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DEPARTMENT OF DEFENSE
HANDBOOK

WASTEWATER TREATMENT SYSTEM
OPERATIONS AND MAINTENANCE
AUGMENTING HANDBOOK

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ABSTRACT

This handbook augments the series of O&M field study training manuals prepared by California State University, Sacramento, and the California Water Pollution Control Association for the United States Environmental Protection Agency (EPA). This series, commonly known as the "Sacramento" series, has been adopted for use by the military. It addresses most topics pertinent to wastewater treatment O&M. However, some topics important to military facilities are not sufficiently covered in the Sacramento series or require particular emphasis. This handbook addresses those topics and includes the following: regulatory compliance and monitoring; septic tanks; grease traps; oil/water separators; septage management; extreme climate operation; corrosion control; and chemical shipping and feeding.

FOREWORD

This handbook is approved for use by all Departments and Agencies of the Department of Defense. It is intended to guide the reader in the operations and maintenance of wastewater treatment systems. Commercial equipment and materials mentioned in this handbook are included for illustration purposes and do not constitute an endorsement.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document or the Sacramento Series should be submitted on the DD Form 1426, Standardization Document Improvement Proposal, and addressed through major commands to:

Air Force: HQ AFCESA/CESC, 139 Barnes Dr., Suite 1, Tyndall AFB, FL 32403-5319.

Army: U.S. Army Center for Public Works, ATTN: CECPW-ES, 7701 Telegraph Rd., Alexandria, VA 22315-3862

Navy: LANTNAVFACENGCOM, Code 161B, 1510 Gilbert St., Norfolk, VA 23511-2699

DO NOT USE THIS HANDBOOK AS A REFERENCE IN A PROCUREMENT DOCUMENT FOR FACILITIES CONSTRUCTION. IT IS TO BE USED IN THE PURCHASE AND PREPARATION OF FACILITIES PLANNING AND ENGINEERING STUDIES AND DESIGN DOCUMENTS USED FOR THE PROCUREMENT OF FACILITIES CONSTRUCTION (SCOPE, BASIS OF DESIGN, TECHNICAL REQUIREMENTS, PLANS, SPECIFICATIONS, COST ESTIMATES, REQUEST FOR PROPOSALS, AND INVITATION FOR BIDS). DO NOT REFERENCE IT IN MILITARY OR FEDERAL SPECIFICATIONS OR OTHER PROCUREMENT DOCUMENTS.

WASTEWATER TREATMENT SYSTEM O&M CRITERIA MANUALS

Military-adopted commercial wastewater treatment system O&M guidance (from the Sacramento series of field study training manuals):

- Operation of Wastewater Treatment Plants, Volume 1
- Operation of Wastewater Treatment Plants, Volume 2
- Operation and Maintenance of Wastewater Collection Systems, Volume 1
- Operation and Maintenance of Wastewater Collection Systems, Volume 2
- Industrial Waste Treatment, Volume 1
- Industrial Waste Treatment, Volume 2
- Advanced Waste Treatment
- Treatment of Metal Wastestreams

Although not adopted by the military as a commercial O&M guidance document, the final manual in the Sacramento series, Pretreatment Facility Inspection, may be valuable to environmental offices responsible for environmental compliance.

WASTEWATER TREATMENT SYSTEM
OPERATIONS AND MAINTENANCE GUIDANCE DOCUMENT
AUGMENTING HANDBOOK

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Section 1: INTRODUCTION

1.1 Scope of This Handbook. This handbook provides technical guidance for operations and maintenance (O&M) of wastewater treatment systems. It supplements site-specific O&M manuals and a military-approved set of commercial O&M guidance documents. Those documents, commonly known as the "Sacramento" series of O&M field study training manuals, have been adopted by the military for use in wastewater treatment facilities at military installations.

1.1.1 Primary O&M Guidance Document. The Sacramento series is the primary technical guidance source for O&M of wastewater treatment systems. The Sacramento series is a set of nine volumes prepared by the California State University, Sacramento, in cooperation with the California Water Pollution Control Association, for the United States Environmental Protection Agency (EPA). The series includes the following publications:

a) Operation of Wastewater Treatment Plants, Volume 1

b) Operation of Wastewater Treatment Plants, Volume 2

c) Operation and Maintenance of Wastewater Collection Systems, Volume 1

d) Operation and Maintenance of Wastewater Collection Systems, Volume 2

e) Industrial Waste Treatment, Volume 1

f) Industrial Waste Treatment, Volume 2

g) Advanced Waste Treatment

h) Treatment of Metal Wastestreams

i) Pretreatment Facility Inspection

The final volume in this series, Pretreatment Facility Inspection, has not been adopted by the military as an O&M guidance document. However, it may prove a valuable resource for environmental office personnel responsible for environmental compliance. Operations personnel at each installation are advised to obtain those volumes pertinent to their wastewater treatment system. Most installations will not require all the volumes.

MIL-HDBK-353, Planning and Commissioning Wastewater Treatment Plants, provides additional information useful to operators planning or in the process of constructing new or upgraded wastewater treatment systems.

1.1.2 Augmenting Handbook. This handbook provides technical guidance on topics that are not covered in the Sacramento series or that deserve special emphasis. Both the Sacramento series and this handbook apply to all personnel responsible for operating and maintaining fixed-base wastewater treatment systems, including decision makers, mid-level managers, and operators.

1.2 Organization of Handbook. It is suggested that the reader become familiar with the organization, content, and intended use of this handbook by first looking at the table of contents.

To aid the reader in locating other topics concerning wastewater treatment systems, a list of chapter titles for each of the Sacramento series manuals has been included as Appendix A. Appendix B provides a cross reference for readers, listing each topic along with the section location in this handbook and corresponding chapter in the Sacramento Series volumes that contain the referenced information.

1.3 Cancellation. This handbook supersedes TM 5-655, MO 212, and AFM 91-32, Operation and Maintenance of Domestic and Industrial Wastewater Systems.

Section 2: REGULATORY COMPLIANCE AND MONITORING

2.1 Federally Owned Treatment Works (FOTWs). Generally, FOTWs are operated and administered under the same permitting and operational provisions set forth for publicly owned treatment works (POTWs). That is, these facilities usually comply with the construction permitting, operational permitting, and effluent discharge and residuals handling permitting requirements as administered by individual states and/or the EPA.

Operations and management staff at FOTWs are expected to understand and comply with these requirements and to keep the installation's environmental office informed of any problems that may affect compliance. A review of the general requirements for permitting, monitoring, and reporting appears below in par. 2.2. Operator training and certification needs are covered in par. 2.3. Trends that affect plant operations are discussed in par. 2.4, including a description of water quality-based effluent limits, wastewater reuse, the Part 503 sludge regulations and beneficial reuse of sludge, and operations certification programs.

2.1.1 FOTW Provisions. One area in which FOTWs are administered differently from POTWs is the pretreatment program requirements and a limited provision to exclude POTW hazardous waste from some regulation under the Resource Conservation and Recovery Act (RCRA). These differences are discussed in the following subparagraphs.

2.1.1.1 Hazardous Waste Exclusion Requirements. It is unlawful to introduce into an FOTW any pollutant that is a hazardous waste. POTWs are excluded from this hazardous waste restriction because of special provisions for POTWs in the RCRA regulations. POTWs must comply with pretreatment programs to ensure that commercial and industrial contributors to the collection system do not deposit excess hazardous or toxic materials/waste into the sewer system. Such pretreatment program standards are not required for FOTWs, although military FOTWs have generally followed them.

2.1.1.2 Special Provisions. A military wastewater treatment works qualifies for FOTW status and the potential for exclusion under RCRA Section 3023, 42 USC Section 6939e, if the treatment works is owned or operated by the DoD, if the majority of the influent received at the treatment works is domestic wastewater, and if the effluent of the treatment works is discharged to a surface water under a National Pollutant Discharge Elimination System (NPDES) permit. There are additional hazardous waste quantity and pretreatment requirements for dischargers to FOTWs. The relationship between military FOTWs and each activity or facility that discharges industrial process waste or other non-domestic wastewater should be controlled by local installation policies and instructions. Operating personnel should contact the installation’s environmental office if they find hazardous waste or if a shop or other activity requests permission to discharge a hazardous waste in the collection system.

2.2 Permitting Requirements. Permits are issued for the construction or modification of FOTWs, discharge of treated effluent, discharge of stormwater runoff, and solids management practices. These permits can be issued by Federal (EPA), state, or local governments. Sometimes all three levels of government issue separate permits. More often, the FOTW operating permits are combined. This discussion focuses primarily on Federal permits.

Plant operations staff should coordinate with the environmental office in the permitting process. General permitting requirements are discussed in the subparagraphs below to alert operations staff to areas where they may assist the environmental office.

2.2.1 FOTW Permits. The Code of Federal Regulations Section 40 (40 CFR) Part 122 describes the NPDES permitting program used by the Federal Government to control pollution in the environment. The NPDES permit program has separate regulations found in 40 CFR Parts 125, 129, 133, 136, 400 through 460, and 503. Nothing in the Federal rules precludes individual states from having more stringent requirements. The NPDES program is managed by EPA, but many states have received authorization to issue permits and administer the program on a day-to-day basis. In these states, a single permit is issued from the state and Federal governments. FOTW operators need to know if their state has been delegated the operation of the NPDES program.

Responsibility for the NPDES permit cannot be delegated below the state level, so local governments may have separate requirements. FOTW operators should check with their installation's environmental office to determine what local requirements may also pertain. Local governments are often involved with emergency reporting requirements in permits.

2.2.1.1 Operating NPDES Permit. An NPDES operating permit is required before an FOTW can discharge any process water into surface waters of the state. A valid NPDES permit will identify the owner, describe the process, describe the discharge location and frequency, and contain specific and general conditions.

Some states also have their own discharge permitting program. This program requires the permittee to obtain a state discharge permit in addition to the NPDES discharge permit. The NPDES permit program can be administered either by the regional EPA office or by the states that have obtained authorization with EPA oversight. Those states that have obtained the NPDES program are said to have "NPDES primacy." Typically, states with NPDES primacy incorporate any unique state requirements into the NPDES permit.

An NPDES permit is not a construction permit. In some states, an owner may construct or modify a facility, but it is a violation to place the modified facility in operation until a valid operating permit is obtained. Other states limit all construction activities until the changes or modifications are approved. Your environmental office should review any change or modification to the process with the permitting agency before implementation to determine if a permit modification is required. Operations staff should be aware of both state and EPA surface water discharge requirements. Contact your installation's environmental office for this information.

2.2.1.2 Permits for Other Disposal Options. Treated effluent that is entirely disposed into the groundwater or onto land application sites does not need an NPDES permit from EPA to discharge, but it may be subject to NPDES permits for stormwater or solids. (In addition to treated wastewater, NPDES permits can also address stormwater and solids.) The state may also establish groundwater monitoring or discharge requirements. For example, disposal of treated effluent to the subsurface will require an Underground Injection Control (UIC) permit from the state as required by the Safe Drinking Water Act (SDWA).

2.2.1.3 Stormwater NPDES Permit. FOTWs that treat more than 1 million gallons per day (mgd) are included in the stormwater NPDES permitting program as a categorical industrial facility. Although stormwater could be included in the operating permit described above, most facilities obtain a general stormwater NPDES permit. This permit is maintained separately from the operating permit. Its requirements typically involve developing a stormwater pollution prevention plan, visually monitoring runoff on a quarterly basis, routinely inspecting the stormwater system, and maintaining records onsite. Your environmental office should contact the NPDES authority to obtain the necessary stormwater permit information. EPA delegates operation of the stormwater program to the local government as much as possible. The local stormwater program may be separate from the wastewater program and may require special reporting or applications.

2.2.1.4 Solids NPDES Permit. FOTW residual solids management has received special attention under the Federal program (40 CFR Part 503). Solids management will typically be addressed as part of the FOTW operating permit. However, if there is no surface discharge and, consequently, no discharge permit, an NPDES permit for the solids may still be required. Par. 2.4.3 covers Part 503 sludge regulations.

2.2.2 NPDES Compliance. Failing to comply with the NPDES permit may result in fines and other penalties. In some cases, it may even result in criminal prosecution. The specific and general conditions in the permit are the compliance provisions. Monitoring reports and emergency conditions bear special note. Since the NPDES program relies on self-reporting for implementation, EPA places special emphasis on timely and complete reporting. Enforcement actions are often swift and severe for being late with the monthly operating reports or for failing to report violations. Emergency failures or spills typically require notice within 24 hours to the agencies.

Exceedance of water quality limits will also draw regulatory attention and possible enforcement action. Some parameters, like residual chlorine, cannot always be monitored at the low permit limit levels. The FOTW operator needs to be sure that readings below detection limits are properly reported on the monthly operating reports. Compliance exceedances because of process failures or overloading need to be corrected in a timely manner. Sometimes the permitting agency will enter into a compliance implementation schedule to allow the treatment facility time to come into compliance. However, proactive planning prior to the permit renewal application can reduce the likelihood of enforcement actions.

2.2.3 Permit Renewal. NPDES permits are valid for 5 years but may be modified at earlier intervals by regulators. Permit renewal applications need to be submitted 180 days (about 6 months) before the expiration date. Ideally, preparation for the application begins approximately 1 year before the permit application is due. Preparation involves assessing plant performance and improvement needs and conducting the necessary planning and design required to keep the facility in compliance. Your installation's environmental office may ask you to assist in evaluating performance needs by assisting with development or review of a Capacity Analysis Report and an Operation and Maintenance Report, as described below. These reports are typically conducted by licensed engineering staff with operations staff input. Each of these reports may take a couple of months to develop and may lead to additional work, so a 1-year lead time is not excessive.

If the permit renewal is due and the assessments are not complete, the FOTW still needs to apply 180 days before the deadline. Failure to apply in a timely manner is a permit violation. If you have objections to your existing or proposed permit you must file them during the official comment period. Even if your changes are not adopted, you are on record with the objections, making it easier to negotiate changes at a later date. Changes to the permit can be applied for at any time during the permit duration. There may be an additional fee for each permit modification application. Combining requests for changes with the permit renewal application is often convenient. If the existing permit is being violated regularly, the FOTW may need to conduct the following assessments and act before permit expiration.

2.2.3.1 Capacity Analysis Report. This report documents the predicted future flows and loads within the treatment facility, and evaluates the capacity of existing unit processes to reliably treat those loads for the next permitting cycle. The historical flows and the treatment performance of the preceding 5 years need to be analyzed. The carbonaceous biochemical oxygen demand (CBOD) and total suspended solids (TSS) loading (in pounds per day) also need to be verified. Population, flow, and load projections are then made to estimate what future loads will be, based on historical growth trends. The capacity of each unit process needs to be determined. Note that these capacity assessments may already have been done for past renewals. However, the capacity rating of each process needs to be checked against the latest loadings and flow. Reliability and backup provisions must also be adequate.

Finally, an assessment of the future 5-year flow and loads needs to be conducted. New mission and realignment decisions must be incorporated and future projections considered.

If the plant is undersized, then an expansion needs to be initiated and a Preliminary Engineering Report for improvements developed. Higher discharge rates will also precipitate additional permit application requirements to address antidegradation issues.

2.2.3.2 Operation and Maintenance Report. This report reviews plant operations data over the last permit cycle to evaluate needed improvements to the facility. Any upsets or spills need to be reviewed to determine the cause and possible solution. Some water quality exceedances may be a result of operation practices and need to be reviewed. The condition of the facilities is evaluated, such as the need for painting and other routine maintenance. Some needs may require changes to the process or construction approval. Permit renewal is a good time to include major changes. However, not every maintenance item needs to be reported to the agencies. Confirmation from the agency on which items need permitting is recommended after the Operation and Maintenance Report is completed.

2.2.3.3 Preliminary Engineering/Feasibility Report. Use this report only if changes to the FOTW are required. This is a preliminary design study that will outline what changes are required to attain or maintain compliance. Typically, this report will contain a summary of the future flows and loads to be treated (from the Capacity Analysis Report), a review of any alternative evaluations used to select the appropriate treatment technologies, and a conceptual-level design for upgraded facilities. A professional engineer sizes and plans for appropriate process changes. The Preliminary Engineering Report is submitted as part of the permit application renewal. Some states may require final construction drawings and specifications before approving the changes, while others may issue a construction permit based solely on the Preliminary Engineering Report.

2.2.3.4 Permit Application Forms. The environmental office should contact the permitting agencies to obtain the latest forms required for permit renewal or changes. The NPDES permit application forms will vary depending upon the primary agency (EPA or state) and the characteristics of the discharge. NPDES applications usually consist of a Form 1, containing general owner information, and Form 2A, containing a substantial amount of FOTW information. These forms require historical plant operation data and much of the same information required for the Capacity Analysis and Operations and Maintenance Reports. There is no fee required from the Federal Government, but state and local agencies may assess fees to process applications.

2.3 Operator Certification

2.3.1 Definition. Operator certification is a process in which an individual is awarded a certificate from the state water quality regulatory agency for meeting specific criteria associated with the operation of wastewater treatment plants (WWTPs). Most states require that the responsible WWTP operator possess a current state operator certification for the plant to meet the state’s standard permit requirements. This certification process varies from state to state. Most states have different levels of certification that depend upon plant complexity and size or individual expertise. Certification requirements are usually contained in the permit and/or in state regulations.

2.3.2 Benefits of Obtaining Certification. Professional WWTP operators should attempt to learn all that they can about their profession. By being certified, operators demonstrate a specific level of proficiency in their selected field. An operator may be able to apply for wastewater treatment positions in other states that have reciprocity with the state issuing an operator’s first certificate. As a member of the professional wastewater operator organization, a certified operator demonstrates his or her commitment to the profession.

2.3.3 FOTW Requirements. Many states require that the chief operator be certified to complete the reports that are necessary to comply with state and Federal water pollution control laws and regulations. Some facilities are required to have a certified operator on shift work when the chief operator is off shift. In some locations, all operators may require certification for the operation of a treatment plant. The EPA has suggested that it would like to have all plants operated by qualified personnel; certification is a method of demonstrating an operator's level of qualification. Failure to have the correct number and level of certified operators can be considered a serious compliance violation.

2.3.4 Attaining Certification. Each state regulatory agency has a program for achieving its certification. It is suggested that operators contact the state agencies to obtain specific information about requirements and reciprocity programs. Although reciprocity exists between many states, certifications should not be considered to be transferable. The Association of Boards of

Certification (ABC) can help with these issues. See Appendix C for contact information.

2.3.5 Training for Certification. There are various methods of obtaining training for certification. State regulatory agencies or ABC can help. The California State University, Sacramento, has correspondence courses available that provide the basics for most state examinations and certification processes. (The Sacramento series of O&M manuals has been adopted by the military as the general reference source for plant operations personnel.) See Appendix C for contact information.

The Water Environment Federation (WEF) is also an excellent source for training materials. WEF has wastewater courses both in printed and computer CD-ROM formats. See Appendix C for contact information.

State and regional professional associations in the wastewater treatment field can also help operators find local classroom-type training. WEF can provide valuable assistance in locating these organizations.

2.4 Current Trends in the Wastewater Industry That Affect Plant Operations. The regulatory agencies (state and/or EPA) responsible for the issuance of discharge permits are implementing more comprehensive programs to ensure protection of the water quality standards of the state’s streams. A comprehensive stormwater permitting program is now in place in all states. This program requires industries and municipalities to permit stormwater outfalls and to implement best management practices (BMPs) that will reduce the impact of stormwater runoff on the receiving stream. In addition, the regulatory agencies are implementing basinwide permitting programs designed to bring streams that have been identified as not currently meeting water quality standards into compliance. This program evaluates all sources of contamination (point and non-point sources); through the development of total maximum daily loads (TMDL) for the watershed, the program allocates allowable discharge levels from all sources within the drainage basin. This could mean that more restrictive effluent limits will be placed in discharge permits. The use of TMDL in the permitting process will be prevalent when permits are renewed.

2.4.1 Water Quality-Based Effluent Limits. Effluent limits contained in the NPDES permit are developed by the permit writer and are based on state water quality standards for the receiving stream. These effluent limits are called water quality-based effluent limits. Each stream in the state is classified in the water quality standards according to its existing or potential uses. Specific and general standards apply to each classification. These standards are then used in the development of the effluent limits for the discharger.

The inclusion of water quality-based effluent limits in the permit is based on a review of the effluent characterization presented in the discharger's permit application (EPA Form 2C). This review, conducted by the permit writer, assesses the presence of compounds that have the potential to violate the water quality standards. For these compounds, permit limits will be identified wherever possible.

2.4.1.1 Waste Load Allocation. Most NPDES permits include limits on oxygen demanding substances (such as CBOD and ammonia). Development of these limits is typically based on a waste load allocation for the receiving stream. Stream modeling is used to assess the assimilative capacity of the stream based on the applicable dissolved oxygen standard. This capacity is then allocated among all the dischargers in the area. Generally, some portion of the stream's capacity is reserved for future dischargers.

Waste load allocation modeling typically consists of a desk-top effort for small discharges and a calibrated and verified model based on field measurements for larger discharges. Modeling can be performed by the discharger or by the state agency. Regardless of who performs the modeling, the results receive a detailed review by both the state and the EPA. Typically, these results are put out for public comment. In many cases, the public comment period is concurrent with the public notice for the NPDES permit.

2.4.1.2 Chemical-Specific Criteria. Water quality-based effluent limits can be based on chemical-specific criteria from the water quality standards (such as for metals or toxics) or on general narrative criteria. Specific criteria are used in the development of effluent limits, and in many cases an allowance for dilution in the receiving stream is provided. Typically, some portion of the 7Q10 low-flow for the receiving stream is used for dilution purposes. (7Q10 is a hydrogeological determination of the lowest average flow over 7 consecutive days with an average recurrence frequency of once in 10 years.) Background concentrations in the receiving stream must also be considered in the dilution calculations. Where the 7Q10 low-flow is zero, the criteria will apply at the point of discharge, prior to any dilution.

2.4.1.3 Aquatic Life Criteria. For aquatic life criteria, acute or chronic values apply. The application of acute versus chronic criteria is dependent on a number of items, including the use classification and the available dilution in the receiving stream. (Generally, if the available dilution is greater than 100 to 1, then the acute criteria apply.)

2.4.1.4 General Narrative Criteria. An example of a general narrative criteria follows:
Toxic substances should not be present in receiving waters, after mixing, in such quantities as to be toxic to human,animal, plant or aquatic life or to interfere with the normal propagation, growth and survival of the indigenous aquatic biota.

To address this narrative criteria, most states apply a whole-effluent toxicity requirement in the permit. The whole-effluent approach to toxics control for the protection of aquatic life involves the use of acute and/or chronic toxicity tests to measure the toxicity of wastewaters. The acute test assesses the lethality of the wastewater to the test organisms and is typically conducted for 96 hours or less. The chronic test assesses growth and reproduction in addition to lethality and is typically conducted over a 7-day period. Whole-effluent toxicity tests use standardized surrogate freshwater or marine plants, invertebrates, and vertebrates. The test is run at the same dilution as is allowed for the wastewater in the receiving stream. Failure to meet the criteria results in the need to conduct a toxicity reduction evaluation on the discharge.

2.4.1.5 Negotiation of Effluent Limits. Careful review by the discharger of the specific basis used for the water quality-based effluent limits is advisable. In many cases, the basis used in the development of the effluent limits is open to negotiation. These issues should be addressed during the permit renewal process.

2.4.2 Wastewater Reuse. Several states and communities are promoting the reuse of wastewater as a beneficial way of reducing both drinking water demands and wastewater discharge to the environment. The most common reuse projects involve large uses of water for irrigation purposes (e.g., golf courses). Other uses of water may include residential irrigation, fire protection, landscape features (ponds or fountains), and industrial supply. Generally, a project is only considered a reuse project if the reclaimed effluent replaces drinking water demand.

Groundwater discharge is sometimes referred to as "groundwater recharge" and may be considered reuse if it is used to replenish the drinking water supply. However, contamination of the drinking water supply is a concern, and the discharge may have as many disincentives as incentives. Most land application projects that rely on groundwater infiltration for effluent disposal would be considered disposal projects, not reuse projects. Any disposal to natural surface waters will be considered an NPDES discharge and will be subject to all applicable rules.

2.4.2.1 Reuse Feasibility Study. An engineering study is required to determine the actual water usage for a given reuse project. For example, an irrigator will not need water in wet periods or winter. The FOTW may therefore need to dispose of all of its effluent for extended periods of time. The permit requirements need to be flexible to accommodate such seasonal effects. The objective of the engineering study is to determine a conceptual reuse system, including customers, available capacity, the size of the pipeline, pumps, and storage. This study is not a design-level project. Further design and permitting is required to implement a project.

2.4.2.2 Reuse Treatment Facilities. An FOTW may need additional treatment capability to provide reuse-quality water. If there is a possibility of public contact with the water, then the effluent must have high-level disinfection (<20 MPN [most probable number] per 100 mL). Filtration before disinfection or discharge to an irrigation system would also be likely. If only a portion of the effluent flow is used for reuse, then these additional facilities would need to be sized accordingly and would treat only a side-stream. An engineering feasibility study would need to determine the size and layout of these treatment facilities.

2.4.3 40 CFR Part 503 Sludge Regulations. Biosolids have beneficial plant nutrients and soil-conditioning properties. However, biosolids may also contain heavy metals, bacteria, viruses, protozoa, parasites, and other microorganisms that can cause disease. If improperly treated and applied, they may also attract nuisance vectors, such as insects and rodents. The EPA actively promotes management practices that provide for the beneficial reuse of biosolids while maintaining or improving environmental quality and protecting human health. However, while the Part 503 regulations encourage the beneficial reuse of biosolids, they do not mandate it; traditional disposal methods such as landfilling may still be selected.

