chlorine) into the water (33). The proprietary “Kastone” process is basically a hydrogen peroxide-formaldehyde method of cyanide oxidation. Formaldehyde reacts with the cyanide to form formaldo-cyanohydrin which is readily oxidized by the hydrogen peroxide. This process is particularly advantageous for plating waste treatment because the hydrogen peroxide also precipitates bevy metals as oxides (124).

(c) Ion exchange. Ion exchange using a strong base anion exchange resin can remove cyanides effectively from plating wastes, although not always from photographic wastes due to resin poisoning by the iron cyanide complexes. Wastewater is first passed through a cation exchanger to remove metals, breakup complex metal cyanides, and free the cyanide for removal by the successive anion exchanger. The anion resin may be regenerated with caustic, recovering the cyanide as sodium cyanide. The volume of the recovered cyanide solution is only 10 to 20 percent of the original waste volume (34)(109)(111).

(4) Oil removal. Wastewater from munitions metal parts manufacturing and flows from aircraft and vehicle washing, paint-stripping and metal-working operations may contain large quantities of oils in any of three forms: free floating oil, emulsified oil or soluble oil. Physical, chemical and biological treatment steps may be used in various combinations in order to reduce oil concentrations to levels required by water usage or regulatory criteria.

(a) Free oils. Free oils readily float to the water surface to be removed by gravity separators such as conventional primary clarifiers with surface skimming devices or separators designed according to American Petroleum Institute (API) criteria. The effectiveness of these and other means of removing free oil from wastewater varies depending on the type of oil, temperature of the waste, and other factors. As a guide, however, some generalizations can be made. Gravity separation devices are effective in reducing oil concentrations to about 150 to 200 mg/L. Dissolved air flotation, similar to that used to thicken sludge, is effective in reducing oil levels to 50 to 100 mg/L. Granular media filters, preceded by gravity or flotation separators, can reduce oil concentrations to 10 to 20 mg/L. Chemical coagulation and precipitation, followed by gravity separation or dissolved air flotation, can remove all but about 5 mg/L of oil (95)(129)(156).

(b) Emulsified oils. Emulsions can be either oil-in-water or water-in-oil types. The more common oil-in-water emulsions are dispersions of tiny droplets or oil suspended in water. Emulsifying agents such as soaps, sulfated oils and alcohols and various fine particles enhance the stability of the dispersed oil, preventing the droplets from merging together into larger droplets which could be removed from the water (95). Prepared emulsions are used as coolants and lubricants in machining operations. Emulsions are also formed when oily wastewater comes in contact with steam, soaps, caustic or agitation. The emulsion must first be broken, then the oil released is removed as a free oil. Emulsion cracking is the term used to describe treatment of wastewater containing large amounts (2 to 7 percent) of emulsified oils, such as emulsions used in machining operations. Cracking involves addition of chemicals such as sulfuric acid, iron salts, alum, calcium chloride, or proprietary organic compounds, followed by heating to 100 to 140 degrees F. This is followed by two to four hours of coalescence. The effluent may still contain a few hundred mg/L of emulsified oil, and should be further treated, along with other waste streams having a similar level of oil content, by adding coagulating salts to lower the oil concentration. Wastewaters with less than 500 to 1000 mg/L of emulsified oil, or the effluent from the cracking step, may be treated by adding iron or aluminum sulfate salts, forming a metal hydroxide-oil sludge (95)(108)(129). A typical treatment scheme is shown on figure 6-2.

(c) Soluble oils. Soluble oils, such as certain animal and vegetable oils, may be readily removed by conventional biological treatment processes (89)(120). In general, oils derived from petroleum are neither readily soluble nor biodegradable, although biological systems can be developed to provide treatment of some of the soluble fractions of petroleum oils. Domestic sewage helps to provide inorganic nutrients essential for the biological degradation of the high BOD oils.

(5) Deep well injection. Pumping waste liquids into deep wells which tap porous rock formations has been used to dispose of “untreatable” or hard-to-treat organic and inorganic wastes from various industries.

(a) Pretreatment requirements. Wastes must be pretreated to remove any suspended solids which could clog the pores of the receiving rock formation. In addition, biological growth (and the resultant slime formation or corrosion) must be inhibited with the addition of biocides. Typical pre-injection treatment is costly and includes chemical addition, neutralization, oil removal, clarification and multi-stage filtration.

(b) Geological requirements. Careful geology and soils investigations must be undertaken to find a deep strata which is confined so that waste fluids will never reach a fresh water aquifer (92). The underground disposal area must also have satisfactory reservoir storage (107). The waste must not be capable of reaction with the brine at disposal level to form an insoluble material. Extreme care must be taken in drilling, constructing, and sealing the well to prevent any contamination of groundwater in other subterranean formations (37). Well casings must be highly

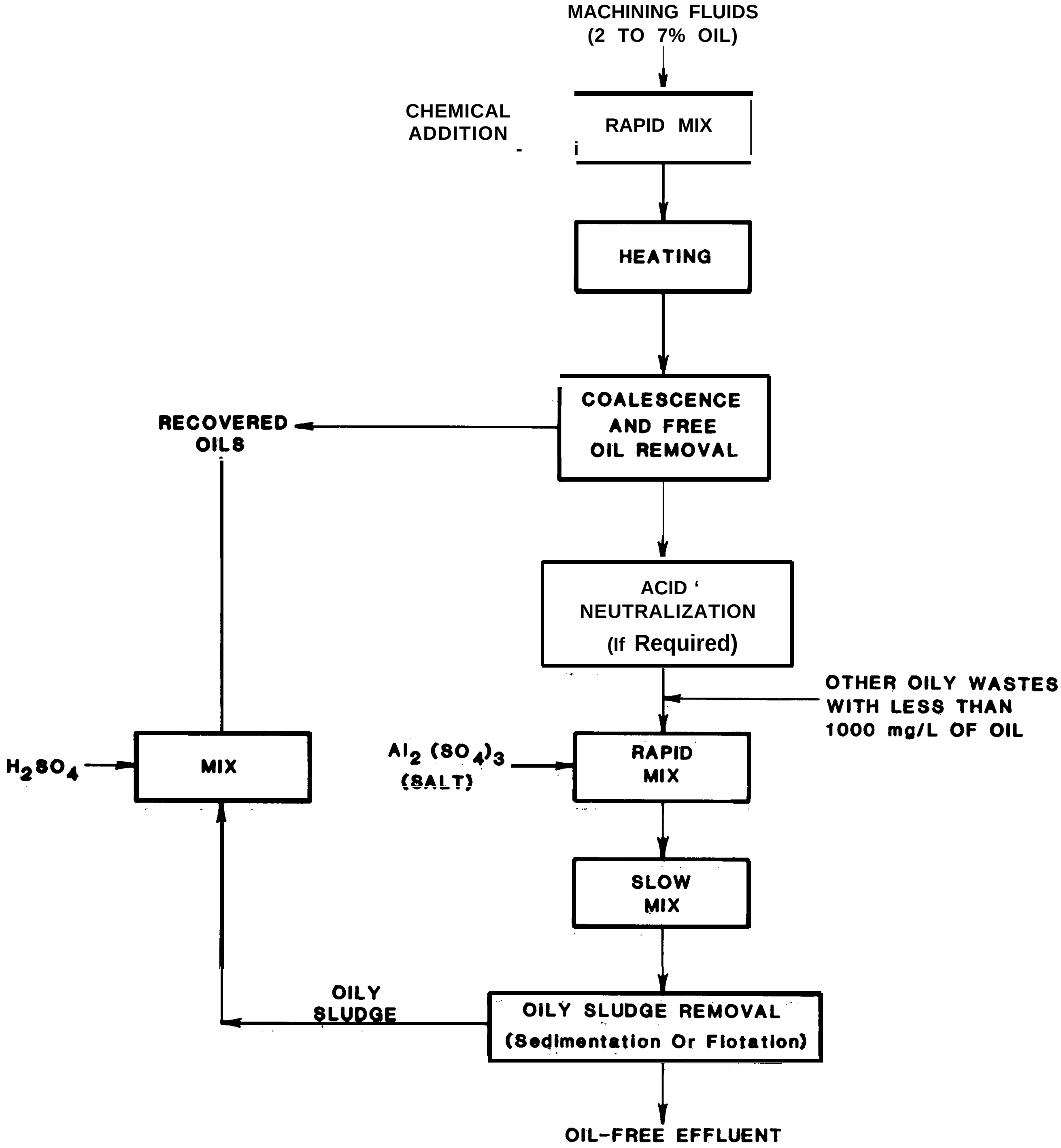


Figure 6-2. Emulsified oil removal by cracking and chemical coagulation.

corrosion-resistant to prevent leakage from corrosion caused by high pressure injection of acids and salts. Duplicate wells should be drilled if there is no alternative treatment or holding capacity in case the disposal well should fail. In addition, a number of sample wells must be drilled and maintained in order to monitor any leakage into ground water (72)(107). Trace leakage may be impossible to identify.

(c) Application to military wastes. Due to the extreme need for providing a fail-safe system, deep well injection is an expensive undertaking. Because of uncertainties with deep well operations (well leaks or clogging), careful comparison should be made of all other possible treatment alternatives prior to initiating a deep well system. Present U.S. EPA and Army policies discourage deep well disposal. The U.S. EPA requires proof that no adverse environmental impacts will result from construction or operation of the well (99)(102). This can often require involved, and expensive, research effort. In general, deep well injection is an unacceptable process for handling military installation wastewaters.

CHAPTER 7

SOLIDS HANDLING AND DISPOSAL

7-1. Introduction

a. Most treatment processes normally employed in water pollution control yield a sludge from a solids-liquid separation process or produce a sludge as a result of a chemical or biological reaction. Solids handling and disposal represent 30 to 50 percent of the total cost of treatment. Cost-effective treatment requires efficient solids handling and disposal along with liquid treatment procedures. Process use is limited by sensitivity to the quantity handled, climatological effects, land area and soil constraints, and technological development. Information on proven processes applicable to handling domestic sewage sludge from military installations is presented herein. Industrial wastes may place constraints on the use of some sludge processes and must be evaluated on a case-by-case basis.

b. The ultimate objective in solids handling and disposal methods is to reduce the water and organic content of sludges. These methods include:

–Thickening.
–Digestion.
–Conditioning.
–Dewatering and drying.
–Incineration.

Digestion and incineration are primarily used for the removal of organic matter in sludge while thickening, conditioning and dewatering are primarily used for the removal of water from the sludge. This chapter discusses these methods and describes the application in which they should be used.

7-2. Sludge characteristics

All evaluations of sludge systems should include a detailed mass balance of solids in the system. The mass balance defines the sludge quantities, dry solids content, volatile solids content and extent of recycle or supernatant flow back to the liquid treatment processes, and thus identifies the basis for evaluating different sludge systems.

a. *Quantity.* The quantity of dry solids produced per day from domestic sewage at military facilities will generally range as shown in table 7-1. Variations in primary sludge quantities are due to the type of collection system, i.e. combined systems yield more grit and other suspended material which require solids handling. For secondary sludges, all of the activated sludge systems generate the higher values except extended aeration which produces very low quantities. Most treatment plants at military installations are trickling filters and sludge from the final clarifiers is routinely returned to the primary settling tanks for subsequent solids withdrawal. Thus, the combined primary-secondary sludge quantities in table 7-1 are most appropriate and should be used for planning purposes. When chemical precipitation methods are employed for phosphorus removal or other purposes, the solids shown in table 7-1 will increase to a level dependent on the type and quantity of chemical addition and the chemical characteristics of the raw wastewater. The quantity of chemical sludge must be estimated for each application and, in most instances, will warrant bench testing prior to facility design.

Table 7-1. Typical raw sludge quantities

Sludge Type	Dry Solids Per Day lb/capita
Primary Sludge	0.12-0.20
Secondary Sludge	0.05-0.20
Combined Primary & Secondary	0.17-0.40

b. *Volatility.* The volatile solids content of undigested primary and/or secondary sludges is 60 to 80 percent. The volatile solids loading is particularly important for sizing digesters.

c. *Specific gravity.* The specific gravity of the dry volatile solids is about 1.0 and dry fixed solids about 2.5. The specific gravity of a particular mixture of sludges depends upon the relative fraction of volatile solids. Most wet raw sludges have a specific gravity ranging from about 1.01 to 1.03.

d. *Solids content.* The percent dry solids of fresh sludges drawn from clarifiers range as shown in table 7-2. Sludges can be efficiently pumped when the dry solids content is under 5 to 6 percent. Most sludges over 10 percent dry solids content must be transported as a semi-solid using such equipment as conveyor belts.

Table 7-2. Typical raw sludge solids content

Sludge Type	Solids Content (percent dry solids by weight)
Primary	2.5-5.0
Trickling Filter	5.0-8.0

Table 7-2. Typical raw sludge solids content–Continued

Sludge Type	Solids Content (percent dry solids by weight)
Combined Trickling Filter and Primary	3.0-6.0
Activated Sludge	0.5-1.5
Combined Activated and Primary	3.0-5.0

7-3. Conditioning and stabilization

For most military installations, disposal of sludge in landfills or on the land will be cost-effective and must be utilized. The rare exceptions are areas where incineration can be justified by the excessively long hauling distances required for reaching an acceptable disposal site or by the presence of industrial wastes that preclude land disposal. These land disposal methods require some previous stabilization step to avoid environmental degradation.

a. Anaerobic digestion. Anaerobic digestion, although sometimes difficult to control, is a very desirable and proven stabilization step. It conserves energy when the system produces a combustible gas that can be used for sludge heating and for other purposes. The process will function well in most climates and renders a stabilized sludge. For military installations, anaerobic digestion shall be used unless highly variable solids loads are expected or unless local factors justify use of alternative processes. The most important factor for sizing digester capacity is the volatile solids loading. TM 5-814-3 should be referred to for acceptable design criteria.

b. Aerobic digestion. Aerobic digestion is a stabilization process applicable to facilities where blowers are installed or are required for the liquid treatment operations. Since most military plants do not have blower systems, aerobic digestion will not be feasible. Other disadvantages are high power requirements and low efficiencies for military installations located in extreme northern climates. Aerobic digestion may have application at small package plant facilities or where wide load variations cause difficulties with anaerobic digestion.

c. *Thermal conditioning. "Cooking"* sludge under elevated temperature and pressure is a thermal conditioning and stabilization process receiving more attention in the U.S. It eliminates chemicals needed to condition a sludge prior to dewatering and also increases dewatering rates. Disadvantages are that it is a fuel consumer unless heat recovered from a combustion process is available, and supernatant recycle flows can add 15 to 30 percent additional BOD load on the liquid treatment system. Generally, thermal systems are only practical for larger plants, greater than 10 mgd, or for special applications where high bacteriological kills are necessary for land disposal.

d. Chemical conditioning. Where mechanical dewatering is utilized, some form of chemical conditioning is common. Most plants find that lime and/or ferric chloride produce the best results and are most economical. Where disposal of nondigested sludges occur, high lime treatment (pH of 11.5 for over 2 hours) will render a stabilized sludge. Lime, unlike ferric salts, is a bactericide which assists in treating the sludge.

7-4. Thickening

Most military facilities recycle secondary sludges to the primary tanks. Since most plants are trickling filters, the resulting sludge mixture is in the 5 percent dry solids range and thickening is therefore not warranted. At new activated sludge installations, thickening may be necessary due to the low solids content; flotation will usually be cost-effective for these applications. Gravity thickening is appropriate for combined sludges.

a. *Gravity.* Gravity thickening is accomplished in a tank equipped with a slowly rotating rake mechanism that breaks the bridge between sludge particles, thereby increasing settling and compaction. The primary objective of a thickener is to provide a concentrated sludge underflow. The design of a mechanical thickener is generally based upon a solids loading rate. Typical solids loading rates are in the range of 10 to 30 lbs/sq ft/day. Gravity thickeners should be designed to maintain aerobic conditions in the unit. Anaerobic conditions may cause floating sludge and odor problems with the unit. Thickener performance can be improved by the addition of coagulant to the influent feed. Polyelectrolytes are the most common type of coagulant aid used in thickening.

b. Dissolved air flotation. Thickening through dissolved air flotation is becoming increasingly popular and is particularly applicable to gelatinous sludges such as activated sludge. Flotation thickeners can be loaded at higher levels than gravity thickeners because of a more rapid separation of the solids from the sewage. Loadings are typically in the range of 10 to 55 lbs/sq ft/day depending on the sludge and the degree of conditioning. In flotation thickening, small air bubbles released from solution attach themselves to and become enmeshed in the sludge floes. The air-solid mixture rises to the surface of the basin, where it concentrates and is removed. The primary variables are recycle ratio, feed solids concentration, air-to-solids (A/S) ratio, and solids and hydraulic loading rates. Air pressures between 40 to 60 psi are commonly employed. The recycle ratio is related to the air-to-solids ratio and the feed solids concentration (72). Experience has shown. that in some cases dilution of the feed sludge to a lower concentration increases the concentration of the floated solids. The use of polyelectrolytes will usually increase the solids capture and the thickened sludge concentration.

c. *Centrifuges.* Centrifugation is employed both for the thickening and the dewatering of sludges. The process of centrifugation is an acceleration of the process of sedimentation by the application of centrifugal forces. There are three types of centrifuges available; the solid bowl, the basket type and the disc-nozzle separator. The basic difference between the types of centrifuges is the method in which solids are collected in and discharged from the bowl. Sludge solids settle through the liquid pool and are compacted by centrifugal force against the walls of the bowl and are then conveyed by the screw conveyor to the drying or beach end of the bowl. The beach area is an inclined section of the bowl where further dewatering occurs before the solids are discharged over adjustable weirs at the opposite end of the bowl (80) Typically, centrifuges can thicken an activated sludge to a concentration of 5 to 10 percent without chemical addition.

