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Technology Transfer

EPA

Handbook

Septage Treatment and Disposal

NOTICE

This document has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for publication. Mention of trade names or commerical products does not constitute endorsement or recommendation for use.

FOREWORD

The formation of the Environmental Protection Agency marked a new era of environmental awareness in America. This Agency's goals are national in scope and encompass broad responsibility in the areas of air and water pollution, solid wastes, pesticides, hazardous wastes, and radiation. A vital part of EPA's national pollution control effort is the constant development and dissemination of new technology.

The proper treatment and disposal of septage is becoming an increasingly difficult management problem for nonurban communities where the use of on-site sewage disposal systems is prevalent. Federal and state regulations regarding the disposal of septage have become significantly more restrictive in recent years. As a result, traditional methods of disposing of septage may not be appropriate in many areas. In addition, more and more local nonurban communities are beginning to recognize the importance of encouraging proper septic system maintenance (routine septic tank pumping), in order to maximize the life of individual septic systems, and thereby avoid the expense of centralized sewer systems.

In light of this, the demand for septage disposal facilities is great, and is expected to be even greater in the near future. Unfortunately, most local public officials and many design engineers are not fully aware of all the options for managing the proper treatment and disposal of septage. The purpose of this handbook is to present a full range of practical alternatives, and provide technical advice to aid in the evaluation of these alternatives. This includes general design criteria and cost information, as well as advice concerning the operation and management of septage facilities.

This handbook is one of several publications available from Technology Transfer to describe technological advances and present new information.

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CONTENTS

Chapter		Page
	FOREWORD	iii
	ACKNOWLEDGMENTS	iv
	LIST OF FIGURES	viii
	LIST OF TABLES	xiii
1	INTRODUCTION	
	1.1 Purpose	1
	1.2 Scope	1
	1.3 Use of the Handbook	2
2	TECHNICAL OPTIONS AND STRATEGIES	
	2.1 Introduction	4
	2.2 Septage Management Options	4
	2.3 Selecting a Septage Management Option	9
	2.4 Legal and Regulatory Considerations	11
	2.5 Other Considerations	14
	2.6 References	15
3	SEPTAGE CHARACTERIZATION	
	3.1 Introduction	16
	3.2 Septage Quantity	18
	3.3 Characteristics of Septage	23
	3.4 Comparison of Septage and Domestic Wastewater Characteristics	31
	3.5 References	34
4	RECEIVING STATION DESIGN	
	4.1 Introduction	37
	4.2 Dumping Station	43
	4.3 Screening	48
	4.4 Grit Removal	50
	4.5 Storage and Equalization	56
	4.6 Odor Control	58
	4.7 References	68

CONTENTS (continued)

Chapter		Page
5	LAND DISPOSAL	
	5.1 Introduction	70
	5.2 Raw Septage versus Septage Residuals (Sludge)	70
	5.3 Disposal Options	72
	5.4 Project Development	79
	5.5 Management, Operations, and Monitoring	104
	5.6 References	104
6	CO-TREATMENT OF SEPTAGE AND SEWAGE	
	6.1 Introduction	106
	6.2 Feasibility of Co-Treatment	106
	6.3 Modes of Septage Addition	107
	6.4 Co-Treatment of Septage in the Liquid Stream	113
	6.5 Co-Treatment of Septage in the Solids Stream	135
	6.6 References	140
7	INDEPENDENT TREATMENT OF SEPTAGE	
	7.1 Introduction	143
	7.2 Lagoons	146
	7.3 Composting of Septage	153
	7.4 Biological Secondary Treatment Processes	160
	7.5 Aerobic Digestion	161
	7.6 Anaerobic Stabilization of Septage	171
	7.7 Lime Stabilization of Septage	182
	7.8 Chlorine Oxidation	194
	7.9 Conditioning	201
	7.10 Dewatering	214
	7.11 Disinfection	229
	7.12 Odor Control	241
	7.13 Ultimate Disposal	242
	7.14 Mobile Septage Dewatering	247
	7.15 References	252

CONTENTS (continued)

Chapter		Page
8	OPERATION AND MANAGEMENT CONSIDERATIONS	
	8.1 Overview of Management Concerns	259
	8.2 Onsite Systems Management	262
	8.3 Management of Septage Pumping and Hauling Activities	265
	8.4 Monitoring the Quantity and Quality of Incoming Septage	268
	8.5 Facility Operation and Maintenance	271
	8.6 Performance Monitoring	273
	8.7 Financial Arrangements	273
	8.8 References	277
9	FACT SHEETS	
	9.1 Introduction	279
	9.2 References	294
APPENDIX	SUMMARY OF STATE REQUIREMENTS REGARDING LAND DISPOSAL OF SEPTAGE	298

FIGURES

Number		Page
1-1	Sequence of Chapters	3
2-1	Basic Septage Management Options	5
2-2	Illustration of Decisions In Selecting Most Appropriate Technical Option	6
2-3	Sequenced Selection of a Septage Disposal Option	10
3-1	Typical Septic System	17
3-2	Septage Loading Pattern at Lebanon, Ohio	20
3-3	Volume of Septage Received at Enga Treatment Plant, Norway	20
3-4	Variation in Monthly Average Septage Quantities at Lebanon, Ohio	22
3-5	Variation in Daily Average Septage Quantities at Enga, Norway	22
3-6	Variations in NH_3 and H_2S Concentrations at TAU Treatment Plant When Receiving Septage, February 24, 1976	30
3-7	Variations in NH_3 and H_2S Concentrations at TAU Treatment Plant When Receiving Septage, May 31, 1976	30
4-1	Receiving Station for Septage at Ekebyhov Treatment Plant, Sweden	38
4-2	Receiving Station Where Septage Is Fed to An Anaerobic Digester in West Germany	38
4-3	Receiving Station Including Screening and Grit Removal at Lillehammer Treatment Plant, Norway	38
4-4	Receiving Station with Pretreatment Prior To Equalization (Batch Pretreatment)	39

FIGURES (continued)

Number		Page
4-5	Receiving Station with Equalization Prior To Pretreatment (Controlled Rate Pretreatment)	39
4-6	Interceptor Receiving Station	41
4-7	Receiving Station at STP Where Existing Pretreatment Facilities Can Be Used to Treat Septage	41
4-8	Computerized Interceptor Receiving Station	42
4-9	Septage Transfer Station	44
4-10	Basic Layout of Dumping Station	45
4-11	Recommended Dumping Station Inlet Arrangement	47
4-12	Mechanically Cleaned Bar Screen at Dokka Treatment Plant, Norway	49
4-13	Drained Screw Conveyor Used for Dewatering Material from the Bar Screen	51
4-14	Helical Flow Pattern in Aerated Grit Chamber	53
4-15	Typical Section Through Aerated Grit Chamber	53
4-16	Aerated Grit Dewatering Unit Placed Above the Grit Chamber at Lillehammer Treatment Plant, Norway	53
4-17	Cyclone Degritter	55
4-18	Chemical Scrubber, Type Steuler	59
4-19	Chemical Scrubber, Type Pepcon	59
4-20	Carbon Filter for Odor Reduction	61
4-21	Full Scale Soil Filter at TAU Treatment Plant, Tonsberg, Norway	63

FIGURES (continued)

Number		Page
4-22	Soil Filter System - Mercer Island, WA Pump Station Odor Control	63
4-23	Effect of Input Concentration of H_2S Removal Efficiency by Soil Filters	65
4-24	Soil Filter Installation at TAU Treatment Facility	66
4-25	Air Collection and Blower Equipment at TAU Treatment Facility	66
5-1	Technical Options For Land Application of Septage	71
5-2	Liquid Sludge Spreading System in Forest Land Utilizing Temporary Storage Ponds	76
5-3	Ridge and Furrow Irrigation Method for Applying Septage to Land	76
5-4	Overland Flow Method of Applying Septage to Land	76
5-5	Subsurface Soil Injection	78
5-6	Terreator Apparatus for Subsurface Soil Injection	78
5-7	Technical Evaluations Involved In Implementing A Land Disposal Project	80
5-8	Typical Septage Disposal Site	87
6-1	Technical Options for Co-Treatment of Septage	108
6-2	Septage Addition in A Typical Sewage Treatment Plant	110
6-3	Allowable Septage Volume to Be Added to Municipal Treatment Plant per German Guidelines	116
6-4	Estimated Waste Sludge Production in Primary Clarifier Treating Septage and Sewage	120
6-5	Allowable Rates of Equalized Septage Addition (8)	123

FIGURES (continued)

Number		Page
6-6	Additional Oxygen Required for Septage Additions in Activated Sludge Treatment Plants	123
6-7	Estimated Waste Sludge Production from Biological Treatment Processes Receiving Septage	126
6-8	Acceptable Septage Flows As A Function of Plant Capacity (without Equalization Facilities)	131
6-9	Estimated Oxygen Requirements for Biological Treatment Processes Receiving Septage	133
7-1	Technical Options For Independent Treatment of Septage	145
7-2	Septage Lagoon Variations	147
7-3	Alternating Lagoons - Batch Treatment	149
7-4	Parallel Operation of Continuous Discharging Lagoons	149
7-5	The Lebo Aerator	154
7-6	Forced Aeration Static Pile Composting System	156
7-7	RBC Septage Treatment Facility-Wayland Sudbury Massachusetts	162
7-8	Fecal Coliform Colonies Remaining After Aerobic Digestion	164
7-9	Fecal Streptococci Colonies Remaining After Aerobic Digestion	164
7-10	Reduction of VSS in Batch Aerobic Digestion With Time	167
7-11	Oxygen Uptake Rate Versus Detention Time in Aerobic Digester	172
7-12	Change in pH During Storage of Septage Vs Lime Dosage	184

FIGURES (continued)

Number		Page
7-13	Change in Odor Intensity Index During Storage of Lime Stabilizaed Septage	184
7-14	Common Lime Stabilization Process Trains	188
7-15	Lime Dosage Vs Desired pH Endpoint	191
7-16	Chlorine Oxidation System	198
7-17	Typical Sand Drying Bed Construction	217
7-18	Vacuum Filtration Process	221
7-19	Vacuum Assisted Drying Bed System	226
7-20	Sequence of Operations in Vacuum Assisted Drying Bed System	227
7-21	Electron Beam Scanner and Septage Spreader	241
7-22	Cobalt-60 Irradiation Facility at Geiselbullach, West Germany	242
7-23	Reduced Travel Distance Through On-the-Road Dewatering	248
7-24	Mobile Dewatering/Hauler Truck	250
7-25	Vacuum Filter for Septage Dewatering	250
8-1	Septage Management System for Acton, Massachusetts	276

TABLES

Number		Page
3-1	Septic Tank Sludge Received at Enga Treatment Plant, Norway	21
3-2	Monthly Peaking Factors for Selected Localities in the United States and Norway	24
3-3	Variations of Septage Volume Received at Four Municipal Treatment Plants in Norway	25
3-4	Physical and Chemical Characteristics of Septage, as Found in the Literature, with Suggested Design Values	27
3-5	Heavy Metal Concentrations Found in Septage as Reported in the Literature and as Compared to Those Values Reported in Typical Domestic Wastewater Sludges, with Suggested Design Values	29
3-6	Pathogen Concentrations in Domestic Sludges Based on Niva Research	32
3-7	Indicator Organism and Pathogen Concentrations in Domestic Septage	32
3-8	Comparison of Septage and Municipal Sewage	33
4-1	Typical Design Information for Aerated Grit Chambers	52
4-2	Screened-Raw-Septage Supernatant Characteristics Following Aeration and Two Hours Settling	57
4-3	Specifications for Future Soil Filters at Mercer Island, Washington Pumping Station	62
4-4	Design Parameters for Soil Filters Used for Odor Reduction	67
5-1	Characteristics of Land Disposal Options	73
5-2	Annual Nitrogen, Phosphorus, and Potassium Utilization by Selected Crops	83

TABLES (continued)

Number		Page
5-3	Annual Cadmium Limits	85
5-4	Suggested Total Amount of Septage Metals To Be Applied To Agricultural Land	85
5-5	Recommended Slope Limitations for Land Application of Sludge	88
5-6	General Guide to Months Available for Septage Application to Different Crops in North Central States	90
5-7	Estimated Annual Nitrogen Uptake by Forest Species	92
5-8	Organic Nitrogen Mineralization Factors	94
6-1	Characteristics of Primary Clarifier Effluents at Marlborough, Massachusetts	118
6-2	Characteristics of Influents and Effluents at Marlborough, Massachusetts	125
6-3	Characteristics of Influents and Effluents at Medfield, Massachusetts	134
7-1	Lagoon Performance Data -- Acton, Massachusetts	150
7-2	Septage Lagoon Design Guidelines As Suggested by the New England Interstate Water Pollution Control Commission	151
7-3	Operational Parameters for Septage Composting	159
7-4	Summary of Research Studies on Aerobic Digestion of Septage	165
7-5	Aerobic Stabilization of Septage Typical Design Criteria	170
7-6	Removal of Pathogenic Bacteria During Anaerobic Digestion of Sewage Sludge	173

TABLES (continued)

Number		Page
7-7	Summary of Anaerobic Digestion of Septage Studies	174
7-8	Comparison of Sludge Digestion Design Criteria with Reported Values for Mesophilic Anaerobic Digestion of Septage	176
7-9	Typical Design Criteria for Anaerobic Stabilization of Septage	179
7-10	Substances and Concentrations Causing Toxicity in Wastewater Sludge Digestion	181
7-11	Bacteria in Raw and Lime-Stabilized Septage at Lebanon, Ohio	186
7-12	Chemical Composition of Raw and Lime Stabilized Septage at Lebanon, Ohio	187
7-13	Reported Values of Lime Requirements for Septage Stabilization	190
7-14	Typical Design Criteria - Lime Stabilization of Septage	193
7-15	Bacteriological Data Purifax ™ Treatment of Septage	196
7-16	Typical Design Criteria for Chlorine Stabilization of Septage	200
7-17	Summary of the Characteristics of Septage-Conditioning Chemicals	202
7-18	Summary of Studies on Thickening Raw Septage	203
7-19	Summary of Ferric Chloride and Ferric Chloride/Lime Conditioning Studies	204
7-20	Summary of Alum Conditioning Studies	205

TABLES (continued)

Number		Page
7-21	Summary of Acid and Acid/Lime Conditioning Studies	206
7-22	Typical Design Criteria Conditioning with Metal Salts and Lime	212
7-23	Summary of Septage Dewatering Studies	215
7-24	Summary of Studies on Sand Bed Dewatering of Septage	219
7-25	Vacuum Filtration of Septage	222
7-26	Septage Dewatering by Solid-Bowl Centrifugation	224
7-27	Summary of Septage Centrate Water Quality	225
7-28	Pathogenic Human Viruses Potentially in Septage	231
7-29	Pathogenic Human Bacteria Potentially in Septage	232
7-30	Pathogenic Human and Animal Parasites Potentially in Septage	234
7-31	Time and Temperature Tolerance for Pathogens and Indicators in Septage	237
7-32	Laboratory Study on Days of Storage Required for 99.9% Reduction of Viruses and Bacteria in Sludge	240
7-33	Treatment/Disposal of Liquid Fraction -- Advantages, Disadvantages, and Design Criteria	243
7-34	Ultimate Disposal of Raw Septage and Septage Solids -- Advantages, Disadvantages, and Design Criteria	245
8-1	Institutional Capability Matrix	263
8-2	Conventional and Alternative Financing Techniques for Septage	274

CHAPTER 1

INTRODUCTION

1.1 Purpose

The principal purpose of this handbook is to present an up-to-date review of available design, performance, operation and maintenance, cost, and energy information pertaining to the receiving, treatment, and disposal of septage. Septage is the liquid and solid material pumped from a septic tank or cesspool when it is cleaned. Recommended procedures for planning and design, along with state-of-the-art information on treatment performance, energy considerations, and health and environmental effects, are presented. Cost information is provided for selected processes in the form of Fact Sheets contained in Chapter 9.

This document should serve as a practical guide for planners, design engineers, state and Federal reviewers, and local government officials involved in planning, evaluating, and designing septage handling facilities in response to the increasing demands for such facilities.

1.2 Scope

This handbook provides information needed to facilitate the design of septage receiving stations, pretreatment processes, new sewage treatment plants with provisions for receiving septage, and independent septage treatment and disposal alternatives. Methods for septage treatment and disposal discussed in this handbook are:

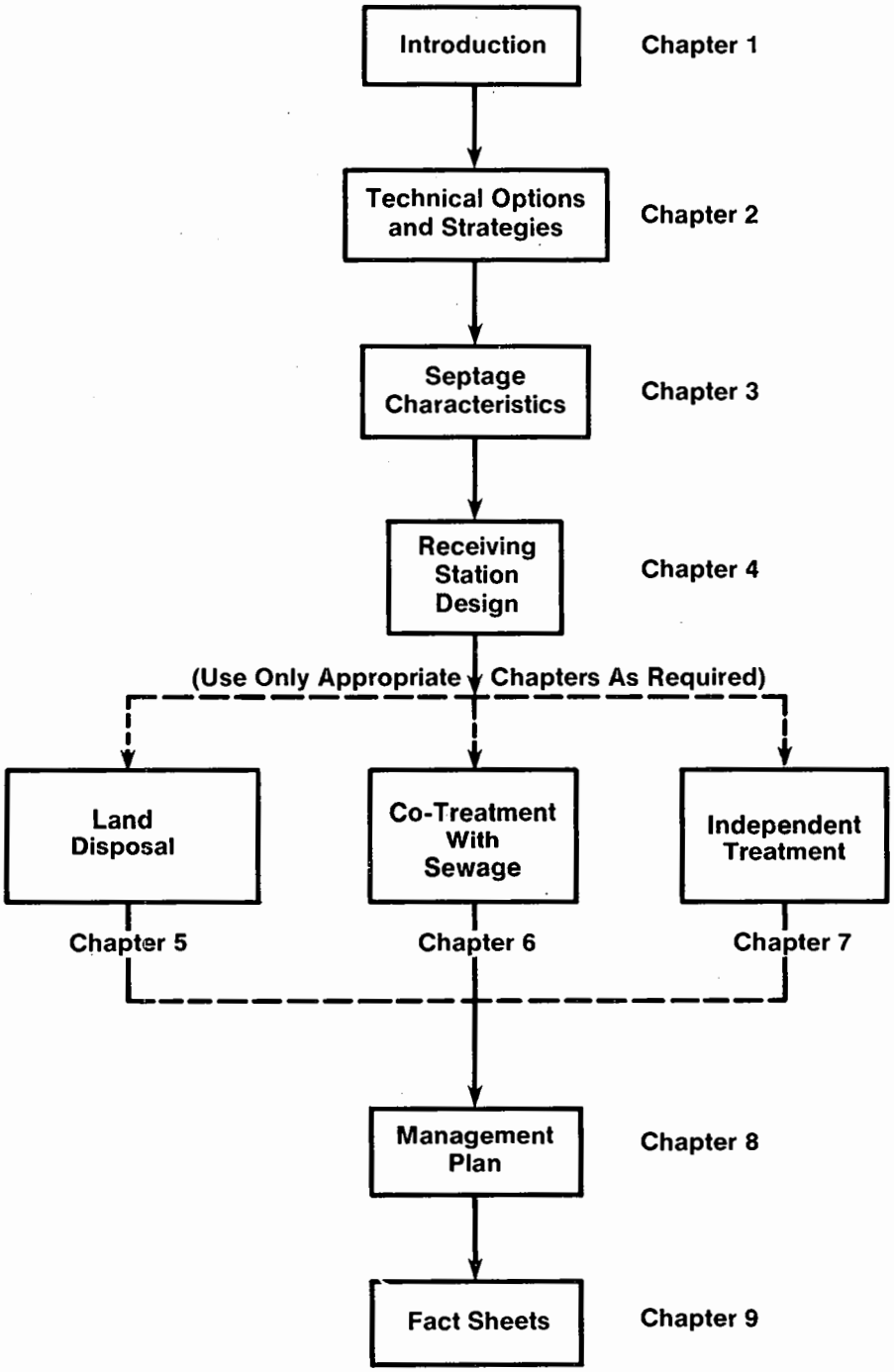
1. Land treatment and disposal.
2. Co-treatment at existing wastewater treatment facilities.
3. Independent facilities for treatment and disposal.

Individual treatment processes are discussed in detail and specific design guidance is provided.

1.3 Use of the Handbook

Figure 1-1 presents the suggested sequence to follow when using this handbook. Chapter 2 presents the technical options applicable for the management of septage in sufficient detail to enable a planner/designer to begin the decision process. A detailed discussion of septage characteristics, including quantities generated, is contained in Chapter 3. Chapter 4 discusses septage receiving station design. Chapters 5 through 7 offer specific technical advice pertaining to the design of land treatment, co-treatment, and independent septage treatment facilities, respectively. Chapter 8 discusses facility operation and program management considerations. Fact Sheets are presented in Chapter 9. These are a series of two-page capsule summaries of selected septage treatment methods, with generalized capital and operation and maintenance costs.

FIGURE 1-1
SEQUENCE OF CHAPTERS



CHAPTER 2

TECHNICAL OPTIONS AND STRATEGIES

2.1 Introduction

This chapter presents the information needed by a planner or designer to begin making decisions relevant to the receiving, treatment, and disposal of septage. Topics covered in this chapter include septage management options, technical considerations (i.e., selection criteria), applicable Federal and state guidelines, and other considerations, such as potential environmental impacts, public acceptability, and cost.

2.2 Septage Management Options

The basic methods of treating and disposing of septage are briefly described in the following sections, although each is discussed in greater detail in the individual design chapters (5 through 7). Figure 2-1 illustrates the various pathways (i.e., technical options) available for septage management. Figure 2-2 depicts the various decisions that must be made in selecting the most appropriate technical option.