The use and disposal of biosolids, including domestic septage, are regulated under 40 CFR Part 503. This regulation, promulgated on February 19, 1993, was issued under the authority of the Clean Water Act, as amended in 1977, and the 1976 Resource Conservation and Recovery Act. For most sludges, the new regulation replaces 40 CFR Part 257—the original regulation governing the use and disposal of sludge that has been in effect since 1979. Sludges generated at an industrial facility during the treatment of domestic wastewater, commingled with industrial wastewater in an industrial wastewater treatment facility, are still covered under 40 CFR Part 257 if the solids are applied to the land. For most FOTWs, however, 40 CFR Part 503 is the applicable regulation.

For additional information on the Part 503 regulations, refer to EPA/G25/R-92-013, Environmental Regulations and Technology: Control of Pathogens and Vector Attraction in Sludge (Including Domestic Septage) Under 40 CFR Part 503.

2.4.3.1 Solids Definitions. The Part 503 regulations promulgated the word “sludge” to describe a variety of solids residuals from wastewater treatment processes. The wastewater treatment industry and regulatory agencies have recently tried to minimize the use of the word “sludge” because the term is too general and its negative connotations do not accurately reflect the industry’s goal: to promote the beneficial reuse of properly treated wastewater solids as useful soil amendments for agricultural users and the general population. In keeping with current industry practices, this document avoids the word “sludge” except when directly referred to in Part 503 regulations or a widely accepted process name such as the “activated sludge process.” Figure 1 shows a secondary wastewater treatment plant and identifies the terminology used by industry and this document to replace the word “sludge.”

The primary solids referred to in Figure 1 are those derived from primary treatment processes. Solids drawn from the secondary treatment system are referred to as “waste activated sludge” or “biosolids.” The word “biosolids” refers to the residual treatment bacteria and inert solids contained in the biological treatment process. Solids that have undergone treatment for beneficial reuse are generally referred to as "residual solids" or can be classified according to their level of treatment, such as "Class A Solids." In some cases, treatment facilities do not further treat primary or secondary solids and dispose of these in a permitted landfill; in this case, the residuals are referred to as "sludge," meaning the product has not received treatment to reduce pathogens or vector attraction. The phrase "other residual solids" refers to the dense, grit-like solids that accumulate in process tanks and are removed when the tanks are periodically emptied and cleaned.

2.4.3.2 Protection of Public Health and the Environment. In the judgment of the Administrator of EPA, Part 503 protects public health and the environment through requirements designed to reduce the potential for contact with the disease-bearing microorganisms (pathogens) and heavy metals in biosolids applied to the land or placed on a surface disposal site. These requirements are divided into the following categories:

a) Requirements designed to control and reduce pathogens in solids

b) Requirements designed to reduce the ability of the solids to attract vectors (rodents, birds, insects, and other living organisms that can transport solids pathogens away from the land application or surface disposal site)

c) Requirements designed to limit the amount of heavy metals in solids applied to land or placed on a surface disposal site

Subpart D of Part 503 includes both performance- and technology-based requirements that aim to reduce pathogens and vector attraction. It is designed to provide a more flexible approach than Part 257, which required solids to be treated by specific listed or approved treatment technologies. Under Part 503, treatment works may continue to use the same processes they used under Part 257, but they now also have the freedom to modify conditions and combine processes with each other, as long as the treated solids meet the applicable requirements.

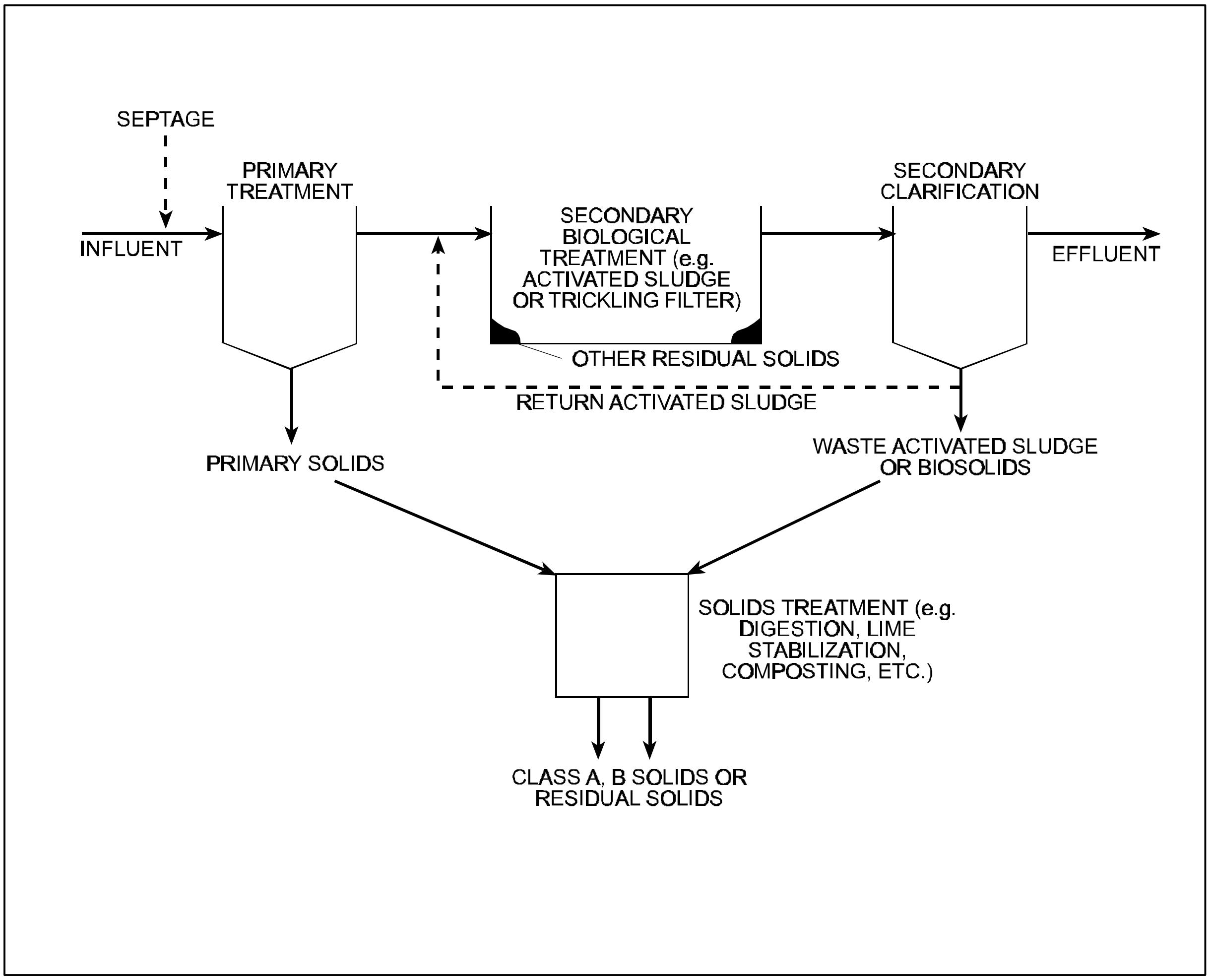

Figure 1
Definitions of Solids

2.4.3.3 Applicability of the Requirements [503.15]. Part 503.15 covers the applicability of the pathogen and vector attraction reduction requirements. The Subpart D requirements apply to solids (both bulk solids and solids that are sold or given away in a bag or other container for application to the land) and domestic septage applied to the land or placed on a surface disposal site. The regulated community includes persons who generate or prepare solids for application to the land, as well as those who apply it to the land, including anyone who:

a) Generates solids that are land-applied or placed on a surface disposal site

b) Derives a material from solids

c) Applies solids to the land

d) Owns or operates a surface disposal site

2.4.3.4 Requirements for Land Application or Disposal. Solids cannot be applied to land or placed on a surface disposal site unless they have met the two basic types of requirements in Subpart D: pathogen and vector attraction reduction requirements. These two types of requirements are separated in Part 503 (they were combined in Part 257) which allows flexibility in how they are achieved. Compliance with the two types of requirements must be demonstrated separately. Therefore, demonstration that a requirement for reduced vector attraction has been met does not imply that a pathogen reduction requirement also has been met, and vice versa.

2.4.3.5 Pathogen Reduction Requirements. Sewage Sludge [503.32(a) and (b)]. The pathogen reduction requirements for sewage sludge are divided into two categories: Class A and Class B. These requirements use a combination of technological and microbiological requirements to ensure reduction of pathogens.

The implicit goal of the Class A requirements is to reduce the pathogens in sewage sludge (including enteric viruses, pathogenic bacteria, and viable helminth ova) to below detectable levels. The implicit goal of the Class B requirements is to ensure that pathogens have been reduced to levels that are unlikely to pose a threat to public health and the environment under the specific use conditions. For Class B solids that are applied to land, site restrictions are imposed to minimize the potential for human and animal contact for a period of time following land application, until environmental factors have further reduced pathogens. Class B solids cannot be sold or given away in bags or other containers for application to the land. There are no site restrictions for Class A solids.

Domestic Septage [503.32(c)]. Domestic septage is a form of sewage sludge. The requirements for domestic septage vary depending on how it is used or disposed. Domestic septage applied to a public contact site, lawn, or home garden must meet the same requirements as other forms of sewage sludge. Separate, less complicated requirements for pathogen reduction, apply to domestic septage applied to agricultural land, forests, or reclamation sites. These requirements include site restrictions to reduce the potential for human contact and to allow for environmental attenuation, or pH adjustment with site restrictions only on harvesting crops. No pathogen requirements apply if domestic septage is placed on a surface disposal site.

2.4.3.6 Vector Attraction Reduction Requirements [503.33]. Subpart D specifies 12 options to demonstrate reduced vector attraction. Eight of the options apply to sewage sludges that have been treated in some way to reduce vector attraction (e.g., aerobic or anaerobic digestion, composting, alkali addition, and drying). These options consist of operating conditions or tests to demonstrate that vector attraction has been reduced in the treated solids. Three options cover methods for injection or incorporating solids into the soil to reduce vector attraction.

One option is a requirement to demonstrate reduced vector attraction in domestic septage through elevated pH. This option applies only to domestic septage.

2.4.3.7 Frequency of Monitoring

a) Sewage Sludge [503.16(a) and 503.26(a)]. The Class A and Class B pathogen requirements and the first eight vector attraction reduction options (the treatment-related methods) all involve some form of monitoring. The minimum frequency of monitoring for these requirements is given in Part 503.16(a) for land application and Part 503.26(a) for surface disposal. The frequency depends on the amount of solids used or disposed of annually. The larger the amount used or disposed of, the more frequently monitoring is required.

b) Domestic Septage [503.16(b) and 503.26(b)]. One of the options that can be used for demonstrating both pathogen reduction and vector attraction reduction in domestic septage is to elevate pH to ≥12 for 30 minutes. When this option is used, each container of domestic septage (e.g., each tank truck load) applied to the land or placed on a surface disposal site must be monitored for pH.

2.4.3.8 Recordkeeping Requirements [503.17 and 503.27]. Recordkeeping requirements are covered in Part 503.17 for land application and Part 503.27 for surface disposal. Records are required for both sewage sludge and domestic septage. All records must be retained for 5 years except when the cumulative pollutant loading rates in Part 503 Subpart B (Land Application) are used. In that case, certain records must be kept indefinitely. Some records must be reported to the permitting authority.

a) Land Application. Records must be kept to ensure that the solids meet the applicable pollutant limits, management practices, one of the pathogen requirements, one of the vector attraction reduction requirements and, where applicable, the site restrictions associated with land application of Class B biosolids. When bulk solids are applied to land, both the person preparing the solids for land application and the person applying them must keep records. The person applying solids that are sold or given away does not have to keep records.

b) Surface Disposal. When solids are placed on a surface disposal site, both the person preparing the solids and the owner/operator of the surface disposal site must keep records. In the case of domestic septage applied to agricultural land, forest, or a reclamation site or placed on a surface disposal site, the person applying the domestic septage and the owner/operator of the surface disposal site may be subject to pathogen-related recordkeeping requirements, depending on which vector attraction reduction option was used.

c) Certification Statement. In every case, recordkeeping involves signing a certification statement that the requirement has been met. Parts 503.17 and 503.37 of the regulation contain the required certification language.

2.4.3.9 Reporting Requirements for Sewage Solids [503.18 and 503.28]. Reporting requirements for these solids are found in Part 503.18 for land application and Part 503.28 for surface disposal. These requirements apply to Class I solids management facilities and to publicly owned treatment works and FOTWs with a design flow rate equal to or greater than 1 mgd and/or that serve

10,000 or more people. These facilities must submit to the permitting authority the records they are required to keep as "preparers" of biosolids and/or as the owner/operators of surface disposal sites on February 19 of each year. There are no reporting requirements associated with the use or disposal of domestic septage.

2.4.3.10 Permits and Direct Enforceability [503.3]

a) Permits. Under Part 503.3(a), the requirements in Part 503 may be implemented through: (1) permits issued to treatment works treating domestic sewage by EPA or by states with an EPA-approved solids management program, and (2) by permits issued under Subtitle C of the Solid Waste Disposal Act; Part C of the Safe Drinking Water Act; the Marine Protection, Research, and Sanctuaries Act of 1972; or the Clean Air Act. Treatment works treating domestic sewage should submit a permit application to the approved state program, or, if there is no such program, to the EPA Regional Sludge Coordinator.

b) Direct Enforceability. Under Part 503.3(b), the requirements of Part 503 automatically apply and are directly enforceable even when no permit has been issued.

Section 3: SEPTIC TANKS

3.1 Description. Septic tank systems are used to treat and dispose of wastewater from individual homes and buildings where it is not feasible to provide a community wastewater collection and treatment system. All components of the septic tank system are underground. Figure 2 depicts a standard two-compartment septic tank system.

3.1.1 System Components. The individual home or building discharges through a pipeline to the septic tank, which in turn discharges to the effluent leaching system. Where groundwater levels are high, the elevation may be insufficient for gravity flow and pumps may be required on either side of the septic tank. Pumps located before the septic tank require diligent maintenance because they directly receive untreated wastewater. Refer to manufacturer's recommendations for maintenance of these pumps.

3.1.1.1 Tank. The septic tank is an underground, watertight concrete or fiberglass receptacle that typically has a liquid depth of at least 42 inches (1 m). Inlets and outlets are located at opposite ends of the tank. The inlets generally have invert elevations 1 to 3 inches (3 to 8 cm) above the liquid level of the tank. The outlets generally have a vented tee so that the intake to the outlet device is below the liquid level. A system may have two or more septic tanks placed in a series.

3.1.1.2 Effluent Leaching Systems. Wastewater discharges through a pipe from the septic tank to the underground effluent leaching system. The effluent leaching system consists of a distribution box or header pipe and a drain field. The drain field is a system of open-jointed or perforated piping that allows the wastewater effluent to be distributed gradually into the soil. Typically, all portions of the effluent leaching system are installed below the elevation of undisturbed native soil. A mound system is used in locations where the depth is insufficient for the effluent leaching system because of high groundwater levels, insufficient permeable soil, or other conditions. For mound systems, all or part of the leaching system is located above the elevation of undisturbed native soil. Mound systems require a pump to deliver the effluent to the elevated leaching system. Electric controls outside the dosing chamber and a power supply may be required to operate the pump.

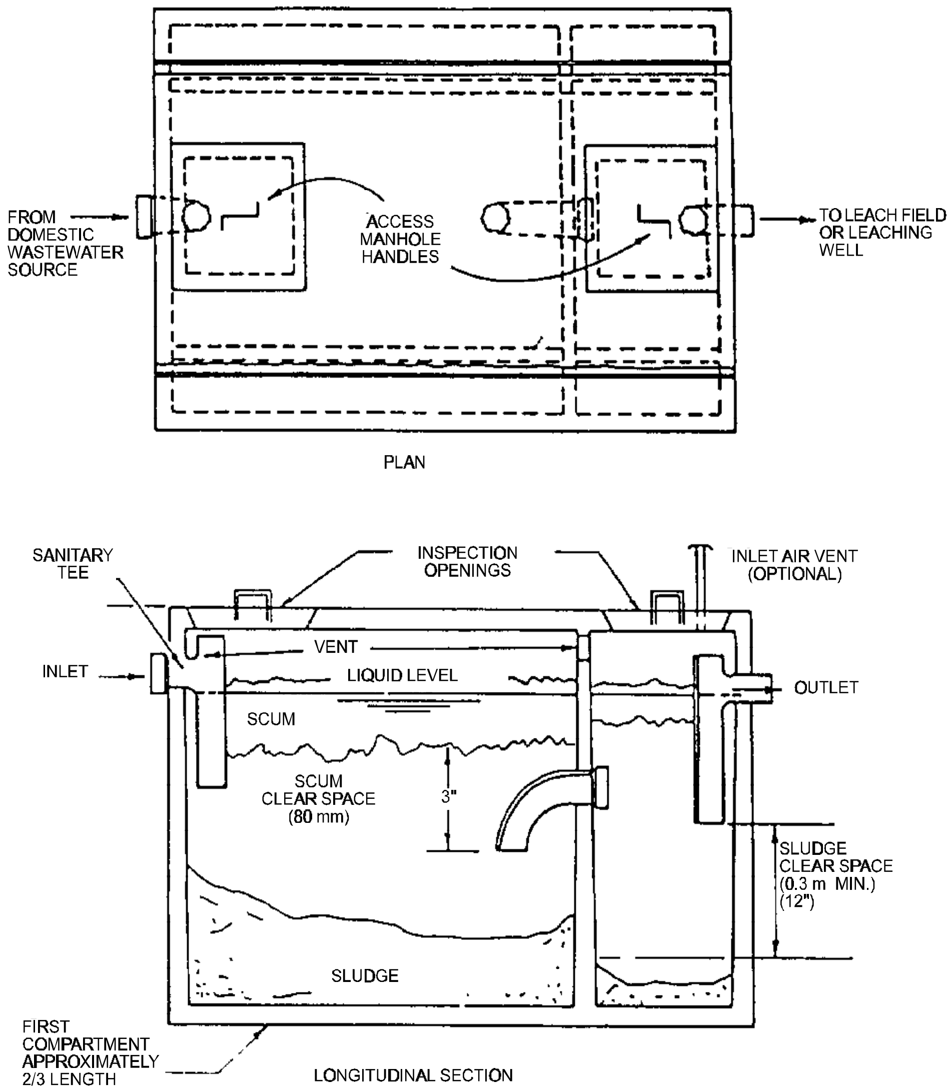

Figure 2
Typical Two-Compartment Septic Tank

3.1.2 System Operation Principles. Wastewater flows out of the building through a pipe into the septic tank. In the tank, bacteria attack and digest organic matter by anaerobic digestion. The wastewater itself provides the bacteria for this process. The anaerobic digestion process changes the waste into gas, biosolids (residual organic and inorganic material), and treated effluent. The gas escapes into the air, the treated effluent is discharged to the leaching system, and the residual solids remain in the tank. The solids should be pumped out of the tank periodically. The treated effluent is discharged into the soil through the perforated or open-jointed pipes in the drain field. Soil bacteria destroy remaining organic material in the effluent.

3.2 Septic Tank System O&M. The primary O&M requirement for the septic tank system is periodic removal of settleable solids. In addition, take preventative care of the system by monitoring waste disposed to the system and ensuring that trees or shrubs are not planted over any of the system components. It is not necessary to add yeast or bacteria to the system as a maintenance procedure. As long as human and kitchen wastes are being discharged to the system, there will be sufficient bacteria in the tank for treatment.

3.2.1 Inspecting the Septic Tank. Check the septic tank every 3 to 5 years to determine if solids need to be removed. Check the tank once a year if garbage disposals discharge to the tank.

Caution: Exercise extreme care when inspecting the septic tank. Never inspect a septic tank alone or enter a tank. Toxic gases are produced by the natural treatment processes in septic tanks and these gases can kill in minutes. Details on confined space entry requirements are found in the Sacramento Series Operation of Wastewater Treatment Plants, Volume 2, Chapter 14.

3.2.1.1 Measuring Solids and Scum Inside the Tank. The following information comes from Pipeline: Maintaining Your Septic System—A Guide for Homeowners, National Small Flows Clearinghouse, 1995.

There are two frequently used methods for measuring the solids and scum layers inside your tank. The contractor may use a hollow clear plastic tube that is pushed through the different layers to the bottom of the tank. When brought back up, the tube retains a sample showing a cross-section of the inside of the tank. The layers can also be measured using a long stick. To measure the scum layer using a stick, a 3-inch (8 cm) piece of wood is attached across the end of the stick to form a "foot," and the stick is pushed down through the scum to the liquid layer. When the stick is moved up, the foot meets resistance on the bottom of the scum layer, and the contractor marks the stick at the top of the layer to measure the total thickness. As a general guideline, if the scum layer is within 3 inches (8 cm) of the bottom of the inlet baffle, the tank should be pumped.

The solids layer is measured by wrapping cloth around the bottom of the stick and lowering it to the bottom of the tank. Insert the stick either through a hole in the scum layer or through the baffle or tee, if possible, to avoid getting scum on the cloth. The solids depth can be estimated by the length of solids sticking to the cloth. If the solids depth is equal to one-third or more of the liquid depth, the tank should be pumped.

3.2.2 Removal of Settleable Solids. Clean the tank whenever the bottom of the floating scum layer is within 8 inches (20 cm) of the bottom of the outlet device. Table 1 shows the estimated tank pumping frequencies, based on tank size and household size.

Table 1
Estimated Septic Tank Pumping Frequencies in Years(1)

Tank Size (gallons)	Household Size (number of people) 1	2	3	4	5	6
500	5.8	2.6	1.5	1.0	0.7	0.4
750	9.1	4.2	2.6	1.8	1.3	1.0
900	11.0	5.2	3.3	2.3	1.7	1.3
1,000	12.4	5.9	3.7	2.6	2.0	1.5
1,250	15.6	7.5	4.8	3.4	2.6	2.0
1,500	18.9	9.1	5.9	4.2	3.3	2.6
1,750	22.1	10.7	6.9	5.0	3.9	3.1
2,000	25.4	12.4	8.0	5.9	4.5	3.7
2,250	28.6	14.0	9.1	6.7	5.2	4.2
2,500	31.9	15.6	10.2	7.5	5.9	4.8

(1) These figures assume no garbage disposal is in use.
Source: Pennsylvania State University Cooperative Extension Service, as reprinted in Pipeline: Maintaining Your Septic System—A Guide for Homeowners, National Small Flows Clearinghouse, 1995

When cleaning the tank, remove all contents, including scum, liquid, and solids. Use only the access ports on the tank for cleaning; do not pump out the tank through the distribution box. Do not use toxic or hazardous chemicals for cleaning the tank and do not use organic chemical solvents or petroleum products for degreasing or declogging the system. These chemicals and products are potentially harmful to the system and to the groundwater in the vicinity of the system.

3.2.3 Monitoring Waste Discharged to System. Because the septic tank treatment system is a biological process, it is particularly important that toxic or hazardous chemicals are not discharged into it. These chemicals would kill the bacteria used for treatment of the wastewater. Discharge of industrial wastewater to septic tanks violates the underground injection provisions of the SDWA. In addition, grease and non-biodegradable products should not be discharged into the system. The system is not designed to treat these products and they can cause clogging in the system components. Household cleaners such as bleach, disinfectants, and drain and toilet bowl cleaners should be used in moderation and only in accordance with product labels. Overuse of these products can harm the septic tank system.

3.2.4 Water Conservation. Water conservation is critical for proper operation of the drain field. Continual saturation of the soil in the drain field can significantly reduce the ability of the soil to naturally remove toxins, bacteria, viruses, and other pollutants from the wastewater. In addition to conserving water discharged to the septic tank and drain field, try to restrict water from roof drains, sump pumps, and other sources from draining into the area of the drain field.

3.2.5 Vegetation Over System Components. Do not plant trees or shrubbery over any of the system components. If a tree or bush has a strong root system, the roots can choke the drain field and/or get into the septic tank. Roots in the septic tank can reduce its capacity and block the inlet or outlet.

3.3 Leachate System O&M. The only remedy for a leachate system that is not functioning is replacement. There are no conclusive data to support the premise that enzymes and chemical treatment can revitalize a drain field. To construct a new drain field on top of an existing field, dig trenches parallel to the existing drain field pipes or widen the existing trenches.

3.4 Septic Tank System Failures. Several warning signs can indicate that a septic tank system is failing and that more than cleaning of the system is necessary:

a) Obnoxious odors in the area of the system or inside the building

b) Soft ground or low spots in the area of the system

c) Grass growing faster or greener in the area of the system

d) Gurgling sounds in the plumbing or plumbing backups

e) Sluggishness in the toilet when flushed

f) Plumbing backups

g) Tests showing the presence of bacteria in nearby well water

Table 2 shows possible causes of septic tank system failures and suggests remedial procedures.

Table 2
Maintenance Checklist for Septic Tank System Failures

Possible Causes of Failure	Possible Remedial Procedures
Underdesign	
Tank size insufficient for wastewater flow quantity and/or characteristics	Replace septic tank or add additional septic tank(s) in parallel.
Drain field too small	Enlarge drain field. Reduce water consumption.
Faulty drain field installation	
Plugged pipes Insufficient stone in trenches Uneven grades	For plugged pipes, insufficient stone, and uneven grades, install a new drain field on top of existing field.

Table 2 (Continued)
Maintenance Checklist for Septic Tank System Failures

Possible Causes of Failure	Possible Remedial Procedures
Poor soil conditions	
High groundwater	Improve surface drainage; install curtain drains; elevate field; and/or reduce water consumption.
Insufficient distance below drain field to bedrock	Elevate drain field and/or reduce water consumption.
Relatively impervious soils	Elevate drain field and/or reduce water consumption.
Overload	
Excessive wastewater loading	Increase tank size or reduce water consumption.
Poor stormwater drainage away from system	Improve surface drainage.
Leaking plumbing fixtures	Repair plumbing fixtures.
Wastewater flow quantity and/or characteristics greater than anticipated in design due to changes in use of building, garbage grinders, etc.	Remove garbage grinders; increase drain field.
Lack of Tank Maintenance	
Septic tanks not pumped out at sufficient intervals, causing solids to be discharged to drain field	Pump out tank; construct new drain field on top of existing drain field; relieve drain field by draining into a pit and pumping out and let field rest for a month.