7-5. Dewatering

a. Drying beds. When stabilized sludge is deposited in a wet condition on the land, no dewatering is practiced. For facilities that require dewatering prior to disposal and have sufficient land area, drying beds are cost-effective and should be used. Usually drying beds will be feasible up to plant capacities of about 1 mgd. Sufficient storage should be provided in digesters to allow operational flexibility.

b. Vacuum filters. Vacuum filtration is the most widely applied mechanical dewatering method in the U.S. This method is well established for removing moisture from sludge and can achieve from 15 to 25 percent solids concentration in the cake after dewatering. Vacuum filters shall be used for mechanical dewatering unless other methods are cost-effective for special applications.

c. *Belt presses.* The belt press is a recently developed piece of dewatering equipment that presses sludge between two porous belts that forces water from the sludge through compression. The pressing operation is continuous and is usually preceeded by a chemical addition phase where flocculants are added to improve the dewatering characteristics of the sludge. With the proper conditioning, belt presses can achieve a cake solid in the 20 to 30 percent range for activated sludge and up to 35 to 40 percent cake solids for metal hydroxide sludges.

d. Plate presses. Filter presses are an alternative to vacuum filters and belt presses. Filter presses have higher capital and operating costs than either of the previous alternates, but produce a drier cake (solids concentrations in the range of 25 to 40 percent). These units may be desirable at some installations to minimize fuel requirements when a combustion process follows or to reduce haul costs when long distances are involved.

7-6. Incineration

Sludge incineration reduces the volume handled in the transportation and ultimate disposal steps and sterilizes the residue. High investment and operating costs, and stringent air pollution criteria are significant considerations in determining the need for incineration. Fuel is also a factor and without sufficient dewatering (to at least 35 percent solids) the furnaces will be energy consumers. Rarely has incineration been used at military treatment facilities and it shall be evaluated only for special applications or land scarce areas. Fluidized bed furnaces may be considered for some industrial wastes. Multiple hearth units are predominantly used to burn sewage sludge. Mixing sludge with refuse for burning takes advantage of the net heat generated by refuse combustion.

7-7. Other processes

Many other sludge handling, processing and disposal operations have been tried and are in use at other than military installations and some processes are currently in the technical development stage. These include pyrolysis, heat drying, comporting, freeze dewatering, drying lagoons, rail and barge transport systems, fertilizer production and others. Most of these are not practical or feasible for military facilities. Authority to deviate from using the proven processes presented in this section must be obtained from HQDA (DAEN-ECE-G) WASH DC 20314.

7-8. Solids handling process comparisons

Table 7-3 presents a general comparison of the sludge unit processes which may be considered for military facilities. These comparisons of preliminary treatment steps, applications, resource consumption, operations and other factors are merely to summarize typical applications. Local factors will, of course, cause some exceptions.

Table 7-3. Summary of solids handling and disposal

Unit Processes	Purpose	Major Equipment Required	Preliminary Treatment Steps	Application
A. Thickening	Reduce volume handled in subsequent steps by removal of water.	Gravity or flotation equipment, tanks, usually covers for flotation.	None.	All plant sizes and sludge types. Usually not used for military plants since trickling filter sludges predominate which are returned to the primary.
9. Anaerobic Digestion	Biologically stabilizes and transforms sludge into a material suitable for disposal on the land.	Tanks, covers, gas collection equipment, heat exchangers, and mixing equipment.	Sometimes thickening.	All plant sizes. Is particularlydesirable for military installation.
C. Aerobic Digestion	Biologically stabilizes and transforms sludge into a material suitable for disposal on the land.	Tanks and aeration equipment.	Sometimes thickening.	Usually plants under 15 to 20 mgd.
D. **Thermal Conditioning/ Stabilization**	Thermally conditions sludge for dewatering without chemicals and-stabilizes the material by heat disinfection for subsequent land disposal.	Thermal reactor, steam generating equipment, heat exchangers, sludge, grinder, pumps and piping, and decant tanks.	Must have a thickened sludge for economical operation.	Usually economical for plants larger than 10 mgd.
E. Sludge Drying Beds	Reduces the sludge moisture content for easier handling in final disposal, changes sludge from a liquid to a semi-solid.	Land, sand and gravel beds, and underdrain system.	Must have digestion to avoid odors.	Usually plants under 1 mgd. Limited to areas which have sufficient land.
F. Mechanical Dewatering	Reduces the sludge moisture content for easier handling in final disposal, changes sludge from a liquid to a semi-solid.	Filter units, pumps, piping, conveyor equipment, chemical conditioning facilities, and building.	Digestion, thermal conditioning or chemical conditioning, usually thickening.	May be used for raw or digested sludges. Equipment selection dependent on means of disposal
G. Sludge Incineration	Reduces hauling and final disposal land requirements. Provides acceptable material for disposal.	Furnaces, feed and air blower equipment, ash handling equipment, and air pollution control	Dewatering.	Mainly for very large plants (over 10mgd) in metropoliton areas where land is extremely scarce and costly.
H. Landfill	Dispose of sludge solids under soil cover in an envirornmentally acceptable manner.	Land and landfill equipment.	Stabilization and dewatering	All plant sizes.
I. **Land** Spreading	Disposes of sludge solids on the land in an environmentally acceptable manner.	Land, pumping, piping, storage ponds, mixers, and spray equipment for liquid sludge; or tractors, and solids storage and spreading equipment for dewatered sludge.	Stabilization.	**May be used for either liquid or dewatered sludges. Applicable to all plant sizes. Some limitations for cold climates.**

Table 7-3 (Cont'd). Summary of solids handling and disposal

	Performance	Economics	Resource Consumption	Operation	Side Streams	Aesthetic Problems
A.	Increases solid content to the 4 to 6 percent range	Flotation is usually lower in capital but higher in operating.	Lower power use; flotation is higher than gravity.	Flotation requires closer operator attention, particularly if chemicals are used.	Supernatant or subnatant return must be considered in design.	Potential odors if improperly operated.
B.	Digested sludge readily dewaters and is stabilized for subsequent disposal.	Relatively high capital costs.	Produces combustible gas for the process and other uses; also produces a soil conditioner.	Requires close operator attention; subject to upsets with wide variations In load.	Supernatant return must be considered in design.	Improperly operated units will produce odors.
C.	Digested sludge sometimes difficult to dewater. Stabilized sludge for subsequent disposals.	Lower capital costs than anaerobic digestion, but operating costs are higher.	Higher energy use than anaerobic digestion.	Relatively free of upsets Poor operation in cold climates. Simpler operation than anaerobic digestion.	Surpernatant return must be considered in design.	Improperly operated units will produce odors
D.	Eliminates use of chemicals for conditioning. Stabilizes sludge for land disposal. Improved cake moisture.	High capital and operating costs.	Large fuel use.	Skilled labor required	A major portion of the sludge is resolubilized and is returned as a supernatant. This load must be considered in the liquid treatment facilities design loading.	Odors may result with improper operation.
E.	Proper dewatering can be accomplished, but is usually difficult to control since it is weather dependent.	Usually lower costs than mechanical dewatering until large areas are required.	Minimal power or chemical use. Large land usage.	Normally poor winter operation.	Underdrainage must be returned to the plant.	Potential odors.
F.	Sludge cake solids content: vacuum filter 15 to 25 percent; belt press 20 to 30 percent; filter press 25 to 40 percent.	High capital and operating costs.	Power use high. Small land area used.	Nearly continuous operator attention required.	Filtrate return must be be considered in design.	Odors for personnel working in building with equipment.
G.	Renders a sterile ash which can be readily disposed of on the land. Air pollution control can be a problem.	High capital and operating costs.	Large fuel use. Disregards other beneficial uses of the waste solids.	Skilled operators required.	Air emissions must be controlled, scrubber water return must be considered	Potential odor and particulates from exhaust gases If not properly operated.
H.	Suitable disposal technique with proper facility siting and operation.	Moderate costs. Dependent on land values in the specific area.	Minimal fuel and land use.	Mixing with refuse is desirable for efficient operation.	None unless material is improperly stabilized or landfill is not properly located or operated.	Potential odors If improperly operated.
I.	Suitable disposal techniques with proper facility siting and operation. Careful control of application rates and other factors are particularly important for liquid sludge.	Moderate costs. Oependent on land values in the specific area.	Minimal fuel use. Moderate power use with liquid spreading. High land use, but solids used beneficially as a soil conditioner.	Winter storage facilities are needed in cold climates. Application to the land is quite dependent on crops, soils, and weather.	None unless material is Improperly stabilized or applied.	Potential odors if improperly operated. Use of large land areas for sludge disposal may be a problem in some areas.

CHAPTER 8

SYSTEM ALTERNATIVES AND PERFORMANCE

8-1. Introduction

This chapter will discuss system alternatives and performance data for wastewater treatment and solids handling systems commonly used for military installations. Information and descriptive data on available unit operations and processes have been included and are presented herein to enable the establishment of sound engineering and economic relationships among alternatives. This chapter principally addresses domestic treatment methods with notations concerning the impact of industrial or military wastes. Theoretical and design factors are not covered and reference should be made to textbooks and the U.S. EPA design manuals listed in the bibliography for more detailed description of wastewater treatment methods and limitations. Appendices C and D present design and cost factors also.

8-2. Wastewater treatment systems

a Treatment system alternatives.

(1) Treatment evaluations. For some installations, certain alternatives may readily be excluded from consideration due to climate, land requirements, flow quantity and other factors. Most installations, however, will require evaluation of several treatment alternatives to either upgrade existing systems or provide new facilities. The treatment alternatives presented herein are proven methods which are most practical for wastes from military installations. Many other processes have been tried or are in use at other than military installations and some are currently in the technical development stage. Authority to deviate from using the proven methods in this section must be obtained from HQDA (DAEN-ECE-G) WASH DC 20314.

(2) Treatment alternatives. Wastewater treatment methods which shall be considered for military wastes are categorized in figure 8-1. System alternatives are arranged by increasing degree of treatment:

–Preliminary.
–Primary.
–Secondary.
–Advanced.

Within each of the broad treatment classifications, there is a listing of principal unit processes. These represent those alternatives most generally applicable to military facilities. Combinations of processes can be arranged to effect the desired degree of treatment.

(3) Size of installations requiring treatment. Specific data are not presented in this manual on the sizes and types of unit processes or operations employed at Army installations, but statistical data indicate over one-half of the Army installations are receiving less than 1.0 mgd of wastewater flow. Table 8-1 shows that less than 2 percent exceed 10.0 mgd. These data are based on all reported Army installations including both domestic and industrial wastewater sources, government-owned, government-operated (GOGO), at U.S. as well as overseas facilities. The intent of this information is to classify the size range of existing facilities and thus determine which unit processes or operations must receive emphasis on the basis of size alone. It is apparent that processes applicable to small installations will predominate (97).

Table 8-1. Classification of Army facilities by wastewater flow

Average Wastewater Flow Category mgd	Number of Facilities	
	In Category	As Percent of Total
0.1	14	10.8
0.1-1.0	61	47.3
1.0-10.1	52	40.3
10.0	2	1.6
	129	100.0

(4) Type of installations requiring treatment. These are five basic types of military installations, all of which require different considerations for wastewater treatment.

(a) Large camps-equivalent to a Division plus families and day workers; usually have year-round domestic flows in the *2* to 5 mgd range.

(b) Summer training camps-Division size load during the summer; very small flows in winter.

(c) Reserve training centers–about one week per month may have up to 600 personnel; other times, only 5 to 10.

(d) Army depots–essentially warehouse operations; up to about 1000 personnel, including families; relatively steady year-round flows.

(e) Industrial installations-small domestic flows.

(5) Degree of treatment required. Under Executive Order 12088, Federal agencies must en-

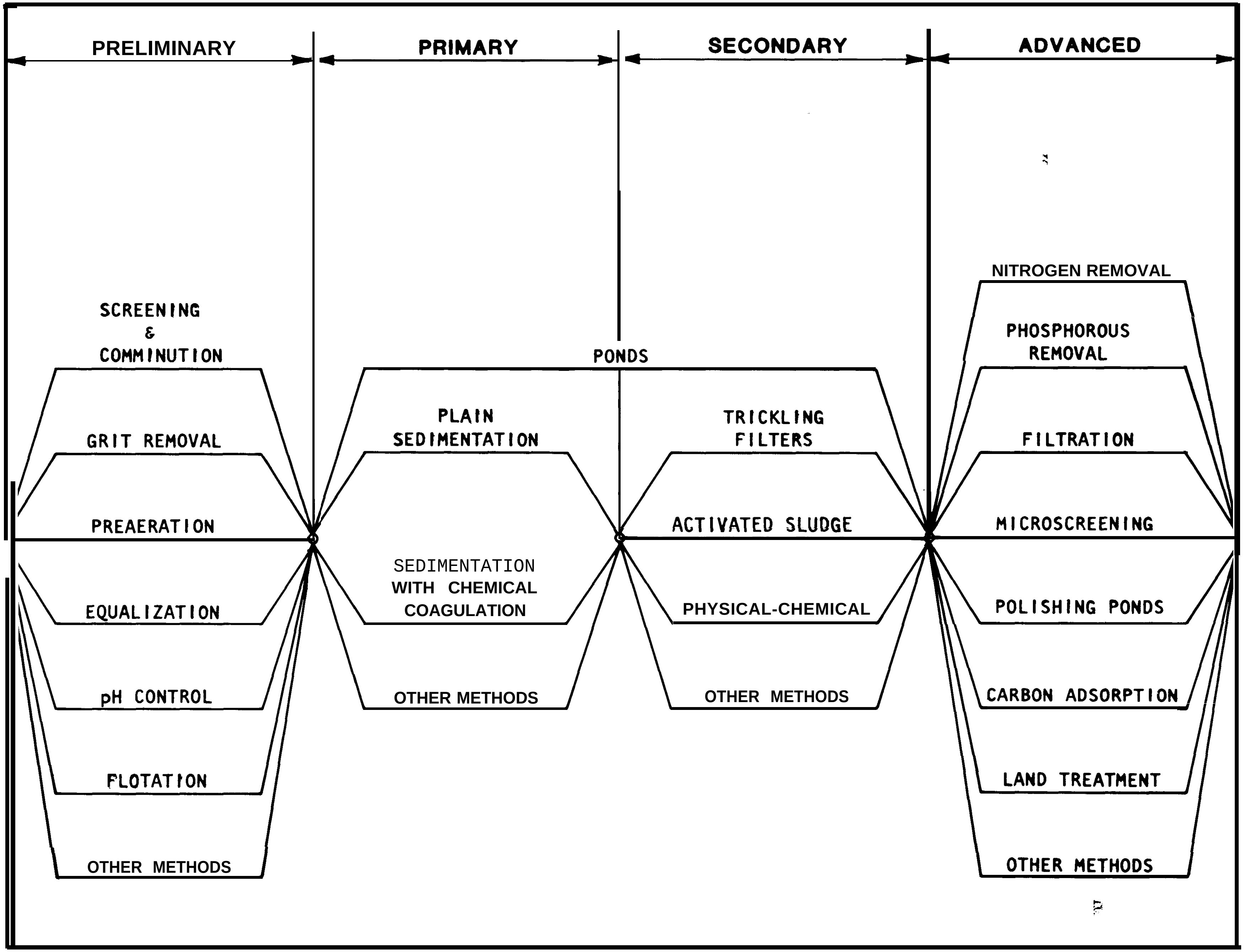


Figure 8-1. Alternative wastewater treatment processes for military installations.

sure that their facilities are designed, constructed, managed, operated and maintained to conform with Federal, State, interstate and local water quality standards and effluent limitations. These standards are or will be established in accordance with the Federal Water Pollution Control Act, as amended. All the U.S. EPA wastewater treatment requirements in furtherance of the Act have not yet been established. Treatment requirements for some industrial categories have been delayed due to lack of developed technology; however, pertinent U.S. EPA regulations should be investigated for specific details at a particular location. The U.S. EPA has set effluent limitations for publicly-owned and industrial wastewater treatment facilities. Interpretation of these requirements as they apply to military installations is as follows:

(a) Military installations which provide wastewater treatment for principally domestic sources will be required to meet criteria as set forth for publicly-owned facilities.

(b) Military installations which generate industrial or process wastewaters will be required to meet either limitations set forth by that specific industrial classification or limitations formulated by the U.S. EPA for that class of Federal facility.

b. System performance.

(1) Introduction. For the flow schemes presented in table 8-2, typical concentrations of important wastewater constituents are given following various stages of treatment. These concentrations shall serve only as a general guide for preliminary planning purposes. It is emphasized that wastewater concentrations, both raw and treated at various stages, may vary widely from those shown for a specific military installation. In many cases, bench or pilot studies will be necessary to predict the unit process loadings and removal efficiencies that would be used in final design. The wastewater treatment alternatives shown in table 8-2 include treatment processes designed to convert or remove various forms of the following constituents:

–Carbonaceous BOD.
–Suspended solids.
–Nitrogen.
–Phosphorus.

(2) Preliminary and primary treatment. Primary sedimentation will remove a significant fraction of the suspended solids in the raw wastewater. It also removes the insoluble BOD, nitrogen (primarily organic nitrogen), and phosphorus associated with the removed suspended solids.

(3) Secondary treatment. Secondary biological treatment will convert most of the soluble and nonsettleable organic material into biological cell mass. In the process, much of the organic nitrogen will be converted to ammonia. A small fraction of the nitrogen, as well as a portion of the phosphorus, will be tied up in the biological cell mass. The degree of bio-flocculation of the cell mass will determine the efficiency of suspended solids removal in the final sedimentation step. The activated sludge system achieves better bio-flocculation than the trickling filter process; therefore, suspended solids in the final effluent from an activated sludge system are generally lower than a trickling filter system.

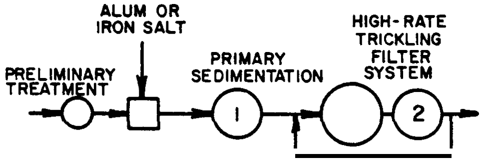
(4) Advanced treatment.

(a) Filtration. Filtration of a secondary effluent will reduce suspended solids considerably. The BOD is also lowered by the amount due to the suspended solids in the secondary effluent. Usually the soluble BOD in a secondary effluent is below 10 mg/L, so the majority of the BOD is exerted by the suspended organic material. Again, trickling filter system effluents are not as well flocculated as activated sludge system effluents; therefore, multi-media filtered effluents from trickling filters will contain higher suspended solids than filtered effluents from an activated sludge system.