2.2.1 Land Disposal

Three basic methods of land application apply for septage disposal. These include:

1. Land spreading.
2. Subsurface incorporation.
3. Burial.

FIGURE 2-1
BASIC SEPTAGE MANAGEMENT OPTIONS

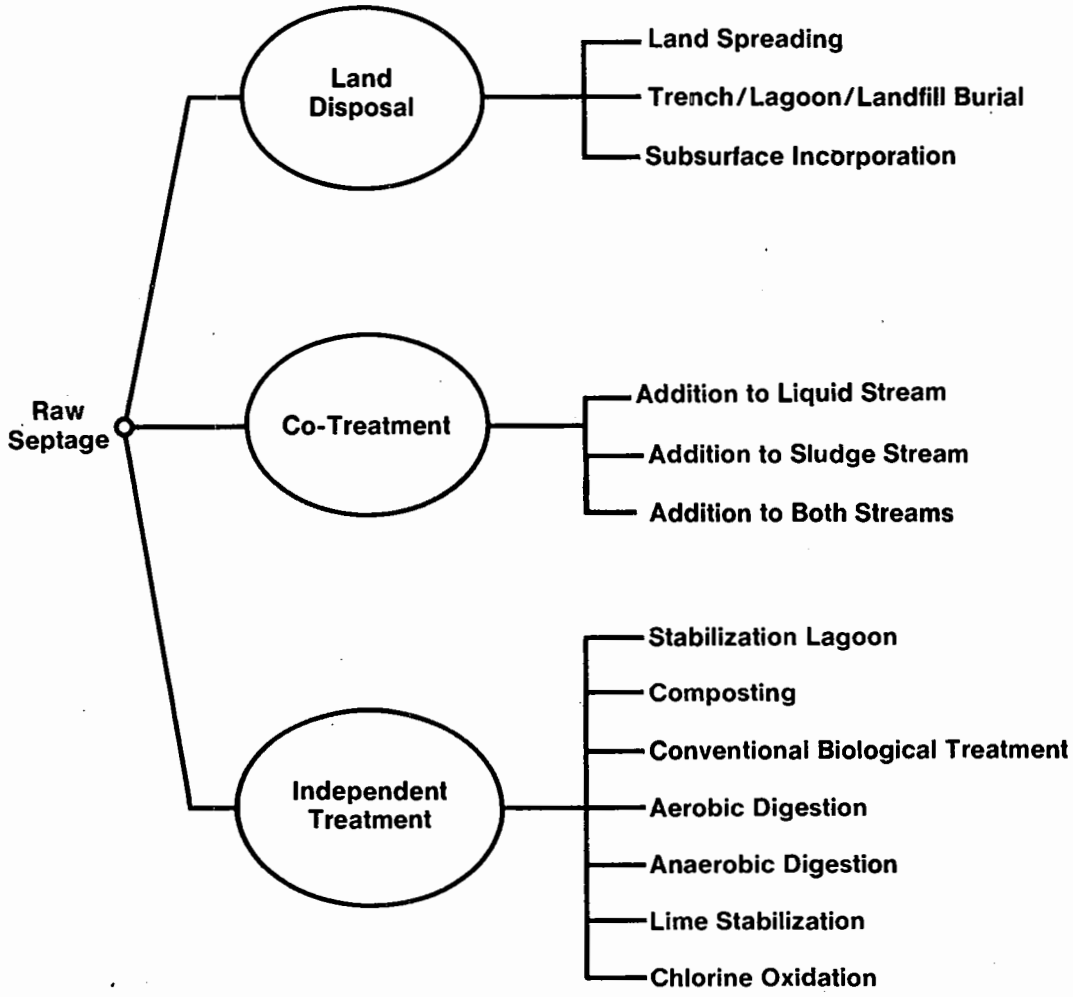
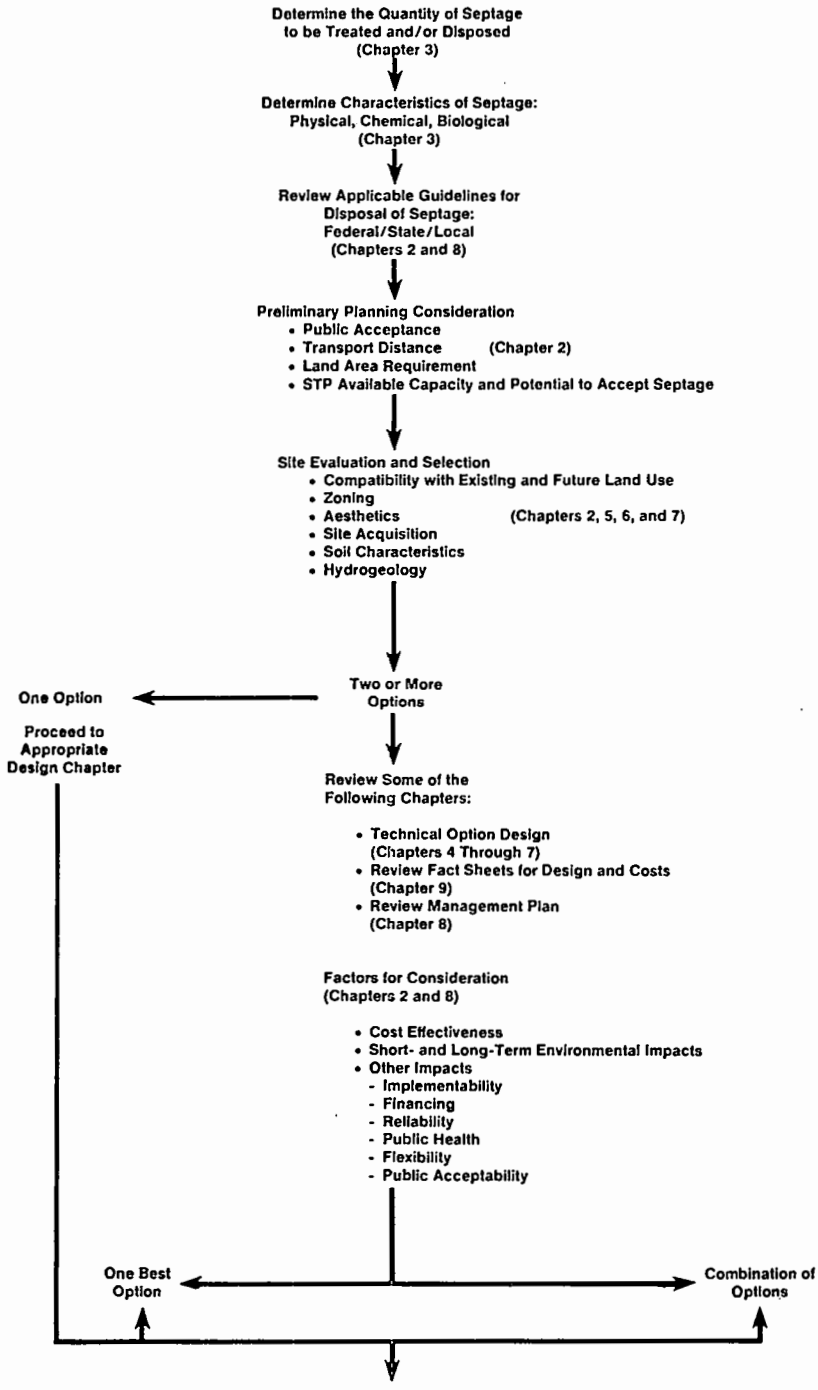


FIGURE 2-2
ILLUSTRATION OF DECISIONS IN SELECTING MOST APPROPRIATE TECHNICAL OPTION



Adapted From "Process Design Manual for Land Application of Municipal Sludge" (1)

Land spreading has been the most common septage disposal method in the United States. Surface spreading of septage is generally accomplished by the same techniques as municipal liquid wastewater sludge spreading, which may simply involve the septage pumping truck emptying its contents on the field while slowly driving across the site. This technique has very low operation and maintenance requirements. A more controlled and preferred approach is to use a holding tank to receive septage loads when the soil is not suitable for spreading due to climatic conditions. A special vehicle can then be used to spread the septage when weather and soil conditions permit. Unfortunately, land spreading is often done without regard to site suitability. However, state regulatory agencies are beginning to exert more stringent control over this practice.

Subsurface incorporation techniques have gained wide acceptance as an alternative for disposal of liquid sludge and, to some extent, septage. Three basic approaches are available:

1. Incorporation using a farm tractor and tank trailer with attached subsurface injection equipment.

2. Incorporation using a special purpose tank truck with subsurface injection equipment.

3. Incorporation using tractor-mounted, subsurface injection equipment in conjunction with a central holding facility and flexible "umbilical cord." Liquid sludge is continually pumped from the holding tank to the injection equipment.

Disposal of septage by burial in excavated trenches is another common disposal technique. Since trench dimensions vary with site location, the space between trenches should be sufficient to allow movement of heavy equipment. A series of trenches is usually dug by a backhoe to allow sequential loading and maximum dewatering. Septage is usually applied in successive layers. When the trenches are full, the solids can be excavated and placed in a landfill if they have dewatered sufficiently, or the trenches can be covered with soil. A thorough site evaluation is essential to prevent groundwater contamination with this disposal technique.

Sanitary landfills in the United States generally accept a multiplicity of materials such as refuse, industrial wastes, and sometimes hazardous or toxic wastes. All of these wastes are compiled on a daily basis at the landfill and are buried under a soil cover. The acceptance of septage at a landfill depends chiefly on the ratio of the mixture of septage to refuse to maintain moisture control. However, a few states do not allow landfill disposal of septage, and some others do not recommend it because of potential runoff and leachate problems.

2.2.2 Co-Treatment

The treatment of septage at municipal sewage treatment plants is practiced in both the United States and Europe. The constituents of septage, although highly concentrated and much stronger than domestic sewage, are generally similar to domestic sewage. Therefore, the same processes used to treat domestic sewage can also be used for co-treatment of septage and domestic sewage. This method of treatment for septage is encouraged by many state, county, and local environmental health agencies (4). Co-treatment is generally considered when homes served by septic tanks are within an economical hauling distance of the sewage treatment plant: 16 km (10 miles) is considered to be an economical distance; a distance greater than 32 km (20 miles) is usually excessive (3).

The quantity of septage that may be treated at a sewage treatment plant is normally limited by available aeration and/or solids handling capacity. At relatively small plants a 4 to 12 m^3 (1,000 to 3,000 gal) truckload of septage, discharged in a period of minutes, can impose a significant shock load on the plant. Before septage is treated at a treatment plant, it should be determined if sufficient capacity exists to handle the increased organic and hydraulic loadings associated with septage.

Three methods exist for treating septage at wastewater treatment facilities:

1. Addition to the liquid stream (upstream from the plant or at various points within the plant).

2. Addition to sludge stream.

3. Addition to both liquid and sludge streams.

The first two each have advantages under certain conditions, while the third offers optimum flexibility. For example, addition to the liquid stream is best when the plant employs primary clarification since this effectively removes most of the septage solids with the primary sludge. However, for extended aeration plants, septage addition to the wastewater flow may have a severe impact on the organic loading, SRT, and aeration capacity of the system. In this case, introducing the septage into the sludge stream is desirable. With each method, solids production will increase. Septage holding facilities allow addition of the septage to the treatment plant at appropriate rates and times to avoid major process upsets.

2.2.3 Independent Treatment

Facilities have been constructed exclusively for handling septage. These systems vary from stabilization lagoons to sophisticated treatment plants. Such processes as lime stabilization, chlorine oxidation, aerobic digestion, composting, anaerobic digestion, and chemical treatment have been used to treat septage. Mechanical treatment systems, as opposed to simple lagoon systems, are generally more capital-intensive and usually cost more to operate. However, such systems have been found to be cost-effective in areas of significant septic system density, such as Long Island, New York (5). In rural areas, simpler, less expensive alternatives are preferred. Lagoons are the most common and among the least expensive independent septage handling alternatives.

2.3 Selecting a Septage Management Option

The selection of a suitable septage management option does not depend strictly on technical considerations. For example, regulatory requirements may take precedence over the technical issues (these are further discussed in Section 2.4). Site availability may prohibit the selection of a particular land disposal option, or the distance to an existing municipal treatment plant may obviate co-treatment due to excessive hauling costs. Figure 2-3 is a useful guide for selecting a disposal option.

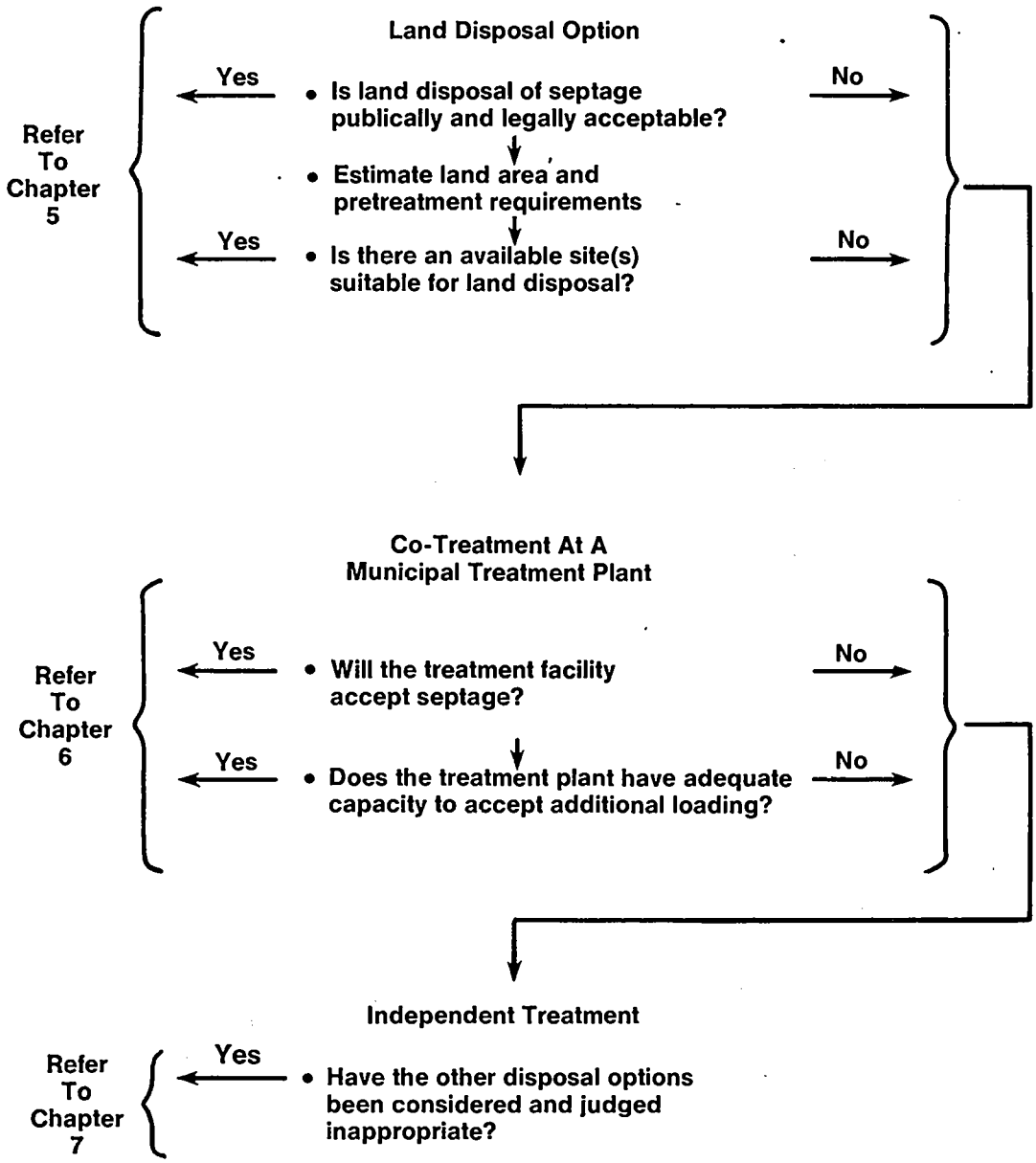
2.3.1 Land Availability and Site Selection

Of the three disposal options presented, the land disposal option is most dependent on the availability of land. The amount of land required for land application includes the area required for treatment, buffer zones, receiving and pretreatment facilities, access roads, and maintenance buildings. After the total amount of land required is estimated, additional work is necessary to determine if the site is suitable. Factors to be considered include soils, topography, hydrogeology, current and planned land use, neighboring land use, zoning, and distance from septage service area. Additional details are contained in Chapter 5.

2.3.2 Transport Distance

The hauling distance to a suitable disposal site must be considered when selecting options. It is desirable to locate the disposal site as close as possible to the area in which the septage is generated. Although there are little data regarding costs for the transport of septage over long distances, studies investigating the liquid transport of wastewater sludge indicate that truck transport may not be economical for one-way distances of greater than 32 kilometers (20 miles) (3).

FIGURE 2-3
SEQUENCE SELECTION OF A SEPTAGE DISPOSAL OPTION



Factors to be considered for hauling septage by truck include:

1. State and local restrictions.
2. Septage volume to be transported.
3. Number of trips per day.
4. Distance to disposal site.
5. Fuel costs.
6. Labor costs.
7. Cost of disposal.

Potential environmental impacts, such as noise and general disruption due to increased truck traffic, will also have to be addressed.

2.4 Legal and Regulatory Considerations

Regulatory factors play a major role in the planning and design of septage treatment and disposal facilities. It is the intent of this section to review those that apply specifically to septage. In many cases, however, septage is dealt with in conjunction with wastewater sludge management.

2.4.1 Federal Regulations

The following are Federal laws that deal with septage as part of overall sludge management:

1. The Clean Water Acts (CWA) of 1981 (PL 97-117) and 1977 (PL 95-217), and the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500), authorize Federal funding of eligible costs involved in the construction of municipal wastewater treatment facilities, including septage treatment and disposal; authorize U.S. EPA to issue comprehensive septage and wastewater sludge management guidelines and regulations; authorize the NPDES (National Pollution Discharge Elimination System) for point source discharges and development of areawide waste treatment or water quality management plans for non-point source pollution; require the implementation of pretreatment standards for industrial discharges that enter POTW's; and establish a research and demonstration program to develop improved wastewater treatment and sludge and septage management practices.

The U.S. EPA is authorized under the CWA, as amended, to provide grant assistance to municipalities for the building of wastewater treatment projects. Grant assistance may be up to 75 percent of the allowable costs of building the project and include an allowance for facilities planning and design. After 1 October 1984, the Federal share will be 55 percent of these costs. Innovative and alternative (I/A) technology projects may receive an additional 20 percent Federal share, up to a maximum of 85 percent (up to 75 percent after 1 October 1984).

Eligible I/A projects include processes and techniques for the treatment and use of effluents, such as land treatment, aquifer recharge and aquaculture; total containment ponds and ponds for treatment and storage of wastewater prior to land application; individual and other onsite treatment systems with subsurface or other means of effluent disposal; and facilities constructed for the specific purpose of septage treatment. The cost of land used as an integral part of the treatment process is allowable for grant funding up to 85 percent (up to 75 percent after 1 October 1984) as are pumper trucks for the transport of septage to a disposal site.

2. The Resource Conservation and Recovery Act of 1976, PL 94-580 (RCRA), authorizes Federal financial assistance to state and local governments for development of solid waste management plans that provide for the safe disposal of solid wastes including septage; provides for technical assistance to help establish acceptable solid waste management methods; requires stringent regulations for the disposal of hazardous and nonhazardous wastes (including septage); and encourages the research and demonstration of more effective solid waste disposal and resource conservation technologies.

3. The Marine Protection Research and Sanctuaries Act of 1977, PL 92-532 (MPRSA), phased out ocean disposal of sewage sludge and septage "which may degrade or endanger human health, welfare, amenities, or the marine environment ecological systems, or economic benefits" as soon as possible or, in any event, no later than 31 December 1981. MPRSA also gave the U.S. EPA the authority to determine a reasonable compliance schedule for the implementation of land-based disposal alternatives. However, there has been increasing interest in and pressure exerted to cause the agency to reconsider the potential for continuing many of the existing ocean disposal projects, as well as allowing the establishment of new projects.

4. The Clean Air Act Amendments of 1970 and 1977, PL 91-604 and PL 95-95 (CAA), authorized the development of State Implementation Plans (SIP's) for the purpose of meeting Federal ambient air quality standards. To meet the CAA objectives, the U.S. EPA has developed an emission offset policy for new or modified incinerator and heat drying facilities, as well as a procedure for preventing the significant deterioration of ambient air quality. The CAA also authorizes regulations for the control of hazardous air pollutants and new source performance standards.

5. The Safe Drinking Water Act of 1975, PL 93-523 (SDWA), requires coordination with the CWA and RCRA to protect drinking water from contamination.

6. The National Environmental Policy Act of 1969, PL 91-190 (NEPA), authorizes regional administrators, at their discretion, to require Environmental Impact Statements (EIS) (40 CFR, Part 6) if potentially adverse social, economic, or environmental impact is suspected for a new or modified sludge or septage disposal facility or practice. An EIS or negative declaration (40 CFR, Part 35, Section 35.925-8) is also required when applying for Federal construction grants.

7. The Toxic Substances Control Act of 1976, PL 94-469 (TSCA), Section 9, requires coordination with the Clean Air Act and the Clean Water Act to restrict disposal of toxic wastes. Presently, only PCB (polychlorinated biphenyl) is specifically addressed by Federal regulations with regard to sludge disposal under TSCA.

2.4.2 State and Local Regulations

State laws and regulations concerning septage vary widely. In some instances, no overall state regulations apply, and septage practices are controlled by local governing bodies at the county or municipal level. Typically, septage regulations deal with licensing requirements, equipment used, pretreatment requirements, allowable disposal practices, and regulation enforcement. A matrix describing pertinent septage regulations regarding land application of septage from various states based on a telephone survey and review of existing regulations is presented in Appendix A.

2.5 Other Considerations

Beyond the technical and regulatory considerations, the planner/designer should be aware of other general factors that might influence the choice of a particular septage management option. In implementing any septage management program, it is critical that the treatment facilities be environmentally safe, reasonable in cost, and acceptable to the public.

Environmental impacts refer to those changes in the environment brought about by the implementation of a particular septage management option. Many of the regulations and guidelines that exist have been developed so that septage hauling and disposal practices will not result in an adverse impact on the environment or human health.

The cost of a project not only includes the capital for initial implementation, but also the cost for operating and maintaining the system. It is important that the entire extent of the cost of the project be estimated as accurately as possible before any option is implemented. Often when dealing with wastewater treatment projects, the extent of this economic impact may not always be realized until the project has been implemented. This may result in a facility having relatively low capital cost but unaffordably high operation and maintenance costs.

The effectiveness of a septage treatment facility is directly dependent on the skill and training of the plant operator. A facility can be designed to provide the highest degree of treatment technology possible, but it is the individual operator who actually makes a plant perform at its design capability. The importance of properly trained operators cannot be over-stressed as a basic design consideration.

The implementation of a particular septage management option depends highly on securing the acceptance of the public. Gaining public acceptance is enhanced by working from the beginning with responsible local officials, landowners, and other affected parties. The public should be made aware of the various options under consideration, along with their benefits, risks, and costs. This may be done by holding public meetings, conducting surveys and workshops, distributing pamphlets, and advertising on local radio, television, and in newspapers. Establishing open discussions with the public will often lead to the selection of the most cost-effective and environmentally-acceptable management option.

2.6 References

1. U.S. Environmental Protection Agency. Process Design Manual for Land Application of Municipal Sludge. U.S EPA Report No. 625/1-83-016, October 1983.

2. U.S. Environmental Protection Agency. Monitoring Septage Addition To Wastewater Treatment Plants, Volume I: Addition To the Liquid Stream. U.S. EPA Report No. 600/2-79-132, NTIS Publication No. PB 80-143613, November 1979.