Source: Adapted from Rein Laak's Wastewater Engineering Design for Unsewered Areas, Lancaster, Pennsylvania: Technomic Publishing Co., Inc., 1986

Section 4: GREASE TRAPS

4.1 Description. Food-service operations typically use grease traps to prevent excessive discharge of grease and oil into the wastewater collection and treatment system. If grease traps are not properly maintained, slug loads of grease will interfere with the performance of both the collection and treatment system. Grease traps are usually located outside the food-service establishment in an underground tank with ground-level access. Sometimes under-sink systems are also used for grease traps; however, these are not recommended because they generally do not provide adequate grease removal. Where under-sink models are used, proper maintenance is especially critical because of the higher potential for release of slug loads of grease into the wastewater system.

4.1.1 Configuration. Grease traps usually consist of an underground, watertight concrete tank with inlet and outlet piping. The outlet pipe has a tee that allows the internal discharge to be located within 12 inches (0.3 m) of the tank bottom. The size of the grease trap depends on the anticipated flow rate, water temperature, and grease concentration. In general, grease traps range from a minimum capacity of 750 gallons (2.8 m^3) to a maximum capacity of 1,250 gallons (4.7 m^3). Where a capacity of more than 1,250 gallons (4.7 m^3) is required, two or more grease traps may be placed in a series. Access to the tank is typically through one or two manhole rings and covers.

4.1.2 Location. Grease traps should be located outside food-service buildings in an accessible location for inspection and maintenance. The traps are installed in the waste line between the sink drains and kitchen fixtures and the wastewater collection system.

4.1.3 Discharges to Grease Traps. Grease traps do not perform effectively if they receive discharges with elevated temperatures or high solids concentrations. Grease traps should not receive discharges from garbage grinders or produce-preparation sinks. Discharges from mechanical dishwashers are also not recommended. However, the preflush/prescraping sinks that serve mechanical dishwashers may be connected to the grease trap, provided no garbage grinders are used at these sinks.

4.2 Maintenance Procedures. The critical maintenance procedure for all grease traps is periodic removal of accumulated waste. If the responsibility and procedures for cleaning grease traps are not clearly identified and implemented, the traps are ineffective. It is recommended that waste be pumped out of the grease traps rather than dissolved with solvents. Grease and solvents may have a negative impact on the wastewater collection and treatment system. Recovered oil and grease from food-service operations can typically be sold to a local rendering company. Other types of oils can often be reclaimed by recyclers. If proper maintenance cannot be maintained, consideration should be given to removing the grease trap and having the user separate the grease before discharging wastewater to the sanitary system.

4.2.1 Pump-Out Frequency. The recommended pump-out frequency ranges from every 2 weeks to every 3 months, depending on the waste characteristics of the establishment and the size of the grease trap. The necessary pump-out frequency can be determined by checking the grease retention capacity in the grease trap. Grease and accumulated wastes should be removed as often as necessary to maintain as least 50 percent of the grease retention capacity.

4.2.2 Maintenance Specific to Manufactured Grease-Removal Systems. In addition to periodically removing the waste, review and implement the manufacturer’s recommended maintenance procedures for all grease-removal systems.

Section 5: OIL/WATER SEPARATORS

5.1 Oil/Water Separators. Oil/water separators are devices commonly used to separate oily waste products from wastewater streams. They are typically installed in industrial and maintenance areas to receive and separate oils at low concentrations from wastewater generated during industrial processes such as maintaining and washing aircrafts and vehicles. The number of separators currently owned and operated by the military is in the thousands. A large installation may have as many as 150 units. In recent years, it has become clear that many of the military's separators are not performing as anticipated. Inadequacies have resulted from poor design, improper selection of pre-manufactured units, misuse by discharging inappropriate wastewaters or excessive quantities, and lack of monitoring and maintenance.

5.2 Types of Oil/Water Separators. There are three predominant types of oil/water separators: conventional gravity separators, corrugated plate gravity separators, and flotation separators. The overwhelming majority of oil/water separators used are conventional gravity separators. Most units, regardless of the type, are purchased as proprietary equipment from vendors. Accordingly, the manufacturer's recommended O&M procedures should be consulted and followed. A brief description of the main types of oil/water separators follows.

The primary types of oil/water separators described in this section are intended for the removal of free and de-emulsified oils and greases, usually as a pretreatment method. There are numerous other polishing oil/water separators marketed for removal of trace quantities of oil and grease. These devices include coalescing filters, oleophilic filters, and adsorption devices. Operators should consult the manufacturer's proprietary operations and maintenance guidance for these devices.

5.2.1 Gravity Separators. The process relies on the different densities of oil, water, and solids for successful operation. The wastewater is fed to a vessel sized to provide a quiescent zone of sufficient retention time to allow the oil to float to the top and the solids to settle to the bottom. Gravity oil/water separators come in two configurations: conventional gravity separators such as those designed in accordance with guidelines established by the American Petroleum Institute (API) and corrugated plate interceptors (CPIs).

5.2.1.1 Conventional Gravity-Type Separators. Conventional gravity separators are typically rectangular in-ground or above-ground tanks with maximum widths of 20 feet (6 m). A diagram of a typical conventional gravity separator is presented in Figure 3. Influent and effluent channels are normally located on opposite ends of the separator. The influent typically passes an inlet section that contains a slotted baffle to distribute influent evenly throughout the depth of the separator. For units without sludge collectors, there may also be a bottom baffle in the separator; this retains settled solids in the front part of the separator to reduce cleaning requirements. Other separators may have automatic sludge removal equipment that will rake accumulated sludge to a sludge hopper where it can be pumped from the tank periodically.

In either case, the sludge level should be monitored routinely, and sludge should be removed when it occupies 10 percent or more of the separator volume. All conventional gravity separators have a surface baffle at the outlet end to retain floating oil and grease. The grease is removed by pumping or by activating a rotary drum or slotted pipe that allows the surface material to drain to a drum or oil holding tank. The depth of the surface oil layer should be checked regularly, and surface skimming should be conducted routinely. Experience gained from operating a conventional gravity separator in a specific application will indicate the required intervals for checking and skimming the oil layer. For example, although the oil layer might need to be checked and skimmed daily, this interval could range from several times per day to several times per month, depending on the rate of oil accumulation on the separator surface.

One criterion to use is that the oil layer should be monitored and skimmed as often as is necessary to prevent an excess amount of oil from being flushed through the separator by an unexpected hydraulic surge (e.g., rainfall). Thus, the frequency may also depend on the sensitivity of downstream processes to increased oil loading. The frequency will have to be determined by experience but it likely will be such that the floating oil layer does not exceed about 2 inches (5 cm) (some operators prefer that there be no floating oil layer on the separator).

5.2.1.2 Corrugated Plate Interceptors. CPIs are typically supplied by vendors and are based on proprietary designs. A CPI

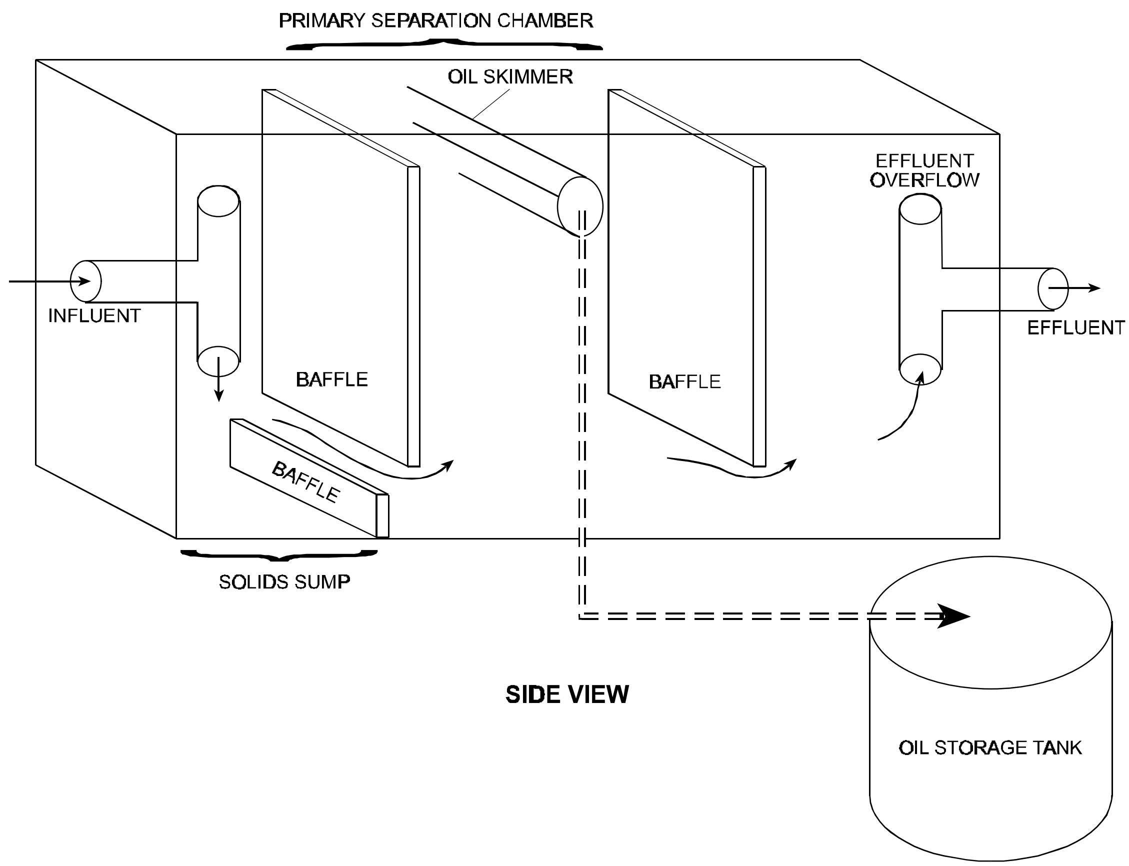

Figure 3
Conventional Gravity Separator

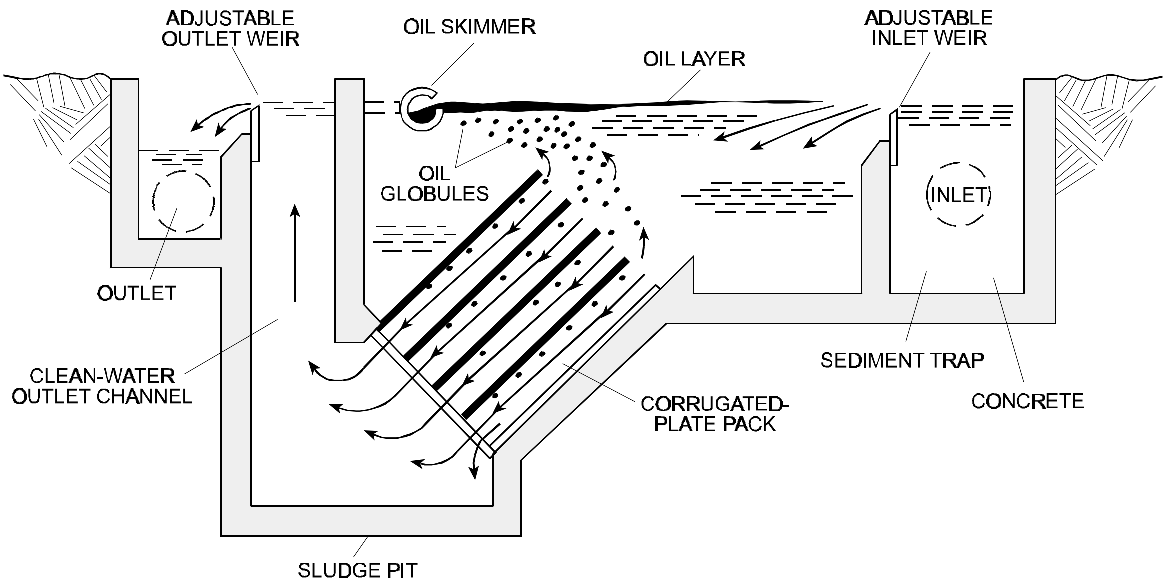

Figure 4
Process Schematic of CPI Separator

consists of a tank containing a number of parallel corrugated plates mounted from 0.8 to 1.6 inches (2 to 4 cm) apart and inclined at an angle to the horizontal. A diagram of a typical CPI is presented in Figure 4. Wastewater may flow either downward or upward between the plates; in the configuration shown, wastewater flows downward through the plates. As this happens, the oil droplets float upward and collect on the underside of adjacent plates where they coalesce. The coalesced oil droplets move up the plates and are retained in the separator to form a floating layer that is skimmed from the surface of the tank. Settled solids from the wastewater collect on the top side of adjacent plates, migrating down the plates and dropping into the bottom of the CPI vessel. In the diagram shown, treated water flows down through the plates, and over a weir into an effluent flume. Some manufacturers use different configurations than the one shown.

CPI separators are smaller and easier to cover for controlling atmospheric emissions, and they may be less expensive than API-type separators. In practice, however, the smaller size has sometimes been a disadvantage since it may not provide sufficient volume to accommodate slugs of oil and it may not provide sufficient detention time for breaking emulsions. In some cases, the plate packs have become severely fouled. CPIs are usually drained and hosed down routinely to clean the plates. Operating experience over time will dictate how often this occurs, but a minimum interval of every 6 months is appropriate.

5.2.2 Dissolved Air Flotation (DAF). DAF is commonly used to remove oil, grease, and suspended solids from industrial wastewaters. Typically, gravity oil/water separators are used in front of flotation units to remove the major fraction of free or floating oils, so flotation units are usually considered polishing units.

In the flotation process, small gas bubbles rising through the wastewater adhere to solids particles and oil globules, causing them to float to the surface where they are skimmed off. A diagram of a typical flotation system is presented in Figure 5. The air bubbles can be added to the wastewater by a variety of means. Diffused air flotation and induced air flotation are the two most common types of DAF units. Both types incorporate a flotation vessel with a baffle to retain floated oil, an oil-skimming mechanism, and sometimes a bottom-scraping mechanism to remove very heavy particles that do not float.

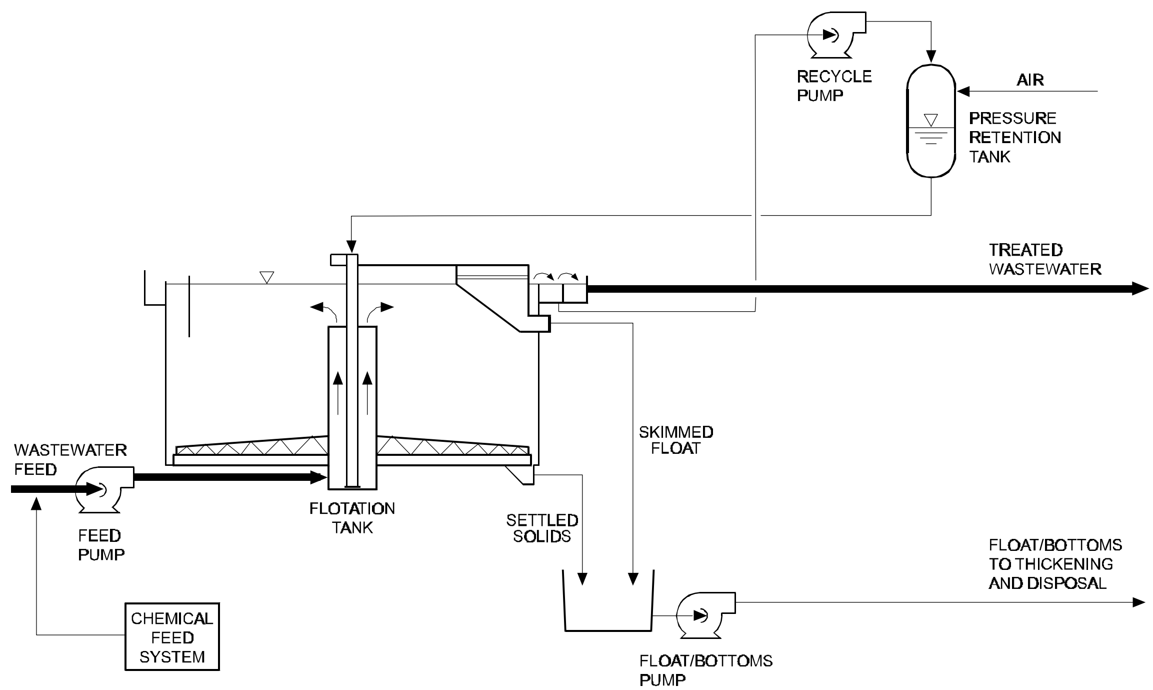

Figure 5
Process Schematic of Dissolved Air Flotation

Significant mechanical equipment is associated with these systems and should be maintained according to manufacturers' directions. Flotation vessel surface skimming generally is continuous, but settled sludge must be drawn off manually. The drawoff frequency will have to be determined by experience but could range from once daily to twice monthly, with weekly being a reasonable starting point.

5.3 Problems with Oil/Water Separator Applications. Oil/water separators are used to remove small amounts of oil and other petroleum products from wastewaters prior to further treatment. The military has historically purchased and installed gravity oil/water separators under the assumption that it has only an oil/water separation problem to solve. However, the most common military applications seldom involve simple oil-and-water mixtures.

Waste streams generated from military applications frequently contain significant quantities of dirt, cleaning aids (detergents, solvents), fuels, floatable debris, and various other items common to military equipment and activities. Oil/water separators are not designed to separate these other products. An oil/water separator must not be used as a catch-all for wastes generated from any maintenance activity, and maintenance personnel need to be made aware of this fact. Improper use can result in illegal discharges of hazardous substances to stormwater systems or WWTPs. Even when discharges are not illegal, misuse of these systems can upset treatment plants, cause discharge permit violations, increase sludge disposal costs, and eliminate beneficial reuse of wastewater or sludge.

The following factors directly affect the efficiency, use, and management of oil/water separators: frequency and intensity of influent flow, design capacity, emulsifying agents, periodic maintenance practices, type of separator system, and other contaminants contained in the waste stream. Installation personnel should be familiar with these factors so they properly design, select, install, operate, and maintain these systems. A separator that is being used improperly should be reported to the environmental office.

5.3.1 Frequency and Intensity of Flow. The longer the residence time of the waste stream in the oil/water separator, the more efficient it will be at separating oil. Contaminated water enters a receiving chamber of the separator where the flow velocity of the wastewater is reduced, thereby allowing heavy solids to settle while larger oil droplets float to the top of the compartment. Further separation continues in a separation chamber where smaller droplets of oil separate from the water and join the larger droplets previously separated. The oil layer that has accumulated on the top of the water spills over an oil skimmer into a holding area; the wastewater then flows, or is pumped, to the stormwater or sanitary sewer system.

A longer separation time increases the efficiency of the oil/water separator by allowing a greater amount of oil to rise to the top of the wastewater. Therefore, restricting the wastewater to design flow rates will improve the efficiency of the separator.

5.3.2 Design Capacity. An oil/water separator has a finite capacity for storing oils and sludges accumulated during its operation. Quite often the oil/water separator holding compartments can become saturated or full of oils and sludges, allowing contamination to flow freely into the wastewater effluent exiting the separator system. Ensuring that the separator capacity meets the needs of the process will aid separation efficiency.

5.3.3 Emulsifying Agents. Detergents and soaps designed to remove oily grime from dirty weapon systems, vehicles, or other components can adversely affect oil/water separator operation. These agents are designed to increase solvency of oily grime in water. Hence, the oil droplets take longer to separate from water, reducing separation efficiency. Overzealous use of detergents can degrade efficiency by completely emulsifying oil in the wastewater stream, thus allowing the oil to pass through an oil/water separator unaffected.

5.3.4 Periodic Maintenance Practices. Sludges and oils that are not periodically pumped from separator holding tanks can render the separator inoperative. Additionally, leaks from oil/water separators can result in environmental pollution that could require investigative studies and extensive cleanup. Regular equipment inspections and a preventive maintenance plan can prevent contaminated discharges from the oil/water separator system. Depending on the wastewater characteristics (e.g., low pH), what material the separator is made of, and the age of the facility, visual equipment inspections should be performed from once per week to once per month. More rigorous inspections should be conducted two to four times per year. Inspections should focus on areas below the water line; equipment construction joints; piping connections and interfaces; and other areas prone to wear, spills, or leaks. See par. 5.5 for more detail.

5.3.5 Type of Oil/Water Separator System. An oil/water separator designed and installed to a past mission requirement may not be suitable for current maintenance operations. For example, a wash rack with an oil/water separator designed to capture contaminants from a small fighter aircraft will not handle larger wastewater volumes from a larger aircraft. Additionally, changes in mission can affect the effluent characteristics of the wastewater being discharged to an oil/water separator (i.e., wastewater with solvents or emulsions versus free floating oil). Thus, as installation missions evolve, treatment system design criteria must be reviewed to confirm continued suitability.

Mission conversions can necessitate modifying stormwater/wastewater drainage systems. Stormwater from areas that are uncontaminated under one mission may be contaminated under another mission, and vice versa. Oil/water separators that do not have a stormwater diversion system can suffer from reduced removals from the hydraulic loading of stormwater that does not need to be treated. Thus, separator collection systems also must be reviewed for excessive stormwater flows.

5.3.6 Contaminants in Wastewater Stream. Particulate heavy metals and solids in the wastewater will settle into the sludge at the bottom of the oil/water separator receiving compartments. The sludge could be regulated as a hazardous waste if levels exceed RCRA or state hazardous waste levels. Solvents or fuels may also be retained in oil/water separator sludge.

5.4 Evaluation of Need for Oil/Water Separators. Unauthorized discharges of industrial pollutants, as well as inadequate O&M of oil/water separators, can create serious liability and noncompliance. If an oil/water separator is not needed to meet pretreatment or discharge permit limits, or to allow for beneficial reuse, it should probably be removed to eliminate the management responsibility and the potential liability associated with it (Figure 6). Although this is an environmental issue, operators can assist by knowing what is discharged to separators, educating others whose activities are generating the wastewater, and alerting their environmental staff of any problems. Because of the potential and significant effect on oil/water separator O&M, it is especially important to ensure that only wastewater associated with vehicle and equipment maintenance activities are discharged to oil/water separators. This wastewater typically contains oil and grease but has a relatively small amount of solids. (By comparison, exterior washing of vehicles and equipment, particularly after field training exercises, can discharge large quantities of solids. Consequently, at many installations, central vehicle wash racks are specifically provided for exterior washing and this is not permitted at maintenance facilities.) Oil/water separator users should assist environmental staff with the tasks detailed below.

In addition, operators can assist environmental management staff in evaluating the need for and effectiveness of existing oil/water separators with the goal of consolidating or eliminating ineffective units. Issues to consider in evaluating the need for oil/water separators are discussed below.

a) The working area for outside maintenance installations should be minimized to reduce the volume of contaminated runoff requiring treatment. Using high-pressure water and/or detergents to clean up the work area increases emulsification and inhibits gravity oil/water separation and is therefore not recommended.

b) Use of dry absorbents should be considered to minimize the amount of oils reaching installation sewers. Dry absorbents may be collected and disposed of with solid waste materials. Evaluate the flash point of spent absorbent for possible hazardous waste designation under RCRA guidelines.

c) Point source controls should be investigated to eliminate or reduce the wastewater volume and contaminant concentrations. For example, segregate used oils and solvents for disposal or reuse rather than allowing them to enter the wastewater stream. Implementing point source controls may be more economical than providing a wastewater treatment system. Also, consider point source control techniques, such as process change or modification, material recovery, wastewater segregation, and water reuse.