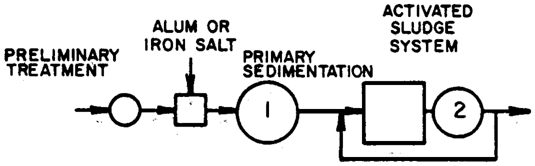
(b) Vitrification. Little vitrification takes place in either the high rate trickling filter or activated sludge process at normal design loadings. To assure good vitrification, a second stage trickling filter system or suspended growth nitrification system should be employed. These systems can reduce ammonia to about 2 to 4 mg/l, and will also result in a reduction in the carbonaceous BOD.

(c) Phosphorus removal. Phosphorus removal may be accomplished by mineral or lime addition to the primary sedimentation tank, lime clarification of the secondary effluent, or addition of lime or minerals to the final clarifier of trickling filter systems. Side benefits of these processes are suspended solids removal along with removal of nitrogen and carbonaceous BOD associated with the suspended solids. Mineral addition to the primary sedimentation tank is the least expensive process where phosphorus removals of less than 90 percent are required. Bench or pilot studies are necessary to determine the best chemicals to use as well as the required chemical dosage. Lime clarification of the secondary effluent is the process to use if high degrees of phosphorus removal are required. With low alkalinity wastewaters, a two-stage lime clarification

Table 8-2. Performance of typical wastewater treatment system alternatives

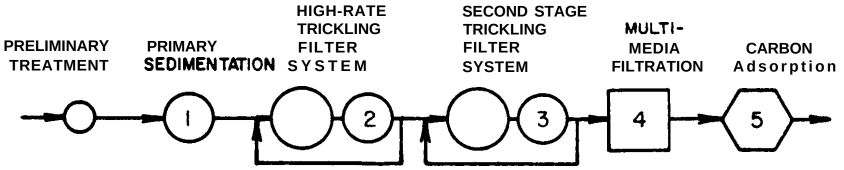


Constituent	Influent Concentration (mg/L)	Concentrations Following Treatment Units (mg/L) 1	2
BOD	300	150	40
Suspended Solids	300	90	40
Phosphate (as P)	20	4	2
Ammonia (as N)	25	25	22
Organic Nitrogen (as N)	25	10	4
Nitrate (as N)	0	0	5

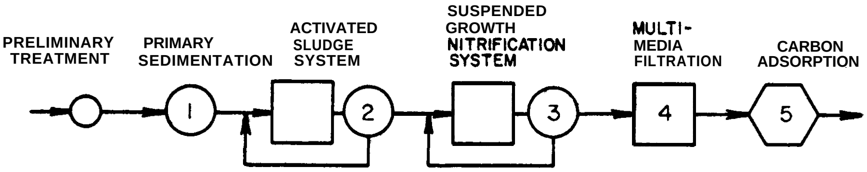


		1	2
BOD	300	150	25
Suspended Solids	300	90	25
Phosphate (as P)	20	4	2
Ammonia (as N)	25	25	26
Organic Nitrogen (as N)	25	10	3
Nitrate (as N)	0	0	2

Table 8-2 (Cent'd). Performance of typical wastewater treatment system alternatives

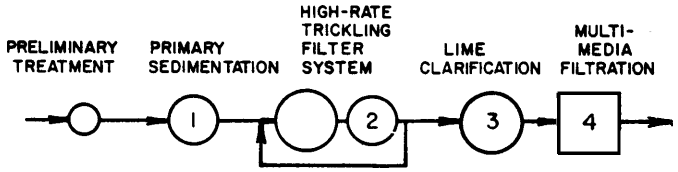


Constituent	Influent Concentration (mg/L)	Concentrations Following Treatment Units (mg/L) 1	2	3	4	5
BOD	300	195	45	25	10	2
Suspended Solids	300	120	50	30	10	10
Phosphate (as P)	20	18	14	12	11	11
Ammonia (as N)	25	25	26	4	4	4
Organic Nitrogen (as N)	25	15	5	3	1	1
Nitrate (as N)	0	0	4	27	27	27

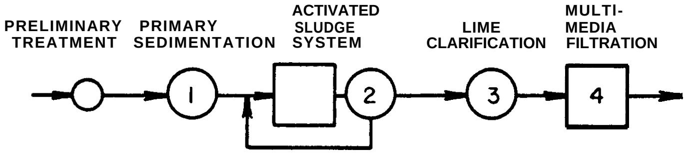


		1	2	3	4	5
BOD	300	195	30	15	5	1
Suspended Solids	300	120	30	20	3	3
Phosphate (as P)	20	18	14	13	11	11
Ammonia (as N)	25	25	30	3	3	3
Organic Nitrogen (as N)	25	15	4	2	1	1
Nitrate (as N)	0	0	1	29	29	29

Table 8-2 (Cont'd). Performance of typical wastewater treatment system alternatives

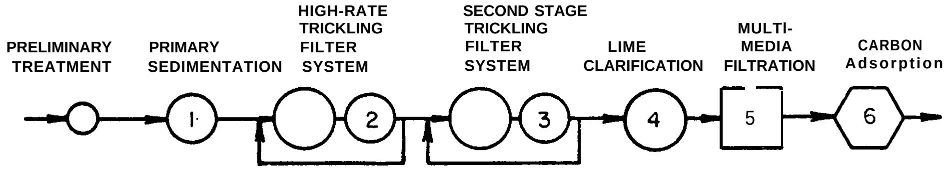


Constituent	Influent Concentration (mg/L)	Concentrations Following Treatment Units (mg/L)			
		1	2	3	4
BOD	300	195	45	20	10
Suspended Solids	300	120	50	20	2
Phosphate (as P)	20	18	14	2	1
Ammonia (as N)	25	25	26	24	24
Organic Nitrogen (as N)	25	15	5	2	1
Nitrate (as N)	0	0	4	4	4

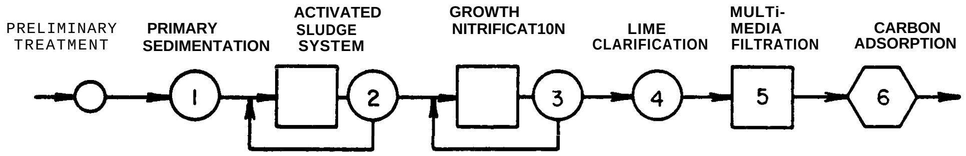


		1	2	3	4
BOD	300	195	30	10	5
Suspended Solids	300	120	30	15	2
Phosphate (as P)	20	18	14	2	1
Ammonia (as N)	25	25	30	28	28
Organic Nitrogen (as N)	25	15	4	2	1
Nitrate (as N)	0	0	1	1	1

Table 8-2 (Cent'd). Performance of typical wastewater treatment system alternatives

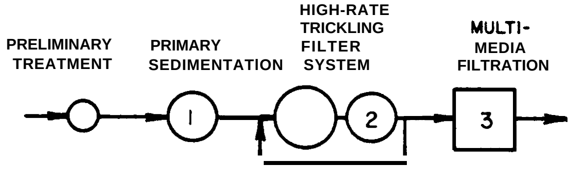


Constituent	Influent Concentration (mg/L)	Concentrations Following Treatment Units (mg/L)					
		1	2	3	4	5	6
BOO	300	195	45	25	10	7	2
Suspended Solids	300	120	50	30	15	1	1
phosphate (As P)	30	18	14	12	2	1	1
Ammonia (as N)	25	25	26	4	4	4	4
Organic Nitrogen (as N)	25	15	5	3	2	1	1
Nitrate (as N)	0	0	4	27	27	27	27

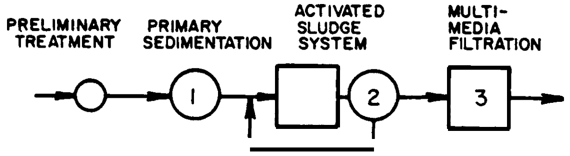


		1	2	3	4	5	6
BOD	300	195	30	15	5	4	1
Suspended Solids	300	120	30	20	10	1	1
Phosphate (as P)	30	18	14	13	2	1	1
Ammonia (as N)	25	25	30	3	3	3	3
Organic Nitrogen (as N)	25	15	4	2	2	1	1
Nitrate (as N)	0	0	1	29	29	29	29

Table 8-2 (Cont'd). Performance of typical wastewater treatment system alternatives



Constituent	Influent Concentration (mg/L)	Concentrations Following Treatment Units 1	2	3(mg/L)
BOO	300	195	45	15
Suspended Solids	300	120	50	15
Phosphate (as P)	20	18	14	12
Ammonia (as N)	25	25	26	26
Organic Nitrogen (as N)	25	15	5	1
Nitrate (as N)	0	0	4	4



		1	2	3
BOD	300	195	30	10
Suspended Solids	300	120	30	6
Phosphate (as P)	20	18	14	12
Ammonia (as N)	25	25	30	30
Organic Nitrogen (as N)	25	15	4	1
Nitrate (as N)	0	0	1	1

process may be necessary. The need for a single-stage or two-stage process along with required lime dosages can only be determined from bench or pilot studies. Filtration of a lime clarified secondary effluent will generally result in effluent phosphorus concentrations less than 1 mg/L because of the removal of phosphorus tied up with the suspended solids in the effluent from lime clarification (142).

(d) Additional suspended solids and organic removal. Various combinations of lime clarification and/or filtration can reduce wastewater BOD to the 5 to 10 mg/L range, and suspended solids to 1 mg/L or less. In order to get the BOD below 5 mg/L, it is almost always necessary to use a granular carbon adsorption step. Carbon will adsorb most of the soluble organic compounds that cause the remaining BOD. A properly designed and operated carbon adsorption step can reduce the final wastewater BOD to as low as 1 to 2 mg/L.

(e) Land treatment. An alternative to the several mechanical treatment processes following secondary treatment in table 8-2 is land application. Many military installations which have considerable land of the proper soil characteristics may find that land treatment is a cost-effective alternative. With proper site location and operation, disposal of a secondary-treated effluent to the land will provide treatment equivalent to or better than that from a carbon adsorption system or other mechanical facilities.

8-3. Effluent discharge alternatives

a. Surface water. Analysis of the impact of wastewater discharge on the receiving surface water (stream, lake, ocean, estuary) requires information on a number of parameters for proper formulation. For example, the impact of a discharge on the oxygen resources requires knowledge of the deoxygenation rate of the wastewater; reaeration rate of the stream; physical characteristics of the stream including flows, geometry and velocities; stream and waste temperatures; quality of the stream prior to discharge; and characteristics of other waste discharges along the stream. Methods for analyzing the impact of effluents discharged to surface waters are well documented (43)(147)(149). The impact of constituents other than those which affect oxygen can be evaluated using some of the same analytical techniques as indicated for oxygen. Normally in the U. S., State and Federal pollution control regulatory agencies will provide performance criteria for treatment which negates the need for extensive stream surveys. In foreign locations, however, more analyses of the impact of an effluent on the stream may be necessary.

b. Land application. Land treatment can be an effective means of providing advanced treatment for secondary effluents and shall be considered for military installations requiring a high degree of treatment. Approaches for spreading treated effluent on the land can be classified as either rapid infiltration-percolation, overland flow, or spray irrigation. Evaluation, design and costing methods for land application are available (53)(71)(72)(126). Regulatory agencies should be consulted for specific project applications.

(1) Rapid infiltration-percolation. This method consists of dosing spreading basins on an intermittent basis to maintain high infiltration rates. The main portion of the wastewater enters the groundwater after filtering and treatment by the soil, although there is some loss to evaporation. Soils are usually deep, permeable types such as coarse textured sands, silty sands or sandy silts.

(2) Overland flow. This technique is the controlled discharge, by spraying or other means, of effluent onto the land with a large portion of the wastewater appearing as run-off. Soils suited to overland flow are clays and clay silts with limited drainability. The land for an overland flow treatment site should have a moderate slope. In the U. S., overland flow has been developed mainly for treatment for high-strength wastewater, such as that from canneries. This process has not been extensively used for the treatment of domestic wastewater in the U. S., although Australia has used it for this purpose for a number of years, with BOD and suspended solids removals of about 95 percent.

(3) Spray irrigation. This process is the controlled discharge of secondary treated effluent, by spraying on land to support plant growth. Maximum amounts of wastewater consistent with crop yields may be applied. Although overland flow and infiltration-percolation may have merit under special circumstances, irrigation is probably the best method for application to different soil types and cultural practices. In addition, irrigation maximizes nutrient benefits of the wastes. However, precautions and safeguards against contamination by aerosol dispersion of pathogenic organisms or viruses by spray application is necessary (7).

(4) Design considerations. Some factors to be considered when evaluating the applicability of an irrigation system are the amount of available land, the need for reclaimed water, wastewater characteristics and flow rates, and type of soil at

available sites. Other factors which are important in site selection include climate, soil characteristics and depth, topography, and hydrologic and geologic considerations. For land treatment applications, the equivalent of secondary treatent should be provided. Normally, the chlorinated effluent from existing ponds or trickling filters at military installations can be applied to the land without further treatment.

(a) Hydraulic capacity. Whenever possible, the site should be selected so the pollutant removal capacity of the soils is the limiting factor rather than the hydraulic capability. This will minimize the land area needed. The hydraulic capacity will vary with each site since it is dependent upon the type of soil, local precipitation and whether or not underdrains are provided. Where agricultural crops are the means by which the wastewater effluent is reused, an application rate of about two inches per week seems to be a controlling factor. The local precipitation, winter climate, type of crops and soils all dictate the proper schedule and the area of land needed for land application.

(b) Nitrogen capacity. One of the aspects of wastewater irrigation that is not well defined is the allowable nitrogen loading. Some nitrogen is evaporated during application, the soil can eliminate some, the crops can utilize a portion, but nitrates can still be transported to the groundwater. The acceptable nitrogen loading rate depends upon the type of soil and crop. It is often necessary to limit the nitrogen loading to the amount that crops can assimilate in certain types of soil. This may require a reduction in the liquid loading rate in some areas and at certain times of the year.

(c) Phosphorus capacity. Some limitations on long term use of sites for land treatment may develop from the phosphorus balance. The soil can accumulate a certain amount, but after a period of time phosphorus will leach with the renovated water. Special soil surveys are needed to assess the life of a site when the phosphorus loading is considered.

(d) Organic capacity. The biodegradable organics measured by the BOD test can be almost totally removed by the soil matrix. This overall removal generally occurs in the upper 5 to 6 inches of soil, and the major filtration often occurs in the top few centimeters.

(e) Beneficial use. In climatic zones where irrigation is required, land application of effluents from military installations handling primarily domestic wastes is quite feasible. In areas where irrigation is of less benefit, the need for an economic and feasible alternative to surface water disposal is an important factor for considering land applications.

c. *Other.* Several other methods of effluent discharge are available depending on the circumstances at particular military installations. At facilities needing large quantities of cooling water, reuse of a well-treated (secondary) wastewater for such purposes is often practical. Similarly, water reuse occurs indirectly when discharge is to a stream rather than to the land. Reuse is also practiced quite often when treated effluents are used to spray golf courses, park facilities, and other such areas which may exist at military installations. In arid areas, effluent discharge may approach zero with proper use of evaporation ponds. Some wastewater treatment facilities now utilize this technique of evaporation for final effluent disposal. Both water reuse evaporation methods should be considered in planning pollution control programs at military installations.

8-4. Solids handling systems

a. System alternatives. A line diagram of the sludge handling and disposal systems which should receive consideration at military installations is presented as figure 8-2. The sludge handling steps are arranged in sequential order from left to right with various alternatives under each major step. These systems are discussed in this section and figure 8-1 shows the system which is applicable to most military installations considering the size and existing facilities. Available references (55) and (125) can provide a comprehensive summary on detailed design criteria and extensive bibliographies on sludge handling. Some design criteria are summarized in appendix B for sludge handling processes that can be utilized to make preliminary cost-effective comparisons with cost curves presented in appendix A.

b. Existing systems. Military facilities commonly have existing sludge handling facilities consisting of anaerobic digestion plus dewatering and landfill or land spreading disposal. These handle settled solids from primary units or the combined solids from both primary and secondary units. Evaluations of facility upgrading must consider the interrelationship of the existing liquid and solids handling operations. For example, where sufficient digester capacity exists, it may be cost-effective to utilize a liquid treatment process which produces more solids than another alternative. When the sludge system is near capacity, the choice of a particular liquid treat-

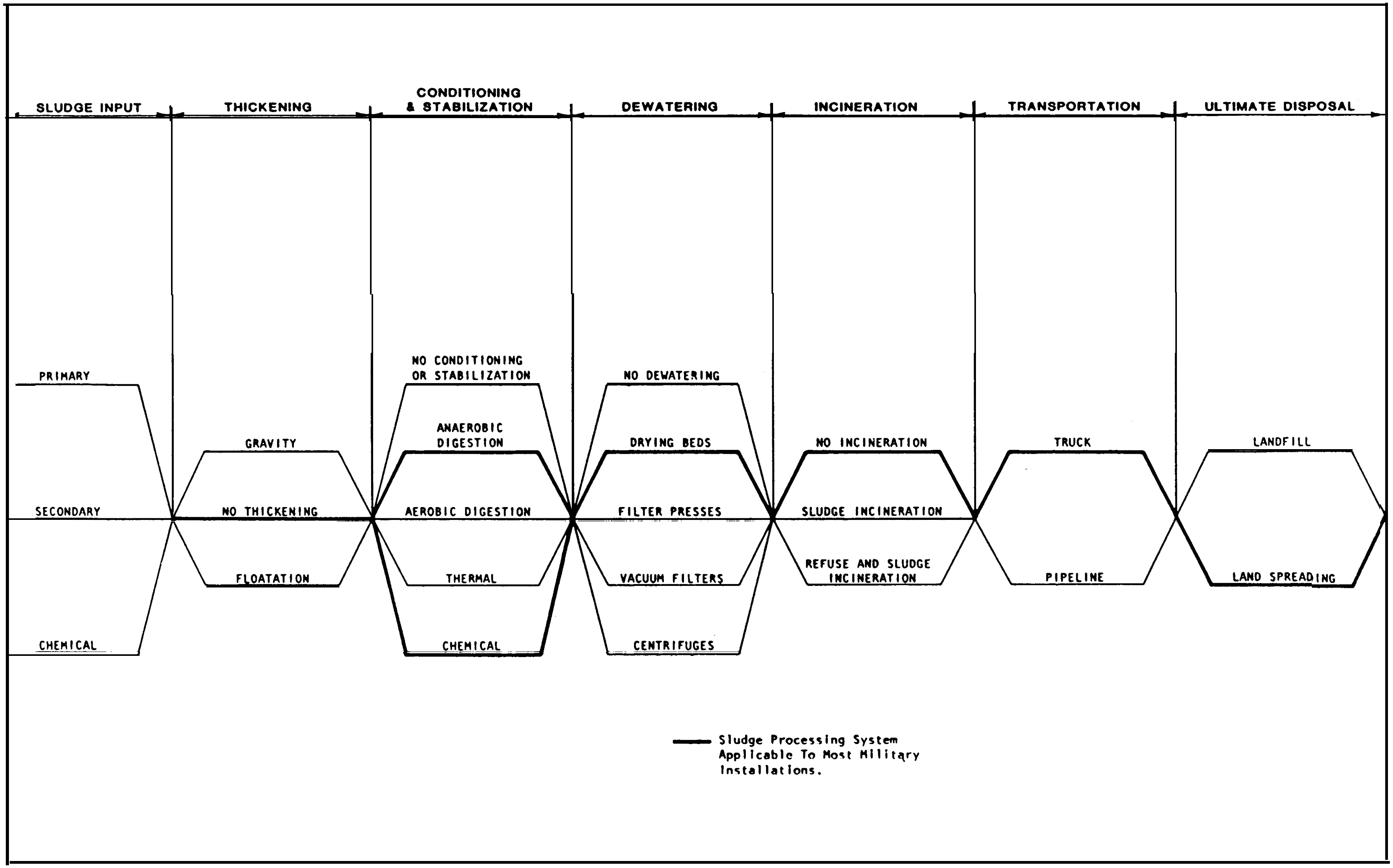


Figure 8-2. Alternative sludge processing systems for military installations.

ment plan may be dictated by the need to expand the solids processing facilities.

c. *Solids disposal alternatives.* The two most feasible methods for disposing of sewage solids from military installations include sanitary landfill and land spreading.