3. U.S. Environmental Protection Agency. Process Design Manual for Sludge Treatment and Disposal. U.S. EPA 625/1-79-011, 1979.

4. Florida Department of Environmental Regulation. Resource Recovery and Management, Part IV FAC, Chapter 17-7, Tallahasee, Florida,1984.

5. Rezek, J.W. and I.A. Cooper. Septage Management. U.S. EPA Report No. 600/8-80-032, NTIS Publication No. PB 81-142481, August 1980.

CHAPTER 3

SEPTAGE CHARACTERIZATION

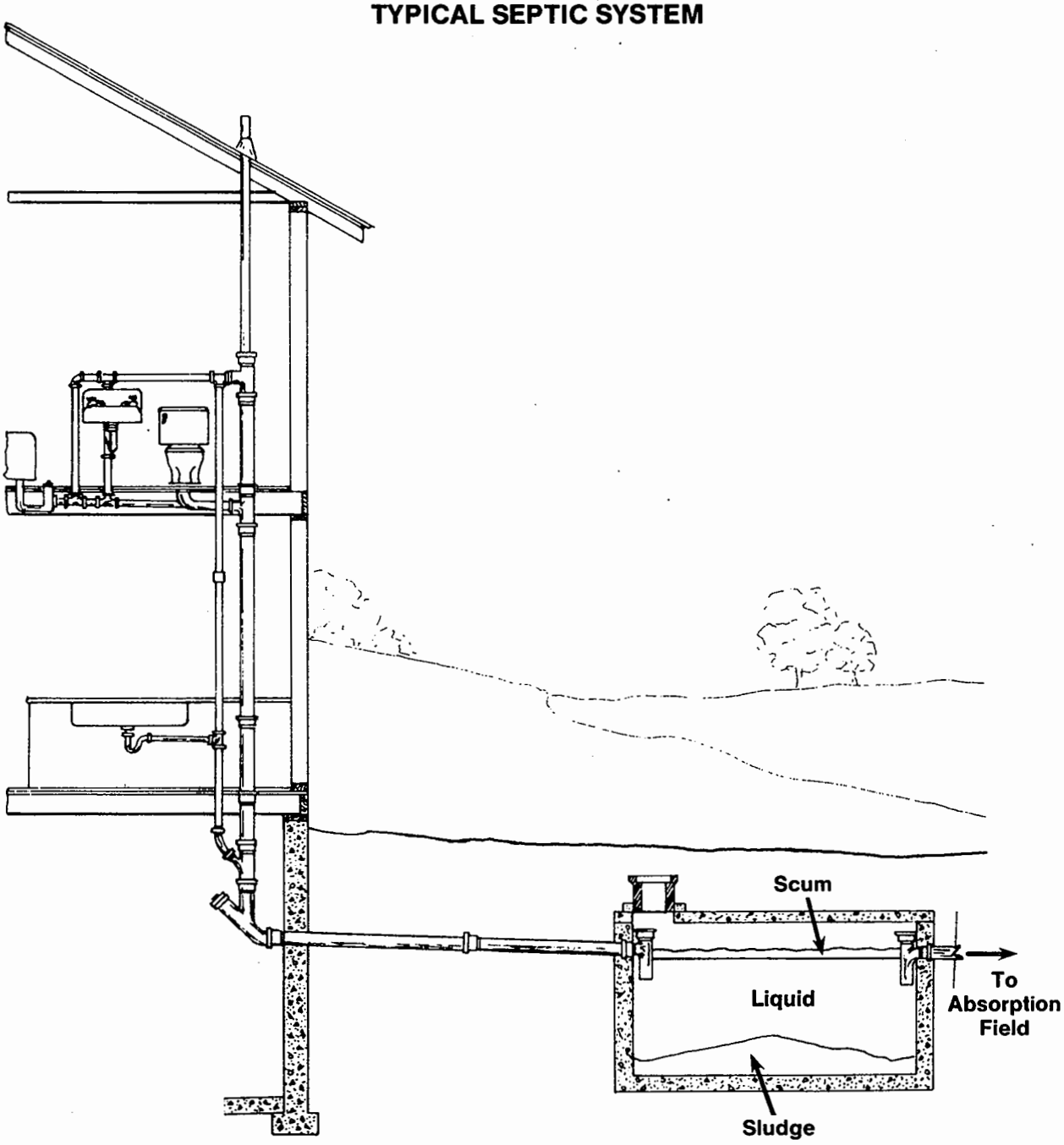
3.1 Introduction

Septage is generally defined as the liquid and solid material pumped from a septic tank or cesspool during cleaning. Septage is normally characterized by large quantities of grit and grease, a highly offensive odor, great capacity to foam upon agitation, poor settling and dewatering characteristics, and high solids and organic content. Its high waste strength is due to the accumulation of sludge and scum in the septic tank. Typically, a septic tank will retain 60 to 70 percent of the suspended solids and oil and grease introduced from the dwelling served. The bulk of the suspended solids settles to the bottom of the tank, and the oil and grease and other flotable materials are retained between the inlet and outlet baffles, as shown in Figure 3-1. Over a period of time, the sludge and scum can build up to a point where it occupies from 20 to 50 percent of the total septic tank volume.

In addition to being a highly concentrated waste, septage characteristics vary widely from one location to another. This variation is due to several factors, including: the number of people utilizing the septic tank and their cooking and water use habits; tank size and design; climatic conditions; pumping frequency; and the use of tributary appliances such as garbage grinders, water softeners, and washing machines.

Knowledge of septage characteristics and variability is important in determining the proper handling and disposal alternatives. Data on local septage characteristics are extremely valuable for design purposes; however, they are not always available. In such cases, engineering judgement must be utilized in applying typical design values.

FIGURE 3-1
TYPICAL SEPTIC SYSTEM



3.2 Septage Quantity

The 1980 U.S. Department of Commerce, Census Bureau, estimated that the number of housing units with septic tanks in the United States was 21.9 million (1). This number represented a 31.9 percent increase over the 16.6-million units noted from the 1970 census (1). Based on an average septic tank volume of 2.84 m^3 (750 gallons), and being pumped out once every three years, approximately 21-million cubic meters (5.5 billion gallons) of septage are generated annually.

3.2.1 Per Capita Septage Generation Rates

Septage generation rates reported in the literature vary widely. Based on the assumptions presented above and 3.5 persons per housing unit, an estimate of septage generation rate in the U.S. is approximately 237 liters (55 gallons) per capita per year. A study in Suffolk County, New York estimated 340 to 380 liters (90 to 100 gallons) per capita per year, based on frequent pumpouts and larger than average tank volumes (2). Septage generation in the Poughkeepsie, New York area was estimated to be 190 liters (50 gallons) per capita per year (3). The State of Connecticut recommends using 190 to 265 liters (50 to 70 gallons) per capita per year in its lagoon-design guidelines. Recent Norwegian guidelines recommend 250 liters (66 gallons) per capita per year, while Swedish guidelines recommend 225 liters (60 gallons) per capita per year (4). Results of a survey carried out in Germany reveal values varying between 110 and 4,380 liters (30 to 1,160 gallons) per capita per year (4).

In light of the significant variation in septage generation rates from one locality to another, every effort should be made to obtain actual records of septage quantities (i.e., from existing treatment plants receiving septage, or from local haulers) for a particular service area. When these data cannot be obtained, an average per capita septage generation rate of 230 liters (60 gallons) per capita per year can be used for planning and design purposes. An alternate method of estimating septage quantities is to multiply the number of septic tanks in the service area by the average annual pumpout volume per unit (i.e., the total volume of a typical septic tank divided by the average number of years between pumpouts). This method tends to give more accurate results than the per capita method, provided the number of septic tanks is known and the estimate of average pumpout interval is realistic. Commercial, institutional, and industrial sources should be accounted for by addition to the results from either method. The two methods are illustrated as follows:

Method 1: Per Capita Generation Rates

Annual Volume = Service Area Population x 230 liters/Capita/Year
= (Service Area Population x 60 Gal/Capita/Year)

(Note: Per capita generation rate (volume/person served by septic tanks) can be adjusted up or down based on local knowledge of septic tank cleaning practice.)

Method 2: Typical Tank Volume/Pumpout Frequency Assumption

Annual Volume =

$$\frac{\text{No. Septic Tanks x Typical Volume (gallons or liters)}}{\text{Pumpout Interval (years)}}$$

(Note: A pumpout interval of 3 to 5 years is realistic in areas where homeowners are moderately conscientious about septic tank cleaning.)

3.2.2 Seasonal Variations in Septage Quantities

The pumping of septic tanks usually follows a seasonal pattern, with most of the pumping occurring during times of high groundwater or extended periods of rainfall or snowmelt (i.e., early spring, fall, and summer) due to the mistaken belief that tank pumping would relieve surface failure symptoms. In colder climates, less septage is pumped during the winter due to the difficulty of uncovering septic tanks in frozen ground. Some septage pumping does take place year round, such as for emergency system repair, and for service of institutions and commercial establishments such as schools, restaurants, and motels. Thus, septage volumes are not uniformly distributed throughout the year. While a mandatory pumping schedule would normalize septage volumes throughout the year, the development of such regulations, although very practical, have proven to be difficult to implement.

Figure 3-2 shows a typical septage pumping pattern taken from the Lebanon, Ohio STP for the year 1972 (5). As can be seen from the figure, most of the pumping occurs during the months between May and August, with significantly less pumping in the months between December and March. On an extended scale, daily peaks must be considered in determining receiving station component sizing. It is extremely important to provide adequate capacity for peak loading periods in order to avoid having to deny discharges, which will undoubtedly result in illegal dumpings.

FIGURE 3-2
SEPTAGE LOADING PATTERN AT LEBANON, OH 1972

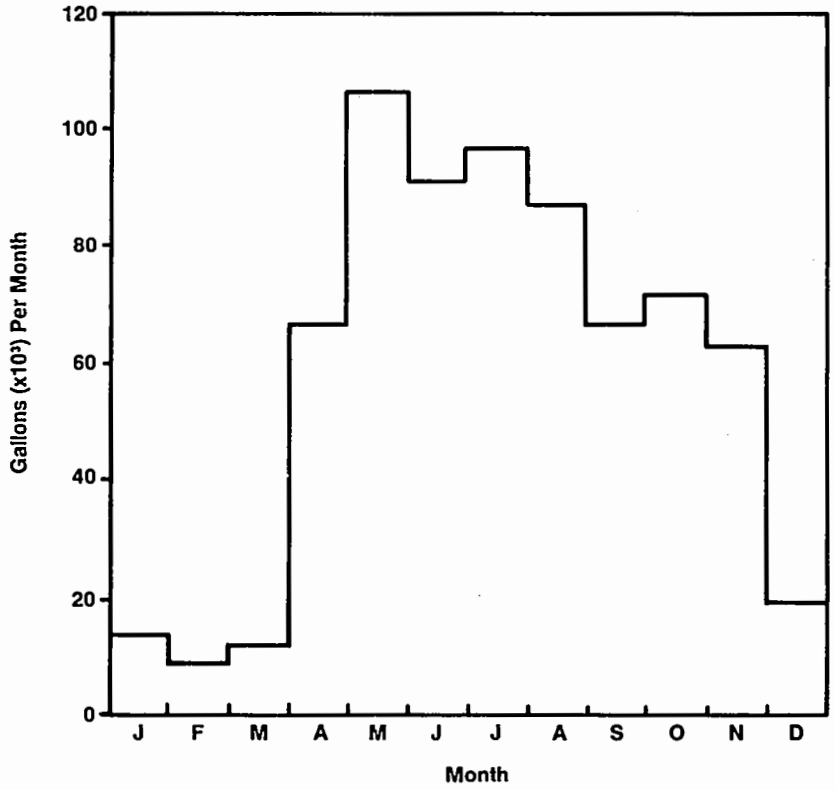
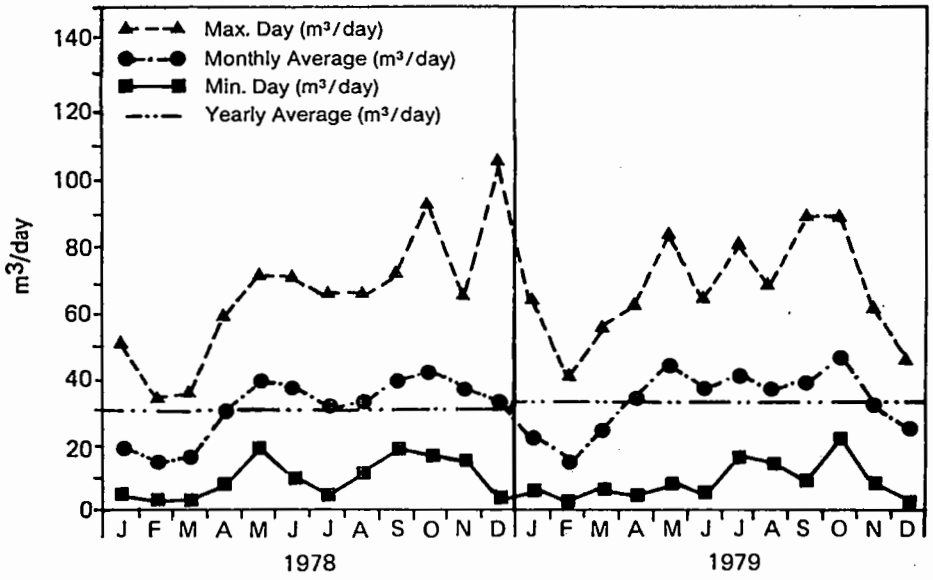


FIGURE 3-3
VOLUME OF SEPTAGE RECEIVED AT
ENGA TREATMENT PLANT, NORWAY (4)



Additional information on the variations in septage quantities is available from a Norwegian study that analyzed actual operating data for several municipal treatment plants with facilities for handling septage (4). A representative plot of septage quantity variability characteristics for one of these facilities (Enga, Norway) is given in Figure 3-3. Maximum days and minimum days for each month are plotted, as well as monthly averages. Table 3-1 presents the data with which these plots were made, including coefficients of variation.

TABLE 3-1

SEPTIC TANK SLUDGE RECEIVED AT ENGA TREATMENT PLANT, NORWAY (4)

Year/Month	No. Days Receiving Sludge	Monthly Volume m^3	Daily Volume Average	Daily Volume Maximum m^3	Daily Volume Minimum
1979					
January	20	433	22	64	6
February	19	279	15	41	3
March	20	499	25	55	6
April	19	640	34	62	5
May	21	927	44	84	8
June	21	768	37	65	5
July	22	890	41	81	16
August	22	785	36	69	14
September	20	821	39	89	9
October	24	1088	46	90	22
November	22	691	31	61	8
December	20	487	24	46	3
Average		692	33		

The variability data from Lebanon, Ohio, and Enga, Norway have been used to produce the plots given in Figures 3-4 and 3-5, which show the variation in septage quantities produced in different months of the year in terms of the ratio of monthly and daily averages to annual averages. The pattern shown in Figure 3-2 for Lebanon, Ohio is believed to be more applicable in the U.S. based on general knowledge of septic tank cleaning practices in various parts of the country.

FIGURE 3-4
VARIATION IN MONTHLY AVERAGE SEPTAGE QUANTITIES LEBANON, OH (5)

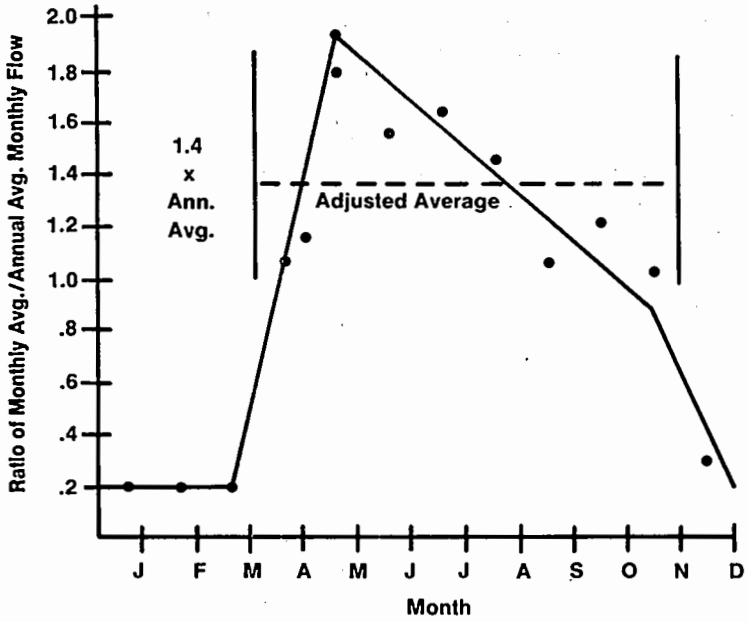
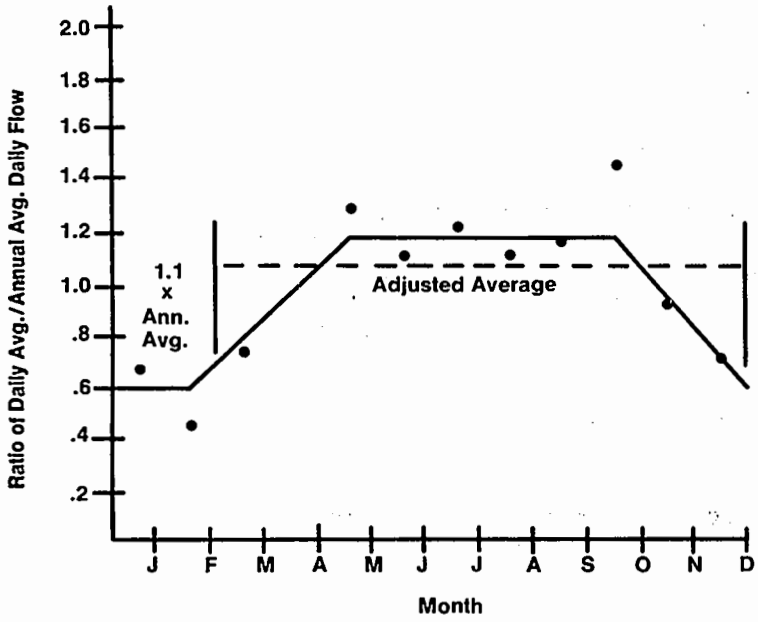


FIGURE 3-5
VARIATION IN DAILY AVERAGE SEPTAGE QUANTITIES ENGA, NORWAY (4)



These plots illustrate that the bulk of the septage quantities produced are generated in the spring, summer, and fall, specifically April through November for Lebanon, and March through December for Enga. If the data points for these periods alone are averaged, an adjusted average daily or average monthly septage generation rate can be determined. This adjustment factor can be used to develop a more realistic estimate of daily or monthly average septage flow during the critical spring-summer-fall period, based on annual septage quantity estimates. Based on the Lebanon, Ohio data, an adjustment factor of 1.4 is indicated. For general planning and design purposes, the average design capacity for septage handling and treatment facilities can be estimated as being approximately 1-1/2 times the annual average daily generation rate.

3.2.3 Peaking Factors

It is of the utmost importance to estimate the volume of septage to be treated and the rate at which it will be received as correctly as possible. The rate at which it is generated (i.e., daily flows) depends on many factors, including time of year, weather conditions, and local septic tank cleaning practices. The use of peaking factors allows the designer to estimate the range of flow conditions to be expected. The peaking factor may be defined as the ratio of the maximum/average septage quantity received over a particular period (i.e., week, month, year). Table 3-2 lists the ratio of the peak monthly to the mean monthly septage volume received at various treatment facilities in the U.S. and Norway, corresponding to the month when the maximum septage volume is received over a period of a year. Table 3-3 is a summary of peaking factors for the four municipal treatment plants studied in Norway.

In addition to monthly variations, weekly and daily variations must be taken into consideration. While little data exist on actual weekly and daily peaking factors, various planning studies in the U.S. have recommended weekly peaking factors ranging from 1.8 to 3.6, and daily peaking factors ranging from 4.0 to 4.8 (6) (7).

3.3 Characteristics of Septage

The following section presents data that describe the characteristics of septage. However, the data presented are not intended to replace site-specific data. Due to the extensive variation in septage characteristics between loads, it is recommended that nearby facilities with similar service areas be investigated and proper factors of safety be applied in designing receiving and treatment facilities.

TABLE 3-2

MONTHLY PEAKING FACTORS FOR SELECTED LOCALITIES IN THE UNITED STATES AND NORWAY

Location	Month	Year	Ratio of Peak Monthly to Mean Monthly Septage Volume	Reference
Essex, Connecticut	June	1978	2.0	(25)
Old Saybrook, Connecticut	July	1975	2.5	(25)
	August	1976	2.1	
	June	1977	1.9	
	October	1978	1.5	
Salem, New Hampshire	June	1974	1.3	(6)
	May	1975	1.2	
Lebanon, Ohio	May	1972	1.8	(5)
Winston-Salem, North Carolina	May	1972	1.8	(26)
Enga, Norway	October	1978	1.4	(4)
	October	1979	1.6	
Heisted, Norway	September	1979	1.7	(4)
Brumunddal, Norway	November	1977	1.9	(4)
	October	1978	2.1	
	October	1979	2.2	
Lillehammer, Norway	October	1979	1.9	(4)

TABLE 3-3

VARIATIONS OF SEPTAGE VOLUME RECEIVED AT FOUR MUNICIPAL TREATMENT PLANTS IN NORWAY (4)

Treatment Plant	Year	Maximum Month Annual Monthly Average	Maximum Day Annual Daily Average
Enga	1978	1.42	3.42
	1979	1.57	2.73
Heistad	1979	1.73	2.94
Brumunddal	1977	1.93	4.42
	1978	2.14	3.70
	1979	2.22	4.52
Lillehammer	1979	1.88	4.88

Table 3-4 reports septage characteristics from 12 studies conducted in the U.S. and from 6 studies conducted in Europe and Canada. The data for a particular parameter were often reported as a range and a mean value; however, the parameters reported, as well as the number of individual samples taken varied widely from one study to another. As can be seen from the table, there is a close correspondence between the data collected in the U.S. and those collected in Europe and Canada. The lower values found in Europe/Canada, versus the U.S. for total solids and total volatile solids, may be related to pumping frequency. The Norwegian Department of Ecology requires each homeowner to empty his septic tank at least once a year (once every three years for tanks at recreational homes). German guidelines do not comment specifically on how often the septic tanks should be emptied; however, in a study by Resch, it was found that for those in the study, 25 percent were cleaned annually and 34 percent were cleaned every two years (8).

It is important to note the range of values reported for many of the parameters. As mentioned previously, the cause of this variability may be the result of a number of factors, including user habits, tank size and design, pumping frequency, climate and seasonal weather conditions, and tributary appliances such as garbage grinders, water softeners, and washing machines, as well as difficulties in obtaining representative samples of the entire tank contents.