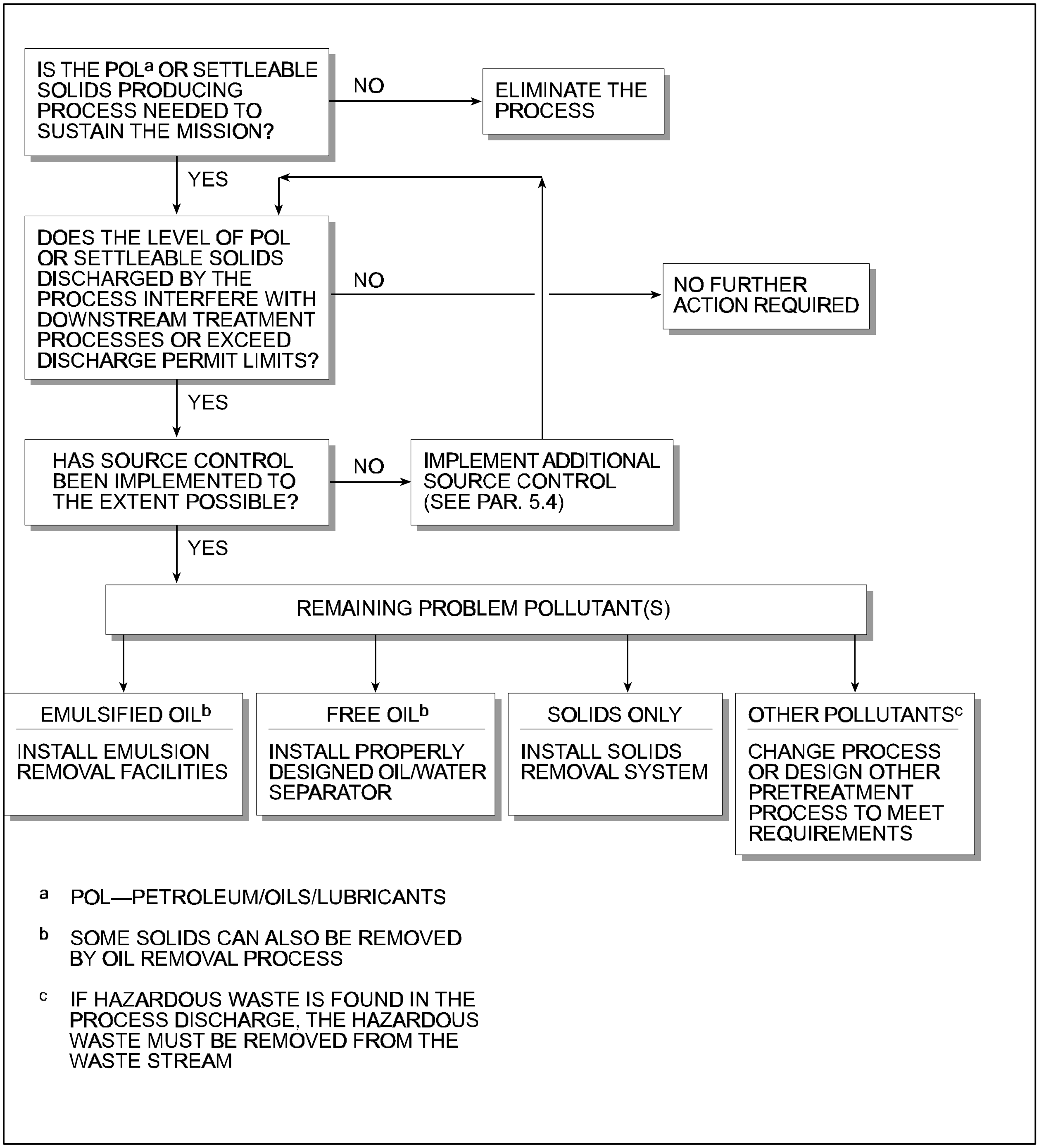

Figure 6
Decision Tree for Pretreatment of Oily Waste

d) Making process changes may eliminate the perceived need for an oil/water separator. Is the floor drain in the maintenance bay necessary? The drain should be protected against hazardous substance spills if there is a potential for spills in that area. Can a dry process replace a wet process? This approach would completely eliminate a wastewater stream. An oil/water separator should not be installed to capture spills. A holding tank can accomplish this.

e) The formation of oil emulsions should be minimized and emulsions should be segregated for special treatment whenever possible. Emulsions are usually complex, and bench scale or pilot scale testing is generally necessary to determine an effective method for emulsion breaking. For guidance in emulsions treatment, refer to API Publication 421, Design and Operation of Oil-Water Separators.

f) Current process operating practices should be investigated to determine if good housekeeping practices are employed and if changes can be made to reduce waste materials or use of excess water. In many cases, proper attention to control of operations can greatly reduce the amount of soluble oil requiring treatment. Minimizing leaks and contamination, avoiding spills, and discarding oil only when it is no longer serviceable should be a part of any oil disposal program.

g) Know the location of all separators and the point of discharge (such as to storm sewers, sanitary sewers, septic tanks, or discharge to surface waters).

h) Understand where the monitoring points are and what the discharge limits are for separators.

i)Assist in eliminating unpermitted pollutants. Help implement source control plans and identify problem areas where industrial discharges that may contain hazardous wastes, heavy metals, or emulsified oils are being discharged to an oil/water separator system not designed to treat such wastes.

j) Identify to unit/activity personnel and the environmental staff those oil/water separators that contain excessive amounts of soilds. This characteristic may indicate that exterior vehicle or equipment washing (which is usually not allowed in maintenance areas) is being performed at maintenance facilities.

k) Educate installation staff to encourage use of dry cleanup procedures. For example, floor drains from maintenance areas to oil/water separators should be used only for final rinsing of the floor after any oils or other spill materials are cleaned up with dry materials.

l) Remove and test oil/water separator sludge prior to disposal to ensure compliance with the sludge disposal requirements. Normally the sludge is tested once, shortly after the separator is placed in service, to characterize the settled sludge. If the sludge is hazardous, the source of the hazardous pollutants should be immediately identified and eliminated. The sludge must be retested each time a significant change occurs in the influent to the separator. Testing and appropriate sludge disposal should be coordinated through your environmental office.

5.5 O&M of Oil/Water Separators. The ability of oil/water separators to function properly depends on the application of required routine service and maintenance. Mechanical equipment associated with separators should be maintained according to manufacturers' recommendations.

Personnel using and maintaining the system are expected to understand the separation process and the components of the specific oil/water separator. Maintenance personnel are expected to be familiar with the piping and configuration of each separator for which they are responsible. They should periodically inspect all parts of the separator and its draining system to prevent failures caused by operations, breaks, and mechanical settings. Items suggested for inspection and a recommended frequency for inspection are listed in Table 3. System users must also be familiar with the capacity of the separator and holding tanks, uses of the system, and its potential misuses to be able to determine requirements for periodic draining and cleaning.

Separator performance can be an important indicator of the mechanical condition of the device. Performance can be tracked by regular influent and effluent sampling and analysis.

Table 3
Recommended Inspection Points for Oil/Water Separators

Item	Suggested Frequency
Conventional Gravity Separator	
Flight mechanism: flights, chains, sprockets, rails, drive	Visual weekly; detailed annually
Sludge hopper valves: open/close freely, close tight	Weekly
Oil skimmer mechanism: moves freely, level, not plugged	Weekly
Skimmings pump(s)	Weekly
Sludge pump(s)	Weekly
CPI Separator	
Parallel plates: fouling	Weekly
Skimmer weir: level	Annually
Skimmings pump(s)	Weekly
Sludge pump(s)	Weekly
Flotation	
Surface skimmer mechanism: d drive, flight, roller, beach	Visual weekly; detailed annually
Bottom rake: flight	Annually
Pressurization pump and tank	Weekly
Back pressure valve: holds recommended back pressure	Weekly
Sludge valve: operates freely, closes tightly	Weekly
Skimmings/bottoms pump(s)	Weekly

Parameters of concern are those that would be expected to be removed or reduced across the separator: oil, grease, and total suspended solids. Data obtained from the analyses should be plotted in a trend plot showing both influent and effluent concentrations. Effluent concentrations should be compared with influent concentrations to detect performance deterioration and with discharge permit limits obtained from the installation's environmental office to assess permit compliance. Frequency of separator effluent sampling should be as required by the discharge permit. Influent sample frequency should be the same as effluent sampling frequency. At a minimum, twice monthly is recommended.

5.6 Guidance Documents. The following documents provide additional guidance in operating and maintaining oil/water separators.

a) HQ AFCEE Video, Proper Operation and Maintenance of Oil/Water Separator. Brooks AFB, DSN:240-4214 (Web address: http://www/afcee.brooks.af.mil/pro_act). This video provides instruction for installation personnel from Logistics, Maintenance, and CE functions on the operation, effects of abuse, and maintenance of oil/water separators.

b) API Publication 421, Design and Operation of Oil/Water Separators, American Petroleum Institute, February 1990. 1220 L Street, Northwest, Washington, D. C. 22005.

c) HQ USAF/CE Memorandum, Oil/Water Separator: Operations, Maintenance and Construction, October 21, 1994. This memo includes the Environmental Compliance Policy for Oil/Water Separator Operations, Maintenance, and Construction.

d) Thomas D. Aldridge, Jr. "What Is an Oil/Water Separator, and Why Do I Need One"? Pollution Equipment News, December 1996.

e) HQ AFCEE ProAct Fact Sheet: Oil/Water Separators. (Web address: http:/www.afces.brooks.af.mil/pro_act/main//proact4.htm). December 1996. A Base-level Prevention Resource.

f) ETL 1110-3-466, Selection and Design of Oil and Water Separators. Department of Army, U.S. Army Corps of Engineers, Washington, D.C. 20314. August 24, 1994.

Section 6: SEPTAGE MANAGEMENT

6.1 Septage Management Alternatives. This section provides information on the characteristics of septage, the monitoring and management of septage collected from various locations and delivered to the site, and various methods typically used to treat septage.

Approval must be obtained from your environmental office before a treatment system receives septage because the treatment system is likely to be disrupted from the high strength of septage and because there is a potential for toxic components.

6.2 Septage Characterization. Septage is generally defined as the liquid and solid material pumped from septic tanks, grease traps, pit privies, vault toilets, recreational vehicle disposal stations, cesspools, and similar holding tank locations while they are being cleaned. Septage is not industrial waste. The majority of the wastewater that is discharged to a septic tank is absorbed into the surrounding drain field. The material remaining in the tank is characterized by a high content of organics, grease and other floatables, and grit. The quantity and constituents of septage vary significantly depending on the source and seasonal effects such as groundwater levels.

The quality of septage can also be negatively affected by industrial contributions if significant concentrations of industrial process wastewater or by-products have been mixed with a load of septage. Therefore, to minimize the potential for a treatment plant upset or for discharge of toxic materials to the environment, septage entering a treatment facility should be monitored in accordance with par. 6.3.

6.2.1 Septage Quantity. The most accurate method for estimating future septage quantities is to review historical data from local haulers. They should have records of the quantity of septage pumped over specific periods. Septage quantities can also be estimated by multiplying the number of residential septic tanks in a service area by the average pumpout volume per unit, as follows:

$$\frac{\text{No. of Septic Tanks x Typical Volume of Septic Tank}}{\text{Pumpout Interval}}$$

An average volume of a septic tank is approximately 750 gallons (2.8 cubic meters). A typical pumpout interval for a residential home is 3 to 5 years. Any known, significant industrial, institutional, or commercial contributions would need to be added to this estimated volume.

The pumping of septic tanks is typically seasonal, depending on the geographic location. Most of the pumping occurs during periods of high groundwater or significant rainfall or snowmelt. During the winter months in cold climates, less septage is pumped because of the problems associated with locating and uncovering septic tanks under snow or in frozen ground.

6.2.2 Characteristics of Septage. Septage can be generally described as having large quantities of grease, oil, suspended solids, organic matter and grit; foaming upon agitation; being anaerobic and odorous; being difficult to dewater; and having poor settleability. Septage has a high waste strength because of the accumulation of scum and sludge in the tank.

The specific constituents of septage vary significantly depending on the source. Table 4 summarizes septage constituents, the range of concentrations of these constituents, and typical design values used for septage treatment facilities (EPA Septage Treatment and Disposal Handbook, October 1984).

6.2.3 Comparison of Septage and Domestic Wastewater Characteristics. Many of the constituents of septage are similar to those of domestic wastewater. Table 5 compares septage and domestic wastewater characteristics (EPA Septage Treatment and Disposal Handbook, October 1984). The primary difference is that the constituents in septage are more concentrated, including greater amounts of organics, plastics, hair, and grit. Therefore, depending on the volume of septage discharged, septage could impart a significant demand on the wastewater treatment processes and increase the maintenance of pipes and equipment. The organic loading from the daily discharge of septage from one 1,000-gallon (4 cubic meters) tank truck is equivalent to a domestic wastewater flow of about 30,000 gallons (120 cubic meters) per day.

6.3 Monitoring the Quantity and Quality of Incoming Septage. Because of the variability of the constituents and strength of septage, monitoring incoming septage is necessary to ensure its compatibility with the downstream treatment processes and effluent and biosolids disposal requirements. Comprehensive and organized procedures for monitoring, sampling, and recordkeeping should be established and customized for each septage receiving and treatment facility.

Table 4
Physical and Chemical Characteristics of Septage(1),(2)

Parameter	Average	Range	Suggested Design Value(2)
TSS	12,862	310 - 93,378	15,000
VSS	9,027	95 - 51,500	10,000
BOD_5	6,480	440 - 78,600	7,000
COD	31,900	1,500 - 703,000	15,000
TKN	588	66 - 1,060	700
NH_3-N	97	3 - 116	100
Total P	210	20 - 760	250
Alkalinity	970	522 - 4,190	1,000
Grease	5,600	208 - 23,368	8,000
pH	--	1.5 - 12.6	6.0

Source: EPA Septage Treatment and Disposal Handbook, October 1984

(1) Values expressed as mg/L, except for pH.
(2) The data presented in this table were compiled from many sources. The inconsistency of individual data sets results in some skewing of the data and discrepancies when individual parameters are compared. This is taken into account in offering suggested design values.

BOD_5 = 5-day Biochemical oxygen demand
COD = Chemical oxygen demand
NH_3-N = Ammonia-nitrogen
P = Phosphorus
TKN = Total Kjeldahl nitrogen
TSS = Total suspended solids
VSS = Volatile suspended solids

Table 5
Comparison of Septage and Domestic Wastewater(1)

Parameter	Septage(2)	Domestic Wastewater	Ratio of Septage to Wastewater
TSS	15,000	220	68:1
VSS	10,000	165	61:1
BOD_5	7,000	220	32:1
COD	15,000	500	30:1
TKN	700	40	17:1
NH_3-N	100	25	4:1
Total P	250	8	31:1
Alkalinity	1,000	100	10:1
Grease	8,000	100	80:1
pH	6.0	--	--

Source: EPA Septage Treatment and Disposal Handbook, October 1984

(1) Values expressed as mg/L, except for pH.
(2) Based on suggested design values in Table 4.

BOD_5 = 5-day Biochemical oxygen demand
COD = Chemical oxygen demand
NH_3-N = Ammonia-nitrogen
P = Phosphorus
TKN = Total Kjeldahl nitrogen
TSS = Total suspended solids
VSS = Volatile suspended solids

6.3.1 Monitoring Procedures. Procedures should be established to monitor the volume and characteristics of incoming septage flows. These procedures should generally include the following:

a) Record the name of the hauler, the origin of the septage, and the time of arrival.

b) Record the septage volume discharged to the plant. These records are important for reviewing historical septage flows projecting future flows and for estimating the discharge fee to the hauler.

c) Take a grab sample of each truck load and analyze it, or refrigerate the sample for possible future analyses.

d) Supervise the hauler's activities during the discharge to the receiving facilities.

6.3.2 Sampling. A sample should be taken from each load of septage discharged to the plant. The purpose for the sampling is to allow for immediate analysis of the septage if the waste is suspect; to discourage the discharge of unacceptable waste by openly displaying to the hauler that the septage is monitored; and to establish a trend analysis of septage characteristics by periodically analyzing samples.

In most cases, the sample would not need to be analyzed immediately. It can be refrigerated for a period equal to the detention time through the treatment plant. In some cases, however, especially where effluent discharge limits are very stringent, a pH test, toxicity screen, and microscopic examination to confirm the presence of biological activity should be performed on each load.

6.3.3 Recordkeeping. At a minimum, the following records related to the discharge and treatment of septage should be kept:

a) The origin of the septage, including the name, address, and contact for the owner of the septic tank that was pumped

b) The volume of each load

c) The results of any analyses performed on the septage and a summary of any unusual septage characteristics observed, and

d) The name of the hauling company and driver, permit number (if applicable), and time of arrival.

6.4 Modes of Septage Treatment. Because of the similarities in the characteristics of septage and domestic wastewater, the same treatment processes can be used to treat both wastes. The septage can be added to the liquid stream, sludge stream, or both streams of a treatment facility. The selected mode of septage addition will depend on the capacity and type of processes at the facility. The ability of a treatment facility to treat septage is typically limited by the available aeration and solids handling facility. Before the septage enters the treatment facility, it should be pretreated, including, at a minimum, screening, equalization, and adequate blending with the raw sewage.

Septage can also be chemically stabilized by using lime ($CaOH_2$) in a batch operation and by then applying the septage to a permitted land application site. Lime can effectively destroy most pathogenic and odor-producing microorganisms and has been shown to improve dewaterability. The Code of Federal Regulations (Part 503) requires that, to land-apply the septage, it must be mixed with the lime to raise the pH to 12 or higher for a minimum of 30 minutes. Special sludge spreading equipment is necessary to ensure an even application of the septage on the land. Because this treatment method would typically be independent of the domestic wastewater treatment processes, it will not be discussed further in this section.

6.4.1 Estimating Treatment Capacity. The available treatment capacity of a system for receiving and treating septage can be estimated by calculating the difference between the design capacity of the system and the current loading to the system. This information should be available in your environmental office. Given the estimated available capacity, the volume of septage that can be discharged to the treatment system can be estimated by using the suggested organic and nutrient concentrations presented in Table 4.

For example, assume that the available treatment capacity of the treatment system was calculated to be 500 pounds (227 kilograms) per day of BOD. The volume of septage that can be discharged to the system can be estimated by dividing the 500 pounds (227 kilograms) by the estimated BOD concentration in septage of 6,500 mg/L (Table 4). This equates to an allowable septage volume of approximately 9,000 gallons (36 cubic meters) per day [500 pounds per day x 1,000,000/(8.34 x 6,500 mg/L)].

6.4.2 Co-Treatment of Septage in Liquid Stream. Septage addition in the liquid stream is the most common method of septage treatment at a WWTP. The screened and degritted septage can be added upstream of the primary or the secondary treatment units. Adding septage upstream of the primary treatment units will decrease the organic and solids loadings to the secondary treatment units (e.g. activated sludge system) and will reduce the potential for scum accumulation in the downstream processes. Other general considerations when adding septage to the liquid stream include the following:

a) Slug loads versus continuous discharge of septage. The allowable loadings should be reduced by nearly one-half for slug loadings. Estimating allowable loadings is discussed in par. 6.4.1. Because of shock organic loadings and other undesirable process impacts, slug loads are not recommended.

b) Timing of discharge. If the available primary treatment and secondary treatment capacities are limited, the septage could be metered into the plant during off-peak demands.

c) Ultimate disposal from the treatment facility. The permit limitations or other requirements for disposing of the treatment plant effluent and biosolids need to be considered when accepting septage. The organic and inorganic constituents of the septage may affect the effluent and biosolids quality, including concentrations of BOD, TSS, nitrogen, phosphorus, and heavy metals.

d) Scum accumulation in the clarifiers. The scum handling equipment for the primary and secondary clarifiers should have the capacity to handle the increased loadings of oil, grease, and floatables.

e) Increased sludge volumes. The volume of primary and waste activated sludges will increase. Therefore, the processes and equipment used for handling the sludge should have the capacity to accommodate the increased sludge quantities.

f) Location of septage addition to a trickling filter plant. Septage should be discharged upstream of primary clarifiers if trickling filters are used for secondary treatment. This will minimize the potential for filter media fouling.

6.4.3 Co-Treatment of Septage in Solids Stream. The screened and degritted septage can be mixed and treated with primary and secondary treatment plant sludges. Adding septage to the solids stream nearly eliminates any adverse effects on the liquid treatment processes and equipment. The undesirable constituents of septage are kept out of the major flowstreams of the plant, thereby requiring less operation and maintenance.

Depending on the ultimate disposal method, stabilization is normally required prior to disposal. The septage can be treated using either aerobic or anaerobic digestion, the most common methods of sludge stabilization. The following should be considered when adding septage to the solids stream:

a) Increased sludge volumes. The volume of sludges will increase; therefore, the processes and equipment used for handling the sludge should have the capacity to accommodate the increased sludge quantities.

b) Foaming and odor problems. Foaming and odors are common with aerobic digestion. The extent of foaming depends on the amount of detergents present in the septage.

6.5 Receiving Station. In addition to the high organic content, septage typically contains hair and other stringy material, grit, and plastics. Also, the volume of septage loads disposed of at treatment plants is highly variable. Therefore, a septage receiving station with preliminary treatment and storage and equalization capacity is highly recommended.

6.5.1 Receiving Station Description. The extent of facilities necessary at a receiving station depends on the quantity of septage received, the flows to the WWTP, the preliminary treatment available at the plant, the type of septage treatment used, and the WWTP processes. However, the primary components in most receiving stations should include the following:

a) Dumping station

b) Screening facility

c) Grit removal system

d) Grinder pump (if screening and grit removal is not present)

e) Storage and equalization capability

f) Lift station

g) Odor control capability

6.5.2 Dumping Station. The purpose of the dumping station is to provide for the unloading of incoming septage that has been transported to the plant via tank trucks. The dumping station should consist of a truck unloading pad(s), an inlet hose or a grate, and washdown hoses. In most cases, the hauler will notify the operator upon arrival and provide pertinent information such as name of hauler, origin of septage, and certification, if applicable. The monitoring of septage quantity and quality, as described in par 6.3, should take place at the dumping station.

6.5.3 Screening Facility. The septage typically flows by gravity from the dumping station to the screening facility. The purpose of the screening facility is to remove the large solids to protect the downstream treatment processes and associated equipment. The screens, or “bar racks,” can be manually or mechanically cleaned. Provisions should be available to efficiently dewater and dispose of the screened materials. This will minimize the potential for odors.

6.5.4 Grit Removal System. The screened septage will flow by gravity to the grit removal system. The purpose of the grit removal facility is to separate the sand, gravel, cinders, food particles, etc., from the septage while maintaining the organic material in the main flow for downstream treatment. Effective grit removal systems include aerated grit chambers and vortex-type chambers. A grit removal facility may not be necessary if sufficient grit removal is provided as part of the liquid or solids process treatment units.

6.5.5 Grinder Pump Stations. Grinder pumps and other types of wastewater grinders are sometimes used for primary treatment in lieu of screening. Grinders screen and shred material into smaller sizes without removing the particles from the flow. Grinders reduce odors, flies, and unsightliness often associated with screening and essentially eliminate the steps of screening removal and handling, which may not be practical for smaller treatment systems.

Unfortunately, solids from grinders cause problems downstream, including deposits of plastics in sludge handling facilities. Pulverized synthetic materials will not decompose in the sludge digestion process and therefore may affect some sludge disposal methods, especially land application. Using grinders can also result in “ropes” or “balls” of material (particularly rags) that can clog downstream equipment such as pipes, diffusers, pumps, and aerators.

6.5.6 Storage and Equalization. The purpose of septage holding basins is to provide storage, equalization, and mixing prior to further treatment. Storing the septage will help reduce the peak loadings to the downstream processes and help maintain the appropriate blending of septage with the raw sewage. The storage tanks also provide flexibility to store the septage load while analyses are being performed. Provisions should be made for mixing the contents of the storage tank. The storage can be provided either upstream or downstream of the screening and grit removal facilities.

6.5.7 Lift Station. A lift station is typically required to pump the septage from the receiving station to the downstream septage treatment processes.

6.5.8 Odor Control Capability. The extent of the odor control that is required depends on the location of the facility relative to the surrounding area and the land use of that area. Many of the odors can be minimized by following good housekeeping practices. The dumping area should be hosed down after each delivery (preferably by the hauler), the bar screens should be kept clean, and the waste solids removed during pretreatment should be dewatered and disposed of as soon as practicable.

If the odors are excessive and must be eliminated, the specific sources of the odor should be identified and contained, and the odorous air should be vented to a treatment unit. Several treatment technologies are available, including liquid chemical scrubbers, activated carbon filters, biofilters, and the addition of gases to a biological treatment process.

Section 7: EXTREME CLIMATE OPERATION

7.1 Effects of Extreme Cold Climates. Cold weather can have significant and often severe adverse effects on the maintenance, operations, and performance of WWTPs. Temperature-dependent effects include physical, chemical, and biological responses. Often performance efficiency will be affected by extreme cold weather, which can cause treatment processes to suffer. The structures and buildings will also be affected by excessive snow loads, snow drifting, ice formation, and related freezing of system components. These factors will affect the O&M of the facility. Major cold weather operational problems can be divided into four specific categories:

a) Changes in the viscosity of the wastewater and equipment lubricants

b) Reaction rate changes in physical, chemical and biological processes

c) Ice formation and freezing in process components

d) Snow and ice accumulation on structures, control equipment, roads and walkways, and walls and berms

The potential for winter and cold weather problems is not limited to a particular type of treatment process nor to any particular size of treatment plant. Table 6 lists areas within a plant where cold weather may affect plant performance, operations, or maintenance.

Additional information about cold weather problems can be found in U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) Special Report 85-11, Prevention of Freezing and Other Cold Weather Problems at Wastewater Treatment Facilities.

7.2 Preliminary Treatment Processes. As wastewater enters the treatment plant, the preliminary processes will be affected by the cold water and freezing weather. These processes are intended to remove large solids and abrasive material. The failure of any of these units will affect downstream processes. Therefore, it is important to keep these units working as effectively as possible. This discussion is also applicable to collection system pumping stations that may be equipped with similar equipment. Table 7 suggests solutions to these cold weather problems.

Table 6
Treatment Process Components Subject to Freezing Problems

Preliminary Treatment	Clarifiers	Biological Reactors	Solids Management	Disinfection
Pumping	Primary	Activated sludge	Digestion	Chlorination
Screens	Secondary	Extended aeration	Dewatering	
Grinders	Polishing ponds	Oxidation ditches	Disposal	
Grit chamber	Air flotation	Trickling filters		
Flow measurement	Thickeners	Rotary biological contactors		
Flow equalization		Aerated lagoons		
		Facultative lagoons		
Source: U.S. Army CRREL Special Report 85-11				

Table 7
Winter Problems with Preliminary Treatment

Problem	Solution
Ice buildup in headworks area	Keep building heated above 50°F (10°C).
Icing of bar racks	Cover inlet channel. Flush with warm water. Weatherstrip channels to reduce cold air entry into building. Clean by hand frequently.
Septage pumping lines freeze	Use heat tape on lines and valves. Use proper flushing after pumping truck. Use manhole to directly dump into plant. Do not handle septage in winter. Drain all lines.
Septage freezing in truck	Pass engine exhaust through truck tank to prevent freezing.