(1) Landfill. Disposing of dewatered sewage sludge with refuse in a sanitary landfill is normally an economical operation. Sewage solids tend to sift among the voids in compacted refuse, and nominal land savings are achieved. Combining the two waste materials at one facility is also desirable from a management standpoint.

(2) Landfarm. Land spreading dewatered sewage sludge is currently used by several military operations and is a cost-effective alternative to sanitary landfill. The land spreading technique can be utilized for either liquid or dewatered sludge, but the sludge must be stabilized; raw sludge application is unacceptable. This disposal method effectively utilizes the soil conditioning characteristics of the sewage solids. Proper monitoring and close attention to procedures employed during spreading are required to avoid potential environmental difficulties. Land requirements for spreading are greater than landfill; consequently, this method is feasible only where sufficient land area is available.

d. System performance.

(1) Introduction. The performance of solids handling systems is dependent upon many variables including: solids loading, operation, chemical addition, equipment maintenance and waste characteristics. These variables will greatly affect the output of the unit and should be considered when designing the system and when comparing performance data from similar type units. The performance and general design criteria discussed below are recorded average values and should be used as guidelines in preparation of design documents or in reviewing the performance of an existing facility. Bench scale testing or jar tests are recommended to determine the optimum operating point or quantity of chemical required. For additional information, refer to the U.S. EPA Process Design Manual, “Sludge Treatment and Disposal”. For additional description of the types of solids handling systems available, refer to chapter 7.

(2) Conditioning and stabilization. Sludge conditioning is generally described as a pretreatment of sludge to improve water removal by a method of thickening or dewatering. Common conditioning methods include:

—Polymer addition.
—Inorganic chemical addition.
—Heat treatment.
–Ash addition.

(a) Chemical conditioning requirements. Table 8-3 lists the common types of chemicals used for conditioning sludge and enumerates a range of dosages common for various types of sludge.

Table 8-3. Chemical conditioning requirements for various sludge types (167)

Sludge Type	$FeCl_3$ lb/ton dry solids	$Ca(OH)_z$ lb/ton dry solids	Polymers lb/ton dry solids
Raw Primary	20-60	0-100	3-5
Primary & Activated Sludge	80-160	0-300	6-15
Activated Sludge	120-200	100-300	8-25
Digested Primary	40-60	60-160	3-8
Digested Primary & Activated Sludge	120-200	100-300	6-20

(b) Heat treatment. Heat treatment of sludge uses a combination of temperature, time and pressure to condition a sludge without the use of chemicals. The process significantly changes the characteristics of the sludge by breaking down the cellular matter and releasing a major portion of the water in the cell mass. The dewaterability is improved by reducing the specific resistance to the sludge for filtering. Temperatures in the range of 350 to 450 degrees F and pressures in the range of 200 to 500 psig are generally required. Additional information concerning the design of a heat treatment system can be found in the literature (10)(11) (167).

(c) Ash addition. Ash is primarily used as a filler to reduce chemical addition requirements and improve the dewatering characteristics of the sludge. Generally, ash is used to improve the cake release from belt or filter presses and improve the dewatering of sludge in a vacuum filter. Depending on the type of ash available, a hydrolysis between free water in the sludge and ash will result in a dryer cake. Bench scale tests are recommended to determine the optimum dosage of ash because excess quantities may only result in an increased volume of sludge without any additional improvement in the dewaterability.

(3) Thickening. Sludge thickening can be accomplished by a variety of methods. These methods have been discussed in Chapter 7 and include: gravity, air flotation and centrification. Table 8-4 summarizes typical performance data for these processes for different types of sludges.

Table 8-4. Thickening characteristics of various sludge types (percent solids) (167)

Sludge Type	Gravity Thickener	Air Flotation	Centrification (solid bowl type)
Raw Primary	8-12	5-7	28-35
Activated Sludge	2-3	3-6	12-15
Trickling Filter	4-7	3-7	15-20
Primary & WAS	4-6	6-8	18-24

(4) Dewatering. Dewatering is the removal of water from wastewater treatment plant solids to achieve a volume reduction greater than that achieved by thickening. Dewatering is done primarily to decrease the capital and operating costs of the subsequent direct sludge disposal or conversion and disposal process. Dewatering sludge from a 5 to a 20 percent solids concentration reduces volume by three-fourths and results in a non-fluid material. Dewatering is only one component of the wastewater solids treatment process and must be integrated into the overall wastewater treatment system so that performance of both the liquid and solids treatment schemes is optimized and total costs are minimized. The dewatering processes discussed in chapter 7 include: drying beds, vacuum filters, belt presses and plate presses.

(a) Drying beds. Drying beds are the most common type of dewatering equipment in use at military installations today. Drying beds are used throughout the United States in small and large treatment systems; however, their use has declined over recent years. Their most common use is in drying of domestic wastewater sludge but some industries also use this method. Table 8-5 lists the advantages and disadvantages of sludge dry beds.

Table 8-5. Advantages and disadvantages of using sludge drying beds

Advantages	Disadvantages
a. When land is readily available, this is normally the lowest capital cost.	a. Requires more land than fully mechanical methods.
b. Small amount of operator attention and skill is required.	b. Removal usually labor intensive.
c. Low energy consumption.	c. Lack of a rational engineering design approach allowing sound engineering economic analysis.
d. Less sensitive to sludge variability.	d. Must be designed with careful concern for climatic effects.
e. Low to no chemical consumption.	e. Requires a stabilized sludge.
f. Higher dry cake solids contents than fully mechanical methods.	f. May be more visible to the general public.

Table 8-5. Advantages and disadvantages of using sludge drying beds

(b) Vacuum filters. Vacuum filters consume more energy per unit of sludge dewatered than drying beds and are labor intensive. Performance data for vacuum filters is presented in table 8-6.

Table 8-6. Typical sludge concentrations produced by vacuum filtration

Sludge Type	Cake Solids (percent)	Rate (lb/hr/cu ft)
Raw Primary	25-30	5-10
Primary & Activated Sludge	20-25	3-6
Activated Sludge	12-18	2-5
Digested Primary	28-32	4-6
Digested Primary & Activated Sludge	20-24	3-5

(c) Belt presses. Belt press performance is highly dependent upon chemical addition, pressure, cloth type, etc. and it is difficult to generalize their operating efficiency. Table 8-7 has been prepared as a summary of the reported minimum and maximum cake solids for various types of sludges.

Table 8-7. Typical dewatering performance of belt filter presses

Sludge Type	Cake Solids percent	Feed Solids percent	Polymer lb/ton of dry solids
Raw Primary	28-24	3-10	2-9
Activated Sludge	16-32	1-3	2-4
Primary & Activated Sludge	12-28	0.5-1.5	4-12
Anaerobically Digested Activated Sludge	18-22	3-4	4-8
Metal Hydroxide Sludge	35-50	3-5	2-6

(d) Filter presses. Recessed plate pressure filters have been proven to yield the highest cake solids concentration of all the dewatering methods discussed. A disadvantage of the units is a high capital and labor cost and its requirement that it be operated in a batch mode. Table 8-8 provides ranges of performance of filter presses on various sludges. Additionally, cycle times may be as long as 6 to 8 hours per batch before optimum cake solids is achieved.

Table 8-8. Typical dewatering performance of filter presses (167)

Sludge type	Cake Solids (percent dry solids by weight)
Raw Primary	40-50
Activated Sludge	25-40
Primary & Activated Sludge	35-45
Alum Sludge	25-40
Metal Hydroxide Sludge	45-60

(5) Incineration. The two most common types of incinerators in use, both in civil and military installations, are multiple hearth and fluidized sand bed furnaces. The multiple hearth furnace is not designed for intermittent operation primarily because a significant amount of fuel is required for start-up of the unit. For fluidized sand bed furnaces, the sand retains enough heat that the furnace can be shut down for 8 to 10 hours and then be restarted without the use of start-up fuel. Fuel requirements for normal operation of the units are 20 to 25 percent higher for fluidized bed furnaces. The selection of the type of furnace used should be made on a case by case basis.

CHAPTER 9

ECONOMIC CONSIDERATIONS

9-1. Introduction

This section provides economic considerations concerning water pollution control systems. In keeping with the intent of Executive Order 12088, budget requests for water pollution control work at Federal facilities should reflect an effective life cycle cost solution. This involves an evaluation of both capital and annual costs (total life cycle costs). Guidelines have been issued by DOD and DA for making life cycle costing studies. Total system costs are sensitive to materials of construction, i.e., steel tanks cost less than reinforced concrete tanks but have a shorter life; type of equipment; inflationary effects on material, chemical and labor costs; energy availability; and geographical location.

9-2. Construction Costs

Construction costs include expenditures for labor and materials to build facilities including piping, steel, concrete, excavation, buildings, electrical work, heating and ventilation, etc. Costs for special localized site development factors may include site or trench dewatering, piling, and rock excavation.

a. Cost curves. Appendix A contains typical construction cost curves for several treatment unit operations. The curves show the range of cost values associated with varying plant capacities. The bibliography contains additional references pertaining to treatment plant costs.

b. Cost indices. Cost indices relate costs at one time and place to costs at any other time and/or place. For example, if a project was estimated to cost $100,000 in 1973 using an index of 1138, that same project would cost 2233/1 138 multiplied by $100,000 or $196,221 in 1982 when the cost index rises to 2233. Geographical adjustments may also be necessary. AR 415-17 provides guidance on cost adjustment factors.

(1) Commonly used indices. Indices commonly used are the U.S. EPA Sewage Treatment Plant (EPA-STP) Cost Index and the *Engineering News-Record* (ENR) Indices (see figure 9-l). The slopes of the curves represent the relative increase in costs with time. The basic difference between the two indices is that the EPA-STP index includes skilled labor and mechanical equipment costs, while the ENR index includes structural steel, cement, 2 X 4 lumber, and common labor (69). As a result of different price changes for the various types of material and labor, the relative slopes of the lines are different. Costs in appendix A are related to a EPA-STP index value. The ENR indices are updated weekly in the *Engineering News-Record* and the EPA-STP index value is updated quarterly in the *Journal Water Pollution Control Federation.*

(2) Geographic variability. Costs will vary at different geographical locations due to transportation and other expenses. Thus, cost indices at a given time will vary from place to place. Table 9-1 illustrates this point by the variation in the EPA-STP at several key U.S. cities. Appendix A relates all costs to a national index, rather than an index for a particular geographical location. The cost adjustment for foreign locations must be evaluated on a specific case-by-case basis. Sometimes availability of materials is critical and may affect design decisions. Thus, early assessment of foreign economic conditions is important.

Table 9-1. Typical geographical variations in cost indices (values are ENR construction cost index for March 1983). Base Value: 1967 = 100

Location	Index Value
Atlanta	390
Baltimore -	350
Birmingham	352
Chicago	341
Cleveland	380
Dallas	410
Denver	365
Kansas City	406
Los Angeles	418
Minneapolis	347
New York	329
Philadelphia	381
St. Louis	347
San Francisco	390
National Average	374

9-3. Life cycle cost evaluation

All pollution control plans for military installations must include a life cycle cost evaluation when applicable. This evaluation is an analysis to determine the wastewater treatment system or component thereof which will result in the lowest total cost in meeting regulatory criteria. The evaluation must include total capital and annual costs for the complete treatment system and for alternative unit operations within the overall system. For this reason, the construction cost

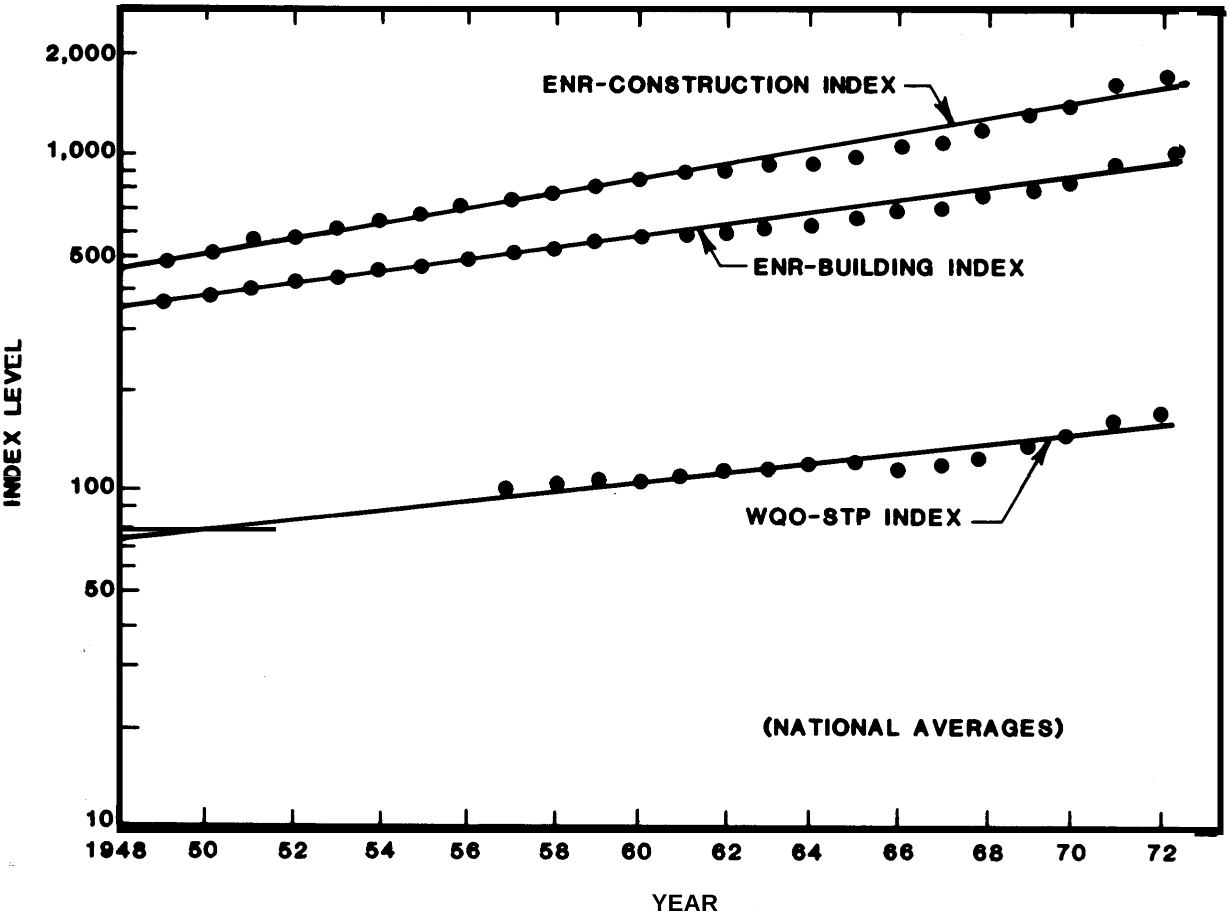


Figure 9-1—Commonly used indices.

curves in appendix A are presented on a unit operation basis such as pumping, sedimentation, filtration, etc., rather than a total treatment system such as trickling filter plant or activated sludge plant. The unit operations should be evaluated individually and assembled into a total treatment scheme capable of effecting the desired treatment. Procedures for more detailed construction cost estimates used in facility design are outlined in TM 5-800-2. Questions relating to those pollution studies which are applicable specifically to water pollution abatement projects should be directed (DAEN-ECE-G) WASH DC 20314.

APPENDIX A

WASTEWATER TREATMENT AND SOLIDS HANDLING COST DATA

A-1. The costs included herein have been related to average wastewater flow so that they may be readily usable for preliminary cost estimating purposes without requiring a preliminary design.