Due to inconsistencies and discrepancies in the data base, the relationship between individual parameters may be misleading. For example, the average TS value is less than the average TSS value for the European data. This is probably caused by TS values not being reported in some cases where the TSS value was atypically high. Certain valid relationships between variables have been observed and are worth noting. For example, Eikum (4) presented data indicating that on the average VSS concentrations are roughly 75 percent of the Total Suspended Solids concentration. Other data presented by Eikum (4) showed COD values to be roughly 25 percent higher than VSS concentrations.

Table 3-4 also presents data compiled by the U.S. EPA's Municipal Environmental Research Laboratory in Cincinnati, Ohio. All three sets of data compare well considering the variable nature of septage. Based on these data, Table 3-4 presents suggested design values for the various physical and chemical constituents of septage where no site-specific data are available.

3.3.1 Nutrients in Septage

Nutrients in septage, specifically nitrogen and phosphorus, are of concern due to the growing interest in the treatment and removal of nutrients from domestic wastewaters. Nitrogen and phosphorus is also of interest with respect to specific loading rates as they apply for land treatment of septage.

The concentrations of both nitrogen and phosphorus found in septage are high as compared to typical domestic wastewater. Typical domestic wastewater may contain from 12 to 50 mg/L of ammonia-nitrogen, and from 4 to 15 mg/L of phosphorus, with average concentrations of 25 and 8 mg/L, respectively (22). By comparison, septage, as shown in Table 3-4, contains average concentrations of 97 and 210 for ammonia-nitrogen and phosphorus, respectively.

3.3.2 Heavy Metals in Septage

Metal contamination may result from one or more of the following sources (21):

1. Household chemicals that contain trace concentrations of heavy metals.

2. Leaching of metal from household piping and joints.

3. Contamination of septage in hauler trucks from a previous industrial waste load.

TABLE 3-4

PHYSICAL AND CHEMICAL CHARACTERISTICS OF SEPTAGE, AS FOUND IN THE LITERATURE, WITH SUGGESTED DESIGN VALUES[a,b]

Parameter	United States (5) (9-19)				Europe/Canada (4) (20)				EPA Mean	Suggested Design Value
	Average	Minimum	Maximum	Variance	Average	Minimum	Maximum	Variance		
TS	34,106	1,132	130,475	115	33,800	200	123,860	619	38,800	40,000
TVS	23,100	353	71,402	202	31,600	160	67,570	422	25,260	25,000
TSS	12,862	310	93,378	301	45,000	5,000	70,920	14	13,000	15,000
VSS	9,027	95	51,500	542	29,900	4,000	52,370	13	8,720	10,000
BOD_5	6,480	440	78,600	179	8,343	700	25,000	36	5,000	7,000
COD	31,900	1,500	703,000	469	28,975	1,300	114,870	88	42,850	15,000
TKN	588	66	1,060	16	1,067	150	2,570	17	677	700
NH_3-N	97	3	116	39	---	---	---	---	157	150
Total P	210	20	760	38	155	20	636	32	253	250
Alkalinity	970	522	4,190	8	---	---	---	---	---	1,000
Grease	5,600	208	23,368	112	---	---	---	---	9,090	8,000
pH	---	1.5	12.6	8	---	5.2	9.0		6.9	6.0
LAS	---	110	200	2	---	---	---		157	150

[a]Values expressed as mg/L, except for pH.

[b]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.

Table 3-5 lists the heavy metal concentrations found in the previously-discussed studies, including the mean, minimum, and maximum concentrations observed, and the variability. Table 3-5 compares the heavy metal concentrations cited in U.S. and European research studies to those compiled by the U.S. EPA MERL (28) and to those typically found in domestic sewage sludges (22). Again, the values presented compare favorably with those observed by EPA. In contrast, the metal concentrations observed in septage are considerably less than those typically observed in domestic sewage sludge. The level of heavy metal concentration is of particular significance when consideration is given to septage application to land. Application of septage to land and the impact of heavy metals is discussed in Chapter 5.

Septage facility designers should be cognizant of the fact that highly contaminated industrial sludges, sometimes disposed of together with domestic septage, can severely upset treatment processes. Monitoring programs aimed at detecting such illegal discharges should be strongly encouraged. The treatment facility should be designed to minimize the effects of such upsets.

3.3.3 Pathogens in Septage

Pathogenic organisms found in septage are discharged by humans who are infected or carriers of a particular disease. The usual bacteriological pathogenic organisms that may be excreted by man cause diseases of the gastrointestinal tract such as typhoid and paratyphoid fever, dysentery, diarrhea, and cholera.

Table 3-6 summarizes the investigations carried out at the Norwegian Institute for Water Research (4). The concentrations of indicator organisms in raw septage were found to be in the same range as those found in untreated primary sludges from municipal treatment plants. The table also indicates that although variations will be found regarding concentrations of pathogens in raw septage, the concentrations are high for all indicator organisms used.

Table 3-7 presents typical concentration ranges for indicator organisms and bacterial and parasitic pathogens in raw septage found in the U.S. Although not indicated here, there is no doubt that a variety of viral pathogens will also be present. These include polio virus, hepatitis A, echovirus, coxsackie, Norwalk-like agents, rotavirus and adenovirus (27). It is evident that raw septage may harbor disease-causing organisms, thus demanding proper management to protect public health.

TABLE 3-5

HEAVY METAL CONCENTRATIONS IN SEPTAGE COMPARED TO TYPICAL DOMESTIC WASTEWATER SLUDGES[a]

Parameter	United States (5) (9-19)			Europe/Canada (4) (20)			Typical U.S. Domestic Sludge Ranges (28)[b]	EPA Mean (5)	Suggested Design Value for Septage
	Average	Minimum	Maximum	Average	Minimum	Maximum			
Al	48	2	200	---	---	---	---	48	50
As	0.16	0.03	0.5	---	---	---	0- 0.7	0.16	0.2
Cd	0.27	0.03	10.8	0.05	---	0.35	0.1- 44	0.71	0.7
Cr	0.92	0.6	2.2	0.63	---	5.0	0.9- 1,200	1.1	1.0
Cu	8.27	0.3	34	4.65	1.25	15.0	3.4- 416	6.4	8.0
Fe	191	3	750	---	---	---	---	200	200
Hg	0.23	0.0002	4	---	0.15	0.2	0- 2.2	0.28	0.25
Mn	3.97	0.2	32	---	---	---	---	5	5
Ni	0.75	0.2	37	0.58	---	2.5	0.5- 112	0.9	1
Pb	5.2	2	8.4	3.88	---	21.25	3.2- 1,040	8.4	10
Se	0.076	0.02	0.3	---	---	---	---	0.1	0.1
Zn	27.4	2.9	153	38.85	1.25	90	79- 655	49	40

[a]Values expressed as mg/L.
[b]Values converted from μg/g assuming TS = 40,000 mg/L.

FIGURE 3-6
VARIATIONS IN NH_3 AND H_2S CONCENTRATIONS AT THE TAU TREATMENT PLANT WHEN RECEIVING SEPTAGE, FEB. 24 - 1976 (4)

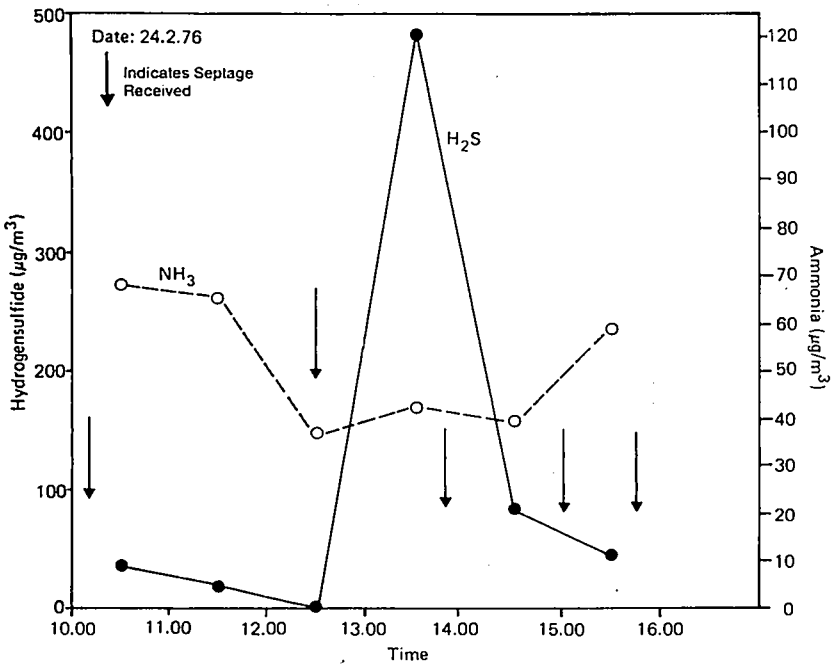
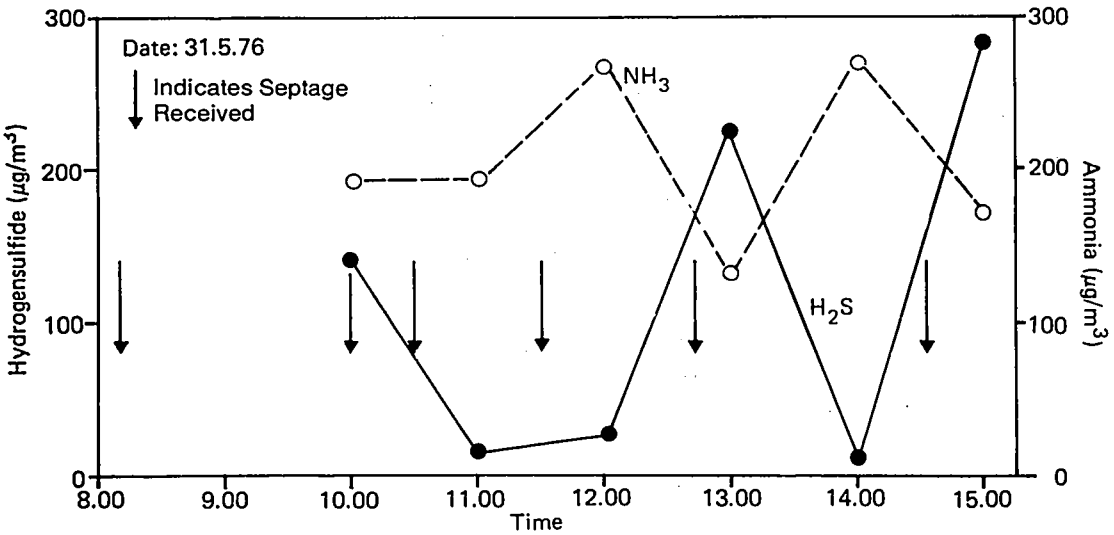


FIGURE 3-7
VARIATIONS IN NH_3 AND H_2S CONCENTRATIONS AT THE TAU TREATMENT PLANT WHEN RECEIVING SEPTAGE, MAY 31 - 1976 (4)



3.3.4 Odors

Traditionally, the collection and handling of wastewater, septage, and sludge has been associated with odor problems at treatment facilities. The most characteristic odor of septage is that of hydrogen sulfide, which is produced by the anaerobic conversion of sulfate to sulfide. The compounds causing bad odors when handling septage are sulfides, mercaptans, amines, aldehydes, skatoles, and organic acids.

Practical experience indicates that the odor intensity varies considerably during the day at plants receiving septage. The reason for this is that each truckload of septage can vary with respect to the amount of odorous gases it gives off when the septage is emptied or aerated at the plant. At the TAU Treatment Plant in Norway, investigations were made regarding H_2S and NH_3 concentrations during the day (4). Composite samples were taken each hour from the room containing the screen and grit chamber. Results from a typical winter and summer day are shown in Figures 3-6 and 3-7. The hydrogen sulfide concentrations varied from approximately 0 to 480 ug/m^3, and the ammonia concentration varied from approximately 10 to 280 ug/m^3.

The real concern with odors is not related to their potential physical harm to humans, but rather to the psychological stress they produce. Offensive odors can cause poor appetite for food, lowered water consumption, impaired respiration, nausea and vomiting, and mental perturbation (24). Often the problem of odors is not recognized in the design of a facility and only becomes apparent after the plant becomes operational. Proper attention to design details in the design phase and good housekeeping practices in facility operation will keep odors to a minimum. The various technologies available for odor control are presented in Chapter 4 as they relate to septage receiving stations, where the odor potential is generally the greatest.

3.4 Comparison of Septage and Domestic Wastewater Characteristics

Table 3-8 is a comparison of constituents present in septage and municipal wastewater. In many respects, septage is a waste similar in characteristics to domestic sewage, except that the former is more concentrated. However, there are also dissimilarities. Septage is anaerobic and odoriferous. It contains plastic material, hair, and grit that clog and wear pumps and conduits. Personal contact with septage for maintenance purposes is highly objectionable from aesthetic and health points of view. These aspects of septage characteristics must be considered in the design of septage handling and treatment facilities.

TABLE 3-6

PATHOGEN CONCENTRATIONS IN DOMESTIC SLUDGES (4)
BASED ON NIVA RESEARCH

Type of Sludge	Total Coliforms	Fecal Coliforms	Fecal Streptococcus	Anaerobic Sporeformers, Clostridium Perfringens
Septage	3.5×10^7	3.9×10^6	4.7×10^3	3.3×10^5
Raw Primary	5.6×10^7	2.0×10^7	1.1×10^6	3.4×10^5

TABLE 3-7

INDICATOR ORGANISM AND PATHOGEN CONCENTRATIONS
IN DOMESTIC SEPTAGE

Parameter	Typical Range (counts/100 ml)	Reference
Total Coliform	$10^7 - 10^9$	(10)
Fecal Coliform	$10^6 - 10^8$	(9) (10) (23)
Fecal Streptococci	$10^6 - 10^7$	(9) (10) (23)
Ps. Aeruginosa	$10^1 - 10^3$	(9) (10) (23)
Salmonella Sp.	$1 - 10^2$	(9) (10)
Parasites		
Toxacara, Ascaris Lumbricoides, Trichuris Trichiura, Trichuris Vulpis	Present	(10)

TABLE 3-8

COMPARISON OF SEPTAGE AND MUNICIPAL SEWAGE[a]

Parameter	Septage[b]	Sewage[c]	Ratio of Septage to Sewage
TS	40,000	720	55:1
TVS	25,000	365	68:1
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	150	25	6:1
Total P	250	8	31:1
Alkalinity	1,000	100	10:1
Grease	8,000	100	80:1
pH	6.0	---	---
LAS	150	---	---

[a]Values expressed as mg/L, except for pH.
[b]Based on suggested design values in Table 3-4.
[c]From Metcalf and Eddy, 2nd Edition, "medium strength sewage" (22).

3.5 References

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CHAPTER 4

RECEIVING STATION DESIGN

4.1 Introduction

The primary functions of a receiving station are: 1) transfer of septage from hauler trucks, 2) preliminary treatment of septage (i.e., screening and grit removal), and 3) storage and equalization of septage flows. Receiving station design should encourage simple and reliable operation, and have the flexibility to accommodate varying flow and loading conditions.

The overall receiving station design varies with the amount of septage to be received, design of the tank truck, type of preliminary treatment to be provided, downstream treatment and ultimate disposal, and odor considerations or requirements. There are, however, certain design elements that are fundamental in most receiving stations. These are listed as follows:

1. Dumping station.
2. Screening.
3. Grit removal.
4. Storage/equalization.
5. Odor control.

Several variations in receiving station design have been reported for various treatment plants in Europe (1)(2), as shown in Figures 4-1, 4-2, and 4-3. These examples illustrate the application of several of the basic design elements mentioned above; however, no one example employs all the elements of a recommended receiving station design. Figures 4-4 and 4-5 illustrate two variations of the basic recommended design incorporating screening, grit removal, and equalization. The specific provisions for septage dumping and odor control should be noted as these are important elements of a receiving station design.

FIGURE 4-1
RECEIVING STATION FOR SEPTAGE AT EKEBYHOV TREATMENT PLANT, SWEDEN (1)

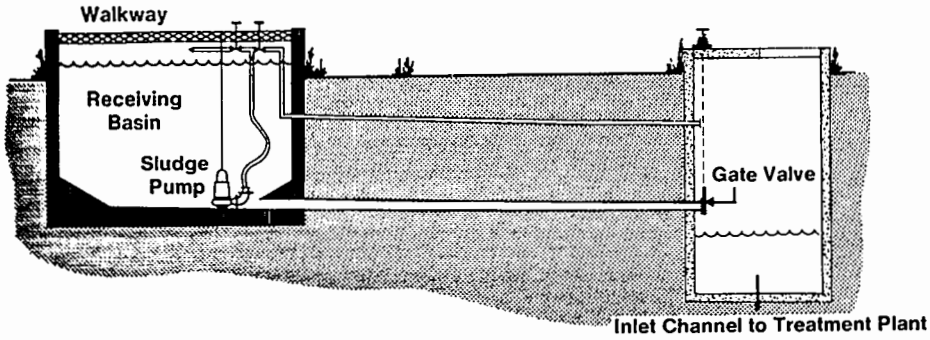


FIGURE 4-2.
RECEIVING STATION WHERE THE SEPTAGE IS FED TO AN ANAEROBIC DIGESTER IN WEST GERMANY (2)

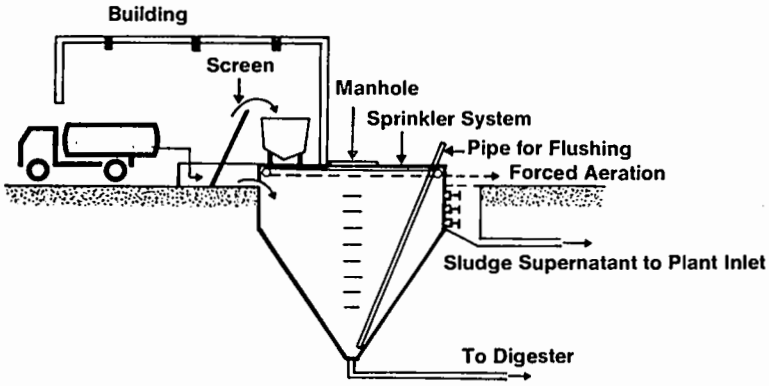


FIGURE 4-3
RECEIVING STATION INCLUDING SCREENING AND GRIT REMOVAL AT LILLHAMMER TREATMENT PLANT, NORWAY (1)

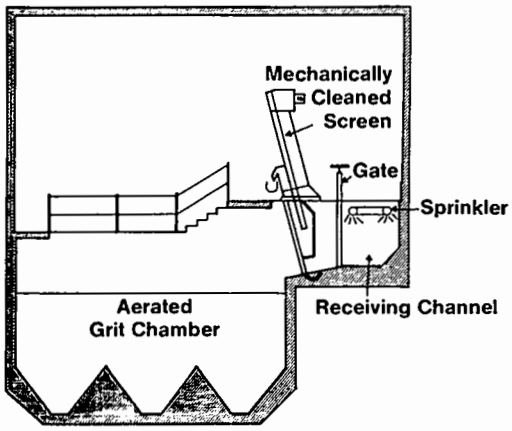


FIGURE 4-4
RECEIVING STATION WITH PRETREATMENT PRIOR TO EQUALIZATION (BATCH PRETREATMENT)

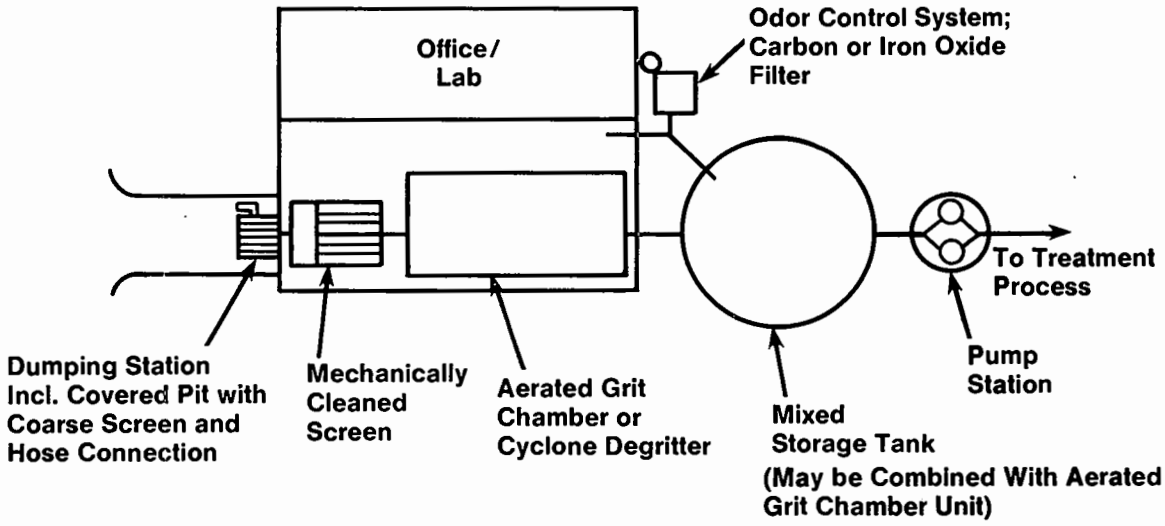
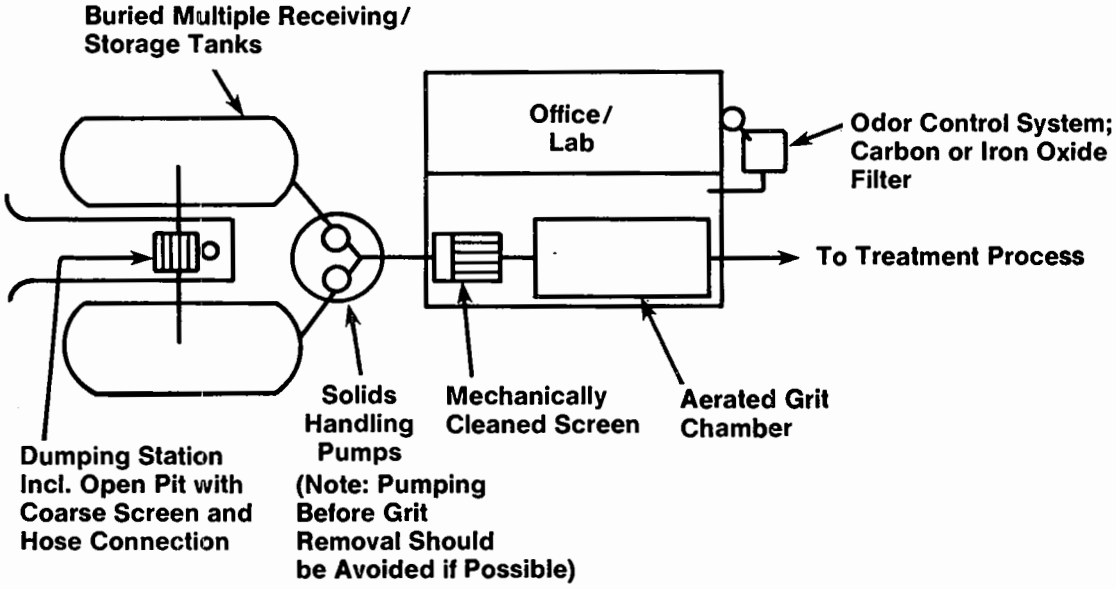


FIGURE 4-5
RECEIVING STATION WITH EQUALIZATION PRIOR TO PRETREATMENT (CONTROLLED RATE PRETREATMENT)



As shown in Figures 4-4 and 4-5, equalization tanks can be placed before or after pretreatment. The advantage of providing storage capacity before pretreatment is that the grit chamber can be sized on the basis of a controlled flow rate averaged over a specified period of time. With pretreatment prior to equalization the grit chamber must have sufficient aeration and flow capacity to handle the maximum possible hydraulic load per dumping. Also, aeration intensity may need to be adjusted as the hydraulic loading rate varies. However, providing equalization before pretreatment may necessitate pumping before the septage has been degritted, which is generally not recommended. In these cases, care should be taken in specifying pumping equipment capable of handling grit.