Table 7 (Continued)
Winter Problems with Preliminary Treatment

Problem	Solution
	Drain truck tank pipings and valves.
Collected grit freezes	Store dumpsters in heated building before emptying. Store truck inside. Remove no grit in winter.
Icing of grit dewatering equipment	Duct kerosene heater into area.
Grit machine freezes	Enclose unit.
Screened rags freeze	Remove regularly by hand.
Spiral lift pumps freeze	Run water on ice to reduce buildup.
Screw pumps freeze	Install timer to "bump" screw once per hour.
Valves and hoses freeze	Drain lines. Keep hoses on.
Automatic sampler freezes	Place sampler inside building Do not use in severe cold. Build insulated structure heated with light bulb. Insulate suction lines. Purge lines after sample taken. Move sampler location to decrease exposure. Install suction lines to give a straight fall.
Flow measurement device freezes	Use heat tape and glass fiber insulation on flow transmitter. Insulate chamber and heat with one light bulb. Put heat tape on Parshall flume linkage.
Float for flow measurement freezes	Heat with light bulb and insulate. Add antifreeze to float box.
Grit removal bypass channel freezes	Temporarily switch flow to by-pass channel, 30 min/day or more often if needed.
Water freezing at comminutor	Build plexiglass structure to keep influent warm.
Doors frozen shut on screening enclosure because of condensation	Put heat tape around door enclosure.

Table 7 (Continued)
Winter Problems with Preliminary Treatment

Problem	Solution
Stairs above screw pumps are slippery from icing condensation	Plant policy requires all operators to keep one hand free at all times to use rails.

Source: Taken in part from U.S. Army CRREL Special Report 85-11.

7.2.1 Screens and Grinders. Screens should be cleaned more frequently during cold weather, either automatically on timers or manually, since the screenings will freeze to the metal bars. Once this occurs, removing screenings from the bars is very difficult. Mechanical mechanisms may also become jammed and inoperable. Weatherproofing or enclosing the area and providing heat may be desirable.

Caution: Be aware of the potential for combustible materials entering with the wastewater. Provide proper ventilation and equipment to prevent explosive conditions.

Screenings may freeze to the sides and bottom of containers; prevent this from happening if at all possible. Grinders may bind because of ice if they are not run often enough. Consider operating the grinders continually or often enough to prevent ice buildup. Covering channels with rigid insulating materials may contain enough heat from the wastewater within the channel to prevent ice buildup on the grinder. Gear oil viscosity will be affected by freezing weather. Follow the manufacturer's recommendations for cold weather maintenance. Condensation will also occur in the gear boxes of this equipment, adversely affecting the gear oil. Check the oil routinely (twice monthly) in the winter.

7.2.2 Grit Removal Processes. Operation of grit-handling facilities may be very difficult during extremely cold weather. The grit that is collected and transported will freeze easily in the equipment used to clean and move it to the holding container. Temporary enclosures may assist in keeping the process warm. If this process is to be enclosed, choose the materials carefully to prevent dangerous or explosive conditions. Heat-tracing the metal equipment may help prevent ice buildup. Heat-tracing involves wrapping an electrified wire loop around the equipment.

Running warm water across cleaning areas may also prevent freezing, depending upon local conditions.

7.2.3 Flow Measurement. Freezing weather conditions may cause the stilling well of flow measurement devices to freeze. A solution of mineral oil, or a small amount of antifreeze or a salt solution, will keep this stilling well liquid. Under low-flow conditions, some of this antifreeze will drain out and may need to be replenished periodically. Other remedies are to enclose the area with rigid insulating board or plywood and to use a light bulb for heat. Enclosing float wires will prevent them from freezing.

A layer of frost may coat ultrasonic sensors inside the cone on the sensor head. Use a thin layer of petroleum jelly on the face of the detector to prevent this problem. Note that the sensor should be recalibrated after the jelly is applied. In systems that have an air bubbler system to measure the level of water, condensate may become trapped within the air line and it may freeze. Heat-tracing the air line will prevent freezing and condensate problems. Dry air will also help prevent condensate freezing in the lines. Using a desiccant on the air supply is recommended.

7.2.4 Other Preliminary Treatment Processes. Sometimes septage trucks discharge material to the headworks of the plant. To ensure that the discharge hoses do not freeze, drain them completely and hang them up so that water does not collect inside. On fixed lines, heat tracing will prevent the liquid from freezing. However, fixed lines should be installed with a slope to drain. Septic trucks should be kept in heated garages because they have many parts in which water may freeze, including the pumps, valves, piping, and tank. Tankers should be completely empty if they are left out in the freezing weather.

Automatic samplers should be housed in a heated and insulated compartment. Sampler suction lines should be heat traced or enclosed in a heated space. A light bulb in the sampler “shed” can supply enough heat to prevent the sampler from freezing. A small shelter the size of a doghouse may be suitable for this purpose, if it is insulated. Operate screw pumps routinely to prevent the shaft from freezing to the walls of the chute. Rotate the screw pumps a few turns every half hour to ensure that they do not freeze. The rotation can be performed with a simple timer.

7.3 Clarifiers. Clarifiers are affected in several ways by the decrease in seasonal temperatures. The density of water changes with temperature, and this change affects the settling characteristics of the solids. Materials at the surface of these quiescent basins will tend to freeze. Weirs and launders may also freeze, depending upon the ambient and wastewater temperature. Table 8 summarizes some potential problems and solutions associated with clarifier freezing.

7.3.1 Surface Freezing Conditions. The most serious problem associated with clarifiers is freezing on the surface, surface scum, and ice buildup on the scum beach plate. These problems damage skimming mechanisms and may even cause the clarifier rake mechanism to fail. Check torque limits on the rake mechanism routinely and adjust them if necessary to ensure that they will work if ice affects the collector. Removing the skimming arm in winter may prevent this problem; however, the problems of scum freezing and removal remain. Hot water sprays, heat tape, and enclosed lamps may be valuable in addressing these problems. Many times, ice must be carefully chopped off the surface of the tanks and removed to the launders.

Table 8
Winter Problems with Clarifiers

Problem	Solution
Scum line freezes	Flush out with hot water. Use sewer bag to free blockages. Install automatic flushing mechanism.
Scum trough freezes	Cover exterior trough. Break ice into pieces and remove by hand. Install automatic flushing mechanism.
Scum freezes on beaching plate	Flush off with hot water. Discontinue scum removal in winter. Shovel and hose down by hand. If adjustable, decrease exposed plate area.
Ice on beaching plate hangs up collector arm and damages mechanism	Remove skimmer during winter. Remove ice by hand.
Scum freezes on outside ring of peripheral feed clarifier	Cover clarifier.
Scum solidifies, won’t flow	Use warm water to flush.

Table 8 (Continued)
Winter Problems with Clarifiers

Problem	Solution
Scum freezes at center feed	Install a warm water sprayer to keep scum moving toward skimmer.
Surface icing	Remove secondary arms to prevent damage. Keep clarifiers on 24 hours/day. Remove thick ice with long-armed backhoe. Shorten detention times.
Icing in idle units	Pump units dry routinely.
Icing in gear units	Install heat tapes on drain line. Drain water in bullgear after rain and when temperature rises.
Hoses and hydrants freeze	Leave lines on. Drain lines after use.
Traveling bridge controls ice-up	Build enclosure over controls.
Icing of bus bar for bridges	Install heat guns or warm air blower.
Switches on monorakes freeze	Shut off units in snow and ice to prevent freezing.
Accumulation of snow on monorake rails stops wheels	Shut down rake during snowstorms and remove snow.
Automatic sampler freezes	Build insulated boxes heated with a 100-watt light bulb.
Waste activated sludge lines freeze	Locate lines deeper. Install proper drainage.

Source: Taken in part from U.S. Army CRREL Special Report 85-11.

Caution: Take care during this operation since slippery footing, loss of equipment (attach lines and floats), and damage may result during ice removal.

Covering clarifiers will eliminate many of these potential problems. When designing covers, consider snow loads, weatherproofing of electrical controls, and the possibility of humidity within the covers.

7.3.2 Mechanical and Electrical Equipment Protection. The viscosity of lubricating oils will change as a result of freezing temperatures. The operator can either change the oil to suit the expected temperature range or use heat tape or immersion-type heaters to maintain higher oil temperatures. Sometimes multi-viscosity year-round synthetic oils may be appropriate. Gear boxes tend to collect moisture and condensate, which may either degrade lubrication oil or cause corrosion. This condition should be monitored. Frost may arc across some electrical circuits; a small warm-air fan at the motor control center vent will keep these components warm and dry if this is a local issue.

7.3.3 Process Concerns. Settling characteristics change when temperatures lower; solids settle at a slower rate in colder (near freezing) waters. Stoke's Law governs the physics of settling in primary clarifiers, and it is affected by temperature. For example, when the temperature drops from 68°F (20°C) to 38°F (3°C), the settling time for a particle increases 64 percent. Under these conditions, additional clarifiers may facilitate the process. However, proceed with caution because the increased detention time caused by additional clarifiers will result in lower water temperatures and a higher risk of freezing. If the solids loading is very high (above 2,000 milligrams per liter [mg/L]), Stoke's Law does not apply.

7.4 Biological Systems. Biological reaction rates depend upon temperature. A drop in temperature of 10°C (18°F) decreases the reaction rates by one-half. Mechanical equipment providing aeration is affected by freezing temperatures, and ice may affect the components. Table 9 suggests some solutions to freezing problems in biological systems.

Table 9
Winter Problems with Biological Systems

Problem	Solution
Ice buildup on surface aerator	Remove by hand. Run on high speed for 15 minutes. Turn off for 1/2 hour, allow mixed liquor to warm aerator, and turn on high speed. Steam ice off. Bump aerator on and off carefully.
Impeller icing causing ponding on fixed shroud	Remove shroud. Ice will still build up, but aerator will not be damaged.
Ice buildup on supporting columns causing rotating shroud to pond on columns	Shorten detention times; run aerators on timers.
Cooling of mixed liquor	Install timers on aerators. Use diffused air instead of surface aeration. Remove some aerator blades.
Icing in idle tank damaging structure	Fill tank 1 foot above baffle. Install small sump pump to keep surface free of ice. Exercise units regularly during sunny days. Care must be taken not to damage units. Use inner tubes to absorb ice expansion. Bubble air to prevent freezing.
Ice buildup on splash guard, electrical conduit, and walkways	Use good snow and ice removal procedures, salt. Plant policy requires operators to keep one hand free to hold railing.
Decreased removal efficiencies	Increase MCRT, decrease F/M.

Source: Taken in part from U.S. Army CRREL Special Report 85-11.

7.4.1 Activated Sludge Systems. Cold weather does not affect conventional activated sludge systems with a detention time of 4 to 6 hours as significantly as systems with longer detention times. Extended aeration systems having detention times of 10 to 24 hours will experience a temperature decrease that will affect the biological process. Systems that use diffused air for oxygen transfer will actually be adding heat to the system in the air flow; conversely, mechanical mixing systems will have significant temperature decreases across the aeration basin as cold air is mixed into the activated sludge. Take these temperature changes into consideration when selecting or changing aeration methods in a cold climate. Avoid ice buildup across the surface of the basins. This buildup will limit the oxygen transfer and may interfere with mixing equipment. Removing floating scum before winter will help prevent this extra material from freezing in the aeration basin.

In cases where the temperature is affecting the process, changes to the process control are required. Process adjustments would include increases to the mean cell residence time (MCRT) or a decrease in the food-to-microorganism ratio (F/M) to maintain the same process performance and loading rates.

Ice buildup around mechanical aeration equipment will also affect safety and may overload equipment if it attaches to equipment surfaces. Continuous operation of mechanical mixers at low speed or intermittent operation will reduce the oxygen transfer and reduce ice buildup. Monitor oxygen concentration closely if this method is attempted. Heat tracing the components may also be helpful.

7.4.2 Fixed Film Treatment Systems. In trickling filter plants, the potential for icing is very high. In winter, turn off the draft in forced-draft systems unless a source of warm air is available.

Note: The forced draft systems are used primarily when the outside air is less than 5°F (3°C) above or below the process liquid temperature. If ice forms within the unit, flood it to melt the ice. Take care when flooding the media, and be cautious of structural loading as well as leaking and overloaded pumping systems, gates, and valves. Ice can form on the top of the media, which may affect the distributor arm. Covers are advised in extremely cold areas to prevent this situation.

Rotating biological contactors (RBCs) are usually covered to control odors, but keep the covers in good condition to keep the heat within the wastewater. If the RBCs do not already have covers, install them to keep the media from freezing and affecting the shaft with additional loading and potential failure.

7.4.3 Lagoon Systems. Aerated lagoons will typically freeze during the winter. Remove mechanical mixers to prevent them from becoming covered with ice and turning over or sinking. Remove any baffles as well, or be prepared to repair them in the spring. Because the ice will affect the depth of the lagoon, winter operations should be run at the highest liquid levels possible to increase lagoon volume. Because of the ice coverage, little to no algae activity will occur under the ice and snow. Adding the lower water temperature to the situation, lagoon performance in the winter may be marginal. With the rise in spring temperatures, the lagoons will have a liquid turnover, with a possible washout of solids.

7.5 Disinfection. Chlorine gas cylinders need to be in a heated environment because evaporation chills the contents when the gas vaporizes in the tank. The EPA recommends keeping the temperature of the chlorine room no lower than 50°F (10°C). External heat sources should not be too high (cylinders should not be higher than 158°F [70°C]), but heat should be considered if it will solve the vaporization problem. Hypochlorite tablets will dissolve more slowly in cold water. Additional tablets may be necessary to achieve the proper levels of disinfection. All lines carrying disinfection chemicals and solutions should be heat-traced where they are exposed to freezing conditions. Table 10 lists disinfection freezing problems and remedies.

Table 10
Winter Disinfection Problems

Problem	Solution
Feed lines freeze	Enclose all storage and pumping facilities in a heated building.
Hypochlorite solution crystallizes in pumps and pipes	Keep in heated room above 65°F (18°C).
Surface contact chamber freezes	Cover and insulate tanks.

Source: Taken in part from U.S. Army CRREL Special Report 85-11.

7.6 Solids Management. Solids digestion is a biological process that slows down as a result of decreasing process temperatures. Solids processing equipment exposed to the elements will be adversely affected by freezing weather. Table 11 summarizes problems associated with solids management in winter and offers possible solutions.

Table 11
Winter Problems with Solids Management

Problem	Solution
Unable to use solids drying beds in winter; beds freeze	Cover beds.
Not able to apply solids to land in winter	Stockpile solids in winter months.
Aerobic digester freezes if blower is shut off to allow thickening by decanting	Cover tank. Decant smaller amounts more often.
Solids mixture freezes in tank	Run mechanical agitator overnight.
Ice forms on digesters	Insulate better.
Icing in gravity thickener	Run final effluent to keep hydraulic loading higher.
Solids holding tank freezes	Take offline during winter.
Solids freeze on truck	Use truck body heated with exhaust gases.
Solids lines freeze; valves freeze	Drain lines correctly. Dismantle and thaw valve. Put heat tape on lines. Increase return rates.
Holding tanks too small to last winter	Use spare clarifier of oxidation ditch.
Extensive heat loss from anaerobic digester	Improve insulation.
Operating temperature could not be reached in a new compost pile	Cover pile and insulate. Mix solids and wood chips with hot compost. Blow hot exhaust from working pile into new pile.

Source: Taken in part from U.S. Army CRREL Special Report 85-11.

7.6.1 Aerobic Digesters. Aerobic digesters will operate at lower efficiencies. Longer detention times will be required to obtain the needed levels of stabilization. Digester solids concentrations should be increased to accommodate these changes.

Thus, decanting the digesters may take longer as a result of increases in viscosity.

7.6.2 Anaerobic Digesters. It will take more energy to keep the contents up to the processing temperature because of the lower feed temperature. Tank insulation (dome and sides) will need to be inspected in the fall of each year and repaired as needed.

7.6.3 Dewatering. Dewatering on drying beds can take longer because of freezing beds. Where solids drying is necessary, maximize the dewatering in the warmer and dryer summer months. It is often faster to apply thin layers of solids, allow the solids to dry, clean the beds, and reapply solids than to apply one thick layer. If adequate capacity exists, keeping the solids on the frozen beds throughout the winter is satisfactory.

7.6.4 Equipment Maintenance. All equipment that contains solids mixtures and can be exposed to freezing temperatures should be insulated and heat-taped. If equipment is not required during the winter, drain it completely and store it for the season. Equipment in which condensate can collect should be emptied often to prevent freezing. For example, enclosed cabinets (switch gears, mechanical enclosures, and pneumatic systems, etc.) that are exposed to liquid streams in which condensation may be generated should be either heat traced, drained, or isolated from the condensation source.

7.6.5 Concrete Repair. Concrete exposed to repeated freeze/thaw cycles is subject to cracking and spalling. In environmental type structures, the concrete becomes saturated with water. When temperatures drop below freezing, the water in the concrete pores will freeze. As the water freezes, it expands and exerts pressure on the concrete. When the pressure exceeds the tensile strength of the concrete, it cracks. The cracks get a little larger each time the concrete freezes. When the water thaws out, the water shrinks, leaving void areas in the cracks. Through capillary action the crack fills up with more water. Repeated freezing and thawing makes the cracks get larger until the concrete spalls off.

Small spalled areas that do not expose the reinforcing are not significant since their effect is more cosmetic than structural. Small spalls should be repaired as part of routine facility maintenance. Patch the concrete with a polymer-modified, silica fume enhanced mortar such as Sika Mono Top (manufactured by Sika Corporation, Lyndhurst, New Jersey), or Emaco (manufactured by Master Builders Inc., Cleveland, Ohio). All loose concrete should be removed and the concrete surface cleaned and prepared as required by the repair mortar manufacturer.

If the spalling is extensive, if the concrete is cracked and leaking, or if the reinforcing steel is corroded, a concrete repair specialist should be consulted. The specialist is needed to evaluate the cause of the problem and to specify the appropriate repair. Patching spalled concrete created by corrosion in the reinforcing will only lead to the patch failing if the corrosion is not addressed first. Cracks in the concrete can be effectively repaired only when the cause of the crack is determined. Otherwise, the crack may just form in another location next to the repaired crack.

Section 8: CORROSION CONTROL

8.1 Causes of Corrosion. Most corrosion present around a WWTP is called aqueous corrosion because it occurs in a wet or damp environment. Other forms of corrosion, such as high temperature corrosion, are not usually found in a WWTP. Aqueous corrosion can occur on metal surfaces that are a) submerged in water, b) buried in the earth, or c) wet from surface moisture, such as rain water, condensation, or high humidity. The rate at which the corrosion occurs depends on the amount of moisture present and what chemicals or other contaminants are present in that moisture. Aqueous corrosion is also called electrochemical corrosion.

8.1.1 Electrochemical Corrosion. Electrochemical corrosion derives its name from the electrical current ("electro") that is flowing and the chemical reactions that occur at the same time. The flow of current is critical, since the amount of current flowing in a corrosion cell will affect the amount of metal that will be corroded. Corrosion currents are direct currents (DC) controlled by Ohm’s Law. Ohm’s Law states that the voltage (E, volts) is equal to the current (I, amperes) times the resistance (R, ohms). The current flow will be directly affected by the resistance of the corrosion circuit. Wastewater is more conductive than distilled water; therefore, a corrosion cell in wastewater will be more active than in distilled water.

For an electrochemical corrosion cell to exist, four elements must be present:

a) an anode or corroding surface;

b) a cathode or noncorroding surface;

c) a metallic connection between the anode and cathode surfaces; and

d) a common electrolyte, which contains both the anode and cathode surfaces.

The anode/cathode surfaces can exist on the same piece of metal and can be very close to each other or at a great distance from each other. The connection, in a single piece of metal, is the metal itself. The typical electrochemical corrosion cell is shown on Figure 7. The electrolyte can be any media capable of conducting an electrical current. If the metal is buried, the electrolyte is the soil; if the metal is submerged in wastewater, the wastewater acts as the electrolyte.

If one or more of the four elements is eliminated, then corrosion cannot occur. As discussed below, this fact plays an important role in controlling corrosion. For example, if a pipeline is buried in the soil, many areas of anodes and cathodes will be present on the surface of the pipeline. These areas are developed during the process of producing the pipe and cannot be eliminated. The connection between the anodes and cathodes cannot be broken, since the pipe wall serves this purpose. However, if the outside of the pipe is coated with a protective coating or wrapped with pipeline tape, the pipe surface will be isolated or separated from contact with the soil (electrolyte). Isolating the pipe from the electrolyte eliminates one of the elements necessary for corrosion. Therefore corrosion cannot occur, even though the anodes, cathodes and connections still exist on the pipe. Methods of handling coating defects are discussed below.

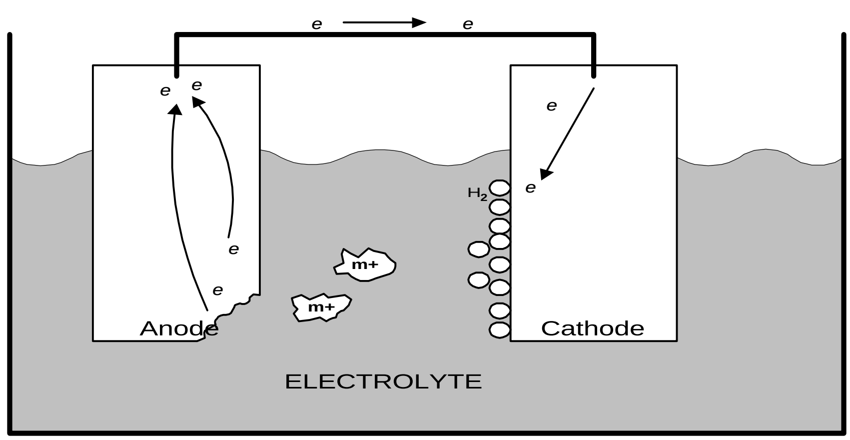

Figure 7
Electrochemical Corrosion Cell

8.1.2 Eight Forms of Corrosion. It is possible to classify several forms of corrosion, based on the general appearance of the corroded metal. In most cases, the forms can be identified with the naked eye, but magnification can help. Not every form of corrosion is likely to be seen in a WWTP, but it is helpful to know each form and be able to recognize it in case it occurs. The eight forms of corrosion are unique but are often interrelated:

a) Uniform corrosion

b) Galvanic corrosion

c) Crevice corrosion

d) Pitting corrosion

e) Intergranular corrosion

f) Selective leaching

g) Erosion corrosion

h) Stress corrosion

8.1.2.1 Uniform Corrosion. Uniform corrosion is one of the most common forms of corrosion and probably accounts for the greatest corrosion loss in the world. It is generally characterized by an electrochemical reaction that proceeds uniformly over all exposed surfaces. Uniform corrosion can be predicted with simple tests, and accurate estimates of equipment life may be made. It is easily controlled by selection of proper materials and by use of protective coatings, inhibitors, and cathodic protection (discussed in par. 8.2). In a WWTP, examples of uniform corrosion would include unpainted steel tanks and structures that are allowed to corrode in the atmosphere, resulting in heavy, flaky rusting of all exposed surfaces.

8.1.2.2 Galvanic Corrosion. Often referred to as two-metal corrosion, galvanic corrosion involves two or more metals that are electrically connected together in an electrolyte. Galvanic corrosion is the second most common form of corrosion. Whenever two metals are connected together, one behaves as an anode and is always corroded, while the other behaves as a cathode and is not corroded. A typical galvanic corrosion cell is shown in Figure 8. This figure is very similar to Figure 7, except that the anodes/cathodes are replaced with specific metals. Which metal becomes the anode and which the cathode depends upon their position in the galvanic series of metals (see Table 12). For example, if a copper valve is installed in a steel pipeline, the steel will always be the anode, since it is lower in the galvanic series than is the copper. Therefore, the steel will corrode in preference to the copper. If two metals are very close to each other in the galvanic series, the resultant corrosion will probably not be too serious. The conductivity of the electrolyte will also affect the corrosion cell; increasing conductivity increases the corrosion activity. The ratio of the surface area of the two metals involved will also affect the corrosion rate. Large anode surfaces to small cathode surfaces is preferable to the opposite ratio.

Galvanic corrosion is commonly found in WWTPs. Control galvanic corrosion using the following procedures:

a) Select materials that are close together in the galvanic series.

b) Electrically isolate the two metals from each other by installing insulating flanges or unions.

c) Maintain a large surface area of the anodic metal compared with the surface area of the cathodic metal.

d) Paint the metals to reduce the surface areas exposed. It is preferable to paint the cathode to maintain a large surface area of the anode metal.

e) Introduce a third metal into the circuit that is more anodic than either of the original metals (lower in the galvanic series). This form of cathodic protection is discussed in detail in MIL-HDBK-1004/10, <u>Electrical Engineering Cathodic Protection</u>.

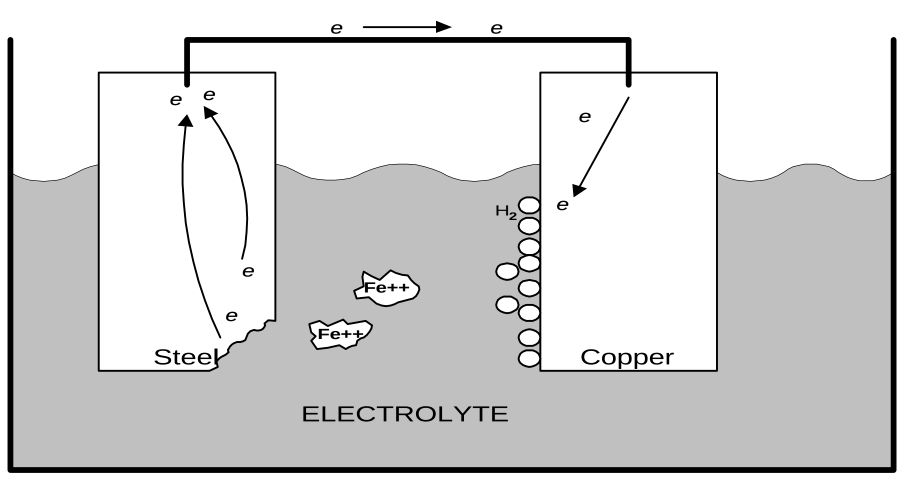

Figure 8
Galvanic Corrosion Cell

Table 12
Practical Galvanic Series of Metals

Platinum	CATHODIC
Gold	
Graphite	
Titanium	
Silver	
Stainless steel (passive)	
Nickel (passive)	
Copper and its alloys	
Tin	
Lead	
Cast iron	
Steel or iron	
Aluminum alloys	
Zinc	
Magnesium alloys	ANODIC

8.1.2.3 Crevice Corrosion. Crevice corrosion is a very intense form of corrosion that is localized within a small crevice or shielded area. Crevice corrosion typically develops in gasketed surfaces, within lap joints, under sludge deposits, or under bolt heads. The crevice must be wide enough to permit the fluid to enter but small enough to create a stagnant condition.