A-2. In order to relate all costs to average wastewater flow, certain assumptions were made. These assumptions are specifically listed on the applicable cost curves and are categorized as follows:

a. Influent waste and wastewater considerations. These include peak to average wastewater flow ratios, influent BOD concentrations, average quantities of sludge produced by specific processes, average efficiencies of upstream treatment units, etc.

b. Unit loading rates. These include total dynamic pumping head, hydraulic detention times, cubic feed of air per pound of BOD, gallons of wastewater per square foot per day, etc.

c. Additional units included in the treatment system package. For example, diffused air aeration system costs are included with the total activated sludge system costs, and carbon regeneration costs are included in the total carbon adsorption system cost.

A-3. The peaking factors and design parameters used for cost development are taken from technical manuals, standard engineering textbooks and other references.

A-4. Construction costs are related to a EPA-STP index value for December, 1983 of 370. This construction cost index value is a national average, and may be adjusted to a specific geographical location in accordance with AR 415-17.

A-5. It must be recognized that costs obtained from these costs curves are sufficiently accurate for preliminary, planning construction cost estimation *only.* For preliminary cost comparisons, additional costs should be included for items such as engineering, legal, administration, and contingency factors. More detailed cost estimates should be prepared as outlined in TM 5-800-2.

A-6. Costs for lagoons, landfills, land treatment and similar land-intensive systems are not presented due to the extremely wide variations in costs that can be experienced at a given location. The main factors influencing these variations include land cost and availability y, soil type and climate.

A-7. Because of uncertainties regarding economies of scale, and in view of the lack of published date concerning costs for treatment plants with design flows less than 1.0 mgd, the curves are presented as broken lines between 0.1 mgd and 1.0 mgd. In this range, the curves should be used with discretion, realizing that the costs are based upon extrapolations of data for larger plants.

A-8. Figures A-1 through A-15 provide approximate costs of unit processes related to system flow rate.

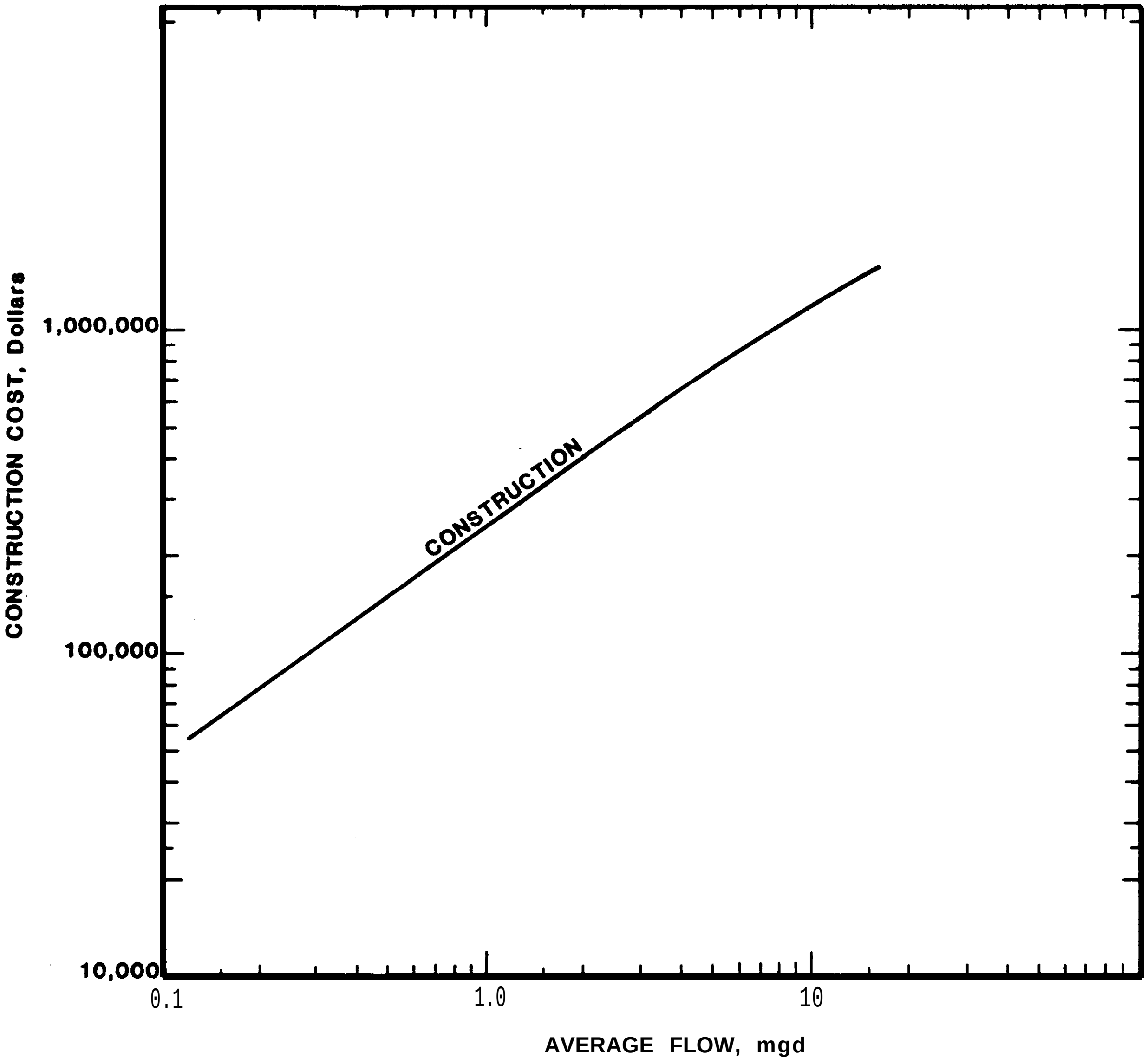


Figure A-1. Cost of raw waste pumping.

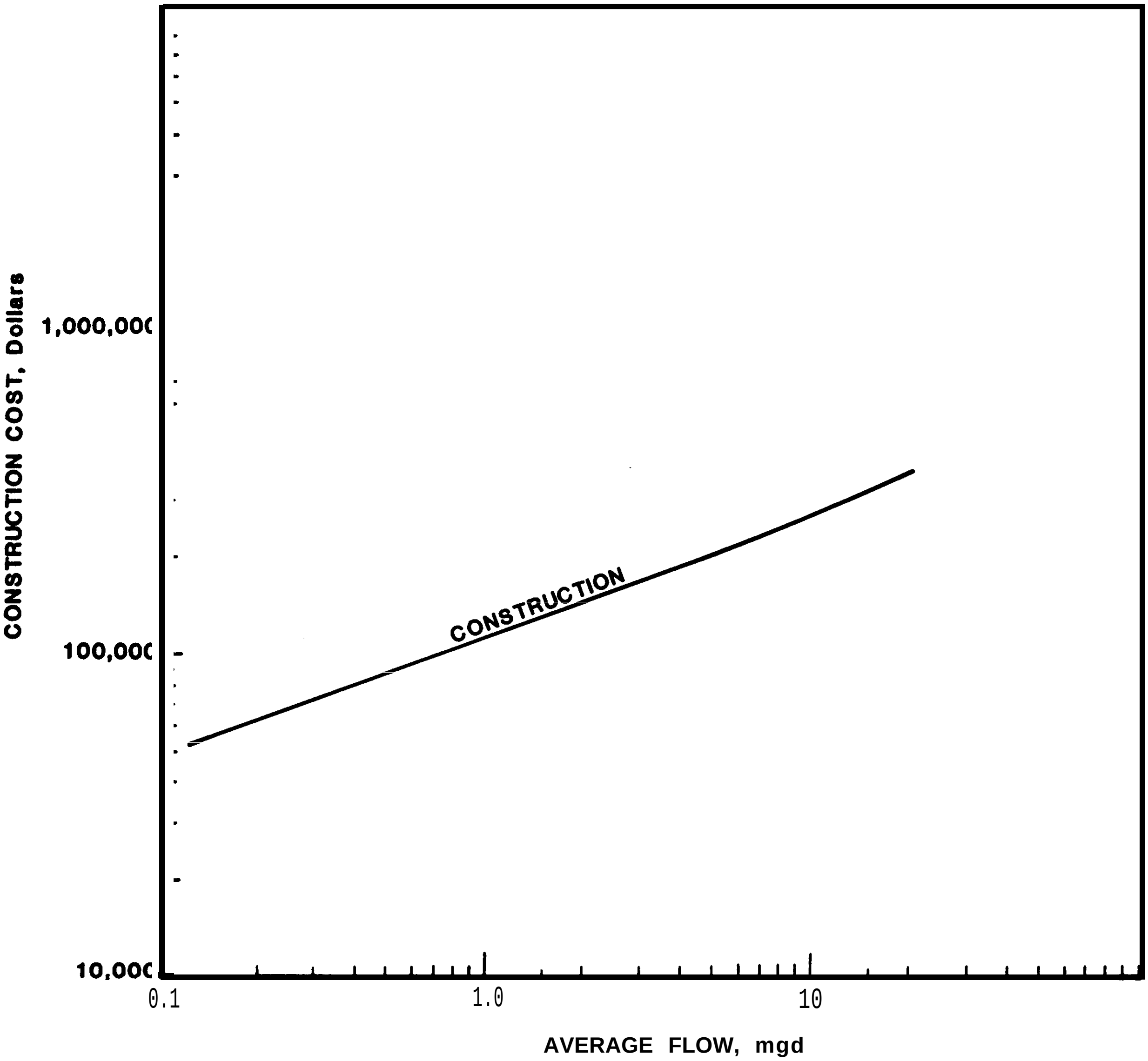


Figure A-2. Cost of preliminary treatment.

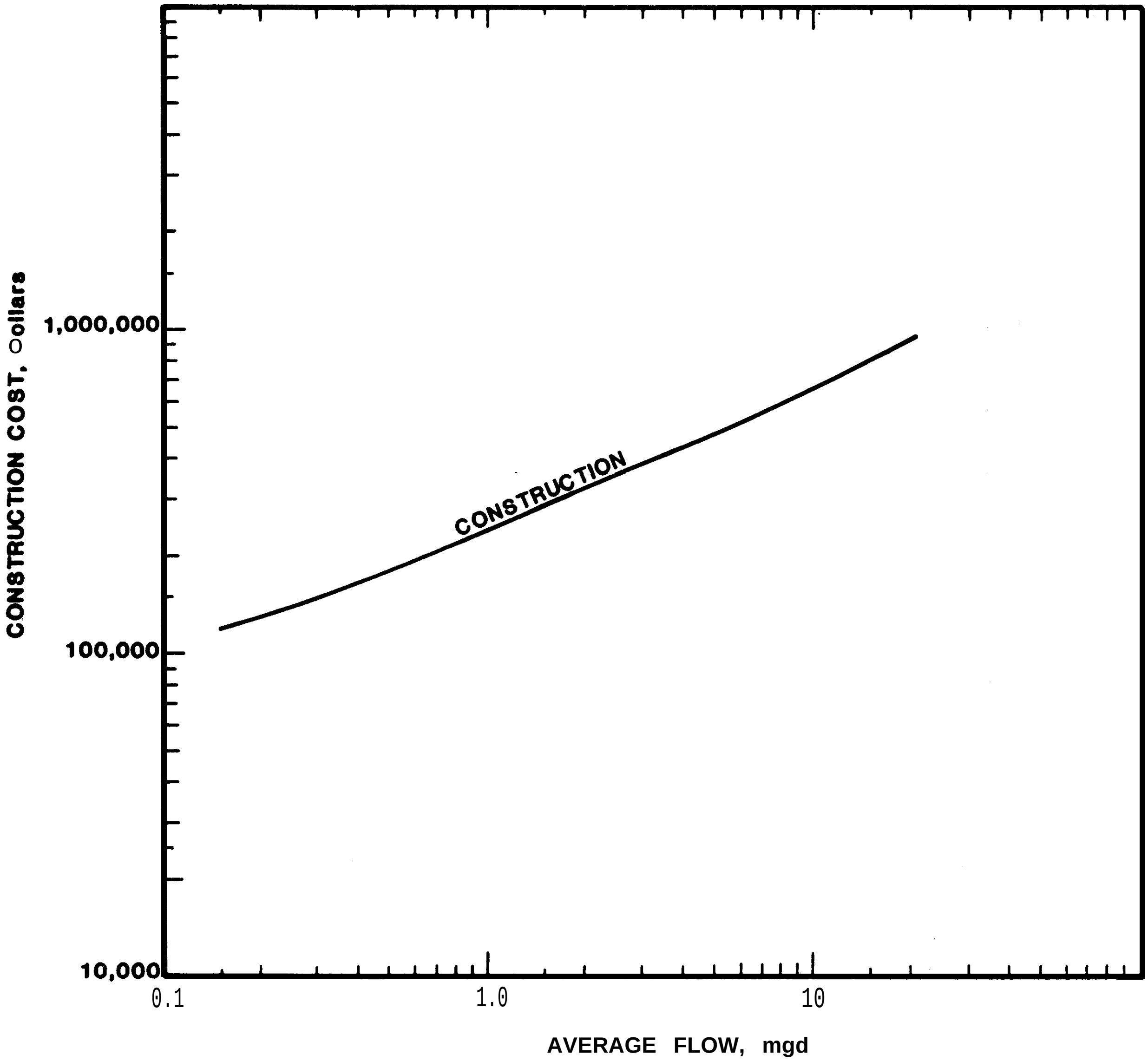


Figure A-3. Cost of primary clarifiers.

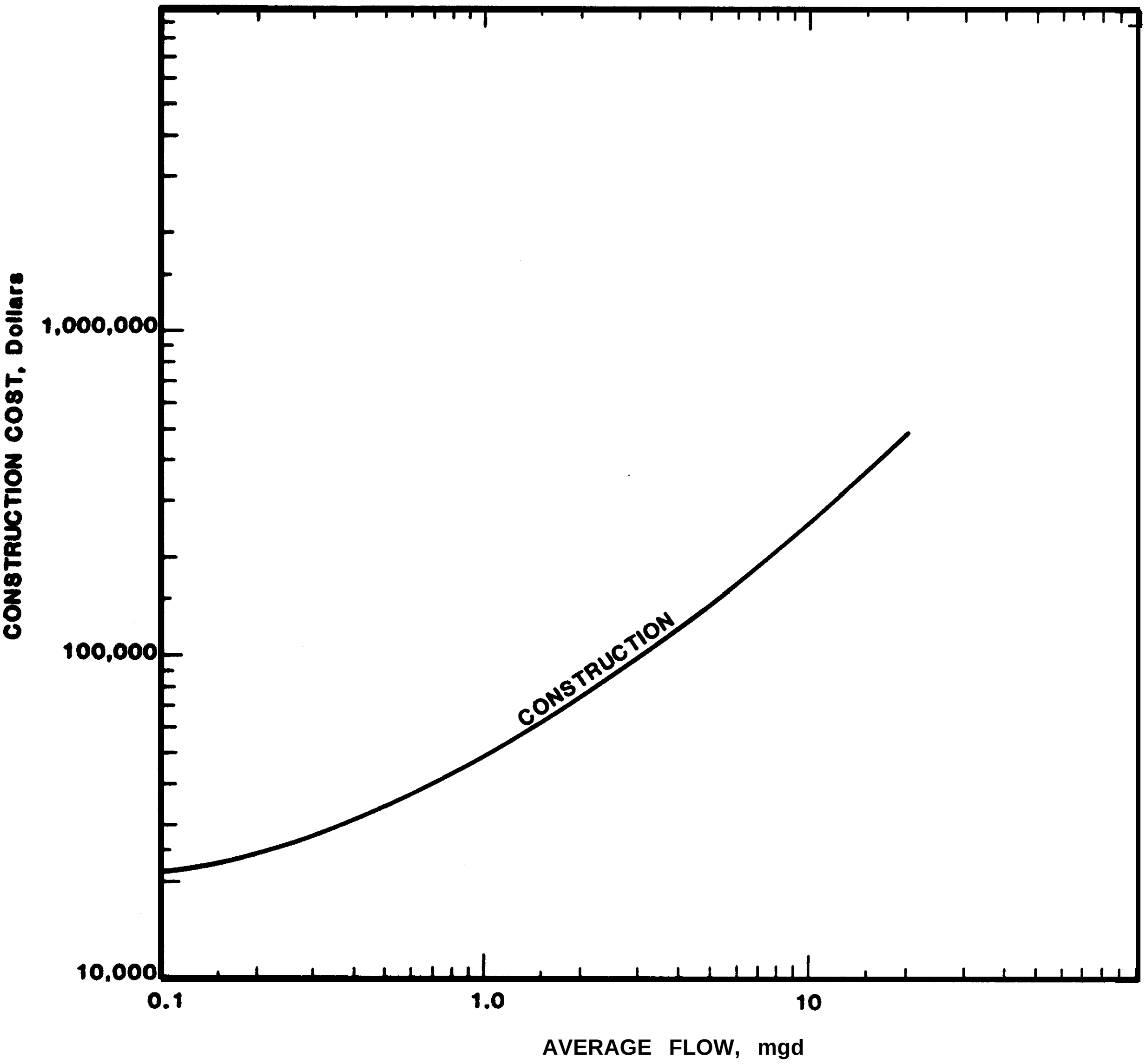


Figure A-4. Cost of $FeCl_3$ addition.