Pretreatment is not usually required when discharging to an interceptor upstream of a plant, or when discharging to the headworks of a large existing treatment facility with adequate pretreatment processes (see Figures 4-6 and 4-7). Equalization is necessary when discharging directly to the head of a treatment plant in order to control the flow of septage proportionately to sewage flow. Equalization is not generally necessary when septage is discharged to an interceptor at a point far enough upstream of the plant to permit complete mixing with the wastewater, provided that the total quantity of septage discharged represents less than 1 percent of the sewage flow at that time and location. This can be achieved by avoiding septage dumpings during daily low-flow periods.

An example of a highly sophisticated remote receiving station which provides for the discharge of septage to an interceptor sewer is shown in Figure 4-8. This system is presently in use in West Germany (1). It consists of one inlet box and two manholes. The first manhole contains a flow meter for measuring the volume of septage discharged to the sewer. In addition, a test pipe for taking samples is connected to the discharge pipe. The second manhole serves as a rough grit chamber where stones, etc. will be collected. This material is removed manually as often as necessary. The discharge system for septage is connected to a control computer. The computer system is used for checking and recording information on the septage entering the sewer system. Each user of the system is issued a coded card that activates the equipment, enabling septage to be discharged into the sewer. The equipment, with printer, emergency power supply, display, keyboard, isolated signal inputs and outputs, and a cardreader, is capable of determining "who" may deposit "how much" of "what" into the sewage system. In addition, it is possible to record the volume of septage deposited per user over a period of time and to print out a list of all users and the quantities of septage deposited by each of them.

FIGURE 4-6
INTERCEPTOR RECEIVING STATION

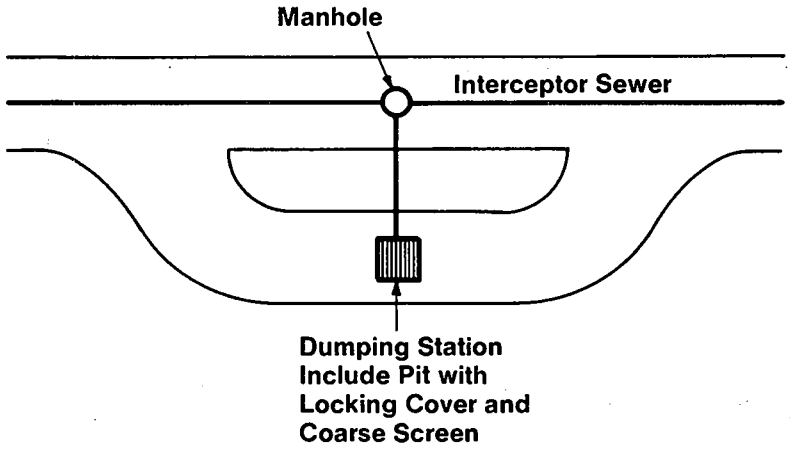


FIGURE 4-7
RECEIVING STATIONS AT STP'S WHERE EXISTING PRETREATMENT FACILITIES CAN BE USED TO TREAT SEPTAGE

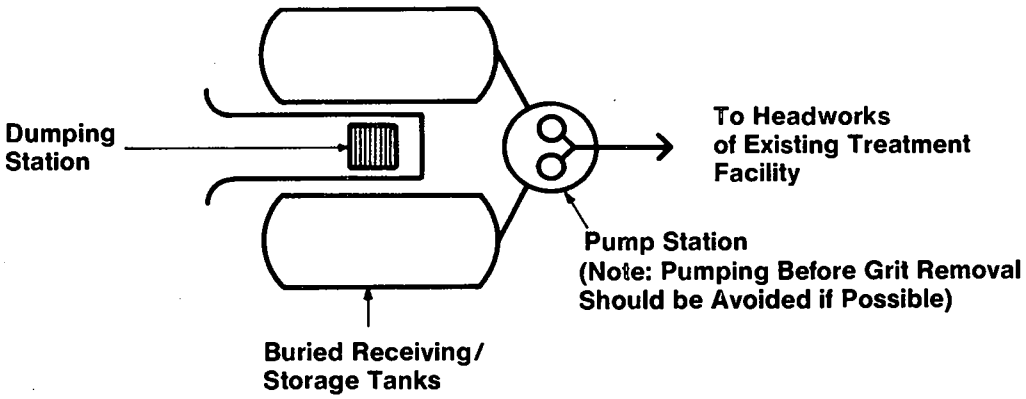
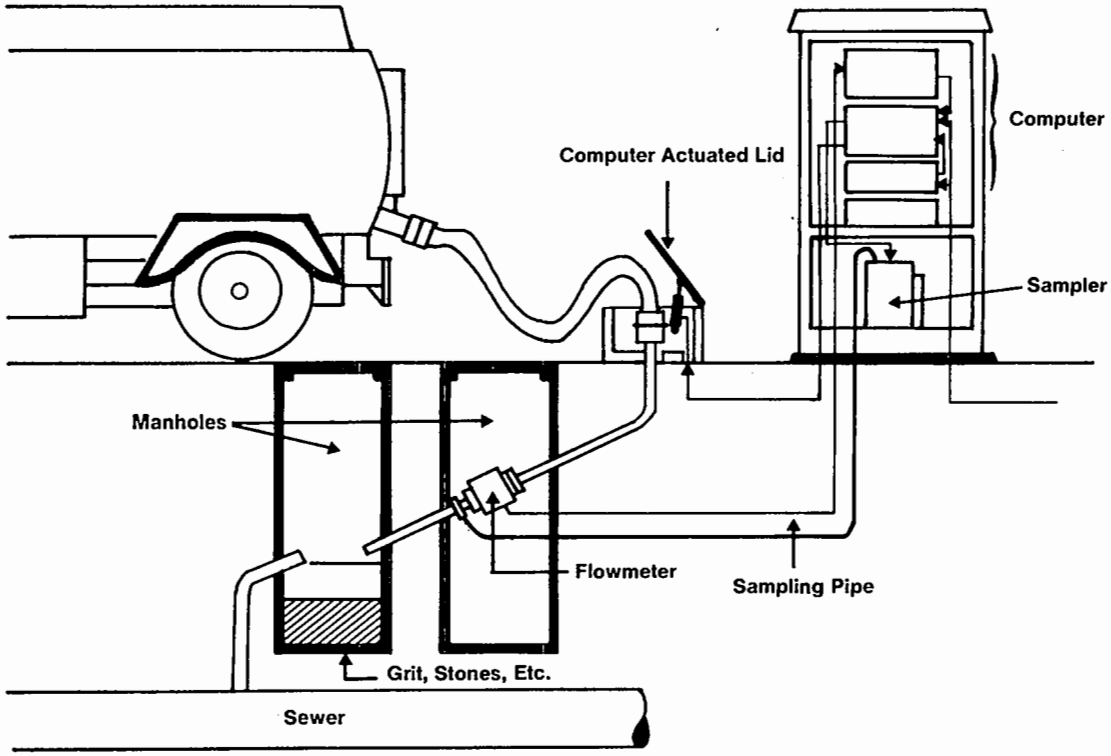


FIGURE 4-8
COMPUTERIZED INTERCEPTOR RECEIVING STATION (1)



When setting up user data records, it is possible to specify "check-marks." This enables extra recording equipment (e.g., sample-takers or pen-recorders) to be switched on when these particular users access the system. The ability to define the times of the day or week when deposits by particular users are allowed makes this equipment suitable for a wide range of waste management applications.

Upper and lower limits for each data input may be set so that if a particular data value goes outside these limits, a message will be printed and a relay operated to enable external action to be taken (e.g., sample-taker switched in). The unit has an internal clock and calendar and headlines all printed messages with the date and time. The normal printout shows the values of up to a maximum of eight possible data inputs. This system enables the municipality to control the septage quantity and quality that enters either the sewer system or the wastewater treatment plant. Since no other such systems are known to exist, it must be considered experimental.

Manual monitoring programs are far more common than automated systems described herein. The most practical approach is to employ a registration system for each truck, e.g., plastic credit card acceptance device which unlocks dumping station access, along with manual spot-check grab samples by operators. Violations by haulers should be accompanied by severe penalties.

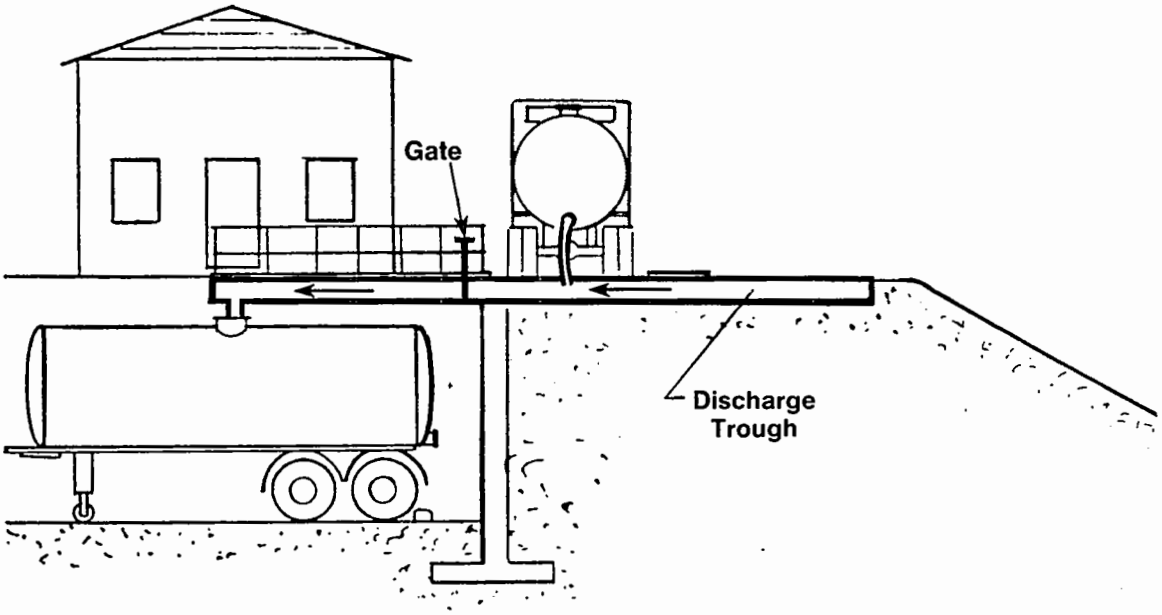
Another variation in receiving station design may be appropriate where the transfer or temporary storage of relatively small quantities of septage is required. One example of such an application would be a transfer station, as depicted in Figure 4-9, where septage from individual hauler trucks is transferred to large tank trucks for transport to a central treatment facility. A transfer/storage station can also be used in conjunction with a land application operation where septage is transferred to specialized application equipment. In this application septage can be stored over short periods when weather conditions do not allow land application.

Only authorized hauler trucks should utilize the facility, since this provides for accurate recordkeeping of septage volumes handled at the station and prevents system overloading. The haulers may discharge their septage either under pressure (i.e., by pumping) or by gravity (through a hose or free discharge).

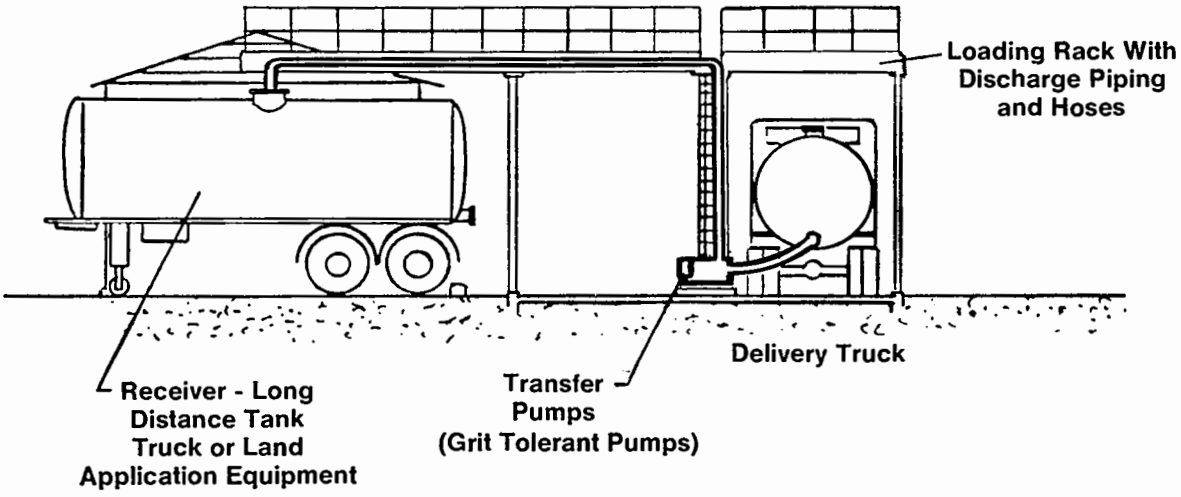
4.2 Dumping Station

The dumping station is the initial point of reception of septage at a receiving facility. It should have a slightly sloped ramp to tilt the truck for complete drainage and facilitate hosing down of spillage to a central drain. The basic layout of a dumping station is shown in Figure 4-10 (4).

FIGURE 4-9
SEPTAGE TRANSFER STATION (3)

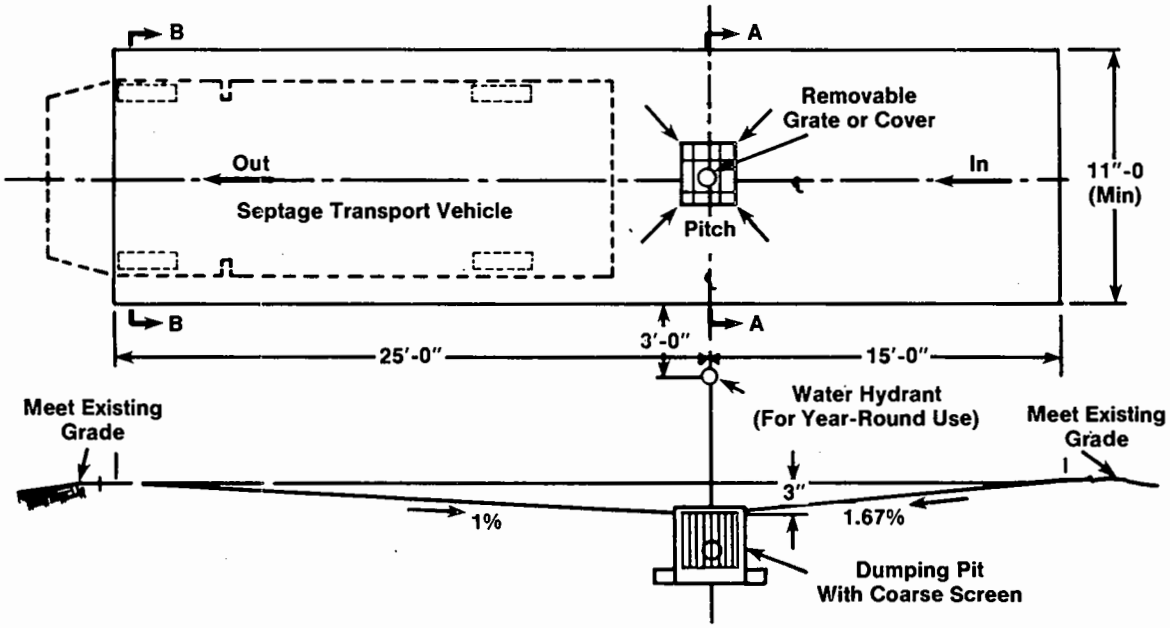


Gravity Transfer Arrangement

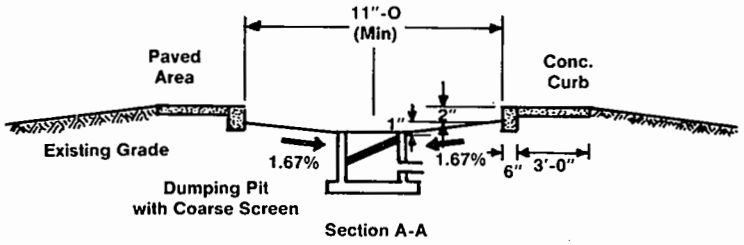


Pumped transfer Arrangement

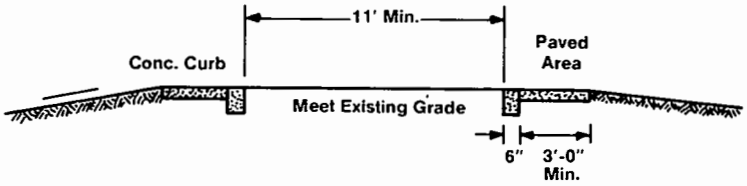
FIGURE 4-10
BASIC LAYOUT OF DUMPING STATION (4)



Profile at Centerline of Pavement



Section A-A



Section B-B

Hoses and other washdown equipment should be provided and should be conveniently located at the dumping station to facilitate cleanup by each individual hauler. Also, in colder climates, hot steam equipment might be provided for thawing frozen valves, hose lines, etc.

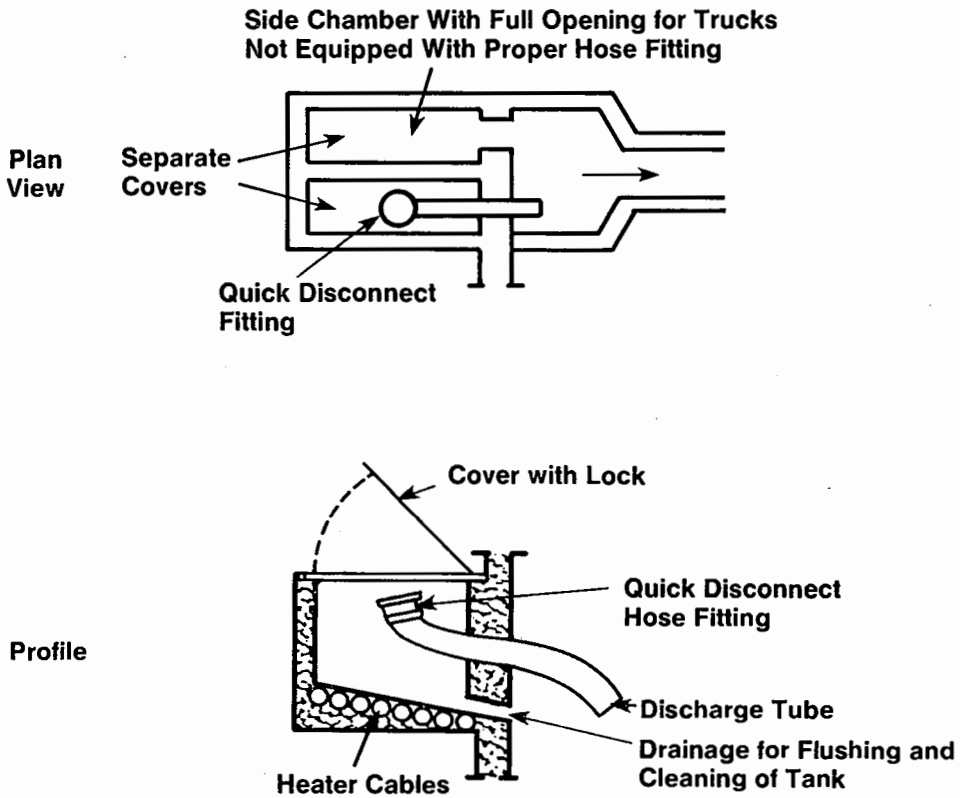
The septage should be discharged through a hose extending from the rear of the truck to the dumping station. The connection at the tank truck must be water-tight in order to prevent spillage and odors. The hose should be connected to a quick-release discharge tube in the dumping station to minimize spillage. Figure 4-11 illustrates a recommended dumping station inlet arrangement, based on several designs in Norway (1). Heater cables are installed in the bottom of the chambers to prevent freezing in the winter. The discharge tube should extend below the liquid level in the receiving chambers to minimize the release of odorous gases. The hose connection and discharge tube is generally 10 cm (4 in.) in diameter.

Discharge into a sewer requires dumping facilities similar to those described previously. However, in many countries, manholes serve as the receiving facility, often without any controls. An exception is West Germany, where it is quite common to discharge septage into manholes, but only under very strict regulations regarding the receiving flow and type of treatment plant downstream (1).

A dumping station should not be designed to allow tank trucks to back up to the discharge point and release septage without any hose connection. This lends itself to substantial spillage and release of odors.

The amount of septage to be received and handled at a dumping station, and the rate at which it passes through the pretreatment facility, must be accurately estimated during the design phase. It is of utmost importance to estimate septage volumes as accurately as possible and to design the receiving facilities to handle the range of daily septage flows expected. The limiting factor affecting a dumping station's peak flow capacity may be the number of discharge points (i.e., unloading docks and hose connections). Multiple discharge points might be considered where high traffic is expected during peak hauling periods. Similarly, the access arrangement should permit efficient queing of several pumper trucks in the dumping station area.

FIGURE 4-11
RECOMMENDED DUMPING STATION INLET ARRANGEMENT (1)



4.3 Screening

Septage will generally contain various forms of untreatable debris such as rags, plastics, sticks, stones, and cans. Such debris is separated from the liquid septage by a coarse bar screen. The screen provides the initial pretreatment of septage in order to protect unit processes downstream. One receiving facility at Barnstable, Massachusetts includes a rock sump (or pit) in the receiving chamber, along with a bar screen to remove a large portion of large debris and gravel present in raw septage (5).