Metals that rely on oxide films for their corrosion resistance (stainless steels and aluminum) are prone to developing crevice corrosion. If chlorides are present in the wastewater (possible in WWTPs near sea-coast installations), they will tend to accelerate breakdown of the oxide film and lead to crevice corrosion. The use of Type 316 stainless steel instead of Type 304 will provide improved resistance to chloride-initiated crevice corrosion.

Prevent or minimize crevice corrosion using the following techniques:

a) Use welded connections instead of bolted connections.

b) Use continuous welds instead of stitch welds.

c) Do not allow solids to settle out in vessels.

d) Use gaskets that do not wick or absorb fluids.

e) For buried structures, provide uniform, clean backfill material.

8.1.2.4 Pitting Corrosion. This form of corrosion is extremely localized and is very destructive because a deceptively small area of the metal surface is corroded. However, pitting corrosion can penetrate the metal wall and lead to leaks. Pitting corrosion is difficult to predict because the conditions that initiate pitting may not always be present (they may be intermittent or may suddenly arise). The rate of material loss in the pit generally increases as the pitting continues, causing pit depth to increase rapidly. Pitting corrosion is more easily initiated in stagnant or low-flow conditions. Often pitting will develop under deposits that settle in the bottoms of pipes and tanks or under material that may be splashed onto a surface. Pitting corrosion will also occur at holidays (holes) in protective coatings.

Metals that rely on oxide films for their corrosion resistance (stainless steels and aluminum) are prone to developing pitting corrosion. In WWTPs, stainless steel or aluminum slide gates, handrails, or other components often develop pits, which initiate under a deposit. If chlorides are present in the wastewater (possible in WWTPs near sea-coast installations), they will tend to accelerate breakdown of the oxide film and lead to pitting corrosion. The use of Type 316 stainless steel instead of Type 304 will provide improved resistance to chloride-initiated pitting corrosion.

8.1.2.5 Intergranular Corrosion. Intergranular corrosion is not usually encountered in the environments typically found in WWTPs. Under certain conditions, the corrosion experienced will be concentrated at the grain boundaries of the metal rather than uniformly across the surface. Grain boundaries most commonly become more sensitive to corrosion because of welding during fabrication. For this reason, intergranular corrosion may also be called weld decay, weld attack, weld corrosion, or corrosion of the heat-affect zone.

Intergranular corrosion often occurs with stainless steels, which develop sensitized areas around the welds because of depletion of one of the alloying elements in the stainless steel. The use of the low-carbon grade of stainless steel (i.e., Type 304L or Type 316L) will usually control this problem. Other methods include heat-treatment after fabrication or with the use of stabilized stainless steels. Intergranular corrosion usually occurs in very aggressive environments that are not commonly found in WWTPs.

8.1.2.6 Selective Leaching. Selective leaching is the removal of one element from a solid alloy by the corrosion process. The results are unusual because the corroded metal may not show any obvious signs of corrosion. Brass alloys are composed primarily of zinc and copper. Selective corrosion of the zinc from the alloy (dezincification) will cause areas of the alloy to take on a red, coppery color in contrast to the yellow color of the brass. The result is a weak, porous, and brittle material. Brasses containing more than 85 percent copper are resistant to this form of corrosion.

Cast iron and, to a lesser degree, ductile iron sometimes show the effects of selective leaching, called graphitization. This is the result of selective leaching of the iron matrix in the cast iron, leaving a weak, brittle, graphite structure. This type of corrosion is often seen with buried or submerged pipelines, sluice gates, and other cast structures in a WWTP. Graphitization can be readily detected by a soft graphite structure that can be cut with a knife. The use of protective coatings and cathodic protection easily controls this form of corrosion.

8.1.2.7 Erosion Corrosion. Erosion corrosion is usually the result of movement between a corrosive media and a metal surface. Most metals are susceptible to erosion corrosion, depending upon their critical velocity. If particles are entrained in the fluid stream (grit streams or sludge streams), erosion corrosion will be accelerated. Typical locations for erosion corrosion are areas of higher velocities, such as:

a) Piping systems, especially at elbows and tees

b) Across valves, especially throttling valves

c) Pumps

d) Propellers, mixers, impellers

e) Orifices and nozzles

f) Inlets to heat exchanger tubes

Other forms of erosion corrosion are fretting corrosion and cavitation. Control erosion corrosion by minimizing the velocities of fluids, selecting materials that are more resistant, or providing special coatings (such as hard-facing metals or ceramics) or rubber linings.

8.1.2.8 Stress Corrosion. This type of corrosion has a number of different names: stress corrosion cracking (SCC), chloride stress cracking (CSC), caustic embrittlement, and season cracking. Stress cracking failures can be very sudden, dramatic, and serious, partly because there are often no outward signs of failure. Stress corrosion occurs under tensile stress in a corrosive environment. The stresses can be applied stresses, residual stresses (from fabrication), thermal stresses, or localized stresses from welding operations. With stainless steels, chlorides can be an initiator; with carbon steel, sodium hydroxide can initiate failure (caustic embrittlement).

Prevent stress corrosion by providing stress relief, using more resistant materials, applying cathodic protection, or using inhibitors. Corrosion fatigue is another form of stress corrosion that occurs after repeated, cyclic stresses. In WWTPs, stress corrosion can occur in sodium hydroxide facilities or in incinerator units without proper stress relief.

8.2 Control and Minimization of Corrosion. With a basic understanding of electrochemical corrosion, it is easier to understand how various methods of corrosion control work. One of the primary methods to control corrosion is to isolate the structure from its environment (electrolyte) by applying protective coating systems (the terms “coating” and “painting” will be used interchangeably in this document; both refer to high-performance products). However, even with a high-quality coating system, some deficiencies can exist, requiring the application of cathodic protection to certain structures. The combination of good protective coatings and adequate cathodic protection can provide good, long-term performance in the aggressive environment of a WWTP.

8.2.1 Protective Coatings. The most important component of a coating is the vehicle, or organic polymer base. This is the material that forms the continuous film over the substrate and protects against corrosion. Common polymer bases include alkyd, epoxy, polyurethane, acrylic, and silicone. These vehicles may be modified with other materials to form combinations, such as coal-tar epoxy. See MIL-HDBK-1110, Paints and Protective Coatings for Facilities, for more information on selection and application of protective coatings.

When dealing with coating systems in an existing WWTP, it is very important to know the generic vehicle type used in the coating. Compatibility between coatings is critical. Incompatible coatings can lead to failures. Generic coatings commonly used in WWTP include the following:

a) Coal-tar Epoxy. Used extensively in immersion applications in wastewater and mild chemical exposures, coal-tar epoxy is generally considered to be a self-priming material, applied in two coats of 8 mils (0.008 inches) each.

b) Polyamide Epoxy. Available as a primer, intermediate, or finish coats, Polyamide epoxy is used in more aggressive environments. Primers are generally about 2 mils thick; intermediate coats may be 4 to 6 mils thick; finish coats 2 to 4 mils thick. Epoxy coatings tend to chalk when exposed to sunlight.

c) Polyurethane. Polyurethane is an excellent, hard coating that has very good color and gloss retention. It is used extensively over epoxy primers and is suitable in all but the most aggressive environments.

d) Alkyd. This excellent coating system has been used for many years on original equipment. Alkyd coating can work in many areas of a WWTP, but not in immersion, high humidity environments, or in exposures to strong alkalis, such as sodium hydroxide or lime.

When selecting coatings, consider the entire system, which includes surface preparation, prime coat, and intermediate and finish coats. Good surface preparation is critical for a successful coating application and good performance. However, when dealing with existing surfaces, compromises may be required.

8.2.1.1 Surface Preparation. The preparation of the surface is the most important variable in good coating performance. Whenever an existing coating system has failed significantly, it is recommended that the surface be cleaned to bare metal. Recoating of an existing painted surface will require cleaning to remove all surface contamination plus roughing of the surface to achieve a good bond of the new coating application.

Excellent guides for surface preparation are available from MIL-HDBK-1110 and the Steel Structures Painting Council (SSPC). Table 13 summarizes the SSPC Surface Preparation Standards. These standards should be followed for all surface preparation of metal substrates that are to be painted. In addition to surface cleanliness, the surface profile (roughness) must also be specified. Refer to the coating manufacturer's requirements for the specific profile.

Although the SSPC standards are specifically addressed to steel substrates, some of the standards are commonly used for concrete substrates. SSPC SP12 specifically is not limited to steel.

Table 13
Surface Preparation Standards

Designation	Title	Typical Uses
SSPC SP1	Solvent Cleaning	For all surfaces
SSPC SP2	Hand Tool Cleaning	Where abrasive blasting not permitted
SSPC SP3	Power Tool Cleaning	Where abrasive blasting not permitted
SSPC SP5	White Metal Blast Cleaning	For immersion service
SSPC SP6	Commercial Blast Cleaning	Noncritical areas
SSPC SP7	Brush-Off Blast Cleaning	New concrete
SSPC SP8	Pickling	For hot dip galvanized
SSPC SP10	Near-White Blast Cleaning	Non-immersion, but critical service
SSPC SP11	Power Tool to Bare Metal	Special, non-immersion
SSPC SP12	High- and Ultrahigh-Pressure Water Jetting	General clean-up; existing concrete

8.2.1.2 Coating Systems for Metals. Maintenance of coating systems in WWTPs depends upon a number of factors: 1) knowing the specific coating systems that currently exist within the plant; 2) implementing an active inspection program; and 3) providing a good maintenance painting program. Maintenance painting operations are different than new construction painting operations. With a proper maintenance painting program, total recoating is generally unusual rather than normal.

Inspection of all coating surfaces should be performed routinely. Be observant for the first signs of coating breakdown, such as rust staining and streaking, blistering of coating, peeling of coating, and other signs of deterioration. Coatings on steel substrates will generally show the first signs of failure at sharp edges, such as edges of structural steel, adjacent to welds, and around threads of bolts and edges of nuts. Failures on flat surfaces take much longer to develop. In immersion service, coating failures also develop first at edges but can also develop on flat surfaces because of imperfections and defects. Linings in tanks and vessels are especially critical.

8.2.1.3 Coating Systems for Concrete. Coating concrete surfaces for merely cosmetic purposes should be discouraged because of increased maintenance costs. The coating systems for concrete surfaces in contact with liquids should be coal-tar epoxy or polyamide epoxy. Maintenance of coating systems on concrete substrates generally follows the general procedures used on steel substrates. However, breakdown of coatings on concrete can lead to absorption of the fluids into the concrete substrate, making surface preparation more difficult. In addition, minor defects in the coating do not develop rust staining, as they do on steel substrates. Therefore, it is more critical to maintain a regular inspection program.

Most chemical storage areas will have concrete containment walls to contain potential spills of the tank contents. These containment surfaces must be coated with a suitable coating system capable of withstanding the spilled chemical. Most monolithic (bonded) coatings will mirror any cracks that may develop in the concrete. Visually inspect these areas to detect any leaks of spills through the concrete.

8.2.1.4 Coating Application. High-quality coatings can usually be applied using the most common coating techniques:

a) Brush application

b) Roller application

c) Conventional spray application

d) Airless spray application

e) Trowel application (often for floor coatings)

Because most coating systems are complex, the mixing and application of coatings requires considerable experience. It is generally recommended that coating application be left to qualified applicators.

Routine maintenance can be performed before coating failures reach the point of requiring major repainting by an outside contractor. With regular inspection, touch-up of damaged coatings can be performed using the appropriate, compatible coating system. Generally, adequate surface preparation can be accomplished with power or hand tools (SSPC SP2, SSPC SP3, or SSPC SP11). Surfaces should also be washed to remove any surface contamination. Application of touch-up paint can best be accomplished by brush or roller. The newly applied paint should carry over onto the sound, old painted surfaces. The coating manufacturer or his or her representative can provide recommendations and guidelines for mixing and applying the coatings.

8.2.2 Cathodic Protection. Cathodic protection systems are generally provided for all critical equipment. Often this equipment includes buried pipelines. Cathodic protection may also be used on submerged equipment, such as clarifier rake mechanisms. Cathodic protection provides additional corrosion protection, supplementing the normal protection offered by protective coating systems. Refer to MIL-HDBK-1004/10.

Cathodic protection systems generally require a certain amount of maintenance to ensure that the systems continue to operate at design levels. O&M personnel need to be aware of any cathodic protection systems at the WWTP. MIL-HDBK-1136, Cathodic Protection Operations and Maintenance, provides specific procedures that must be followed.

8.2.3 Materials of Construction. Much of a typical WWTP consists of cast-in-place concrete structures. With a few exceptions, concrete performs well in the environments associated with WWTPs. Other common construction materials also do well but require careful selection and maintenance to achieve long-term service life. The wastewater associated with treatment plants is usually not extremely aggressive, unless the facility receives wastewater from certain industrial operations. However, hydrogen sulfide is everpresent and must be recognized, especially in the vapor areas above the wastewater surface. The wastewater surface line in steel tanks is typically one of the first areas to become susceptible to corrosion. Where the wastewater is agitated or falls over weirs, hydrogen sulfide is released. Any condensate formed will be very acidic and therefore aggressive to concrete and unprotected carbon steel.

Perform regular inspection of the concrete and steel surfaces in these aggressive areas and take appropriate action when significant corrosion becomes evident. Corrosion of metal surfaces usually occurs faster than on concrete surfaces and corrective action should be performed as soon as possible. In the case of concrete, the application of protective coatings is usually required. For metals, use of protective coatings, application of cathodic protection, or replacement with more resistant metals may be appropriate.

8.2.3.1 Metals. The following metals are used extensively in WWTPs:

a) Ductile iron pipe, both lined (cement-mortar) and unlined. Coatings and cathodic protection may or may not be required.

b) Steel pipe, generally lined with coal-tar epoxy. Buried steel pipe usually requires external coatings, supplemented with cathodic protection.

c) Carbon steel structural. Always requires protective coatings.

d) Aluminum used in most atmospheric exposures, such as ladders, grating, handrails, and covers. Protective coatings are normally not required.

e) Stainless steels, usually Type 304 or Type 316. If there are high chlorides in the wastewater, Type 316 is usually required. If considerable fabrication is involved, specify the low-carbon (L-grade) stainless steel. Coatings are generally not required, unless the steel is buried.

f) Stainless steel fasteners, preferred because a WWTP’s environment is wet and corrosive.

8.2.3.2 Nonmetals. Most nonmetals may be used with success in nearly all areas of a WWTP. In addition to concrete, plastic materials, such as thermal plastics and thermal-sets, are used extensively. Such materials as polyvinylchloride (PVC), chlorinated polyvinylchloride (CPVC), polyethylene (PE), and fiberglass-reinforced plastics (FRP) are used in many applications.

From a maintenance standpoint, the nonmetallic materials require different skills to install, maintain, and repair. PVC and CPVC are joined with special cements, PE is joined usually by heat fusion, and FRP is joined with reinforced resin layup. Maintenance of PVC, CPVC, and FRP can usually be performed by in-plant crews. Repair of PE requires special tooling that is not usually available onsite.

Section 9: Chemical shipping and feeding

9.1 Sources of Information. Process chemicals used in wastewater treatment vary greatly in their specific requirements for safe storage and handling. Several industrial associations, including the Chlorine Institute, the National Lime Association, the Manufacturing Chemists Association, and the National Fire Protection Association (NFPA) provide information for operators. In addition, chemical manufacturers will supply handbooks and material safety data sheets (MSDSs) for specific process chemicals upon request.

Table 14 provides information about various chemicals commonly used at WWTPs, including their common names, formulas, and most common uses. It also covers the forms and containers in which they are usually obtained commercially and general characteristics of the chemicals. Table 15 presents information about feeding these chemicals, including the most common forms for feeding, the amount of water needed for continuous dissolving, types of feeders, handling equipment, and appropriate materials for storage and handling.

Table 14
Chemical Shipping Data and Characteristics

Chemical	Shipping Data		Characteristics			
Common Name/ Formula/ Use	Grades or Available Forms	Containers and Requirements	Appearance and Properties	Weight lb/cu ft (Bulk Density)	Commercial Strength	Solubility in Water gm/100 mL[1]
ALUM: $A1_2(SO_4)_3 \cdot XH_2O$ Liquid 1 gal 36°Be = 5.38 lb of dry alum: 60°F Coag. at pH 5.5 to 8.0 Sludge conditioner Precipitate PO_4	Soln. 32.2°Be to 37°Be	Manufactured near site 6,000: 8,000 gal steel T/C 2,000 to 4,000 gal rubber-lined steel tank trucks High freight cost precludes distant shipment	Light green to light brown soln. F.P. or crystallization point for: 35.97°Be = 4°F 36.95°Be = 27°F 37.7°Be = 60°F 1% soln.: pH 3.4 Visc. 36°Be at 60°F = 25 cp	36°Be sp.g. = 1.33 or 11.1 lb/gal at 60°F	At 60°F 32.2°Be: 7.25% Al_2O_3 35.97°Be: 8.25% Al_2O_3 37°Be: 8.5% Al_2O_3	Completely miscible
ALUMINUM SULFATE: $A1_2(SO_4)3 \cdot 14H_2O$ (Alum, filter alum) Coagulation at pH 5.5 to 8.0 Dosage between 0.5 to 9 gpg Precipitate PO_4	Lump Granular Rice Ground Powder	Bags: 100 & 200 lb Bbl.: 325 & 400 lb Drums: 25, 100, & 250 lb Bulk: C/L	Light tan to gray-green Dusty, astringent Only slightly hygroscopic 1% soln.: pH 3.4	60 to 75 (powder is lighter) To calculate hopper capacities, use 60	98% plus or 17% Al_2O_3 (minimum)	72.5 at 0°C 78.0 at 10°C 87.3 at 20°C 101.6 at 30°C
AMMONIA ANHYDROUS: NH_3 (Ammonia) Chlorine-ammonia treatment Anaerobic digestion Nutrient	Colorless liquified gas	Steel cylinders: 50, 100, 150 lb T/C: 50,000 lb Green gas label	Pungent, irritating odor Liquid causes burns F.P. is -107.9°F B.P. is -28°F sp.g. (gas) 0.59 at 70°C and 1 atm MCA warning label Visc. liquid = 0.27 cps at 33°C	sp.g. of liquid is 0.68 at -28°F	99 to 100% NH_3	89.9 at 0°C 68.0 at 10°C 57.5 at 20°C 47.7 at 30°C

Table 14 (Continued)

Chemical Shipping Data and Characteristics

Chemical	Shipping Data		Characteristics			
Common Name/ Formula/ Use	Grades or Available Forms	Containers and Requirements	Appearance and Properties	Weight lb/cu ft (Bulk Density)	Commercial Strength	Solubility in Water gm/100 mL[1]
AMMONIA, AQUA: NH_4OH (Ammonium hydroxide, ammonia water, ammonium hydrate) Chlorine-ammonia treatment pH control Nutrient	Technical Certified pure Solution 16°Be 20°Be 26°Be	Carboys: 5 & 10 gal Drums: 375 & 750 lb T/C: 8,000 gal	Water white soln. Strongly alkaline Causes burns Irritating vapor Unstable; store in cool place and tight container MCA warning label Vent feeding systems	At 60°F 26°Be Sp.g. 0.8974	16°Be 10.28% NH_3 20°Be 17.76% NH_3 26°Be 29.4% NH_3	Completely miscible
CALCIUM HYDROXIDE: $Ca(OH)_2$ (Hydrated lime, slaked lime) Coagulation, softening pH adjustment Waste neutralization Sludge conditioning Precipitate PO_4	Light powder Powder	Bags: 50 lb Bbl: 100 lb Bulk: C/L (store in dry place)	White 200 to 400 mesh powder Free from lumps Caustic, irritant, dusty Sat. soln.: pH 12.4 Absorbs H_2O and CO_2 from air to revert back to $CaCO_3$ 10% slurry: 5 to 10 cps Sp.g. = 1.08	20 to 30 and 30 to 50 To calcu-late hopper capacity, use 25 or 35	$Ca(OH)_2$ 82 to 95% CaO 62 or 72%	0.18 at 0°C 0.16 at 20°C 0.15 at 30°C

Table 14 (Continued)

Chemical Shipping Data and Characteristics

Chemical	Shipping Data		Characteristics			
Common Name/ Formula/ Use	Grades or Available Forms	Containers and Requirements	Appearance and Properties	Weight lb/cu ft (Bulk Density)	Commercial Strength	Solubility in Water gm/100 mL[1]
CALCIUM HYPOCHLORITE: $Ca(OCl)_2 \cdot 4H_2O$ (H.T.H., Perchloron, Pittchlor) Disinfection Slime control Deodorization	Granules Powder Pellets	Bbl: 415 lb Cans: 5, 15, 100, 300 lb Drums: 800 lb (store dry and cool and avoid contact with organic matter)	White or yellowish white Hygroscopic corrosive Strong chlorine odor (Alkaline pH) Yellow label—oxidizing agent	Granules 68 to 80 Powder 32 to 50	70% avail. Cl_2	21.88 at 0°C 22.7 at 20°C 23.4 at 40°C
CALCIUM OXIDE: CaO (Quicklime, burnt lime, chemical lime, unslaked lime) Coagulation Softening pH adjustment Waste neutralization Sludge conditioning Precipitate PO_4	Pebble Lump Ground Pulverized Pellet Granules Crushed	Moisture-proof bags: 100 lb Wood barrel Bulk: C/L (store dry: max. 60 days and keep container closed)	White (light gray, tan) lumps to powder Unstable, caustic, irritant Slakes to hydroxide slurry evolving heat Air slakes to form $CaCO_3 \cdot$sat. Soln. pH is 12.4	55 to 70 To calculate hopper capacity, use 60 Pulv. is 43 to 65	70 to 96% CaO (below 85% can be poor quality)	Reacts to form $CA(OH)_2$ See $CA(OH)_2$ above[2]
CARBON, ACTIVATED: C (Nuchar, Norit, Darco, Carbodur) Decolorizing, taste and odor removal Dosage between 5 and 80 ppm	Powder Granules	Bags: 35 lb (3 x 21 x 39 in) Drums: 5 lb & 25 lb Bulk: C/L	Black powder, about 400 mesh Dusty, smoulders if ignited Arches in hoppers; floodable[3] Do not mix with $KMnO_4$, hypo-chlorite, or CaO; pH varies	Powder 8 to 28 (avg. 12)	10% C (bone charcoal) to 90% C (wood charcoal)	Insoluble forms a slurry

Table 14 (Continued)

Chemical Shipping Data and Characteristics

Chemical	Shipping Data		Characteristics			
Common Name/ Formula/ Use	Grades or Available Forms	Containers and Requirements	Appearance and Properties	Weight lb/cu ft (Bulk Density)	Commercial Strength	Solubility in Water gm/100 mL[1]
CHLORINE: Cl_2 (Chlorine gas, liquid chlorine) Disinfection Slime control Taste and odor control Waste treatment Activation of silica[4]	Liquefied gas under pressure	Steel cylinders: 100 & 150 lb Ton containers T/C: 15-ton containers T/C: 16, 30, 55 tons Green label	Greenish-yellow gas liquefied under pressure Pungent, noxious, corrosive gas heavier than air Health hazard	sp.g. with respect to air = 2.49	99.8% Cl_2	0.98 at 10°C 0.716 at 20°C 0.57 at 30°C
CHLORINE DIOXIDE: ClO_2 Disinfection Taste and odor control (especially phenol) Waste treatment 0.5 to 5 lb $NaClO_2$ per million gal H_2O dosage	Generated as used from Cl_2 and $NaClO_2$ or from NaOCl plus acid Dissolved as generated	26.3% avail. Cl_2	Yellow solution when generated in water Yellow-red gas Unstable, irritating, poisonous, explosive Keep cool, keep from light	-----	Use 2 lb of $NaCl0_2$ to 1 lb of Cl_2, or equal conc. of $NaClO_2$ and NaOCl plus acid (max. 2% each plus diln. water)	0.29 at 21°C
FERRIC CHLORIDE: $FeCl_3$ - anhydrous $FeCl_3$ - $6H_2O$ = crystal $FeCl_3$ - solution (Ferrichlor, chloride or iron) Coagulation pH 4 to 11 Dosage: 0.3 to 3 gpg (sludge cond. 1.5 to 4.5% $FeCl_3$) Precipitate PO_4	Solution Lumps-sticks (crystals) Granules	Solution Carboys: 5, 13 gal Truck, T/C Crystal Keg: 100, 400, 450 lb Drums: 150, 350, 630 lb	Solution Dark brown syrup Crystals Yellow-brown lumps Anhydrous Green, black Very hygro-scopic, staining, corrosive in liquid form 1% soln.: pH 2.0	Solution 11.2 to 12.4 lb Crystal 60 to 64 Anhydrous 45 to 60	Solution 35 to 45% $FeCl_3$ Crystal 60% $FeCl_3$ Anhydrous 96 to 97% $FeCl_3$	Solution Completely miscible Crystals 91.1 at 20°C Anhydrous 74.4 at 0°C

Table 14 (Continued)