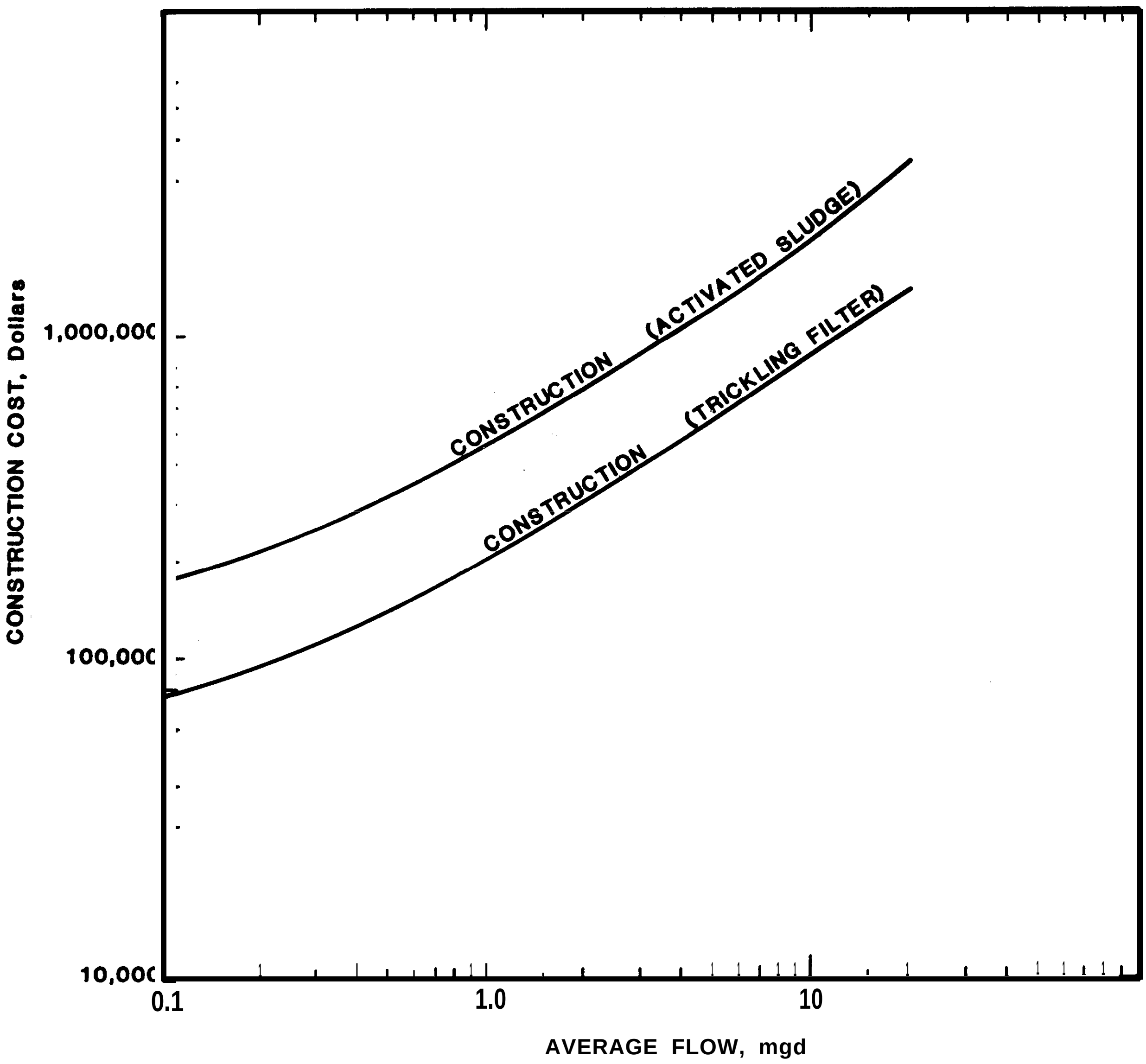


Figure A-5. Cost of activated sludge.

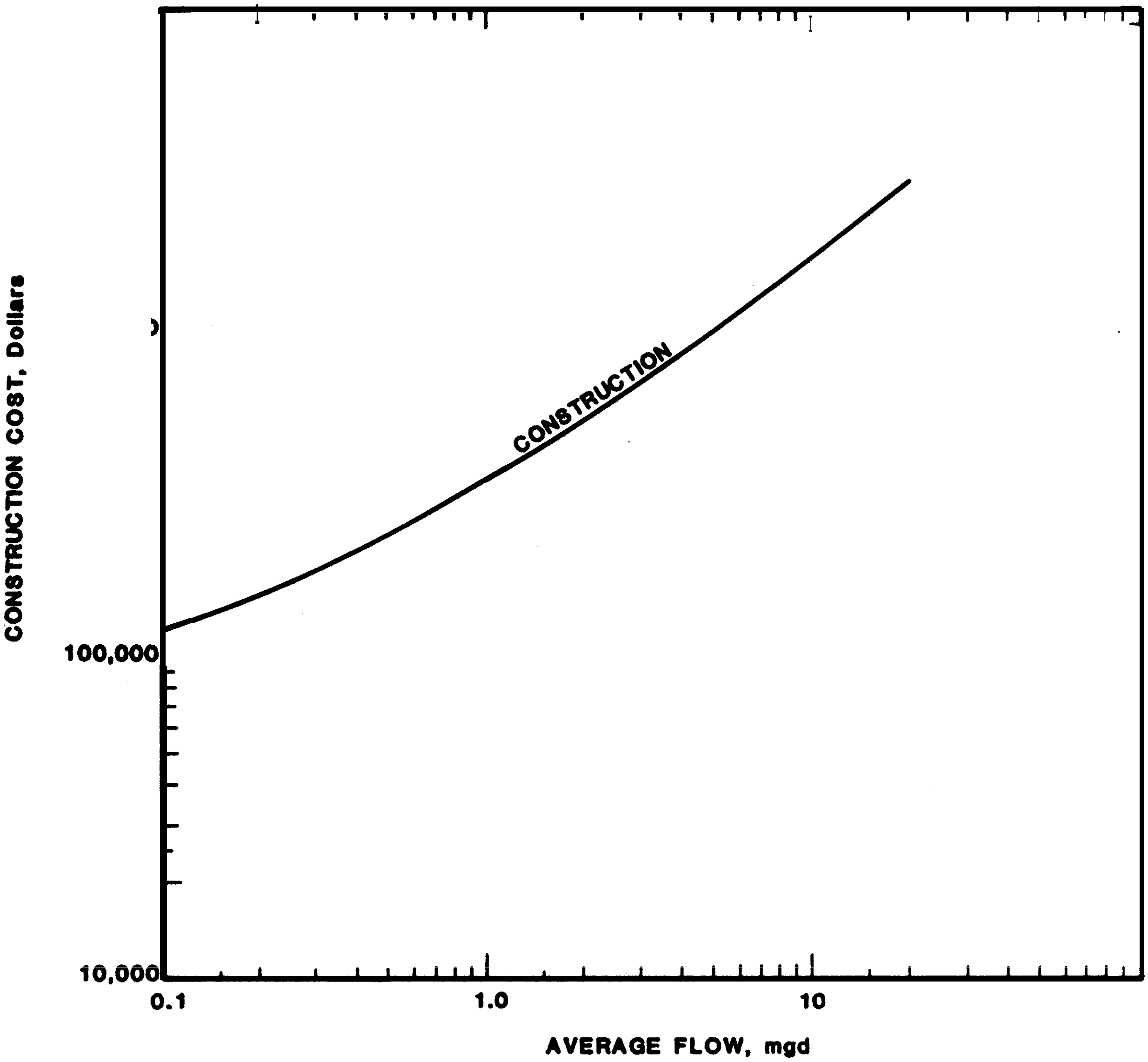


Figure A-6. Cost of high rate trickling filter.

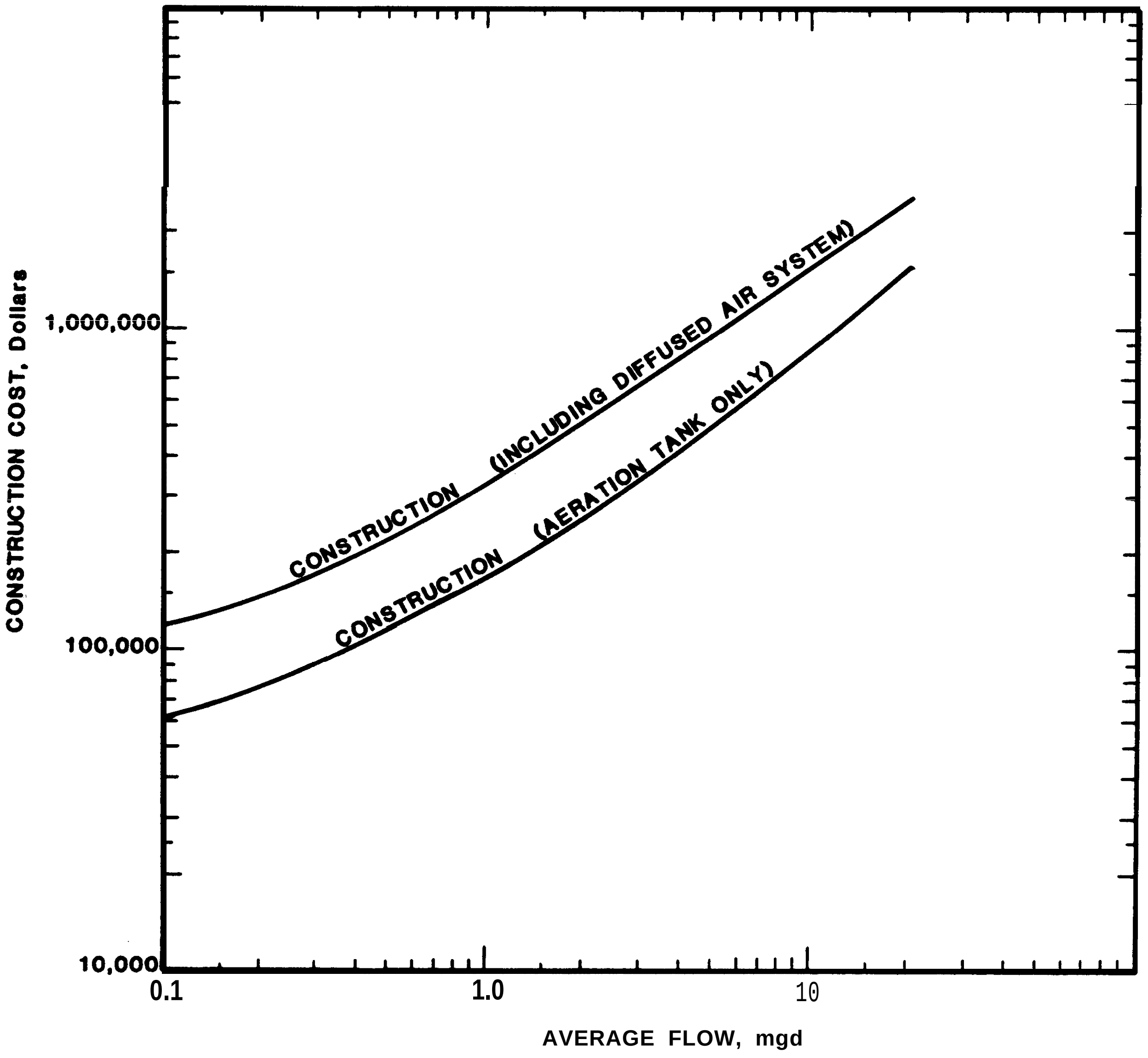


Figure A-7. Cost of suspended growth vitrification system.

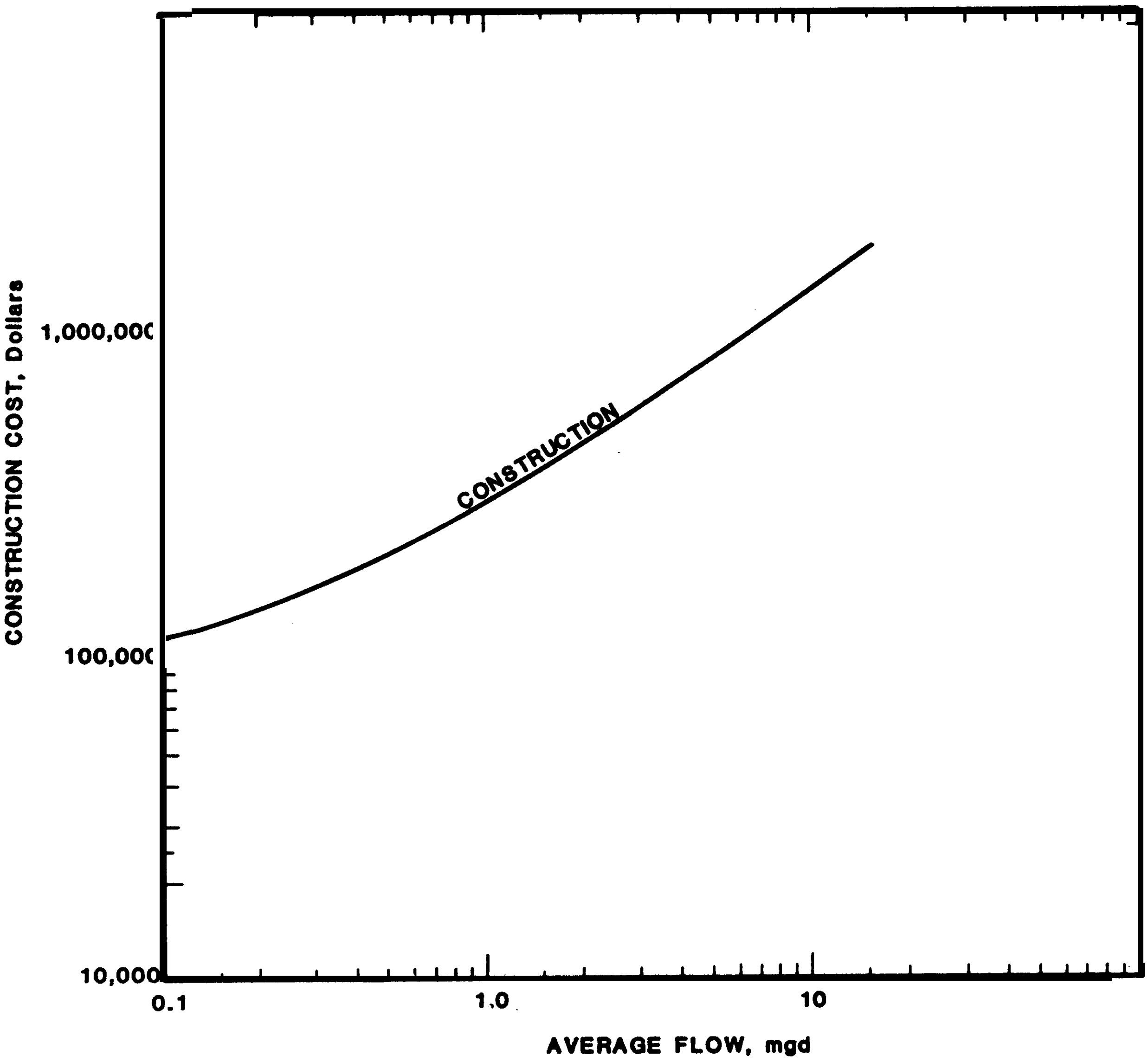


Figure A-8. Cost of final clarifiers.

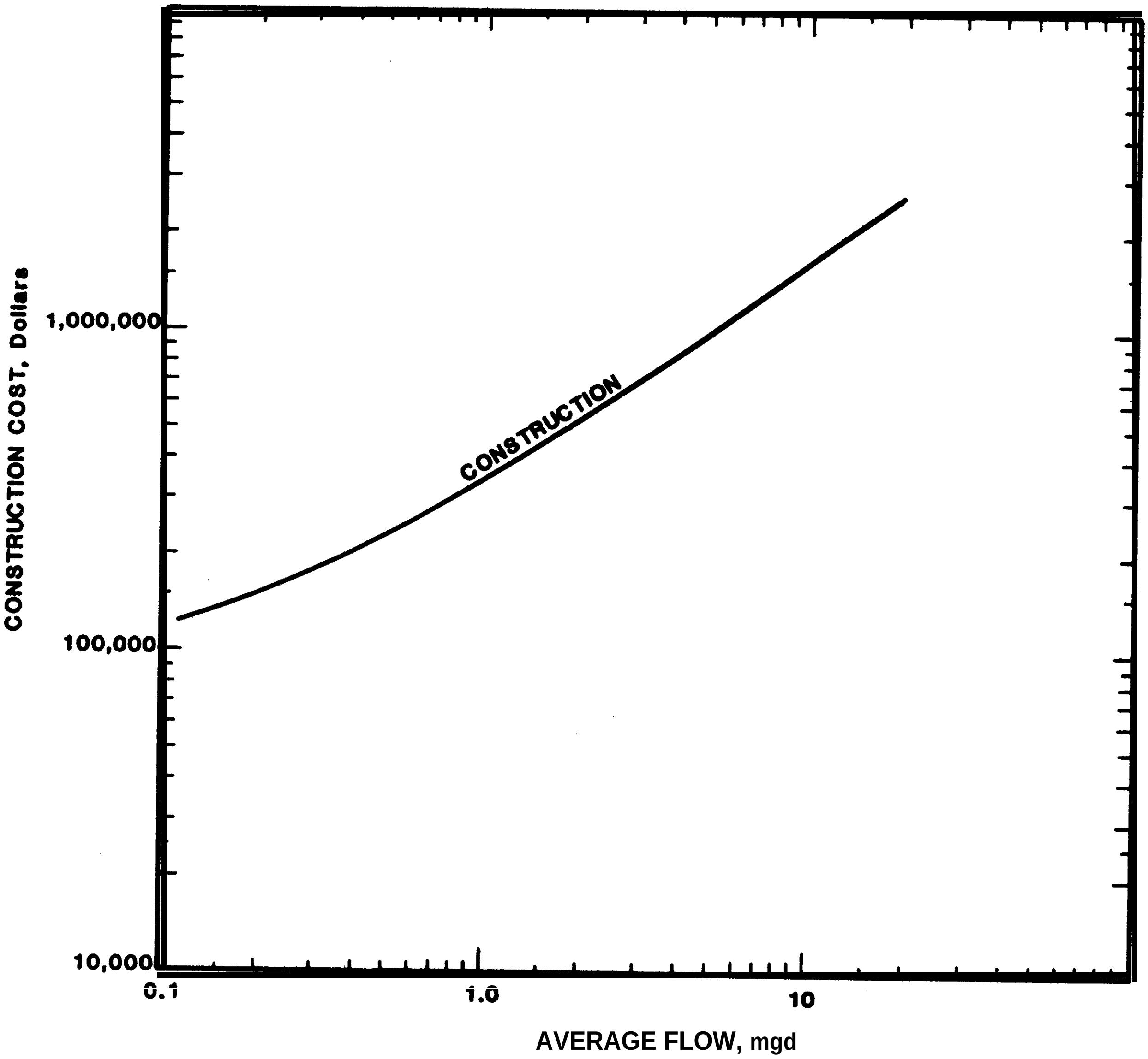


Figure A-9. Cost of two stage lime clarification.