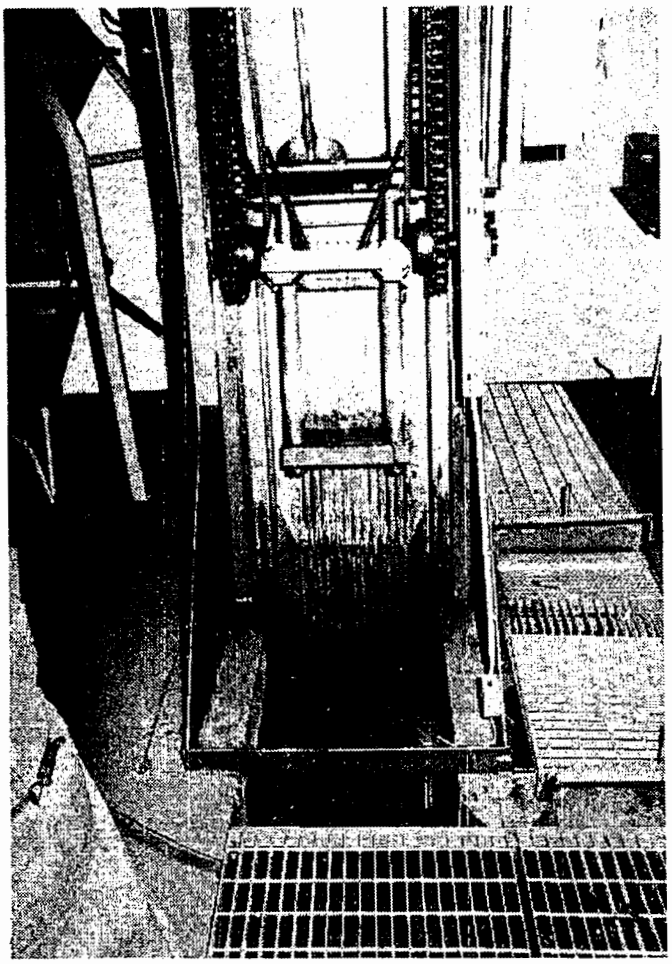
A mechanically-cleaned bar screen is desirable for all septage handling facilities. Different types of mechanically-cleaned screens are in use at plants receiving septage (see Figure 4-12). It is important that the bar screen be designed to handle larger quantities of screenings and heavier material than an ordinary screen designed for sewage. As noted in Figure 4-12, the mechanically-cleaned bar screen should have no moving parts, such as chains, wheels, etc., installed below water level. Experience in Norway shows that such designs cause considerable operational problems (1). If a manually cleaned bar screen is unavoidable, it must be designed with a bypass (i.e., parallel screen chambers) to permit operation during cleaning of a clogged screen. Similarly, mechanically-cleaned screens should have provisions for bypassing during repairs.

All parts coming into contact with septage should be made of stainless steel. Mechanically-cleaned bar screens can be either front-cleaned or back-cleaned. Also, models with fully rotating forks are manufactured. The most common type is the front-cleaned model with an up- and down-moving fork.

Operational problems due to overloading of a bar screen can be avoided by designing the receiving chamber with a short channel, 2- to 3-m (6 to 10 ft) long, in front of the bar screen. This provides for more uniform septage flow and avoids direct discharge of septage onto the screen (i.e., dumping directly from hauler truck on the screen).

Another important design parameter involves spacing between the bars. Too narrow spacing causes clogging and increased organic matter in the screenings, while too wide spacing causes passage of larger objects that should be removed at this point. The recommended space between bars is 10 mm (0.4 in.) in Norway, while the openings in U.S. plants are usually 19 to 38 mm (0.75 to 1.5 in.). The U.S. opening has been found to pass rags and other undesirable materials, but it would be satisfactory if facilities that would remove or macerate the materials were provided downstream (e.g., a fine screen or grinder pump).

FIGURE 4-12
MECHANICALLY CLEANED BAR SCREEN AT DOKKA TREATMENT PLANT, NORWAY (1)



(Note: The bypass channel on the right, and the location of moving parts, i.e., chain drive, above water level.)

Pilot studies have been performed on vibrating fine screens (7). Use of a 6-mesh screen (3.4-mm opening) led to malfunctioning of the apparatus due to hair becoming interwoven in the screen, resulting in complete blinding. Better results were obtained using a 40-mesh vibrating screen (0.42-mm opening), with septage loading rates of 300 to 350 $m^3/m^2/day$ (5 to 6 $gal/ft^2/min$). The screens provided an average total suspended solids removal greater than 70 percent. The screenings volume approximated 3 percent of the original volume of septage, and the resultant screenings had a moisture content of 50 to 75 percent.

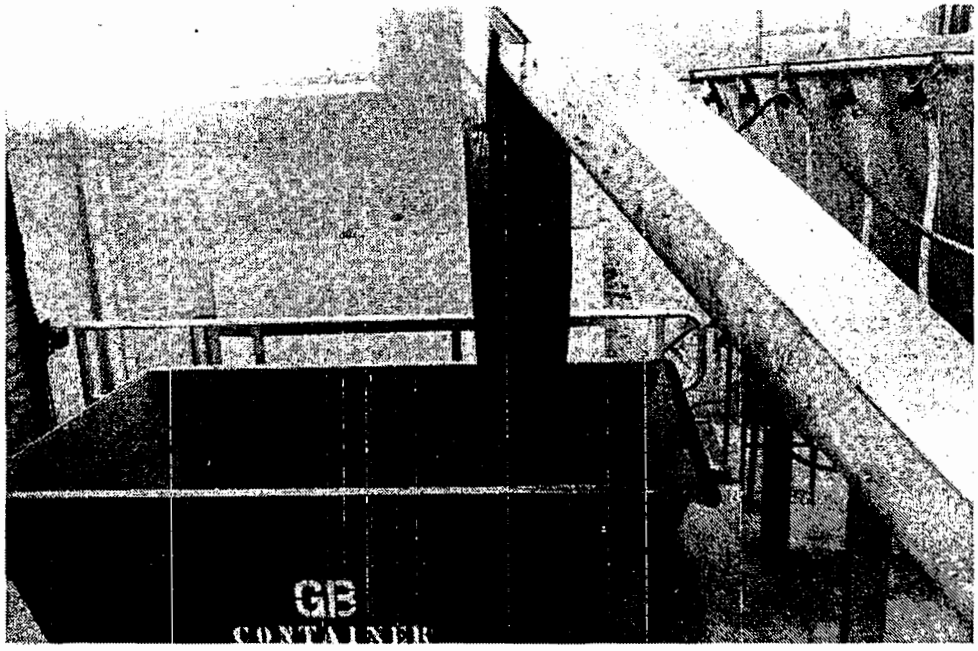
The screenings from septage contain water, organic matter, grease, and grit, in addition to rags, paper, plastic, and other coarse material. It is recommended that the screenings be dewatered in order to facilitate handling prior to disposal. Different types of dewatering units are manufactured. Smaller treatment plants receiving septage most often use a drained screw conveyor to transport screenings from the bar screen to a container for disposal (see Figure 4-13). Presses designed for dewatering screenings are also commercially available. These presses have been used quite successfully on material from screens handling septage.

4.4 Grit Removal

In septage, grit consists of material such as sand, gravel, cinders, and food particles that become enmeshed in the lighter-weight organic matter and grease, making separation of the grit from septage quite difficult. Grit content of septage may be higher than normal in areas with sandy soils and cesspools. The experience in Norway shows that after the septage passes the screen, it should flow by gravity into the grit chamber (1). A pumping step must be avoided, if possible, upstream from the grit chamber because grit material will tend to wear the pump impellers, causing undue operational problems. If this cannot be avoided, recessed-impeller or other grit-resistant pumps should be employed. Enclosed screw pumps might also be considered in these situations.

The two general types of grit chambers are the horizontal flow type and the aerated type. The horizontal flow type was more common in the past, but the aerated chambers have been found to be more effective in septage treatment applications (1). The horizontal flow type grit chamber, which accomplishes particle settling by controlling flow, is not effective at removing grit in septage since the grit particles are embedded into and attached to scum and solids that do not settle at the prescribed velocities.

FIGURE 4-13
DRAINED SCREW CONVEYER USED FOR DEWATERING MATERIAL FROM THE BAR SCREEN



In the aerated grit chambers, diffused air is pumped into the chamber to cause a spiral flow motion that enhances the breakup and ultimate settling of grit. Figure 4-14 shows the theoretical spiral motion present in aerated grit chambers, and Figure 4-15 presents a typical cross-sectional view. Basic design data for aerated grit chambers are given in Table 4-1. For the most part, the same design criteria apply to septage applications, except that longer detention times appear to be warranted.

TABLE 4-1

TYPICAL DESIGN INFORMATION FOR AERATED GRIT CHAMBERS (6)

Item	Value	
	Range	Typical
Dimensions:		
Depth, m (ft)	2-5 (7-16)	
Length, m (ft)	7.5-20 (25-66)	
Width, m (ft)	2.5-7.0 (8-23)	
Detention time at peak flow, min	2-5	3
Air supply, m^3/min · m of length (ft^3/min · ft)	0.3-0.6 (3.6-7.2)	0.5 (6.0)
Transverse velocity, m/sec (ft/sec)	0.4-0.7 (1.5-2.0)	0.6 (1.8)

In Norway, aerated grit chambers are the generally recommended method of removing grit from septage. An aerated grit chamber treating septage at the Lillehammer Treatment Plant, shown earlier in Figure 4-3, represents a typical design. The grit chamber has a volume of 55 m^3 (14,530 gal) and handles a maximum load of approximately 80 m^3 (21,130 gal) of septage per day. The detention time is longer than that ordinarily used, as compared to a normal design detention period of 3 minutes at the maximum flow rate suggested by standard design criteria. The maximum load on the grit chamber occurs when the largest size tanker truck pumps its content of septage through the pretreatment units. Under these conditions, the detention time in the grit chamber is designed to be not less than 30 minutes (1).

FIGURE 4-14
HELICAL FLOW PATTERN IN AERATED GRIT CHAMBER (6)

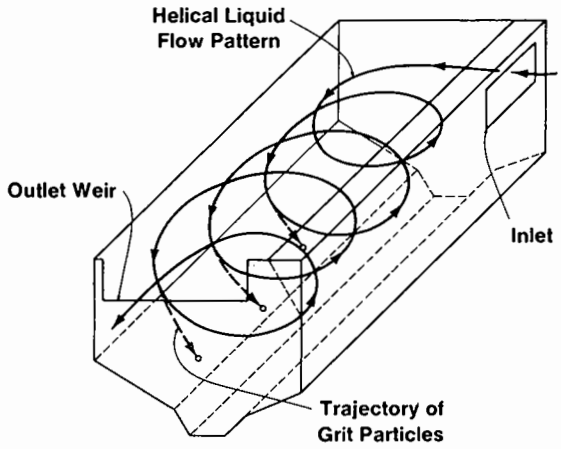


FIGURE 4-15
TYPICAL SECTION THROUGH AERATED GRIT CHAMBER (6)

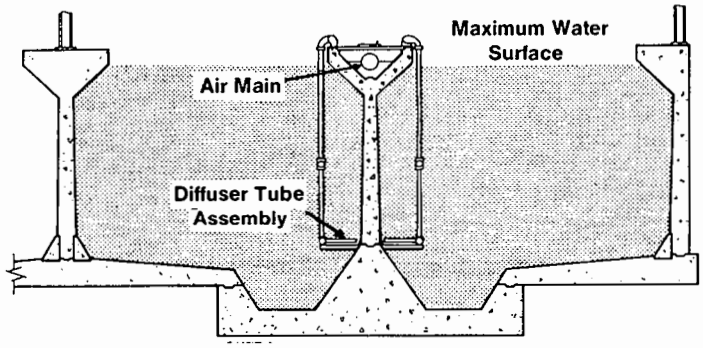
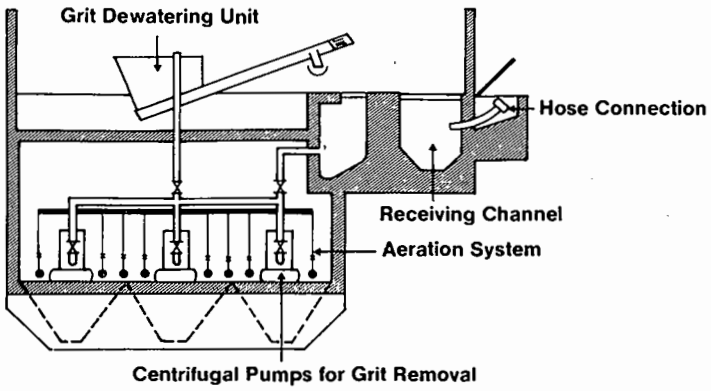


FIGURE 4-16
AERATED GRIT DEWATERING UNIT PLACED ABOVE THE GRIT CHAMBER, AT LILLEHAMMER TREATMENT PLANT, NORWAY (1)



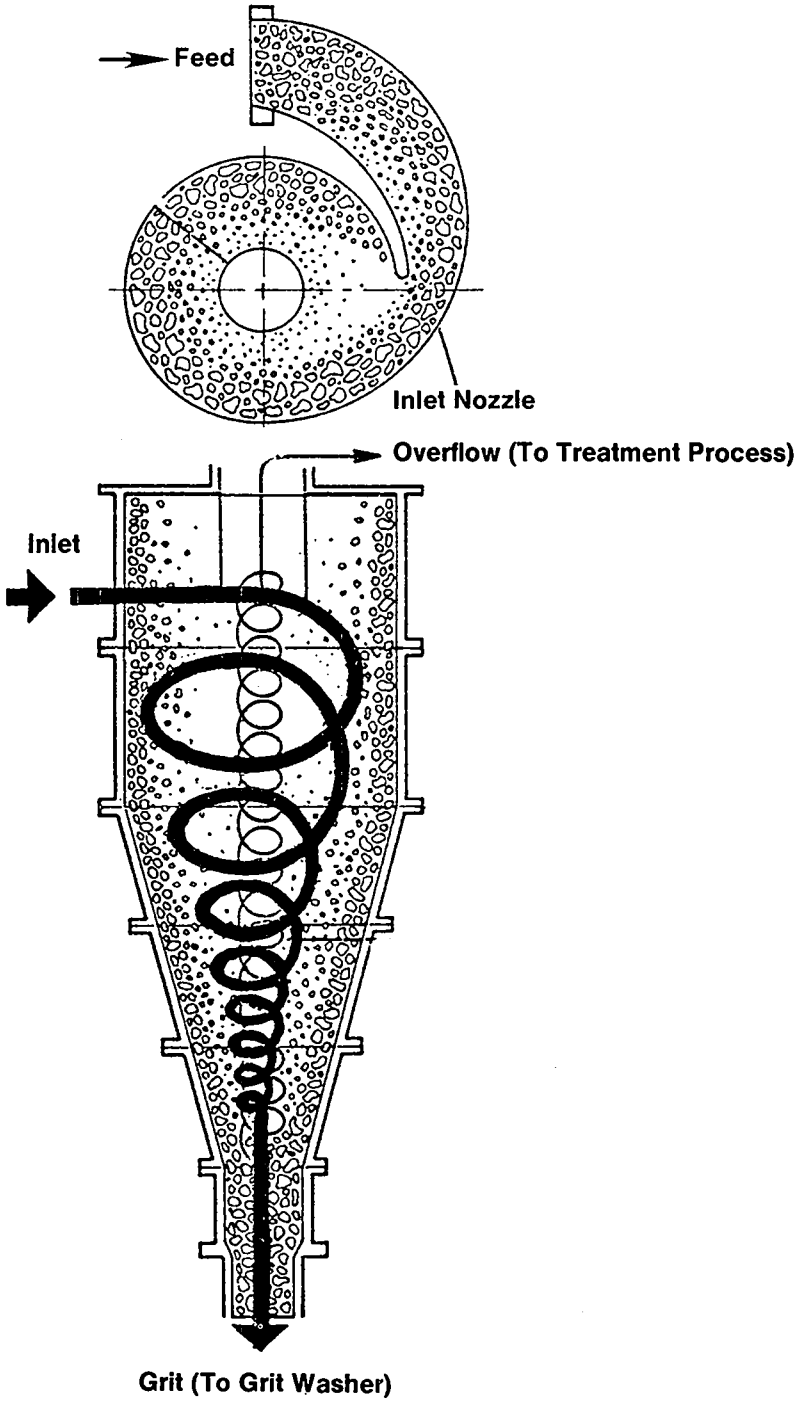
The grit is collected in hoppers at the bottom of the basin. It can be removed with a centrifugal pump, a screw conveyer, etc. At the Lillehammer Treatment Plant, the grit is removed by centrifugal pumps. Generally, this grit material should be dewatered before ultimate disposal. The dewatering unit (see Figure 4-16) consists of a small aerated tank with a dewatering screw that moves the material up an incline and drains the water back to the tank. The tank is supplied with an overflow that drains back to the grit chamber (1). Several commercial grit washing, dewatering and conveying systems are available.

At several plants in Scandinavia, the grit chamber has been designed with enough capacity to serve as a combined holding tank and grit chamber. The water level in the tank will vary, depending on the daily routine with respect to dewatering, etc. This is not recommended, since the change in water level will automatically change the aeration intensity, etc. This change in aeration will alter the spiral flow pattern and separation/ settling of grit from the liquid septage, and thus reduce the effectiveness of the grit chamber. Also, additional attention must be given to operation of the air diffusers to adjust for changes in water level, which is not a practical situation.

Cyclone degritters (see Figure 4-17) may also be effective in the pretreatment of septage since the mixing action achieved is similar to that in an aerated grit chamber. These degritters are designed to operate in a batch operation mode, which is suited to applications where septage is treated as it is dumped from the hauler trucks. An added advantage of the cyclone degritter is that it should generate less odor than an aerated grit chamber since no forced aeration takes place. The primary design control factor is flow velocity which is governed by the pumping units feeding the degritter. The solids concentration should be less than 2 percent for a cyclone degritter to function property (17). Individual loads of septage may exceed this limit and may require equalization or dilution. Cyclone degritters may not be appropriate if average solids concentration is greater than 2 percent.

The grit removed from septage can be handled in a number of ways. Grit is normally hauled to the dumping areas in trucks for which loading facilities are required. In larger plants, elevated grit storage facilities may be provided with bottom gates through which the trucks are loaded. Difficulties experienced in getting the grit to flow freely from the storage hoppers have been minimized by applying air beneath he grit and by the use of vibrators. Facilities for collection and disposal of drippings from the bottom gates are desirable. Grab buckets operating on a monorail system may also be used to load trucks directly from the grit chambers or from storage bins at grade.

FIGURE 4-17
CYCLONE DEGRITTER



In some larger plants, grit is successfully conveyed to grit-disposal areas by pneumatic conveyers. This system requires no elevated storage hoppers and eliminates problems in storage and trucking, but the wear on piping, especially elbows, is considerable (6).

4.5 Storage and Equalization

Septage holding basins can be used to provide for storage, equalization, mixing, and/or aeration of the septage prior to further treatment. Such holding facilities allow a controlled outflow of septage to downstream treatment processes in order to prevent hydraulic and organic shock loading.

The design of a holding facility depends on the prior and subsequent treatment of the septage. The most economical design is an open holding lagoon (sometimes aerated). Lagoons, however, require considerable land area and may create odor problems. The ultimate disposal of settled solids is also of concern since it is difficult to maintain complete mixing in lagoons. For treatment at an existing treatment facility or at independent septage treatment facilities, enclosed tanks with provisions for mixing and aeration are generally recommended to control spillage and odors. However, in situations where long-term storage is required (e.g., during the off-season in land application systems), lagoon storage may be the only feasible means of holding large volumes of septage. The design volume of the holding lagoon is dependent on the required holding time. This holding time may range from several weeks to several months for land application operations.

The role of holding tanks (where septage is handled independently or at existing wastewater treatment facilities) is mainly to equalize flow and mitigate variations in septage characteristics from one load to the next. In co-treatment applications, a holding facility is necessary to allow proper metering of septage addition as a function of treatment plant flow. If the septage is to be added directly to a sewer or to a primary treatment train, mechanical or diffused-air aeration and mixing are desirable in the holding tank to improve treatability and prevent settling of organic solids. However, this tends to aggravate the odor problem (due to the air stipping effect), and therefore requires the use of enclosed tanks to control odors.

The major design criterion for a holding tank is detention time. As a rule, capacity of at least one day's maximum expected volume of septage should be available for storage; however, it may be highly desirable to have storage for several days' peak flow, depending on the

sensitivity of downstream treatment processes and the expected variation in septage volumes received for treatment. The design of the equalization basin is site-specific and dependent on the type and magnitude of the input flow variations and facility configuration. If other preliminary treatment functions, such as preaeration, are to be performed in conjunction with flow equalization, then adequate detention times for these functions should be taken into consideration. Results of pilot studies, shown in Table 4-2, revealed negligible changes in the characteristics of finely-screened septage after 24 hours of aeration (7). After 96 hours of aeration, however, significant changes occurred, including improvement of settling characteristics and reduction of BOD_5. A holding facility, however, is not intended to provide this level of treatment, therefore detention periods of less than 48 hours are generally recommended.

Additional design criteria for preaeration facilities include the rate of air addition, or mixing. Mechanical mixing has been recommended at 0.0071 to 0.0142 kW/m^3 (20 to 40 hp/Mgal) of storage, and aeration at 0.15 to 0.24 $L/m^3 \cdot S$ (1.2 to 2 cfm/1,000 gal) of storage (9). Based on pilot-scale studies, Eikum (1) recommends using 1.3 to 1.7 L/s of compressed air per min/1,000 m^3 (10.7 to 13.4 cfm/1,000 gal) of tank volume to ensure mixing of screened septage.

TABLE 4-2

SCREENED-RAW-SEPTAGE SUPERNATANT CHARACTERISTICS FOLLOWING AERATION AND TWO HOURS SETTLING (7)

Parameter	Aeration Period		
	0 Hours	24 Hours	96 Hours
TSS, mg/L	8,680	9,550	1,480
BOD_5, mg/L	5,850	5,210	295
NH_3-N, mg/L	64	49	6
Organic-N, mg/L	204	249	33
PO_4, mg/L as P	57	45	4

4.6 Odor Control

Designers of septage receiving facilities must address odor control during the design process rather than as a retrofit measure in response to pressure from nearby residents. Odor problems at septage receiving facilities can be solved by proper siting and existing technologies, including chemical scrubbers, filters, combustion, biological processes, etc. It is very important to identify the main sources of odor at the facility and treat only the odorous gases. A simple approach to isolating the odorous gases would be to enclose the component of the facility generating the odors. The gases would be confined in this housing structure and thereby isolated from non-odorous air. This will reduce the volume of air to be treated and thus the overall cost. Designers must be cognizant of the dangers of closed spaces to operating personnel. The following sections discuss various methods for odor control.