Chemical Shipping Data and Characteristics

Chemical	Shipping Data		Characteristics			
Common Name/ Formula/ Use	Grades or Available Forms	Containers and Requirements	Appearance and Properties	Weight lb/cu ft (Bulk Density)	Commercial Strength	Solubility in Water gm/100 mL[1]
FERRIC SULFATE: $Fe_2(SO_4)_3 \cdot 3H_2O$ (Ferrifloc) $Fe_2(SO_4)_3 \cdot 2H_2O$ (Ferriclear) (Iron sulfate) Coag. pH 4-6 & 8.8-9.2 Dosage: 0.3 to 3 gpg Precipitate PO_4	Granules	Bags: 100 lb Drums: 400 & 425 lb Bulk: C/L	$2H_2O$, red brown $3H_2O$, red gray Cakes at high RH Corrosive in soln. Store dry in tight containers Stains	70 to 72	$\underline{3H_2O}$ 68% $Fe_2(SO_4)_3$ 18.5% Fe $\underline{2H_2O}$ 76% $Fe_2(SO_4)_3$ 21% Fe	Very soluble
FERROUS SULFATE: $FeSO_4 \cdot 7H_2O$ (Copperas, iron sulfate, sugar sulfate, green vitroil) Coagulation at pH 8.8 to 9.2 Chrome reduction in waste treatment Sewage odor control Precipitate PO_4	Granules Crystals Powder Lumps	Bags: 100 lb Bbl: 400 lb Bulk	Fine greenish crystals M.P. is 64°C Oxidizes in moist air Efflorescent in dry air Masses in storage at higher temp. Soln. is acid	63 to 66	55% $FeSO_4$ 20% Fe	32.8 at 0°C 37.5 at 10°C 48.5 at 20°C 60.2 at 30°C
HYDROGEN PEROXIDE: H_2O_2 Odor control	Soln. 35% & 50%	4,000 and 8,000 gal T/C and 4,000 T/T	Clear, colorless liquid at all concentrations F.P. for 50% = -40°C	For 35%, sp.g. = 1.13 or 9.4 lb/gal For 50%, sp.g. = 1.20 or 10.0 lb/gal	For 35%, 396 g/L H_2O_2 or 16.5% O_2 For 50%, 598 g/L H_2O_2 or 23.5% O_2	Completely miscible
METHANOL: CH3•OH Wood alcohol denitrification	Liquid	Drums, bulk	Clear, colorless liquid at all concentrations	For 100%, sp.g. @ 20°C = 0.7917	99%	Completely miscible

Table 14 (Continued)
Chemical Shipping Data and Characteristics

Chemical	Shipping Data		Characteristics			
Common Name/ Formula/ Use	Grades or Available Forms	Containers and Requirements	Appearance and Properties	Weight lb/cu ft (Bulk Density)	Commercial Strength	Solubility in Water gm/100 mL[1]
OZONE: O_3 Taste and odor control Disinfection Waste treatment Odor: 1 to 5 ppm Disinfection: 0.5 to 1 ppm	Gas Liquid	Generated at site by action of electric discharge through dry air: 0.5 to 1% produced	Colorless-bluish gas or blue liquid Toxic: do not breathe Explosive Fire hazard Keep from oil or readily combustible materials	Density of gas is 2.1 gm/L Liquid sp.g. is 1.71 at -183°C.	1 to 2%	49.4 cc at 0°C
PHOSPHORIC ACID, ORTHO: H_3PO_4 Boiler water softening Alkalinity reduction Cleaning boilers Nutrient feeding	50, 75, 85, 90% Anhydrous Commercial Technical Food N.F.	Bottles: 1 to 5 lb; 5, 6-1/2, 13 gal Carboys: 55-gal drums & barrels Tank cars and trucks	Clear, colorless liquid F.P. (50%) is 35°C B.P. (50%) is 108°C pH (0.1N) is 1.5 15 to 30 cp viscosity according to % Avoid skin contact MCA warning label Can form H_2 with some metals	50% 11.2 lb/gal 75% 13.3 lb/ gal 85% 14.1 lb/gal	50, 75, and 85% conc.	Liquid miscible with water in all proportions
POLYMERS, DRY[5] High M.W. synthetic polymers	Powdered, flaky granules	Multiwall paper bags	White flake powder pH varies	27 to 35	----	Colloidal solution

Table 14 (Continued)
Chemical Shipping Data and Characteristics

Chemical	Shipping Data		Characteristics			
Common Name/ Formula/ Use	Grades or Available Forms	Containers and Requirements	Appearance and Properties	Weight lb/cu ft (Bulk Density)	Commercial Strength	Solubility in Water gm/100 mL[1]
POLYMERS, LIQUID AND EMULSIONS[5] High M.W. synthetic polymers Separan NP10 potable grade, Magnifloc 990; Purifloc N17 Ave. Dosage: 0.1 to 1 ppm	----	Drums, bulk	Viscose liquid	Liquid: 20 to 5,000 cp at 70°F Emulsions: 200 to 700 cp at 70°F	----	Colloidal solution
POTASSIUM PERMANGANATE: $KMnO_4$ Cairox Taste odor control 0.5 to 4.0 ppm Removes Fe and Mn at a 1-to-1 ratio	Crystal	U.S.P. 25-,110-,125-lb steel keg Technical 25-,110-,600-lb steel drum	Purple crystals sp.g.: 2.7 Decomposes 240°C Can cake up at high relative humidity Strong oxidant Toxic Keep from organics Yellow label	86 to 102	Tech. is 97% minimum Reagent is 99% minimum	2.8 at 0°C 3.3 at 10°C 5.0 at 20°C 7.5 at 30°C
SODIUM ALUMINATE: $Na_2Al_2O_4$, anhy. (soda alum) Ratio Na_2O/Al_2O_3 1/1 or 1.15/1 (high purity) Also $Na_2Al_2O_4 \cdot 3H_2O$ hydrated form Coagulation Boiler H_2O treatment	Ground (pulv.) Crystals Liquid, 27°Be Hydrated Anhydrous	Ground bags: 50-, 100-lb drums Liquid drums	High purity white Standard gray Hygroscopic Aq. soln. is alkaline Exothermic heat of solution	High purity 50 Std. 60	High Purity Al_2O_3 45% $Na_2Al_2O_4$ 72% Standard Al_2O_3 55% $Na_2Al_2O_4$ 88 to 90%	Hydrated 80 at 75°F Std. 6 to 8% insolubles Anhy. 3/gal at 60°F

Table 14 (Continued)
Chemical Shipping Data and Characteristics

Chemical	Shipping Data		Characteristics			
Common Name/ Formula/ Use	Grades or Available Forms	Containers and Requirements	Appearance and Properties	Weight lb/cu ft (Bulk Density)	Commercial Strength	Solubility in Water gm/100 mL[1]
SODIUM BICARBONATE: $NaHCO_3$ (baking soda) Activation of silica pH adjustment	U.S.P. C.P. Commercial Pure Powder Granules	Bags: 100 lb Bbl: 112, 400 lb Drums: 25 lb Kegs	White powder Slightly alkaline 1% soln.: pH 8.2 Unstable in soln. (de- composes into CO_2 and Na_2CO_3) Decomposes 100°F	59 to 62	99% $NaHCO_3$	6.9 at 0°C 8.2 at 10°C 9.6 at 20°C 10.0 at 30°C
SODIUM BISULFITE, ANHYDROUS: $Na_2S_2O_5$ ($NaHSO_3$) (Sodium pyrosulfite, sodium meta- bisulfite) Dechlorination: about 1.4 ppm for each ppm $C1_2$ Reducing agent in waste treatment (as Cr)	Crystals Crystals plus powder Solution (3.25 to 44.9%)	Bags: 100 lb Drums: 100 & 400 lb	White to slight yellow Sulfurous odor Slightly hygroscopic Store dry in tight container Forms $NaHSO_3$ in soln. 1% soln.: pH 4.6 Vent soln. tanks	74 to 85 and 55 to 70	97.5 to 99% $Na_2S_2O_5$ SO_2 65.8%	54 at 20°C 81 at 100°C
SODIUM CARBONATE: Na_2CO_3 (Soda ash: 58% Na_2O) Water softening pH adjustment	Dense granules Med. gran. and pwd. Light powder	Bags: 100 lb Bbl: 100 lb Drums: 25 & 100 lb Bulk: C/L	White, alkaline Hygroscopic: can cake up 1% soln.: pH 11.2	Dense 65 Medium 40 Light 30	99.2% Na_2CO_3 58% Na_2O	7.0 at 0°C 12.5 at 10°C 21.5 at 20°C 38.8 at 30°C

Table 14 (Continued)

Chemical Shipping Data and Characteristics

Chemical	Shipping Data		Characteristics			
Common Name/ Formula/ Use	Grades or Available Forms	Containers and Requirements	Appearance and Properties	Weight lb/cu ft (Bulk Density)	Commercial Strength	Solubility in Water gm/100 mL[1]
SODIUM CHLORITE: $NaClO_2$ (Technical sodium chlorite) Disinfection, taste, and odor control Ind. waste treatment (with Cl_2 produces ClO_2)	Powder Flakes Crystals (tech. and analyt-ical) Soln. (about 40%) crystal-lizes about 95°F	Drums: 100 lb (do not let $NaClO_2$ dry out on combustible materials)	Tan or white crystals or powder Hygroscopic Poisonous Powerful oxidizing agent Explosive on contact with organic matter Store in metal containers only Oxidizer Liquid: white label Solid: yellow label	65 to 75	Technical 81% 78% (minimum) 124% avail. Cl_2 Anal. 98.5% 153% avail. Cl_2	34 at 5°C 39 at 17°C 46 at 30°C 55 at 60°C
SODIUM HYDROXIDE: $NaOH$ (Caustic soda, soda lye) pH adjustment, neutralization	Flakes Lumps Powder Solution	Drums: 25, 50, 350, 400, 700 lb Bulk: Solution in T/C Liquid White label	White flakes, granules, or pellets Deliquescent, caustic poison Dangerous to handle 1% soln.: pH 12.9 50% soln. will crystallize at 54°F	Pellets 60 to 70 Flakes 46 to 62	Solid 98.9% NaOH 74.76% Na_2O Solution 12 to 50% NaOH	42 to 0°C 51.5 at 10°C 109 at 20°C 119 at 30°C

Table 14 (Continued)

Chemical Shipping Data and Characteristics

Chemical	Shipping Data		Characteristics			
Common Name/ Formula/ Use	Grades or Available Forms	Containers and Requirements	Appearance and Properties	Weight lb/cu ft (Bulk Density)	Commercial Strength	Solubility in Water gm/100 mL[1]
SODIUM HYPOCHLORITE: NaOCl (Javelle water, bleach liquor, chlorine bleach) Disinfection, slime control Bleaching	Solution White or yellow label	Carboys: 5 & 13 gal Drums: 30 gal Bulk: 1,300, 1,800, 2,000 gal %/T	Yellow liquid Strongly alkaline Store in cool place Protect from light and vent containers at intervals Can be stored about 60 days under proper conditions	15% 10.2 lb/gal 12.5% 10 lb/gal	15% NaOCl = 1.25 lb Cl_2/gal 12.5% NaOCl = 1.04 lb Cl_2/gal	Completely miscible
SULFUR DIOXIDE: SO_2 Dechlorination in disinfection Filter bed cleaning About 1 ppm SO_2 for each ppm Cl_2 (dechlorination) Waste treatment Cr +6 reduction	Liquified gas under pressure	Steel cylinders: 100, 150, 200 lb Green label	Colorless gas Suffocating odor Corrosive Poison Acid in solution: dissolves to form H_2SO_3	----	100% SO_2	760 mm 22.8 at 0°C 16.2 at 10°C 11.3 at 20°C 7.8 at 30°C
SULFURIC ACID: H_2SO_4 (Oil of Vitriol, Vitriol) pH adjustment Activation of silica Neutralization of alkaline wastes	Liquid 66°Be 60°Be 50°Be	Bottles Carboys: 5, 13 gal Drums: 55, 110 gal Bulk T/T, T/C White label	Syrupy liquid Very corrosive Hygroscopic Store dry and cool in tight container pH: 1.2	66°Be 15.1 lb/gal 60°Be 14.2 lb/gal	66°Be 93.2% H_2SO_4 60°Be 77.7% H_2SO_4 50°Be 62.2% H_2SO_4	Completely miscible

Table 14 (Continued)

Chemical Shipping Data and Characteristics

[1]Solubilities are generally given at four different temperatures stated in degrees Centigrade.

Temperature	Fahrenheit Equivalent
0°C	32°F
10°C	50°F
20°C	68°F
30°C	86°F

[2]Each pound of CaO will slake to form 1.16 to 1.32 lb of $CA(OH)_2$ (depending on purity) and from 2 to 12% grit.

[3]"Floodable" as used in this table with dry powder means that, under some conditions, the material entrains air and becomes "fluidized" so that it will flow through small openings, like water.

[4]For small doses of chlorine, use calcium hypochlorite or sodium hypochlorite.

[5]Information about many other coagulant aids (or flocculant aids) is available from Nalco, Calgon, Drew, Betz, North American Mogul, American Cyanamid, Dow, etc.

anhy.	anhydrous	gpg	grains per gallon
aq.	aqueous	ind.	industrial
avail.	available	max.	maximum
avg.	average	M.P.	melting point
bbl.	barrel	min.	minute
B.P.	boiling point	M.W.	molecular weight
C/L	carload	ppm	parts per million
coag.	coagulation	/	per
conc.	concentration	%	percent
cc	cubic centimeter	lb	pound
cu ft	cubic foot	lb/gal	pounds per gallon
°Be	degrees Baume(a measurement of solution	pulv.	pulverized
°C	degrees Celsius	sat.	saturated
°F	degrees Fahrenheit	soln.	solution
diln.	dilution	sp.g.	specific gravity
esp.	especially	std.	standard
F.P.	freezing point	T/C	tank car
gal	gallon	T/T	tank truck
gm	gram	wt.	weight
in.	inch		

Source: BIF Technical Bulletin Chemicals Used in Treatment of Water and Wastewater. Table modified and reproduced with permission.

Table 15
Chemical-Specific Feeding Recommendations

Feeding Recommendations					
Common Name/ Formula/ Use	Best Feeding Form	Chemical-to- Water Ratio for Continuous Dissolving[1]	Types of Feeders	Accessory Equipment Required	Suitable Handling Materials for Solutions[2]
ALUM: $A1_2(SO_4)_3 \bullet XH_2O$ Liquid 1 gal 36°Be = 5.38 lb of dry alum: 60°F Coag. at pH 5.5 to 8.0 Sludge conditioner Precipitate PO_4	Full strength under controlled temp. or dilute to avoid crystallization Minimize surface evap.: causes flow problems Keep dry alum below 50% to avoid crystallization	Dilute to between 3% and 15% according to application conditions, mixing, etc.	Solution Rotodip Plunger pump Diaphragm pump 1700 pump L-I-W	Tank gauges or scales Transfer pumps Storage tank Temperature control Eductors or dissolvers for dilution	Lead or rubber-lined tanks, Duriron, FRP[3], Saran, PVC-1, vinyl, Hypalon, Epoxy, 16 ss, Carp. 20 ss, Tyril
ALUMINUM SULFATE: $A1_2(SO_4)3 \bullet 14H_2O$ (Alum, filter alum) Coagulation at pH 5.5 to 8.0 Dosage between 0.5 to 9 gpg Precipitate PO_4	Ground, granular, or rice Powder is dusty, arches, and is floodable[4]	0.5 lb/gal Dissolver detention time 5 min. for ground (10 min. for granules)	Gravimetric Belt L-I-W Volumetric Helix Universal Solution Plunger pump Diaphragm pump 1700 pump	Dissolver Mechanical mixer Scales for volumetric feeders Dust collectors	Lead, rubber, FRP[3], PVC-1, 316 ss, Carp. 20 ss, vinyl, Hypalon Epoxy, Ni-Resist glass, ceramic, polyethylene, Tyril, Uscolite
AMMONIA ANHYDROUS: NH_3 (Ammonia) Chlorine-ammonia treatment Anaerobic digestion Nutrient	Dry gas or as aqueous soln.: see "Ammonia, Aqua"	----	Gas feeder	Scales	Steel, Ni-Resist, Monel, 316 ss, Penton, Neoprene

Table 15 (Continued)

Chemical-Specific Feeding Recommendations

Feeding Recommendations					
Common Name/ Formula/ Use	Best Feeding Form	Chemical-to-Water Ratio for Continuous Dissolving[1]	Types of Feeders	Accessory Equipment Required	Suitable Handling Materials for Solutions[2]
AMMONIA, AQUA: NH_4OH (Ammonium hydroxide, ammonia water, ammonium hydrate) Chlorine-ammonia treatment pH control Nutrient	Full strength	----	Solution L-I-W Diaphragm pump Plunger pump Bal. diaphragm pump	Scales Drum handling equipment or storage tanks Transfer pumps	Iron, steel, rubber, Hypalon, 316 ss, Tyril (room temp. to 28%)
CALCIUM HYDROXIDE: $Ca(OH)_2$ (Hydrated lime, slaked lime) Coagulation, softening pH adjustment Waste neutralization Sludge conditioning Precipitate PO_4	Finer particle sizes more efficient, but more difficult to handle and feed	Dry feed: 0.5 lb/gal max. Slurry: 0.93 lb/gal (i.e., a 10% slurry) (Light to a 20% conc. max.) (Heavy to a 25% conc. max.)	Gravimetric L-I-W Belt Volumetric Helix Universal Slurry Rotodip Diaphragm Plunger pump[5]	Hopper agitators Non-flood rotor under large hoppers Dust collectors	Rubber hose, iron, steel, concrete, Hypalon, Penton, PVC-1 No lead
CALCIUM HYPOCHLORITE: $Ca(OCl)_2 \cdot 4H_2O$ (H.T.H., Perchloron, Pittchlor) Disinfection Slime control Deodorization	Up to 3% soln. max. (practical)	0.125 lb/gal makes 1% soln. of available Cl_2	Liquid Diaphragm pump Bal. diaphragm pump Rotodip	Dissolving tanks in pairs with drains to draw off sediment Injection nozzle Foot valve	Ceramic, glass, rubber-lined tanks, PVC-1, Penton, Tyril (rm. temp.), Hypalon, vinyl, Usco-lite (rm. temp), Saran, Hastelloy C (good). No tin.

Table 15 (Continued)

Chemical-Specific Feeding Recommendations

Feeding Recommendations					
Common Name/ Formula/ Use	Best Feeding Form	Chemical-to- Water Ratio for Continuous Dissolving[1]	Types of Feeders	Accessory Equipment Required	Suitable Handling Materials for Solutions[2]
CALCIUM OXIDE: CaO (Quicklime, burnt lime, chemical lime, unslaked lime) Coagulation Softening pH adjustment Waste neutralization Sludge conditioning Precipitate PO_4	1/4 to 3/4 in. pebble lime Pellets Ground lime arches and is floodable Pulv. will arch and is floodable Soft burned, porous best for slaking	2.1 lb/gal (range from 1.4 to 3.3 lb/gal according to slaker, etc.) Dilute after slaking to 0.93 lb/gal (10%) max. slurry	Gravimetric Belt L-I-W Volumetric Universal Helix	Hopper agitator and non-flood rotor for ground and pulv. lime Recording thermometer Water proportioner Lime slaker High temperature safety cut-out and alarm	Rubber, iron, steel, concrete, Hypalon, Penton, PVC-1
CARBON, ACTIVATED: C (Nuchar, Norit, Darco, Carbodur) Decolorizing, taste and odor removal Dosage between 5 and 80 ppm	Powder: with bulk density of 12 lb/cu ft Slurry: 1 lb/gal	According to its bulkiness and wetability, a 10 to 15% solution would be the max. concen.	Gravimetric L-I-W Volumetric Helix Rotolock Slurry Rotodip Diaphragm pumps	Washdown-type wetting tank Vortex mixer Hopper agitators Non-flood rotors Dust collectors Large storage cap. for liquid feed Tank agitators Transfer pumps	316 ss, rubber, bronze, Monel, Hastelloy C, FRP[3], Saran, Hypalon

Table 15 (Continued)

Chemical-Specific Feeding Recommendations

Feeding Recommendations					
Common Name/ Formula/ Use	Best Feeding Form	Chemical-to-Water Ratio for Continuous Dissolving[1]	Types of Feeders	Accessory Equipment Required	Suitable Handling Materials for Solutions[2]
CHLORINE: Cl_2 (Chlorine gas, liquid chlorine) Disinfection Slime control Taste and odor control Waste treatment Activation of silica[6]	Gas: vaporized from liquid	1 lb to 45-50 gal or more	Gas chlorinator	Vaporizers for high capacities Scales Gas masks Residual analyzer	Anhy. liquid or gas: Steel, copper, black iron Wet gas: Penton, Viton, Hastelloy C, PVC-1 (good), silver, Tantalum Chlorinated H_2O: Saran, stoneware, Carp. 20 ss, Hastelloy C, PVC-1, Viton, Uscolite, Penton
CHLORINE DIOXIDE: ClO_2 Disinfection Taste and odor control (especially phenol) Waste treatment 0.5 to 5 lb $NaClO_2$ per million gal H_2O dosage	Solution from generator Mix discharge from chlorinizer and $NaClO_2$ solution or add acid to mixture of $NaClO_2$ and NaOCl. Use equal concentrations: 2% max.	Chlorine water must contain 500 ppm or over of Cl_2 and have a pH of 3.5 or less Water use depends on method of preparation	Solution Diaphragm pump	Dissolving tanks or crocks Gas mask	For solutions with 3% ClO_2: Ceramic, glass, Hypalon, PVC-1, Saran, vinyl, Penton, Teflon

Table 15 (Continued)
Chemical-Specific Feeding Recommendations

Feeding Recommendations					
Common Name/ Formula/ Use	Best Feeding Form	Chemical-to- Water Ratio for Continuous Dissolving[1]	Types of Feeders	Accessory Equipment Required	Suitable Handling Materials for Solutions[2]
FERRIC CHLORIDE: $FeCl_3$ - anhydrous $FeCl_3$ - $6H_2O$ = crystal $FeCl_3$ - solution (Ferrichlor, chloride or iron) Coagulation pH 4 to 11 Dosage: 0.3 to 3 gpg (sludge cond. 1.5 to 4.5% $FeCl_3$) Precipitate PO_4	Solution or any dilution up to 45% $FECl_3$ content (anhy. form has a high heat of soln.)	Anhy. to form: 45%: 5.59 lb/gal 40%: 4.75 lb/gal 35%: 3.96 lb/gal 30%: 3.24 lb/gal 20%: 1.98 lb/gal 10%: .91 lb/gal (Multiply $FeCl_3$, by 1.666 to obtain $FeCl_3.6H_2O$ at 20°C)	Solution Diaphragm pump Rotodip Bal. diaphragm pump	Storage tanks for liquid Dissolving tanks for lumps or granules	Rubber, glass, ceramics, Hypalon, Saran, PVC-1, Penton, FRP[3], vinyl, Epoxy, Hastelloy C (good to fair), Usco-lite, Tyril (Rm)
FERRIC SULFATE: $Fe_2(SO_4)_3 \cdot 3H_2O$ (Ferrifloc) $Fe_2(SO_4)_3 \cdot 2H_2O$ (Ferriclear) (Iron sulfate) Coag. pH 4-6 & 8.8-9.2 Dosage: 0.3 to 3 gpg Precipitate PO_4	Granules	2 lb/gal (range) 1.4 to 2.4 lb/gal for 20 min. detention (warm water permits shorter detention) Water insolubles can be high	Gravimetric L-I-W Volumetric Helix Universal Solution Diaphragm pump Bal. diaphragm pump Plunger pump Rotodip	Dissolver with motor-driven mixer and water control Vapor remover solution tank	316 ss, rubber, glass, ceramics, hypalon, Saran, PVC-1, vinyl, Carp. 20 ss, Penton, FRP[3], Epoxy, Tyril
FERROUS SULFATE: $FeSO_4 \cdot 7H_2O$ (Copperas, iron sulfate, sugar sulfate, green vitroil) Coag. at pH 8.8 to 9.2 Chrome reduction in waste treatment Sewage odor control Precipitate PO_4	Granules	0.5 lb/gal (dissolver detention time 5 min. minimum)	Gravimetric L-I-W Volumetric Helix Universal Solution Diaphragm pump Plunger pump Bal. diaphragm pump	Dissolvers Scales	Rubber, FRP[3], PVC-1, vinyl, Penton, Epoxy, Hypalon, Uscolite, ceramic, Carp. 20 ss, Tyril

Table 15 (Continued)
Chemical-Specific Feeding Recommendations

Feeding Recommendations					
Common Name/ Formula/ Use	Best Feeding Form	Chemical-to-Water Ratio for Continuous Dissolving[1]	Types of Feeders	Accessory Equipment Required	Suitable Handling Materials for Solutions[2]
HYDROGEN PEROXIDE: H_2O_2 Odor control	Full strength or any dilution	----	Diaphragm pump Plunger pump	Storage tank, water metering and filtration device for dilution	Aluminum, Hastelloy C, titanium, Viton, Kel-F, PTFE, CPVC
METHANOL: CH3•OH Wood alcohol denitrification	Full strength or any dilution	----	Gear pump Diaphragm pump	Storage tank	304 ss, 316 ss, brass, bronze, Carpenter 20, cast iron, Hastelloy C, buna N, EPDM, Hypalon, natural rubber, PTFE, PVDF, NORYL, Delrin, CPVC
OZONE: O_3 Taste and odor control Disinfection Waste treatment Odor: 1 to 5 ppm Disinfection: 0.5 to 1 ppm	As generated Approx. 1% ozone in air	Gas diffused in water under treatment	Ozonator	Air-drying equipment Diffusers	Glass, 316 ss, ceramics, aluminum, Teflon
PHOSPHORIC ACID, ORTHO: H_3PO_4 Boiler water softening Alkalinity reduction Cleaning boilers Nutrient feeding	50 to 75% conc. (85% is syrupy; 100% is crystalline)	----	Liquid Diaphragm pump Bal. diaphragm pump Plunger pump	Rubber gloves	316 St. (no F), Penton, rubber, FRP[3], PVC-1, Hypalon, Viton, Carp. 20 ss, Hastelloy C

Table 15 (Continued)