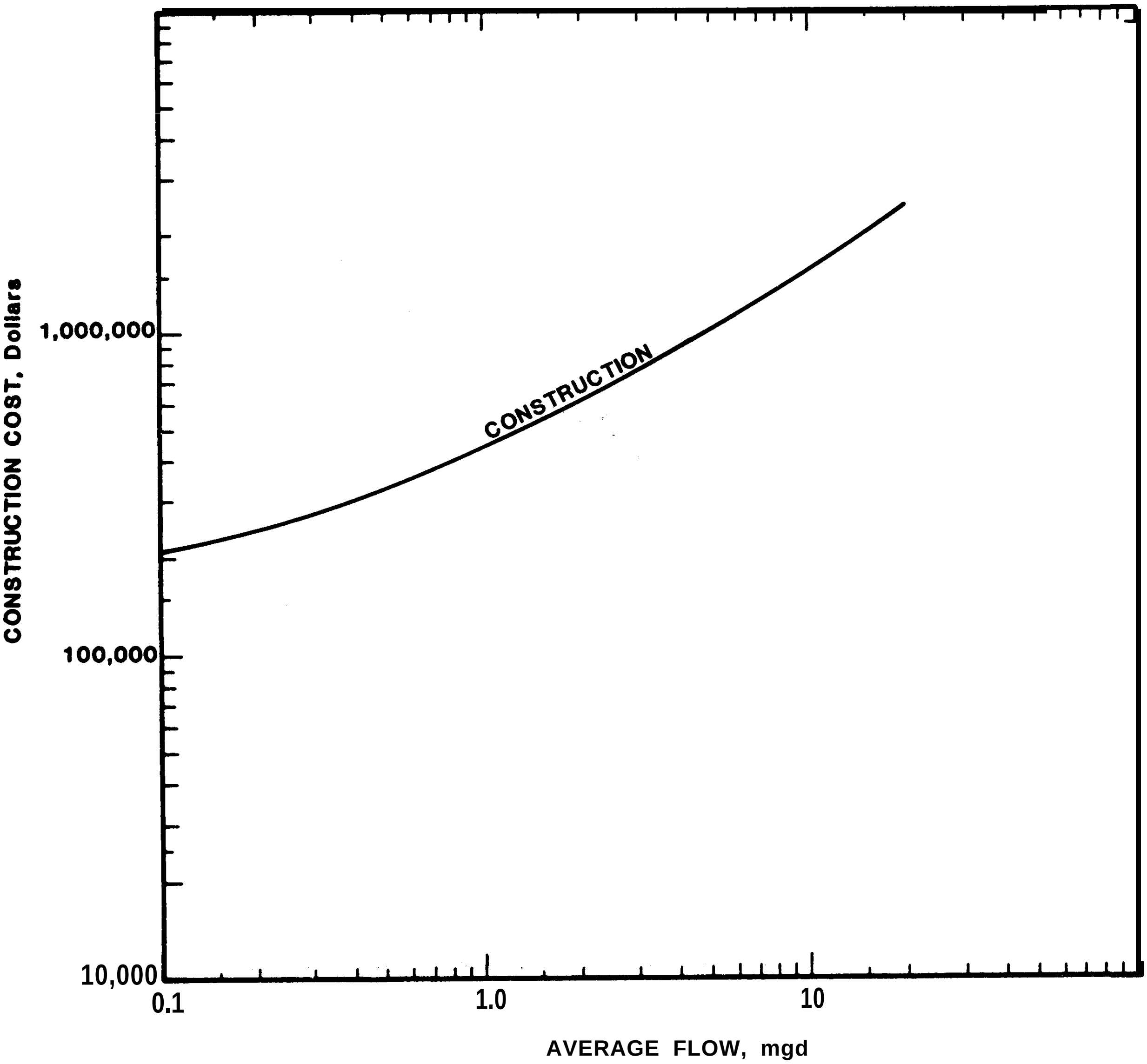


Figure A-10. Cost of multi-media filtration.

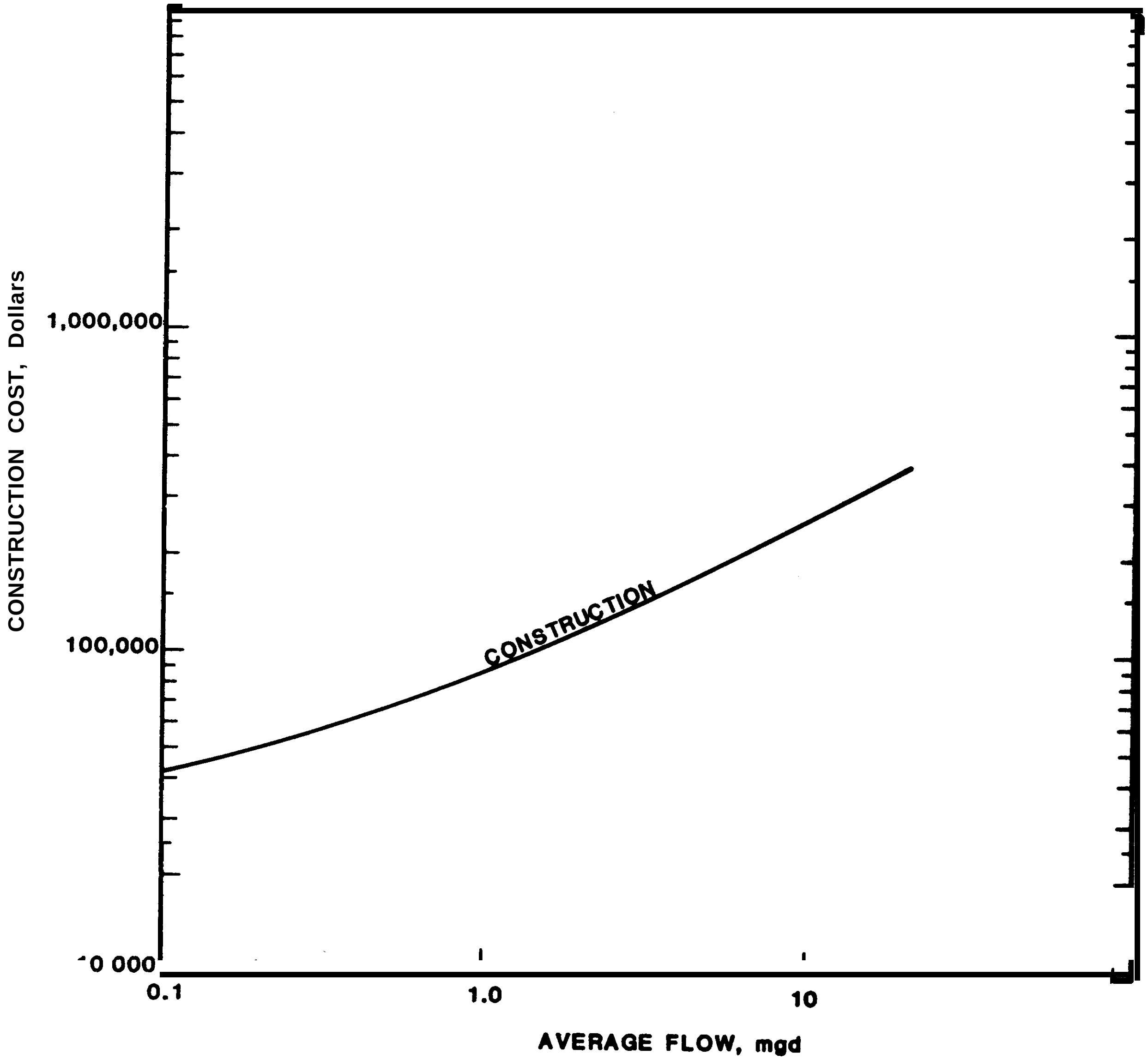


Figure A-11. Cost of chlorination.

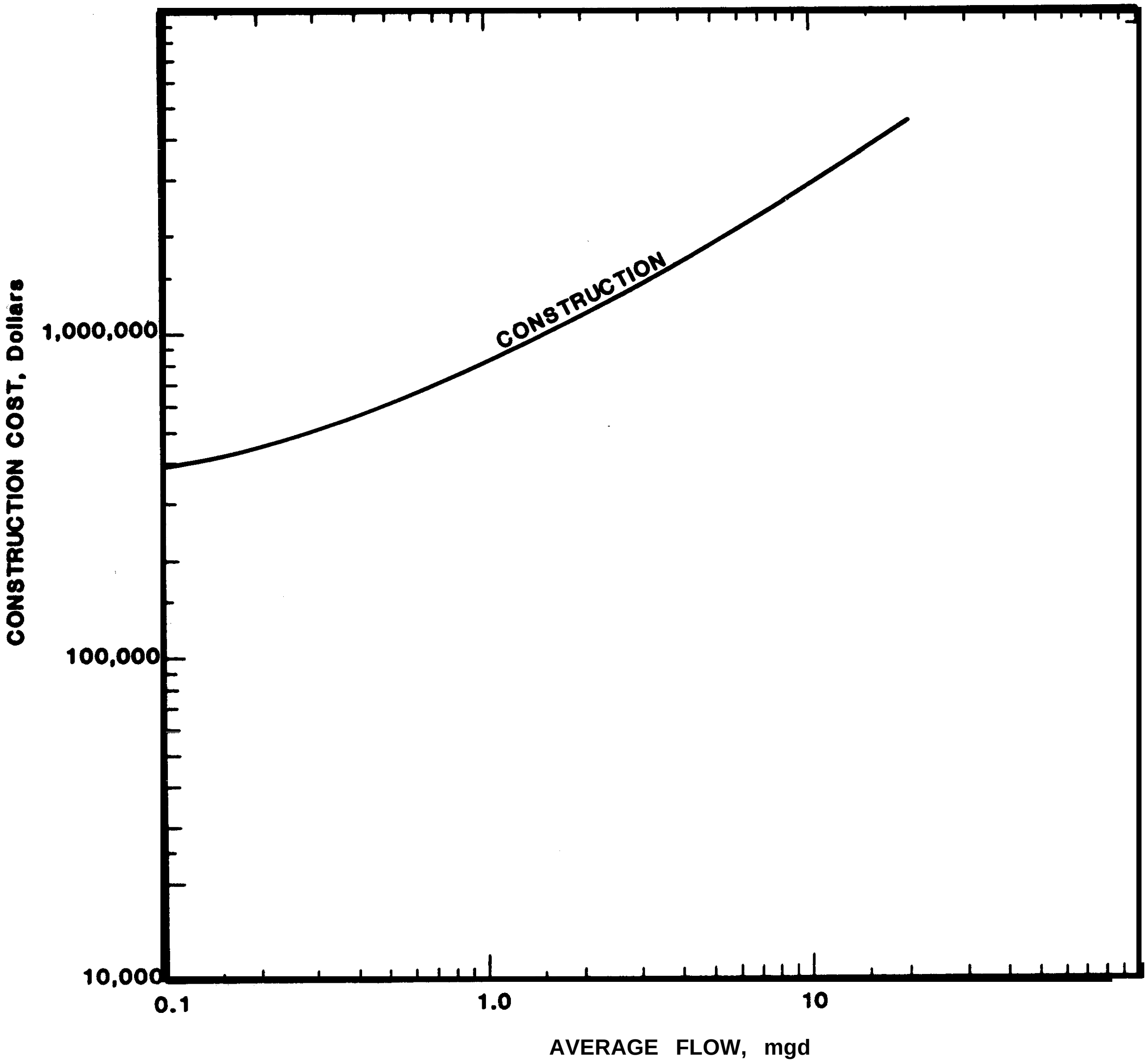


Figure A-12. Cost of granular carbon adsorption.

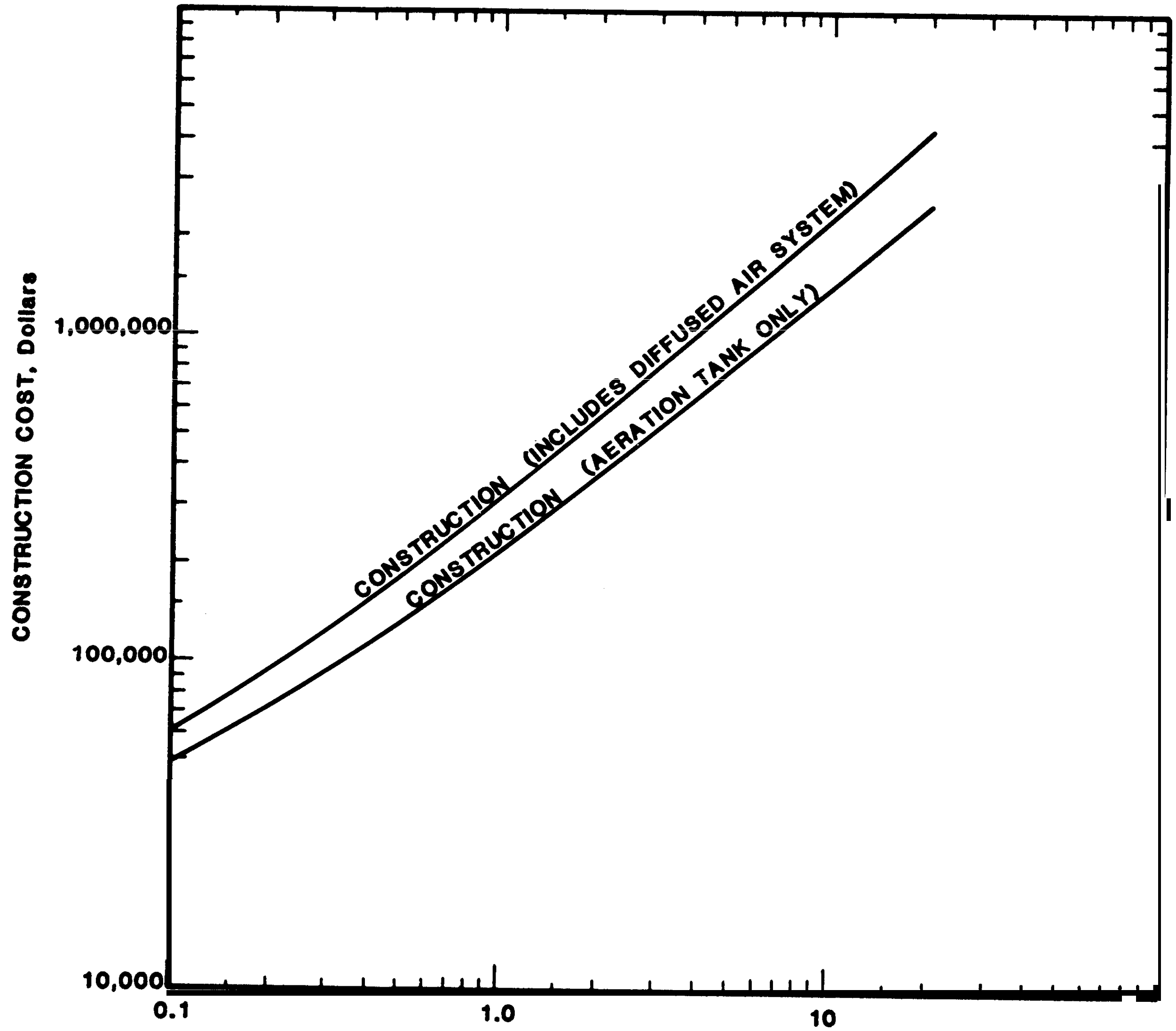


Figure A-13. Cost of two stage anaerobic digestion.

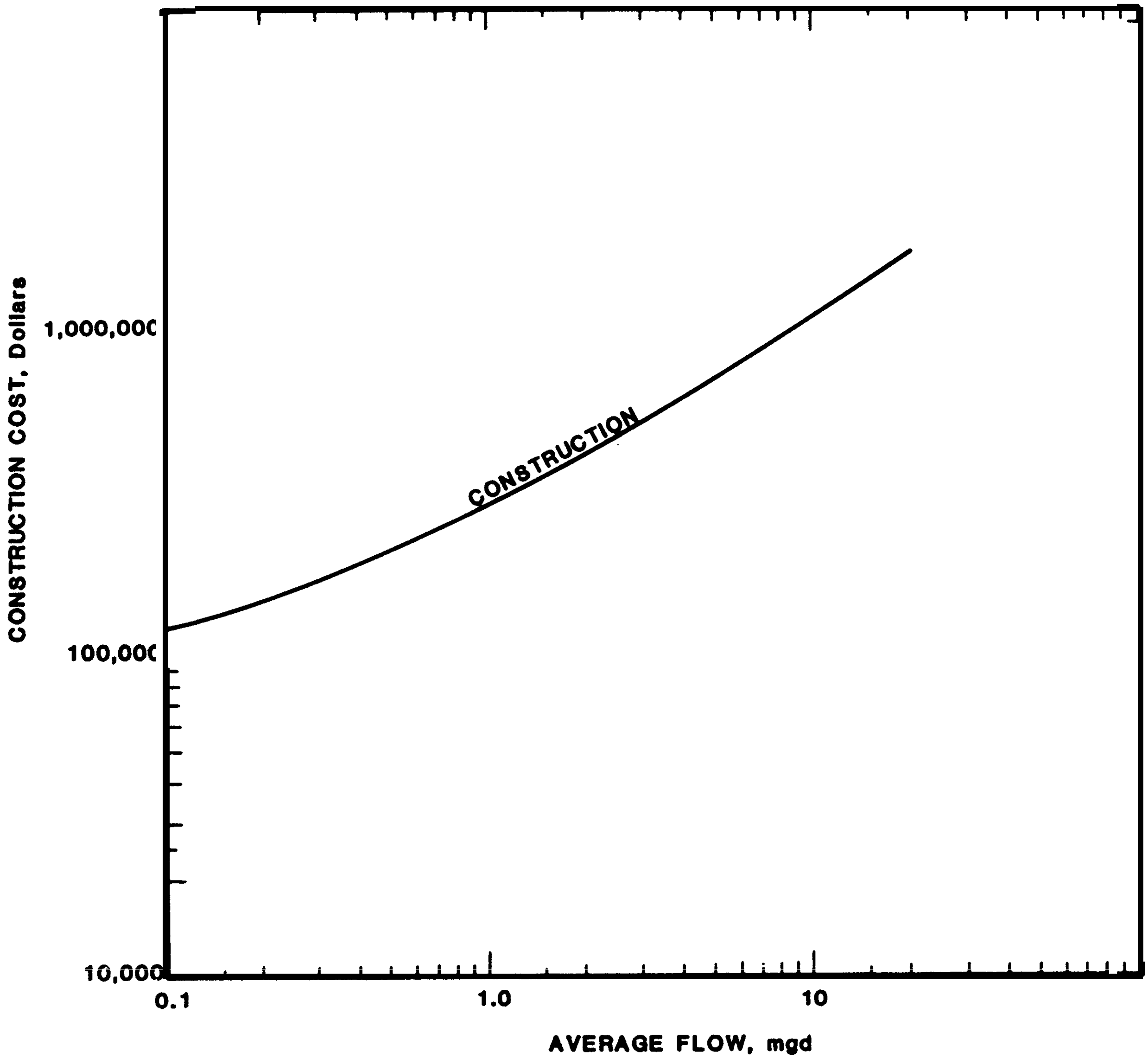


Figure A-14. Cost of vacuum filtration.