4.6.1 Siting

During the site-selection process, consideration should be given to the impact that offensive odors may have on nearby residents. Zoning ordinances and land development patterns must be reviewed. An isolated area, if residentially zoned, may develop in the near future and result in pressure being applied to retrofit a facility with expensive odor control devices. In siting a facility without odor control, care should be taken to locate the facility in a well-ventilated area (e.g., an open space on a hilltop) and downwind from existing or projected population centers. Provisions for adding odor control systems in the future should be considered.

4.6.2 Chemical Scrubbers

Chemical scrubbers use sodium hypochlorite as an oxidizing agent and have been used successfully in controlling odors from sewage treatment plants receiving septage. Single-stage, two-stage, or three-stage scrubbers have been used. In Figure 4-18, a two-stage scrubber is shown. The first stage is alkaline oxidation (NaOH + NaOCl), and the second stage is an acidic wash using H_2SO_4. Automatic dosage systems are a necessity in preventing accidents when using the concentrated chemicals required for this system. Another type of chemical scrubber used at treatment plants that receive septage (shown in Figure 4-19), generates sodium hypochloride by electrolysis of salt (NaCl). Because this scrubber produces hypochlorite and no acidic step is involved, there is less need for special care concerning the delivery, handling, and dosing of dangerous chemicals.

FIGURE 4-18
CHEMICAL SCRUBBER (TYPE STEULER) (1)

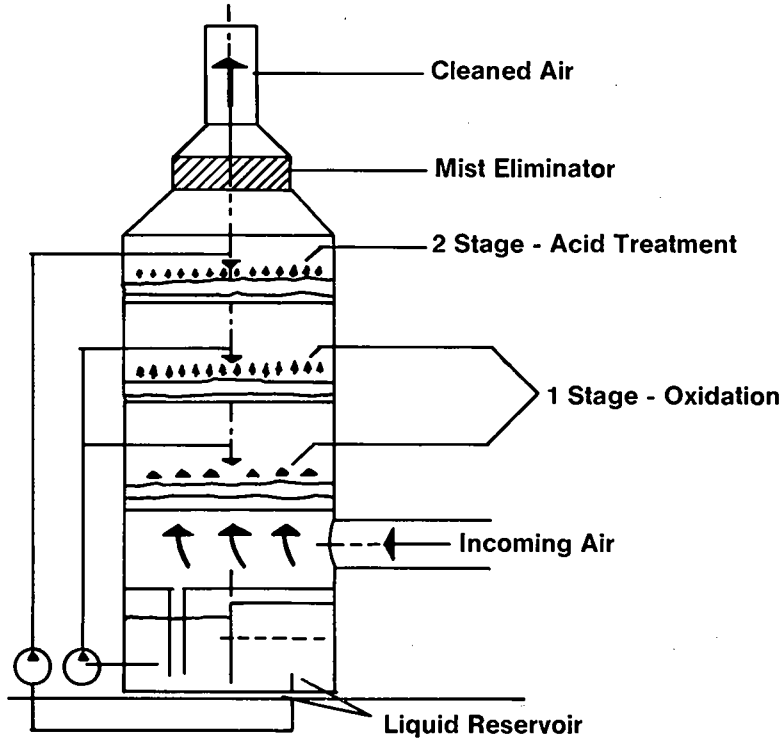
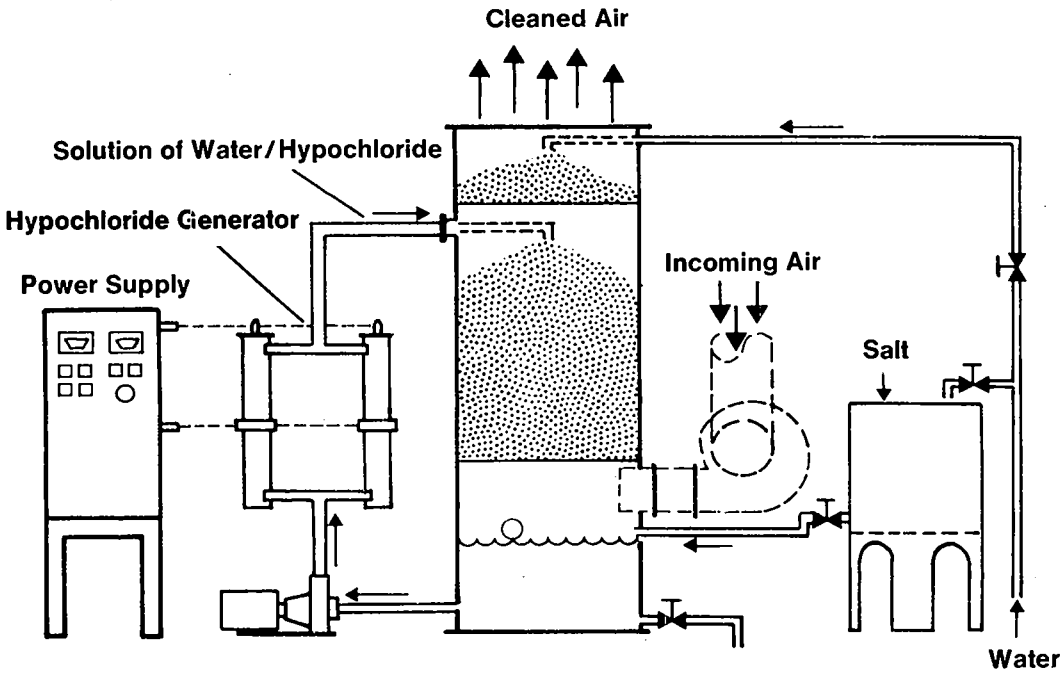


FIGURE 4-19
CHEMICAL SCRUBBER (TYPE PEPCON) (1)



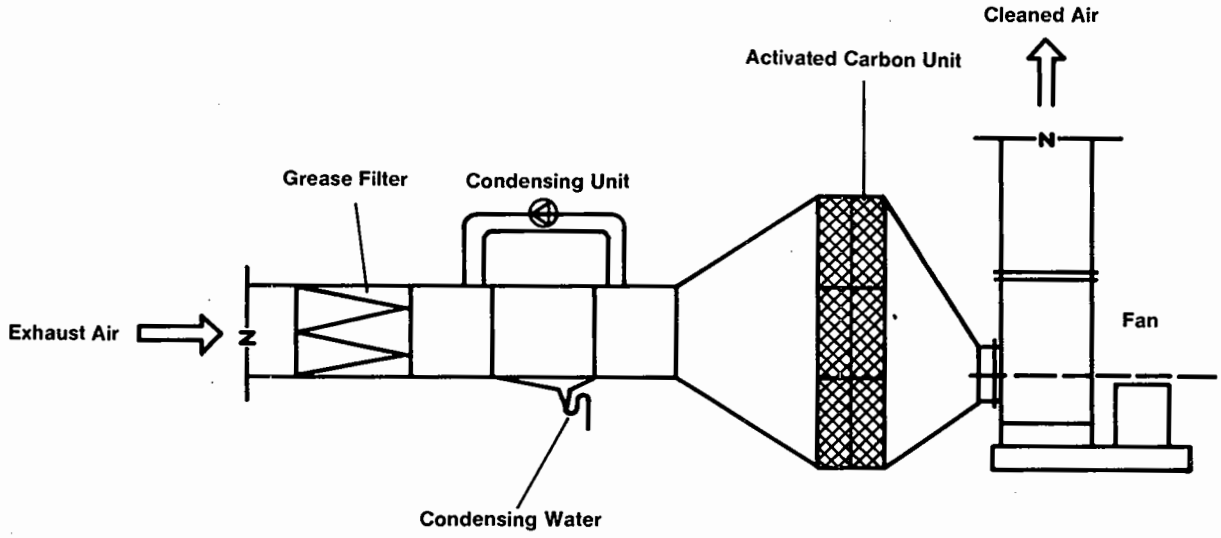
The results from total odor strength measurements of different chemical scrubbers show odor reduction efficiencies between 95 and 98 percent (1). The air has been characterized as being "free from sewage odors, but it smells like chemicals." It seems as if a chemical scrubber always gives this "scrubber odor." If the scrubber, however, is incorrectly operated, this "scrubber odor" changes to a "chlorine odor." Cost for operating the chemical scrubbers can be divided into chemical cost and energy cost. Energy will always contribute most to the total cost of operation. For the two-stage Pepcon scrubber, the energy cost will be approximately two-thirds of the total operational cost. Although some simpler types are available, chemical scrubbers are generally applicable only at larger treatment plants, where biological methods of control are not feasible.

4.6.3 Activated Carbon Filters

Carbon filters do not destroy the odor compounds, but only retain them until the carbon becomes saturated. The depth of the carbon bed must be sufficient to assure complete odor removal and to provide excess capacity. The Calgon Corporation recommends a depth of 45 to 90 cm (18 to 36 in.) in order to achieve maximum removal efficiency (8). Since most odors are caused by a mixture of gases, the possibility exists that odorous compounds not readily adsorbed by the carbon may leave the filter. Flow rates must be carefully selected to ensure adsorption of all compounds. The activated carbon has varying capacity to hold a specific amount of different odorous compounds, and it may be difficult to predict when the filter will become saturated. Inspections at different Norwegian plants identified carbon filters that either should have been changed earlier, or filters that were changed too frequently, which can become very expensive (1). In Figure 4-20 an activated carbon filter used for cleaning exhaust air from a dewatering process is shown. Together with the carbon, the equipment includes a grease filter and a condensation unit.

Odor strength measurements indicated reduction efficiencies of up to 83 percent when a completely new filter was used (1). Alternately, an old filter being used twice as long as the manufacturer recommended showed reduction efficiencies of only 72 percent. The cleaned air from activated carbon units may still have a sewage smell at these efficiencies. When the filter becomes saturated, no reduction of odors occurs in the activated carbon units. Carbon filters are applicable to all sizes of septage handling facilities although cost may become a limiting factor for larger facilities.

FIGURE 4-20
CARBON FILTER FOR ODOR REDUCTION (1)



4.6.4 Other Filter Media

Extensive work has been carried out in the U.S. (9) and Europe (10)(11)(12) regarding the use of soil filters for odor reduction. Filter performance depends on filter loading, type of soil, soil moisture, and temperature and concentration of odorous components. The odor removal mechanism taking place in the filter is both chemical and biological. Figure 4-21 illustrates the typical placement of a soil filter at a septage receiving facility. Another example of a soil filter system is depicted in Figure 4-22. This soil filter design was applied to control pump station odors in Mercer Island, Washington (13). Specifications for the Mercer Island design are given in Table 4-3 as an example of soil filter design criteria.

TABLE 4-3

SPECIFICATIONS FOR FUTURE SOIL FILTERS AT MERCER ISLAND, WASHINGTON PUMPING STATION (13)

Flow		Soil Filter Area		Perforated Pipe Length*	
(L/s)	(gpm)	(m^2)	(ft^2)	(m)	(ft)
<50	<800	2.3	25	0.3 -3.0	1-10
50- 115	800-1,800	4.6	50	0.6 -3.0	2-10
125- 160	2,000-2,500	9.3	100	1.2 -3.0	4-10

*10 cm (4 in.) pipes, bottom perforated and laid 0.6 m (2 ft) deep on 0.76 m (2.5 ft) centers and in 20 cm (8 in.) of pea gravel.

Laboratory studies have been performed to determine the efficiency of hydrogen sulfide gas removal by various soil types (13). It was found that odor reduction is achieved primarily by biological oxidation of sulfide to sulfate. An increase in conductivity and decrease in pH due to this process makes buffering a consideration in order to maintain satisfactory environmental conditions for bacterial activity. The most effective soils were moist loam soils kept at a temperature of about 25 to 30°C. The moisture is necessary to sustain life in the soil and to dissolve the sulfide gas to facilitate utilization by the bacteria. In West Germany this was done by installing sprinklers that were

FIGURE 4-21
FULL-SCALE SOIL FILTER AT TAU TREATMENT PLANT, TONSBERG, NORWAY (1)

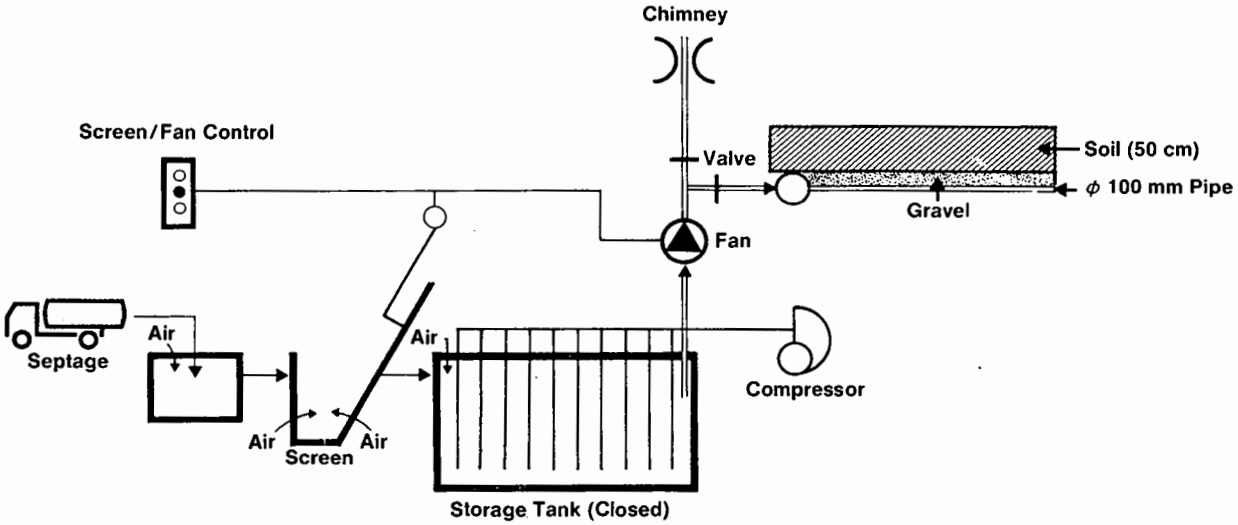
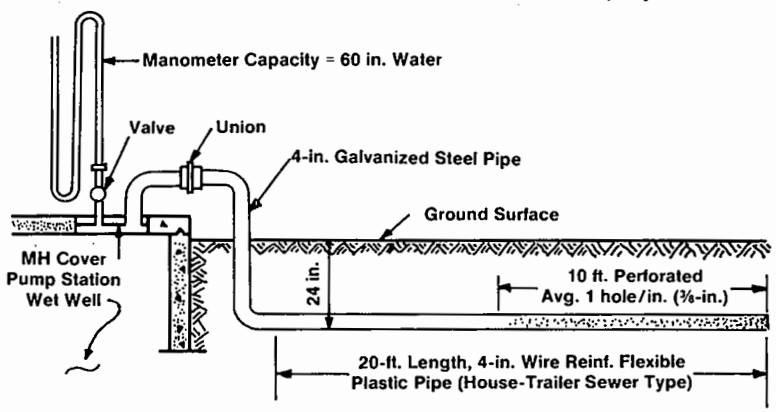
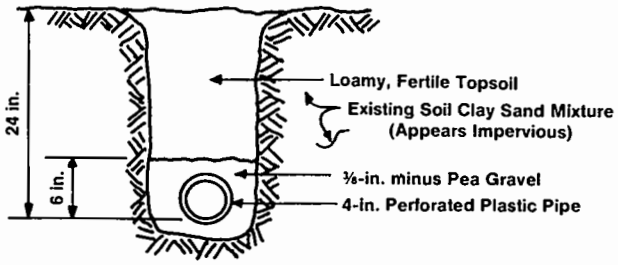


FIGURE 4-22
SOIL FILTER SYSTEM - MERCER ISLAND, WA PUMP STATION ODOR CONTROL (13)





activated when moisture dropped below a certain level (1). Sands and clays were much less effective in the passage of moisture and gas through the soil column. The tests indicated that a maximum concentration of 15 mg/L hydrogen sulfide could be input to a filter if H_2S emanating from the soil filter is to be kept below the threshold odor limit (see Figure 4-23).

A full-scale soil filter was put into operation in the summer of 1981 at Tonsberg, Norway (see Figure 4-21) (1). The filter treats odors from the receiving facility for septage only. This facility handles 14,000 m^3 (3.7×10^6 gallons) of septic tank pumpings annually. It consists of screening, grit removal, a storage basin, and dewatering equipment. The fan inlet is located at the end of the storage basin so that the odorous air is evacuated through the screen and grit removal room and into the storage basin. The fan blows the air either through the soil filter (normal operation) or through the chimney (in case filter media must be changed).

The filter consists of 35 m^2 (375 ft^2) of filter area, 0.5 m (20 in.) thick. The air is distributed through a diffuser system with a 0.4-m (16-in.) header pipe with 10-cm (4-in.) diameter laterals. The pipes are located in the gravel layer. The air flow through the filter is 565 L/s (1200 cfm) under constant operation. When a tank truck empties septage at the plant, the screen automatically goes into operation, and the fan speed increases to a capacity of 850 L/s (1800 cfm). When the screen stops, the fan capacity is again reduced to 565 L/s. The filter loading therefore varies between 57 and 86 $m^3/m^2/h$ (187 to 282 $ft^3/ft^2/h$). Components of the filter are shown in Figures 4-24 and 4-25. Up to September 1983 no odors had been detected out of the filter; however, any conclusions regarding long-term performance are premature.

Design parameters for soil filters from various studies are summarized in Table 4-4. Eikum (1) concluded in his study that a soil filter treating odors from a wastewater treatment plant with septage handling should not be designed with a detention time of less than 30 seconds. As shown, Helmer and Frechen concluded that compost, rather than soil, can be used as filter media.

Guidelines for the replacement of soil filters are very limited. However, it has been suggested that the filter actually regenerates itself during periods when no odorous gases are passing through it (1). Systems with high H_2S mass loadings may require soil liming and watering to maintain pH and moisture content in optimum ranges. Energy requirements are generally low, with effective pressure drops in the range of 5 cm (2 inches) (water).

FIGURE 4-23
EFFECT OF INPUT CONCENTRATION ON HYDROGEN SULFIDE REMOVAL EFFICIENCY BY SOIL FILTERS (10)

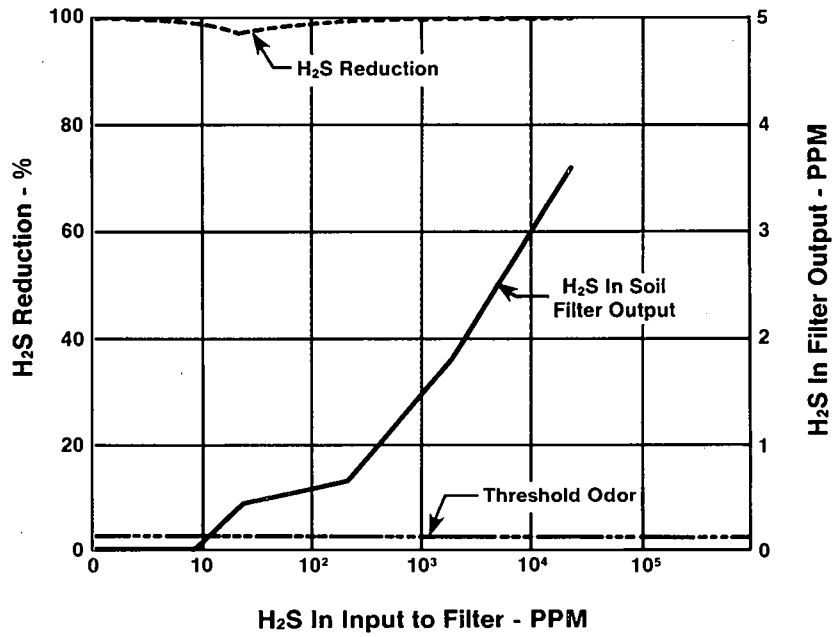


FIGURE 4-24
SOIL FILTER INSTALLATION (LOCATED BEHIND BUILDING) AT TAU TREATMENT FACILITY (1)

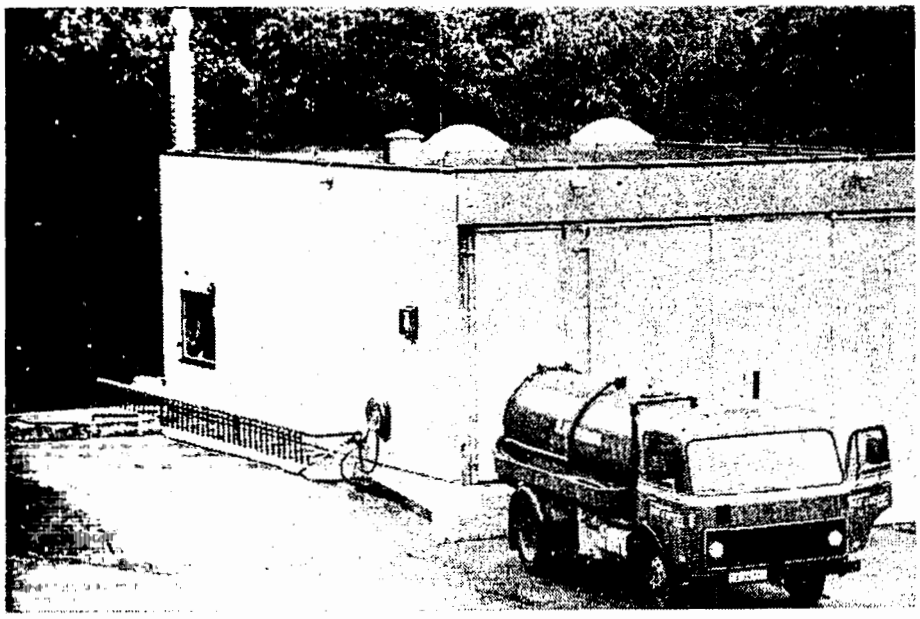


FIGURE 4-25
AIR COLLECTION AND BLOWER EQUIPMENT AT TAU FACILITY (1. GAS INLET, 2. FAN, 3. BYPASS PIPE TO CHIMNEY, 4. PIPE TO SOIL FILTER) (1)

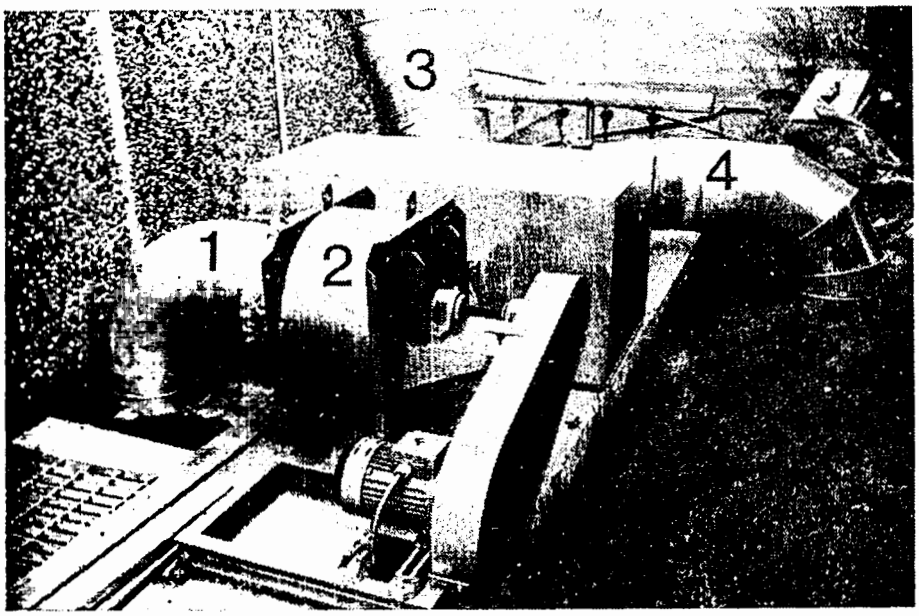


TABLE 4-4

DESIGN PARAMETERS FOR SOIL FILTERS USED FOR ODOR REDUCTION (1)

Reference	Facility	Air Loading Rate ($m^3/m^2/h$) Soil	Compost	Detention Time (sec.)
Carlson, et al. (13)	Test	6	---	500
Helmer (12)	Test	---	1.4	30-100
Eikum (11)	Test	18	---	80
Mayo (14)	Full scale	35-90	---	20- 40
Frechen (15)	Full scale	---	45	75

The use of soil filters is best suited to small installations with gas flows less than 22 m^3/sec (50,000 cfs). Applications involving larger volumes of odorous gas should be investigated on a case-by-case basis.