Chemical-Specific Feeding Recommendations

Feeding Recommendations					
Common Name/ Formula/ Use	Best Feeding Form	Chemical-to- Water Ratio for Continuous Dissolving[1]	Types of Feeders	Accessory Equipment Required	Suitable Handling Materials for Solutions[2]
POLYMERS, DRY[7] High M.W. synthetic polymers	Powdered, flattish granules	Max. conc. 1% Feed even stream to vigorous vortex (mixing too fast will retard colloidal growth) 1 to 2 hours detention	Gravimetric L-I-W Volumetric Helix Solution (Colloidal) Diaphragm pump Plunger pump Bal. diaphragm pump	Special dispersing procedure Mixer: may hang up; vibrate if needed	Steel, rubber, Hypalon, Tyril Noncorrosive, but no zinc Same as for H_2O of similar pH or according to its pH
POLYMERS, LIQUID AND EMULSIONS[7] High M.W. synthetic polymers Separan NP10 potable grade, Magnifloc 990; Purifloc N17 Ave. Dosage: 0.1 to 1 ppm	Makedown to: Liquid: 0.5% to 5% Emulsions: 0.05% to 0.2%	Varies with charge type	Diaphragm pump Plunger pump Bal. diaphragm pump	Mixing and aqueous tanks may be required	Same as dry products
POTASSIUM PERMANGANATE: KMnO4 Cairox Taste odor control 0.5 to 4.0 ppm Removes Fe and Mn at a 1-to-1 ratio	Crystals plus anticaking additive	1.0% conc. (2.0% max.)	Gravimetric L-I-W Volumetric Helix Solution Diaphragm pump Plunger pump Bal. diaphragm pump	Dissolving tank Mixer Mechanical	Steel, iron (neutral & alkaline) 316 st. PVC-1, FRP[3], Hypalon, Penton, Lucite, rubber (alkaline)

Table 15 (Continued)
Chemical-Specific Feeding Recommendations

Feeding Recommendations					
Common Name/ Formula/ Use	Best Feeding Form	Chemical-to- Water Ratio for Continuous Dissolving[1]	Types of Feeders	Accessory Equipment Required	Suitable Handling Materials for Solutions[2]
SODIUM ALUMINATE: $Na_2Al_2O_4$, anhy. (soda alum) Ratio Na_2O/Al_2O_3 1/1 or 1.15/1 (high purity) Also $Na_2A1_2O_4 \cdot 3H_2O$ hydrated form Coagulation Boiler H_2O treatment	Granular or soln. as received Std. grade produces sludge on dissolving	Dry 0.5 lb/gal Soln. dilute as desired	Gravimetric L-I-W Volumetric Helix Universal Solution Rotodip Diaphragm pump Plunger pump	Hopper agitators for dry form	Iron, steel, rubber, 316 st. s., Penton, concrete, Hypalon
SODIUM BICARBONATE: $NaHCO_3$ (baking soda) Activation of silica pH adjustment	Granules or powder plus TCP (0.4%)	0.3 lb/gal	Gravimetric L-I-W Belt Volumetric Helix Universal Solution Rotodip Diaphragm pump Plunger pump	Hopper agitators and non-flood rotor for powder, if large storage hopper	Iron & steel (dilute solns.: caution), rubber, Saran, st. steel, Hypalon, Tyril
SODIUM BISULFITE, ANHYDROUS: $Na_2S_2O_5$ ($NaHSO_3$) (Sodium pyrosulfite, sodium meta-bisulfite) Dechlorination: about 1.4 ppm for each ppm $C1_2$ Reducing agent in waste treatment (as Cr)	Crystals (do not let set) Storage difficult	0.5 lb/gal	Gravimetric L-I-W Volumetric Helix Universal Solution Rotodip Diaphragm pump Plunger pump Bal. diaphragm pump	Hopper agitators for powdered grades Vent dissolver to outside	Glass, carp. 20 ss, PVC-1, Penton, Uscolite, 316 st., FRP[3], Tyril, Hypalon

Table 15 (Continued)

Chemical-Specific Feeding Recommendations

Feeding Recommendations					
Common Name/ Formula/ Use	Best Feeding Form	Chemical-to-Water Ratio for Continuous Dissolving[1]	Types of Feeders	Accessory Equipment Required	Suitable Handling Materials for Solutions[2]
SODIUM CARBONATE: Na_2CO_3 (Soda ash: 58% Na_2O) Water softening pH adjustment	Dense	Dry feed 0.25 lb/gal for 10 min. detention time, 0.5 lb/gal for 20 min. Soln. feed 1.0 lb/gal Warm H_2O and/or efficient mixing can reduce detention time if mat. has not sat around too long and formed lumps—to 5 min.	Gravimetric L-I-W Volumetric Helix Solution Diaphragm pump Bal. diaphragm pump Rotodip Plunger pump	Rotolock for light forms to prevent flooding Large dissolvers Bin agitators for medium or light grades and very light grades	Iron, steel, rubber, Hypalon, Tyril
SODIUM CHLORITE: $NaClO_2$ (Technical sodium chlorite) Disinfection, taste, and odor control Ind. waste treatment (with Cl_2 produces ClO_2)	Soln. as received	Batch solns. 0.12 to 2 lb/gal	Solution Diaphragm Rotodip	Chlorine feeder and chlorine dioxide generator	Penton, glass, Saran, PVC-1, vinyl, Tygon, FRP[3], Hastelloy C (fair), Hypalon, Tyril
SODIUM HYDROXIDE: NaOH (Caustic soda, soda lye) pH adjustment, neutralization	Solution feed	NaOH has a high heat of soln.	Solution Plunger pump Diaphragm pump Bal. diaphragm pump Rotodip	Goggles Rubber gloves Aprons	Cast iron, steel For no contam., use Penton, rubber, PVC-1, 316 st., Hypalon

Table 15 (Continued)

Chemical-Specific Feeding Recommendations

Feeding Recommendations					
Common Name/ Formula/ Use	Best Feeding Form	Chemical-to-Water Ratio for Continuous Dissolving[1]	Types of Feeders	Accessory Equipment Required	Suitable Handling Materials for Solutions[2]
SODIUM HYPOCHLORITE: NaOCl (Javelle water, bleach liquor, chlorine bleach) Disinfection, slime control Bleaching	Solution up to 16% Available Cl_2 conc.	1.0 gal of 12.5% (avail. Cl_2) soln. to 12.5 gal of water gives a 1% avail. Cl_2 soln.	Solution Diaphragm pump Rotodip Bal. diaphragm pump	Solution tanks Foot valves Water meters Injection nozzles	Rubber, glass, Tyril, Saran, PVC-1, vinyl, Hastelloy C, Hypalon
SULFUR DIOXIDE: SO_2 Dechlorination in disinfection Filter bed cleaning About 1 ppm SO_2 for each ppm Cl_2 (dechlorination) Waste treatment Cr +6 reduction	Gas	----	Gas Rotameter SO_2 feeder	Gas mask	Wet gas: Glass, Carp. 20 ss, PVC-1, Penton, ceramics, 316 (G), Viton, Hypalon
SULFURIC ACID: H_2SO_4 (Oil of Vitriol, Vitriol) pH adjustment Activation of silica Neutralization of alkaline wastes	Soln. at desired dilution H_2SO_4 has a high heat of soln.	Dilute to any desired conc.: NEVER add water to acid but rather always add acid to water.	Liquid Plunger pump Diaphragm pump Bal. diaphragm pump Rotodip	Goggles Rubber gloves Aprons Dilution tanks	Conc.>85%: Steel, iron, Penton, PVC-1 (good), Viton 40 to 85%: Carp. 20, PVC-1, Penton, Viton 2 to 40%: Carp. 20, FRP[3], glass, PVC-1, Viton

Table 15 (Continued)
Chemical-Specific Feeding Recommendations

[1]To convert gm/100 mL to lb/gal, multiply figure (for gm/100 mL) by 0.083. Recommended strengths of solutions for feeding purposes are given in pounds of chemical per gallon of water (lb/gal) and are based on plant practice for the commercial product.

The following table shows the number of pounds of chemical to add to 1 gallon of water to obtain various percent solutions:

% Soln.	lb/gal	% Soln.	lb/gal	% Soln.	lb/gal
0.1	0.008	2.0	0.170	10.0	0.927
0.2	0.017	3.0	0.258	15.0	1.473
0.5	0.042	5.0	0.440	20.0	2.200
1.0	0.084	6.0	0.533	25.0	2.760
30.0	3.560				

[2]Iron and steel can be used with chemicals in the dry state unless the chemical is deliquescent or very hygroscopic, or in a dampish form and is corrosive to some degree.

[3]FRP, in every case, refers to the chemically resistant grade (bisphenol A+) of fiberglass reinforced plastic.

[4]"Floodable" as used in this table with dry powder means that, under some conditions, the material entrains air and becomes "fluidized" so that it will flow through small openings, like water.

[5]When feeding rates exceed 100 lb/hr, economic factors may dictate use of calcium oxide (quicklime).

[6]For small doses of chlorine, use calcium hypochlorite or sodium hypochlorite.

[7]Information about many other coagulant aids (or flocculant aids) is available from Nalco, Calgon, Drew, Betz, North American Mogul, American Cyanamid, Dow, etc.

anhy.	anhydrous	in.	inch
approx.	approximate	ind.	industrial
aq.	aqueous	L-I-W	loss in weight
avail.	available	max.	maximum
avg.	average	M.P.	melting point
bbl.	barrel	min.	minute
B.P.	boiling point	M.W.	molecular weight
C/l	carload	ppm	parts per million
coag.	coagulation	/	per
conc.	concentration	%	percent
cc	cubic centimeter	lb	pound
cu ft	cubic foot	lb/gal	pounds per gallon
CVPC	chlorinated polyvinylchloride	Proportioner	proportioning pump
°Be	degrees Baume (a measurement of solution concentration)	pulv.	pulverized
°C	degrees Celsius	PVC	polyvinyl chloride
°F	degrees Fahrenheit	sat.	saturated
diln.	dilution	soln.	solution
esp.	especially	sp.g.	specific gravity
F.P.	freezing point	std.	standard
FRP	fiberglass reinforced plastic	T/C	tank car
gal	gallon	T/T	tank truck
gm	gram	wt.	weight

Source: BIF Technical Bulletin Chemicals Used in Treatment of Water and Wastewater. Table modified and reproduced with permission.

APPENDIX A
SACRAMENTO SERIES TRAINING MANUAL CONTENTS

Operation of Wastewater Treatment Plants, Volume I

1	The Treatment Plant Operator
2	Why Treat Wastes?
3	Wastewater Treatment Facilities
4	Racks, Screens, Comminutors and Grit Removal
5	Sedimentation and Flotation
6	Trickling Filters
7	Rotating Biological Contactors
8	Activated Sludge (Package Plants and Oxidation Ditches)
9	Waste Treatment Ponds
10	Disinfection and Chlorination

Operation of Wastewater Treatment Plants, Volume II

11	Activated Sludge (Conventional Activated Sludge Plants)
12	Sludge Digestion and Solids Handling
13	Effluent Disposal
14	Plant Safety and Good Housekeeping
15	Maintenance
16	Laboratory Procedures and Chemistry
17	Applications of Computers for Plant O&M
18	Analysis and Presentation of Data
19	Records and Report Writing

Operation and Maintenance of Wastewater Collection Systems, Volume I

1	The Wastewater Collection System Operator
2	Why Collection System Operation and Maintenance?
3	Wastewater Collection Systems (Purpose, Components, and Design)
4	Safe Procedures
5	Inspecting and Testing Collection Systems
6	Pipeline Cleaning and Maintenance Methods
7	Underground Repair

Operation and Maintenance of Wastewater Collection Systems, Volume II

8	Lift Stations
9	Equipment Maintenance
10	Sewer Rehabilitation
11	Safety/Survival Programs for Collection System Operators
12	Administration
13	Organization for System Operation and Maintenance

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Industrial Waste Treatment, Volume I

1 The Industrial Plant Operator
2 Safety
3 Regulatory Requirements
4 Preventing and Minimizing Wastes at the Source
5 Industrial Wastewaters
6 Flow Measurement
7 Preliminary Treatment (Equalization, Screening, and pH Adjustment)
8 Physical-Chemical Treatment Processes (Coagulation, Flocculation and Sedimentation)
9 Filtration
10 Physical Treatment Processes (Air Stripping and Carbon Adsorption)
11 Treatment of Metal Wastestreams
12 Instrumentation

Industrial Waste Treatment, Volume II

1 The Industrial Plant Operator
2 Fixed Growth Processes (Trickling Filters and Rotating Biological Contactors)
3 Activated Sludge Process Control
4 Sequencing Batch Reactors
5 Enhanced Biological Treatment
6 Anaerobic Treatment
7 Residual Solids Management
8 Maintenance

Advanced Waste Treatment

1 Odor Control
2 Activated Sludge (Pure Oxygen Plants and Operational Control Options)
3 Residual Solids Management
4 Solids Removal from Secondary Effluents
5 Phosphorus Removal
6 Nitrogen Removal
7 Enhanced Biological (Nutrient) Control
8 Wastewater Reclamation
9 Instrumentation

Treatment of Metal Wastestreams

1 Need for Treatment
2 Sources of Wastewater
3 Material Safety Data Sheets (MSDSs)
4 Employee Right-to-Know Laws

APPENDIX A (Continued)

5 Methods of Treatment
6 Sludge Treatment and Disposal
7 Operation, Maintenance and Troubleshooting

Pretreatment Facility Inspection
1 The Pretreatment Facility Inspector
2 Pretreatment Program Administration
3 Development and Application of Regulations
4 Inspection of a Typical Industry
5 Safety in Pretreatment Inspection and Sampling Work
6 Sampling Procedures for Wastewater
7 Wastewater Flow Monitoring
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9 Pretreatment Technology (Source Control)
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APPENDIX B
Sacramento Series Cross Reference List

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Glossary of Terms	@ End of Volume	Each Manual in Series
General O&M Topics		
Analysis and Presentation of Data		OWTP, Vol. 2, Chapter 18
Records and Reports		OWTP, Vol. 2, Chapter 19
Regulatory Compliance/Mgmt.	Section 2	IWT Vol. 1, Chapter 3
Computerized O&M		OWT Vol. 2, Chapter 17
Collection Systems O&M		
Safety		O&MWCS Vol. 1, Chapter 4
Inspection and Testing		O&MWCS Vol. 1, Chapter 5
Pipeline Maintenance		O&MWCS Vol. 1, Chapter 5
Lift Station Maintenance		O&MWCS Vol. 1, Chapters 8, 9
Odor Control in Collection Systems		O&MWCS Vol. 1, Chapter 6
Grease Traps	Section 4	O&MWCS Vol. 1, Chapter 6
Treatment Operations		
Facultative Lagoons		OWTP Vol. 1, Chapter 9
Imhoff Tanks		OWTP Vol. 1, Chapter 5
Septic Tanks	Section 3	
Preliminary Treatment		
Screenings Process		OWTP Vol. 1, Chapter 4
Comminutors		OWTP Vol. 1, Chapter 4
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Secondary (Biological) Treatment		

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Overview of Activated Sludge		OWTP Vol. 2, Chapter 11
Conventional Activated Sludge		OWTP Vol. 2, Chapter 11
Extended Aeration		OWTP Vol. 2, Chapter 11
Contact Stabilization		OWTP Vol. 2, Chapter 11
Step Feed		OWTP Vol. 2, Chapter 11
Package Plants		OWTP Vol. 1, Chapter 8
Oxidation Ditches		OWTP Vol. 1, Chapter 8
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Rotating Biological Contactors		OWTP Vol. 1, Chapter 7
Sequencing Batch Reactors		AWT, Chapter 7
Aerated Stabilization Basins		OWTP Vol. 1, Chapter 9
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Combined N/P Removal		AWT, Chapter 7
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Suspended Solids Removal		AWT, Chapter 4
Chemical Phosphorous Removal		AWT, Chapter 5
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Disinfection		
Chlorination		OWTP Vol. 1, Chapter 10
UV Disinfection		OWTP Vol. 1, Appendix

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Irrigation	Section 2	AWT, Chapter 8
Rapid Infiltration Basins		AWT, Chapter 8
Underground Disposal	Section 2	
Extreme Climate O&M	Section 7	
Industrial Waste Treatment		
Industrial Waste Monitoring		IWT Vol. 1, Chapters 4, 5, 6
Acceptable Wastewater Characteristics for Biological Treatment		IWT Vol. 1, Chapter 5
Waste Minimization		IWT Vol. 1, Chapter 4
Industrial Waste Pretreatment		
Equalization/ Diversion		IWT Vol. 1, Chapter 7
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Aerobic Digestion		AWT, Chapter 3, OWTP Vol.2, Chapter 12
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Composting		AWT, Chapter 3
Solids Dewatering		AWT, Chapter 3, OWTP Vol.2, Chapter 12
Drying Beds		AWT, Chapter 3, OWTP Vol.2, Chapter 12
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Flow Measurement		OWTP Vol.1, Chapter 3
Odors and Odor Control at WWTPs		AWT, Chapter 1
Laboratory Procedures		
Laboratory Sampling and Testing		OWTP Vol. 2, Chapter 16
Laboratory Control Tests		OWTP Vol. 2, Chapter 16
Record Keeping		OWTP Vol. 2, Chapter 16
Plant Safety		OWTP Vol. 2, Chapter 14
Identification of Hazards		Included in each chapter
Protective Equipment		Included in each chapter
First Aid		Included in each chapter
Maintenance		
Maintenance Planning and Scheduling		Included in each chapter
Preventive Maintenance		Included in each chapter
Equipment Maintenance and Repair		Included in each chapter
Instrumentation		IWT Vol. 1, Chapter 12 AWT, Chapter9
Mechanical Equipment		
Pumps		OWTP Vol. 2, Chapter 15

APPENDIX B
Sacramento Series Cross Reference List

Contents Item	Wastewater Treatment System Operations and Maintenance Augmenting Handbook	Sacramento Series
		OMWCS Vol. 2, Chapters 8, 9
Valves		OWTP Vol. 2, Chapter 15 OMWCS Vol. 2, Chapter 8
Motors		OWTP Vol. 2, Chapter 15 OMWCS Vol. 2, Chapter 9
Couplings and Drive Mechanisms		OWTP Vol. 2, Chapter 15 OMWCS Vol. 2, Chapters 8, 9
Plant Checklist		Throughout each manual
Corrosion Control	Section 8	AWT, Chapter 2
Chemical Storage and Feeding	Section 9	
Emergency Planning		OWTP Vol. 2, Chapter 14 OMWCS Vol. 1, Chapter 4 OMWCS Vol. 2, Chapter 11
Index	At the end of manual	At the end of each manual

OWTP Operation of Wastewater Treatment Plants

OMWCS Operation and Maintenance of Wastewater Collection Systems

IWT Industrial Waste Treatment

AWT Advanced Waste Treatment

APPENDIX C
WWTP OPERATOR CERTIFICATION CONTACT LIST

Association of Boards of Certification
208 Fifth Street
Ames, Iowa 50010-6259
Telephone: 515-232-3623
Fax: 515-232-3778
E-mail: amesabc@aol.com

Kenneth D. Kerri
Office of Water Programs
California State University, Sacramento
6000 J Street
Sacramento, California 95819-6025
Telephone: 916-278-6142
E-mail: wateroffice@csus.edu
Web Site: http://www.owp.csus.edu

Water Environment Federation
601 Wythe Street
Alexandria, Virginia 22314-1994
Telephone: 703-684-2400 or 800-666-0206
Fax: 703-684-2492
E-mail: msc@wef.org
Web Site: http://www.wef.org

BIBLIOGRAPHY

Florida Septic Tank Association. The Magic Box. Lakeland, Florida: Florida Septic Tank Association. 1988.

State of Florida Department of Health and Rehabilitative Services. Chapter 10D-6, Florida Administrative Code, Standards for Onsite Sewage Treatment and Disposal Systems, effective January 3, 1995.

Cold Climate Sewage Lagoons. Report EPS 3/NR 1. Proceedings of the June 1985 Workshop in Winnepeg, Manitoba, Environment Canada. April 1987.

Sewage Lagoons in Cold Climates. Report EPS 4/NR/1. Environment Canada. March 1985.

REFERENCES

NOTE: THE FOLLOWING REFERENCED DOCUMENTS FORM A PART OF THIS HANDBOOK TO THE EXTENT SPECIFIED HEREIN. USERS OF THIS HANDBOOK SHOULD REFER TO THE LATEST REVISIONS OF CITED DOCUMENTS UNLESS OTHERWISE DIRECTED.

FEDERAL/MILITARY SPECIFICATIONS, STANDARDS, BULLETINS, HANDBOOKS, AND NAVFAC GUIDE SPECIFICATIONS:

Unless otherwise indicated, copies are available from the Naval Publishing and Printing Service Office (NPPSO), Standardization Document Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-HDBK-1004/10	Electrical Engineering Cathodic Protection
MIL-HDBK-1005/9	Industrial and Oily Wastewater Control
MIL-HDBK-1110	Paints and Protective Coatings for Facilities
MIL-HDBK-1136	Cathodic Protection Operations and Maintenance
MIL-HDBK-353	Planning and Commissioning of Wastewater Treatment Plants
ETL 1110-3-466	Selection of Design of Oil and Water Separators (Department of Army, U.S. Army Corps of Engineers, Washington, D.C. 20314-1000)

OTHER GOVERNMENT DOCUMENTS AND PUBLICATIONS:

EPA/625/R-92/013	Environmental Regulations and Technology: Control of Pathogens and Vector Attraction in Sewage Sludge (Including Domestic Septage) Under 40 CFR Part 503
EPA-625/6-84-009	Septage Treatment and Disposal Handbook (Cincinnati, Ohio: U.S. Environmental Protection Agency, October 1984)
U.S. Army CRREL Special Report 85-11	Prevention of Freezing and Other Cold Weather Problems at Wastewater Treatment Facilities (Reed et al., Hanover, New Hampshire: U.S. Army CRREL, July 1985)

HQ USAF/CE	Oil/Water Separator: Operations, Maintenance and Construction Memorandum (October 21, 1994)
HQ AFCEE	Oil/Water Separator: ProAct Fact Sheet. Web address: http:/www.afces.brooks.af.mil/pro_act/main/proact4.htm (December 1996)
HQ AFCEE	Proper Operation of Maintenance of Oil/Water Separators. (undated)

CALIFORNIA STATE UNIVERSITY

Operation of Wastewater Treatment Plants, Volume 1

Operation of Wastewater Treatment Plants, Volume 2

Operation and Maintenance of Wastewater Collection Systems, Volume 1

Operation and Maintenance of Wastewater Collection Systems, Volume 2

Industrial Waste Treatment, Volume 1

ndustrial Waste Treatment, Volume 2

Advanced Waste Treatment

Treatment of Metal Wastestreams

Pretreatment Facility Inspection

(Available from California State University, 6000 J Street, Sacramento, California 95819-6025.)

STEEL STRUCTURES PAINTING COUNCIL (SSPC)

SSPC SP1	Solvent Cleaning
SSPC SP2	Hand Tool Cleaning
SSPC SP3	Power Tool Cleaning
SSPC SP5	White Metal Blast Cleaning
SSPC SP6	Commercial Blast Cleaning
SSPC SP7	Brush-Off Blast Cleaning
SSPC SP8	Pickling
SSPC SP10	Near-White Blast Cleaning
SSPC SP11	Power Tool to Bare Metal
SSPC SP12	High- and Ultrahigh-Pressure Water Jetting

(Available from SSPC, 40 24th Street, 6th Floor, Pittsburgh, Pennsylvania 15222-4643.)

AUTHORED PUBLICATIONS:
Aldridge, Thomas. “What is an oil/water separator and why do I need one”? Pollution Equipment News. December 1996.

Laak, Rein. Wastewater Engineering Design for Unsewered Areas. Lancaster, Pennsylvania: Technomic Publishing Co., Inc.: 1986.

OTHER PUBLICATIONS:
National Small Flows Clearing House. Pipeline: Maintaining Your Septic System: A Guide for Homeowners. Morgantown, West Virginia: National Small Flows Clearing House. 1995.

API Publication 421. Design and Operation of Oil/Water Separators: American Petroleum Institute (1220 L Street, Northwest, Washington, D.C. 22005): February 1990.

B/F Technical Bulletin. Chemicals used in Treatment of Water and Wastewater Providence. Rhode Island. May 1970.

GLOSSARY

Abbreviation Or Acronym	Definition
ABC	Association of Boards of Certification
AC	alternating current
API	American Petroleum Institute
BMP	best management practice
BOD	biochemical oxygen demand
CBOD	carbonaceous biochemical oxygen demand
CFR	Code of Federal Regulations
COD	chemical oxygen demand
CPI	corrugated plate interceptor
CPVC	chlorinated polyvinylchloride
CRREL	Cold Regions Research and Engineering Laboratory (U.S. Army)
CSC	chloride stress cracking
DAF	dissolved air flotation
DC	direct current
DoD	Department of Defense
EPA	U.S. Environmental Protection Agency
F/M	food-to-microorganism ratio
FOTW	federally owned treatment works
FRP	fiberglass reinforced plastic
HI	host installation

MCRT	mean cell residence time
mgd	million gallons per day
MPN	most probable number
MSDS	material safety data sheets
NFPA	National Fire Protection Association
NPDES	National Pollutant Discharge Elimination System
O&M	operations and maintenance
PE	polyethylene
POTW	publicly owned treatment works
PVC	polyvinylchloride
RBC	rotating biological contactor
RCRA	Resource Conservation and Recovery Act
SCC	stress corrosion cracking
SDWA	Safe Drinking Water Act
SSPC	Steel Structures Painting Council
TKN	total kjeldahl nitrogen
TMDL	total maximum daily load
TSS	total suspended solids
WEF	Water Environment Federation
WWTP	wastewater treatment plant
UIC	underground injection control
VSS	volatile suspended solids

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