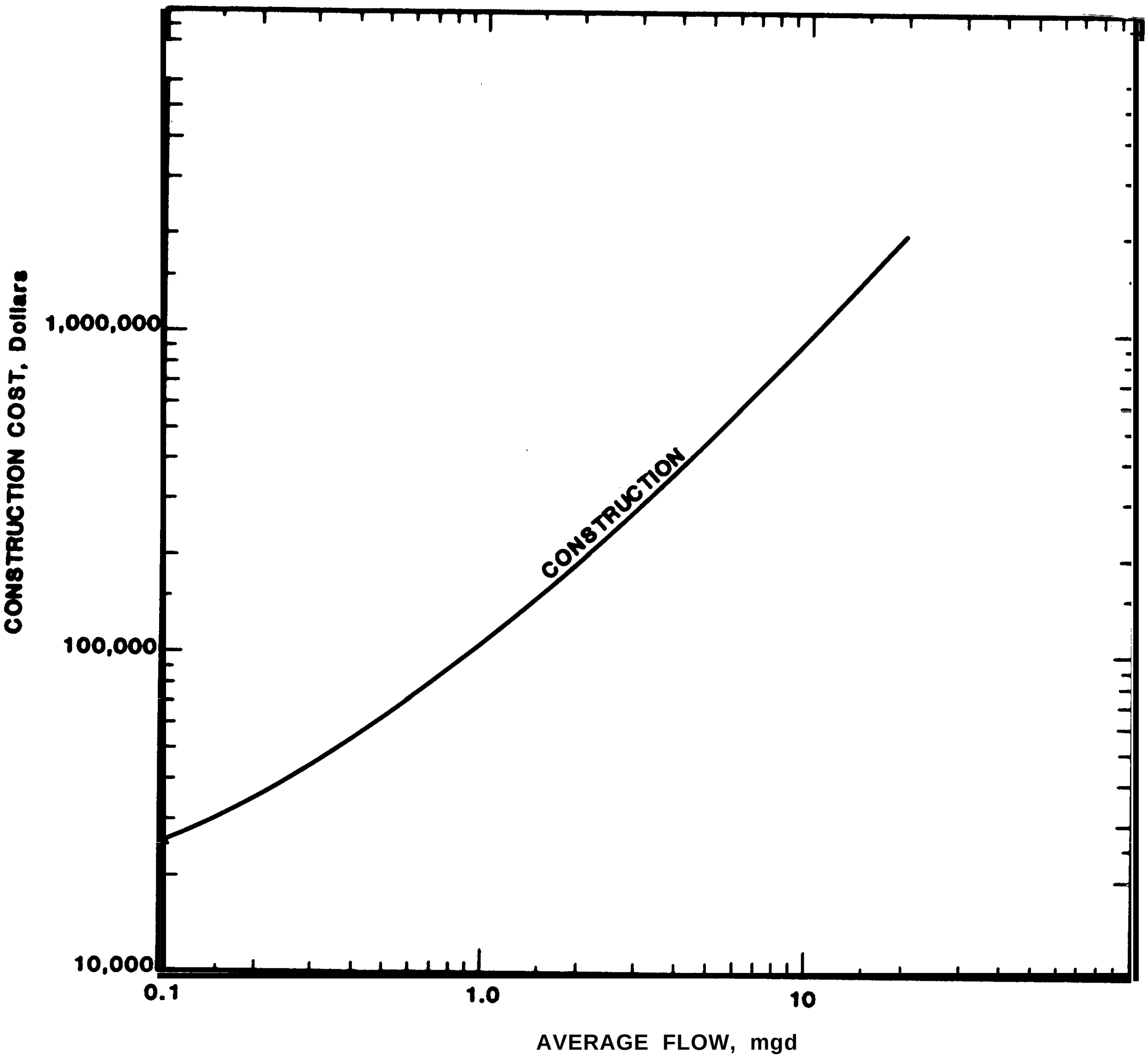


Figure A-15. Cost of sludge drying beds (uncovered).

APPENDIX B

WASTEWATER AND SOLIDS HANDLING DESIGN CRITERIA

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1. Primary sedimentation.

Average Design Flow (mgd)	Surface Loading Rate (gpd/sq ft)
0.01	150
0.01 to 0.10	500
0.10 to 1.00	600
1.00 to 10.0	800
10.0	1,000

Hydraulic detention time = 2 to 2.5 hr.

Air supply capacity based on 1,500 cu ft of air per pound of BOD_5 applied to the aeration tank.

2. Final clarification

Average Design Flow (mgd)	Surface Loading Rate (gpd/sq ft)
0.01	100
0.01 to 0.10	300
0.10 to 1.00	400
1.00 to 10.0	500
10.0	600

3. Suspended growth vitrification
   Hydraulic detention time = 3 to 5 hr at average flow.
   Overflow rate = 500 to 800 gpd/sq ft.
   Diffused air application = 1.0 cu ft/gal
   ph = 8.0 to 8.6
4. Granular carbon adsorption
   Influent suspended solids concentration less than 50 mg/L
   Hydraulic loading = 2 to 10 gpd/sq ft.
   Contact time = 18 to 36 min at average flow.
   Carbon Requirements:
   1. Secondary wastewater treatment: 0.5 to 1.8 lb/1,000 gal
   2. Advanced wastewater treatment: 0.25 to 0.35 lb/1,000 gal
5. Multi-media filtration
   Application rate = 2 to 10 gpm/sq ft at average flow.
6. Lime clarification
   Lime dosage = 150 to 200 mg/L (single stage)
   300 to 400 mg/L (two stage)
7. Chlorination
   Contact time = 15 to 30 min at 4 hr peak (1.75 times average) flow rate.
   Dosage = 15 mg/L for trickling filter effluent.
   8 mg/L for activated sludge effluent.
   6 mg/L for sand filter effluent.
   5 mg/L for multi-media filter effluent.
8. Anaerobic digestion

	Conventional Rate	High Rate
Sludge retention time (days) 30- 60	10- 20	
Solids loading (lb volatile solids/cu ft/day)	0.03-0.08	0.15-0.40

9. Vaccum filtration

	Filter Yield (lb/sq ft/hr)
Anaerobically digested	
Primary	6-7
Primary and trickling filter	5-6
Primary and activated sludge	4-5

10. **Sludge drying beds**

Application rate: 15 to 35 lb dry solids/sq ft/yr

APPENDIX C

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40 CFR Part 124	Environmental Protection Agency Regulations or Procedures for Decision Making Regarding National Pollutant Discharge Elimination System Permits.
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40 CFR Part 433	EPA Effluent Guidelines and Standards for Metal Finishing.
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33 U.S.C. 1251 et. seq.	Federal Water Pollution Control Act as Amended by the Clean Water Act of 1977, PL 96500.
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GLOSSARY

Colloids. Microscopic suspended particles which do not settle in a standing liquid and can only be removed by coagulation or biological action.

Demineralization. The process of removing dissolved minerals from water by ion exchange, reverse osmosis, electrodialysis, distillation or other processes.

Denitrification. The biological process which converts nitrates in the wastes to molecular nitrogen.

Desalinization. The process of removing dissolved salts from water.

Detention (Retention). The dwell or residence of wastewater, usually expressed in hours, in a treatment unit.

Disinfection. The process of killing the major portion of microorganisms in a waste stream with the probability that all pathogenic organisms are killed. This is not necessarily true for viruses.

Dissolved Oxygen. Elemental oxygen dissolved or molecularly dispersed in wastewater. Does not include any oxygen present in the combined form even though a compound may be an oxidizing agent. Expressed in mg/L.

Dissolved Solids. The solids remaining in a waste after filtering by specific test procedures. Expressed in mg/L.

Dragout. The liquid which is removed from a process step such as plating by the film retained on the work or part passing through the process.

Effluent. Wastewater leaving a particular system, treatment process or treatment plant.

Environmental Impact. The effects of a proposed facility or action on the environment, including changes to the air, streams, wildlife habitat, aesthetics, recreation and other similar factors.

Equalization. The holding or storing of wastes having differing qualities and rates of discharge for finite periods to facilitate blending and achievement of relatively uniform characteristics.

Explosive. A material which by the influence of thermal or mechanical shock decomposes rapidly with the evolution of much heat and gas. In the military context, it is the material used to propel a projectile or to produce fragmentation of the projectile at its terminal point. Such explosives are classified into two divisions, termed high and low explosives in accordance. with behavior or use. Detonating or high explosives include primary explosives such as detonators (lead azide, mercury fulminate, etc.) and secondary explosives such as RDX and TNT. Low explosives exert a powerful push with a low burning rate and are used primarily as propellants and are often referred to by that name. Propellants include materials such as nitrocellulose, nitroglycerine and nitroguanidine.

Filtration. A unit operation in which solid or colloidal material is separated from a liquid by movement through a granular or porous sheet type material such as cloth or paper.

Fixed Solids. The non-volatile component of the total solids, either suspended or dissolved, consisting or inorganic materials. The ash residue remaining after igniting dried residue from the total solids test at 550°C. Expressed in mg/L.

Floe. Gelatinous mass formed in liquids by the addition of coagulant, by microbiological processes or by particle agglomeration.

Flocculation. The process of floe formation normally achieved by direct or induced slow mixing.

Flume. An open, inclined channel or conduit for conveying water.

Fume Scrubber. Equipment used to remove objectionable fumes from a gas or air stream. Normally achieved by contact of the gas stream with a counter-current liquid stream in “which objectionable constituents are collected.

Grease. A group of substances including fats, waxes, free fatty acids, calcium and magnesium soaps, mineral oils and certain other non-fatty materials. The grease analysis will measure both free and emulsified oils and greases. Generally expressed in mg/L.

Grit. Heavy suspended mineral matter such as sand, gravel and cinders which is present in wastewater.

Hardness. A characteristics of water imparted principally by the presence of calcium and magnesium compounds. Hardness is undesirable from the standpoint that it reacts with soap resulting in increased consumption. Also it is the prime cause of boiler scale and can adversely affect some industrial processes. Normally expressed in mg/L as $CaCO_3$.

Heavy Metals. Metals that can be precipitated by hydrogen sulfide in an acid solution, for example lead, silver, mercury, copper, chromium, zinc and nickel.

Infiltration. The quantity of groundwater which enters a sewer pipe through faulty joints, porous walls or breaks.

Inflow. Includes storm flows and non-contaminated flows such as cooling water which are diverted to a separate sanitary sewer. Can cause sewer overflows and overloading of treatment facilities.

Ion Exchange. The reciprocal transfer of ions between a solid and a solution surrounding the solid.

Ionization. The process by which, at the molecular level, atoms or groups of atoms acquire a charge by the loss or gain of one or more electrons.

Land Application (Land Spreading or Land Treatment). Disposal of wastewater by discharge to the land (such as irrigation) or disposal of waste sludge by spreading on the land.

Life Cycle Costs. All cost applicable to a facility over the period of its useful life. Such costs include fixed charges such as depreciation, interest, taxes, and insurance as well as operating expenses, labor, maintenance and supplies.

Vitrification (Nitrogen Conversion). The conversion of nitrogenous matter into nitrates.

Nitrogen, Ammonia (NH_3-N). A measure of the amount of nitrogen which is in the form of ammonia. Expressed in mg/L as N.

Nitrogen, Kjeldahl (Total Kjeldahl Nitrogen or TKN). A measure of nitrogen combined in organic and ammonia forms. Expressed in mg/L as N.

Nitrogen, Nitrate ($N0_3$-N). A measure of the amount of nitrogen which is in the form of nitrate. Expressed in mg/L as N.

Nitrogen Removal. Unit operations and unit processes required to remove different forms of nitrogen from a water. This may be accomplished partially in a biological process used in secondary treatment; however, normally it entails subsequent aerobic and anaerobic processes, ammonia stripping, chlorination or other similar steps.

Package Plant. A treatment plant, pumping station or major functional part thereof which has been pre-assembled prior to delivery for installation.

pH. A measure of the intensity of acid or alkaline condition of the solution. The logarithm of the reciprocal of the hydrogen ion concentration. In an aqueous solution, neutral pH is 7.0, alkaline pH greater than 7.0, and acid pH less than 7.0. pH differs from alkalinity and acidity which measure the capacity of a solution to provide hydrogen or hydroxylions.

Phosphatizing. Application of a phosphate-bearing coating to a metal part as a corrosion inhibitor and/or as a base for other coatings.

Phosphorus Removal. The process of removing phosphorus from the wastewater by precipitation, adsorption or biological means.

Physical-Chemical Treatment (PCT). A combination of unit operations arranged to achieve treatment equivalent to conventional secondary biological treatment. Basically suspended solids are removed by addition or a coagulant and coagulant aid followed with a clarification step achieved by settling. The effluent may be filtered to ensure essentially complete suspended solids removal. Dissolved organic pollutants are removed in a subsequent activated carbon unit.

Pickling. The treatment of a metallic material or part with acid to remove surface oxide.

Pond. An engineered impoundment containing raw or partially treated wastewater in which aerobic and/or anaerobic stabilization occurs. Sometimes referred to as a lagoon.

Preliminary Treatment. Treatment operations such as screening, grit removal, comminution and equalization which preceded primary treatment.

Pretreatment. Those treatment operations used at a point source or upstream from the wastewater collection system. This is particularly applicable to industrial process wastewaters to eliminate constituents such as grease or toxic materials which may adversely affect the collection system or subsequent treatment processes.

Primary Treatment. Removal of waste constituents (suspended solids and BOD associated with the settleable solids removed) by settling, usually without addition of coagulant or coagulant aids.

Propellants. See explosives.

Raw Waste. Waste entering a treatment facility.

Reverse Osmosis. A process whereby water is forced to pass through semi-permeable membranes under high pressures. Water passing through the membrane is relatively free of dissolved solids; solids are retained in concentrated form on the feed side of the membrane and are wasted.

Secondary Treatment. A stage of treatment to perform additional waste constituent removal beyond that provided by primary treatment. The most common form of secondary treatment is a biological process such as an activated sludge or trickling filter followed by a secondary settling tank. Equivalent secondary treatment performance can usually be attained by physical-chemical processes.

Sedimentation. Clarification (settling).

Sewers. Lateral Sewer-One that discharges into a branch or main sewer and receives wastewater from individual sources.

Branch Sewer-One that serves a small area and receives wastewater directly from sources or from lateral sewers.

Main or Trunk Sewer-One that receives wastewater from many tributary branch sewers and serves a large area.

Interceptor Sewer-One that receives wastewater from trunk sewers and branch sewers and conducts it to the point of treatment or discharge.

Sludge. A concentrate in the form of a semiliquid mass resulting from settling of suspended solids in the treatment of sewage and industrial wastes.

Sludge Conditioning. Treatment of liquid sludge, usually by heat treatment or addition of chemicals, before dewatering to facilitate water removal and enhance drainability.

Sludge Dewatering. The process of removing a part of the water from the sludge to convert to a semisolid form. Methods used include draining, pressing, vaccum filtration, pressure filtration, centrifugation and others.

Sludge Incineration. The burning of dewatered sludge under sufficiently high temperature to oxidize all organic components. The resulting residue is a sterile ash.

Sludge Stabilization. Any treatment including such operations as anaerobic or aerobic digestion which converts sludge to a form which can be disposed of without a detrimental effect on the environment.

Sludge Thickening. Settling, air flotation, centrifugation or similar operations to decrease the water content of the sludge yet maintain it in a fluid form.

Suspended Solids. Solids retained by filtering a sample of a water or wastewater stream. Retained material is dried at 103°C prior to weighing. Expressed in mg/L.

Total Solids. This dissolved and suspended solids content of a water or wastewater stream. Determined by evaporating liquid and drying to a residue at 103°C prior to weighing. Expressed in mg/L.

Toxic Material. Any material which inhibits normal biological processes in animals, treatment processes, or the environment. Normally these are materials which cause such inhibition at low concentration levels.

Turbidity. A measure of fine suspended material (usually colloidal) in a liquid. Usually expressed in standard Jackson turbidity units. In most cases, suspended material consists of fine clay or silt particles, dispersed organics and microorganisms.

Volatile Solids. Solids, dissolved or suspended, which are primarily organic and exert the significant portion of the BOD during stabilization. Expressed in mg/L.

Wastewater Inventory. A detailed listing of all wastewater sources including data on flow, temperature, BOD, suspended solids and other parameters necessary to define quality.

Weir. A control device placed in a channel or tank which facilitates measurement or control of the water flow.

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Distribution:

To be distributed in accordance with DA Form 12-34B, requirements for TM 5-814 Series: Sanitary & Industrial Wastewater Collection.

*U.S. GOVERNMENT PRINTING OFFICE: 1987-177-656