Another type of filter utilizes an iron oxide/woodchip media. The design and use of iron oxide filters for odor reduction is not well documented. Eikum (11) studied the use of an iron oxide filter at a receiving facility for septage in Norway. The filter media included woodchips mixed with 0.2 kg Fe_2O_3 per kg chips. Chemical processes (ferric sulfide production) are primarily responsible for the odor reduction taking place in the iron oxide filter. A filter installed at the City of Oslo at its Festningen Municipal Treatment Plant recorded high odor removal rates with loadings up to 250 $m^3/m^2 \cdot h$ (820 $ft^3/ft^2 \cdot h$).

4.6.5 Combustion

Combustion of odorous gases from a wastewater treatment plant has been a common practice for a long time. If temperature and contact time of the gases in the combustion chamber are sufficient (temperatures of about 850°C (1562°F), and contact time of up to 3 seconds), odor reductions of up to 98 to 99 percent may be achieved. A special incinerator designed solely for odors at a septage receiving facility, or even at an independent septage treatment facility, would be very expensive compared to the use of chemical scrubbers. If, however, sludge gas from a digester at a large treatment facility is available, the fuel costs can be reduced. The addition of catalysts can lower the temperatures needed to destroy odors and further reduce fuel costs.

4.6.6 Addition of Odorous Gases To Biological Treatment Systems

Limited success has been reported in reducing odors at a Norwegian activated sludge wastewater treatment plant receiving septage by bubbling odorous gases into the aeration basin (1). In the United States, this method of odor control has been successfully practiced at Los Angeles since 1959 (16). The odorous gases are drawn from the septage storage area and blown into the activated sludge basin. The method is very inexpensive and has odor reduction efficiencies of about 90 percent. Acid-resistant air distribution piping is generally required to resist corrosion.

This approach has also been applied at trickling filter plants with mixed results. The design requirements for successful odor control include a media depth of at least 6 m, air retention time of at least 10 seconds, and trickling filter operation in the nitrification stage, along with underdrain construction of corrosion-resistant materials (16).

4.6.7 Other Odor Reduction Methods

Many other methods to reduce odors have been used successfully at wastewater treatment facilities. These include the use of ozone, oxygen, H_2O_2, odor counteraction, and odor masking. These methods have not been applied extensively in connection with septage treatment and will not be discussed further in this handbook. However, these alternatives may be worth further evaluation where existing equipment at an operating facility can be utilized.

4.7 References

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CHAPTER 5

LAND DISPOSAL

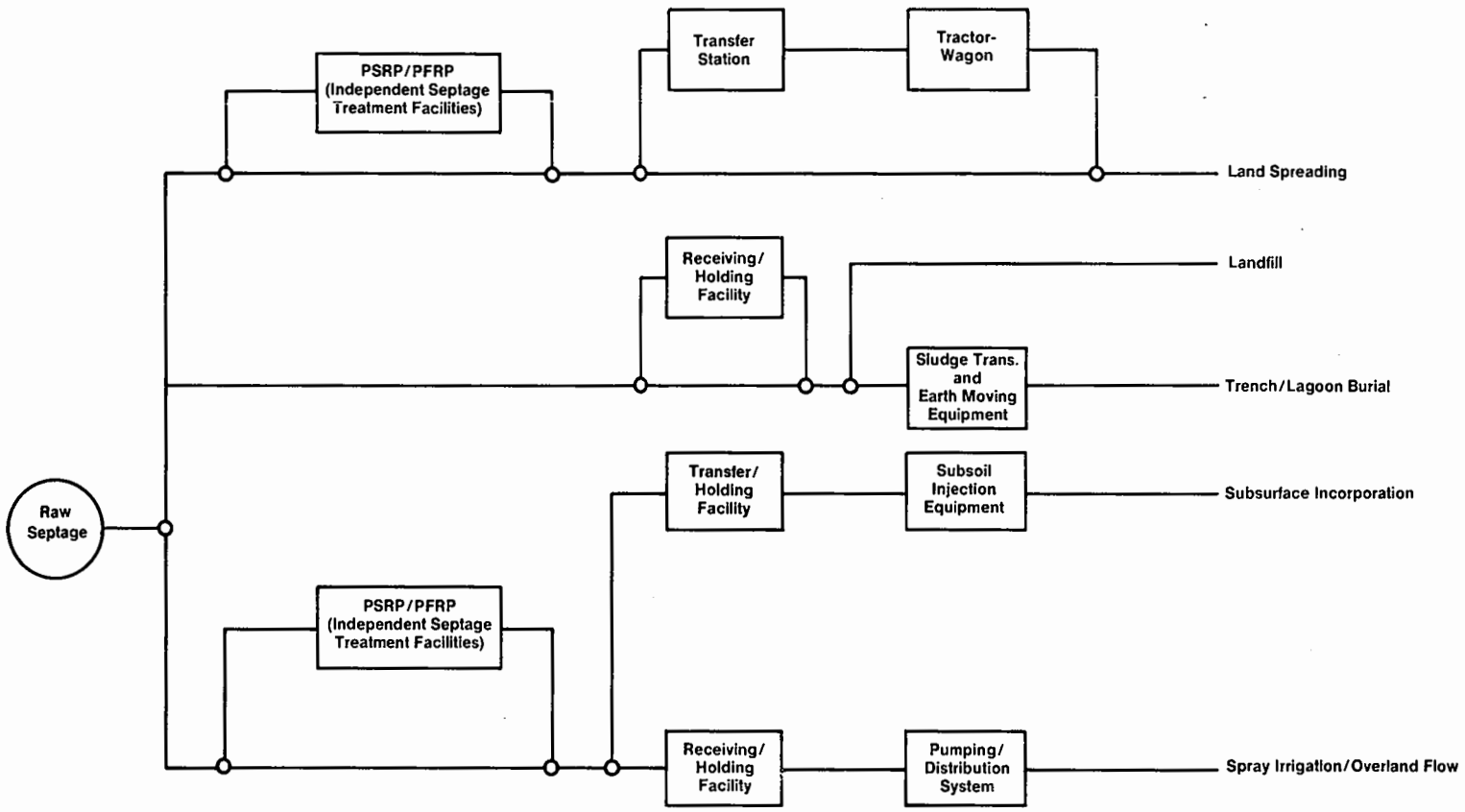
5.1 Introduction

Land application of septage is the most frequently used technique for septage disposal in the United States today. Septage treatment and disposal techniques include land spreading from septage hauler trucks or transfer vehicles such as tank wagons; spray irrigation; ridge and furrow irrigation practices; and overland flow. Subsurface application techniques include plow furrow cover and subsurface incorporation alternatives. Placement in trenches, holding lagoons, and sanitary landfills are classified as burial practices. Septage applied to the land can be stabilized, dewatered, or both, or can be applied without any pretreatment under certain conditions. Figure 5-1 illustrates the various technical options to be considered in evaluating land application alternatives. Properly managed land application is relatively simple, generally the most economical disposal technique, and can make beneficial utilization of the nutrient value of septage. It should continue to be a very common means of disposal, although Federal and state regulations are placing additional restrictions on its use, particularly in regard to pathogen control in agricultural land application. Federal Criteria (4) define the terms "Processes to Significantly Reduce Pathogens" (PSRP) and "Processes to Further Reduce Pathogens" (PFRP). PSRP is defined by the following technologies: aerobic digestion, anaerobic digestion, air drying, composting, lime stabilization, or other techniques which yield similar pathogen reductions. PFRP is defined by the following technologies: beta or gamma ray irradiation, pasteurization, or other equivalents after a PSRP process or high-temperature composting, heat drying, heat treatment, and thermophilic aeration digestion.

5.2 Raw Septage versus Septage Residuals (Sludge)

Currently, as much as two-thirds of the septage generated in this country is disposed of directly on land. Land application of raw septage has created concern over the transmissibility of various pathogenic agents that may be found in septage (viruses, bacteria,

FIGURE 5-1
TECHNICAL OPTIONS FOR LAND APPLICATION OF SEPTAGE



cysts of protozoans, and ova of helminths). In response to this concern, regulations at various governmental levels are being promulgated that will require some form of pretreatment. Ultimate disposal of the resultant solids fraction, liquid fraction, or the combined mass from pretreatment processes is likely to be in some form of land application.

Disposal alternatives that are applicable to the solids fraction, liquid fraction, or the combined liquid/solid mass are listed in Table 5-1 and are discussed in the following sections. The methodologies for determining application rates are presented for the combined liquid/solid mass. The same procedure could be applied to the solids fraction by using the concentrations of nutrients or metals in mg/kg of sludge instead of mg/L of raw septage.

5.3 Disposal Options

A number of techniques that are available for applying septage to the land are briefly discussed as follows.

5.3.1 Surface Application

Land Spreading: The hauler truck that pumps out the septic tank is frequently the vehicle that applies septage to the land. However, septage may be applied to the land in the raw liquid form or as septage solids by a separate designated vehicle. Consideration should be given to intermediate holding facilities during periods of inclement weather when application of septage is impossible due to field conditions, or when it would result in contaminated runoff escaping from the site. Pathogen die-off during storage is an additional benefit gained from onsite storage.

With a storage or transfer facility, disposal can be performed either by the hauler truck or by a tank wagon pulled by a tractor. The choice between the two is one of economics. A larger septage hauling/disposal operation may choose to have its hauler trucks on the road, with septage spreading being performed by a separate spreading crew, thus freeing the tank truck to perform the septic tank cleanout functions. A smaller septage hauler may prefer to use one vehicle to perform both tasks, thus leveling the work load by spreading septage during slack hauling time periods. In some instances, soil conditions may require the use of flotation-type tires, which are not suitable for long-distance highway use. This would dictate the use of separate collection and spreading vehicles (1).

TABLE 5-1

CHARACTERISTICS OF LAND DISPOSAL OPTIONS (1)

Land Disposal Method	Form of Septage	Characteristics	Advantages	Disadvantages
Surface Application				
Spray irrigation*	L	Large orifices for nozzles.	Use on steep or rough land.	Large land area. High power requirements. Odor potential. Possible pathogen dispersal. Storage lagoon for pathogen destruction and during periods of wet or frozen ground. Irrigation lines to be drained after irriagation season.
Ridge and furrow irrigation*	L	Surface preparation and leveling required.	Lower power requirements than spray irrigation.	Limited to 0.5 to 1.50 slopes. Storage lagoon required. Some odor potential.
Overland flow*	L	Use on sloping ground with vegetation.	Can be applied from ridge roads, suitable for emergency operation.	Difficult to get uniform distribution. Extensive site preparation. Slopes limited to ≤8%.
Hauler truck spreading*	L	1.9 to 7.6 m^3 (500 to 2,000 gal) trucks.	Same truck can be used for transport and disposal.	Some odor immediately after spreading. Storage lagoon during periods of wet or frozen ground. Slopes limited to 8%. Larger volume trucks require flotation tires. Land requires rest between applications.
Farm tractor and wagon spreading*	L/S	3.0 to 11.4 m^3 (300 to 3,000 gal) capacity.	Frees hauler truck during high usage periods.	Some odor immediately after dispersal. Storage lagoons. Slopes limited to 8%.. Requires additional equipment. Land requires rest between applications.
Subsurface Incorporation				
Tank truck with plow and furrow cover*	L	Single furrow plow mounted on truck.	Minimal odor.	Slopes limited to 8%. Storage lagoon during wet or frozen ground. Longer time needed for disposal operation.

TABLE 5-1 (Continued)

Land Disposal Method	Form of Septage	Characteristics	Advantages	Disadvantages
Farm tractor with plow and furrow*	L	Septage discharge into furrow ahead of single plow. Septabe spread in narrow swath and immediately covered with plow.	Minimal odor.	Slopes limited to 8%. Longer time needed than surface disposal. Storage lagoon during wet or frozen ground.
Subsurface injection*	L	Septage placed in opening created by tillage tool. Keep vehicles off area for 1 to 2 weeks after injection.	Injector can mount on rear of some trucks.	Slopes limited to 8%. Longer time needed for dispersal. Not usable in wet, frozen, or hard ground.
Burial				
Trench	L/S	New trenches opened when old one filled and covered.	Simplest operation. No slope limits. No climatological limits.	Odor problems. High groundwater restriction. Long-term land commitment after termination of operation.
Disposal lagoon	L	Lagoon is filled and dried, then covered with soil; or sludge bucketed out to landfill from bottom of septage lagoon.	No slope limits. No climatological limits.	Odor problems, High groundwater restrictions. Potential vector problems.
Sanitary landfill	L/S	Septege mixed with solid wastes at controlled rates.	No topographic limits. Simple operation.	Odor problems. Rodent and vector problems. Limited to areas with less than 90 cm/year (35 inches) of precipitation. Rainfall or leachate collection or isolate from groundwater.
Leaching lagoons	L	Settled water usually flows to percolation-infiltration beds. Sludge bucketed out to landfill from bottom of lagoon. Multiple lagoons required.	No slope limits. No climatological limits.	Odor problems. High groundwater and soil permeability restrictions. Vector problems.

*May require PSRP or PFRP, depeding on crop selection and management practices.

L: Liquid Raw Septage.
S: Septage Sludge.

Spray Irrigation: Spray irrigation of liquid septage necessitates a storage lagoon prior to disposal. Portable pipes and nozzle guns are commonly used rather than fixed or solid sets (see Figure 5-2). Since the septage must be pumped at 80 to 100 psi through 3/4- to 2-inch nozzle openings, installation of a screening device either at the transfer station ahead of or on the lagoon pump suction line is mandatory in order to prevent clogging of the distribution nozzles. Since spray irrigation also offers the greatest potential for offensive odors, knowledge of wind patterns and a well-located site are important.

Ridge and Furrow Irrigation: This method of disposal has been used to dispose of septage on relatively level land, usually limited to slopes in the range of 0.5 to 1.5 percent (see Figure 5-3). This method can be used to distribute septage to row crops during their growth, provided the crops are not for direct human consumption.

Overland Flow: This method was studied as part of an overall septage-sewage and septage-sewage-sludge treatment system at the Brookhaven National Laboratory in Upton, New York (10). The overland flow field, as part of a meadow-marsh-pond treatment system, was planted with reed canary grass and had a slope of 3 percent (see Figure 5-4). Although experiments at Brookhaven National Laboratories have been discontinued, the development of the technique, in combination with the marsh-pond system, has shown promise.

5.3.2 Subsurface Incorporation

Soil incorporation techniques offer better odor and pest control than surface spreading techniques and reduce the risk of inadvertent exposure of humans to pathogens. One disadvantage is that less nitrogen removal is achieved since ammonia volatilization is eliminated, thereby decreasing the application rate compared to surface application. Specialized equipment is generally required, depending on the method of subsurface disposal practiced.

Plow-Furrow-Cover: A typical setup using this method consists of a moldboard plow with furrow wheels and coulters. The coulter blade is used to slit the ground ahead of the plow. Septage is applied to the land in a narrow furrow 15 to 20 cm (6 to 8 in.) deep and is immediately covered by the following plow.

FIGURE 5-2
LIQUID SLUDGE SPREADING SYSTEM IN FOREST LAND UTILIZING TEMPORARY STORAGE PONDS (2)

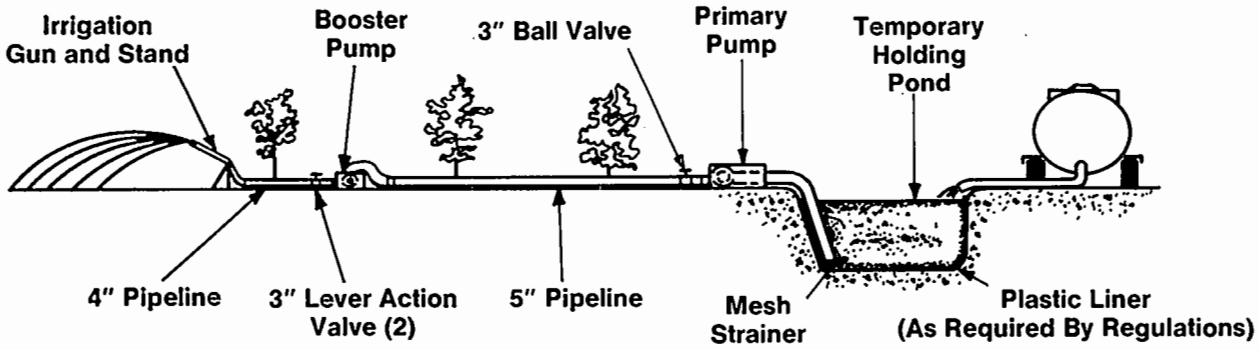


FIGURE 5-3
RIDGE AND FURROW IRRIGATION METHOD FOR APPLYING SEPTAGE TO LAND (3)

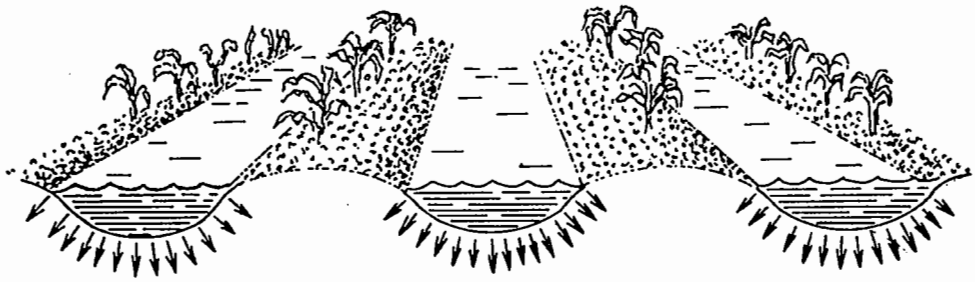
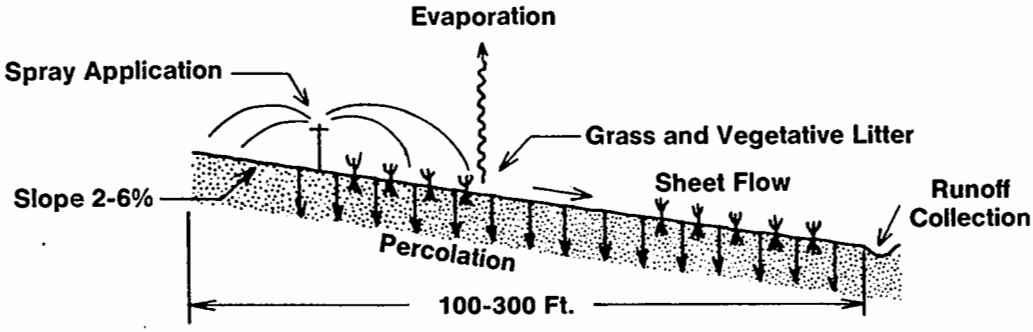


FIGURE 5-4
OVERLAND FLOW METHOD OF APPLYING SEPTAGE TO LAND (3)



Subsurface Injection: This technique employs a device that injects either a wide band or several narrow bands of septage into a cavity 10 to 15 cm (4 to 6 in.) below the surface (see Figure 5-5). Some equipment uses a forced closure of the injection swath.

Terreator: This is a patented device (U.S. Patent No. 2,694,354) that opens a 9.5-cm (3.75 in.) mole-type hole with an oscillating chisel point (see Figure 5-6). An 11.4-cm (4.5 in.) diameter curved tube then places septage 50 cm (20 in.) below the surface.

5.3.3 Burial

Broad forms of septage burial include disposal in holding lagoons, trenches, and sanitary landfills. Foul odors are inherent to all of these operations until a final cover is placed over the applied septage. Site selection is particularly important, not only for odor control, but also to minimize potential groundwater pollution.

Holding Lagoons: These lagoons are usually a maximum of 1.8 m (6 ft) deep and allow no effluent or soil infiltration. These disposal lagoons require placement of septage in small incremental lifts (15 to 30 cm, or 6 to 12 in.) and sequential loading of multiple lagoons for optimum drying. Odor problems may be reduced by placing the lagoon inlet pipe below liquid level and having water available for haulers to immediately wash any spills into the lagoon inlet line.

Trenches: Septage is placed sequentially in multiple trenches in small lifts, 15 to 20 cm (6 to 8 in.), to minimize drying time. When the trench is filled with septage, 0.6 m (2 ft) of soil should be placed as a final covering, and new trenches opened. An alternate management technique allows a filled trench to remain uncovered to permit as many solids to settle, as well as liquids to evaporate and leach out, as possible. Then the solids, as well as some bottom and sidewall material, are removed and the trench is reused.

Sanitary Landfills: Leachate production and treatment and odor are the main problems to be addressed when a sanitary landfill accepts septage. For moisture absorption, New Jersey formerly recommended a starting ratio of 0.05 m^3 of septage to each m^3 of solid wastes (10 gal of septage to each yd^3 of solid wastes). Septage should not be disposed of in landfills in areas with over 90 cm (35 in.)/yr of rainfall, landfills without leachate prevention and control facilities, or those not having isolated hydrogeological underlying rock strata. A 15-cm (6 in.) earth cover should be applied daily to each area that was

FIGURE 5-5
SUBSURFACE SOIL INJECTION (1)

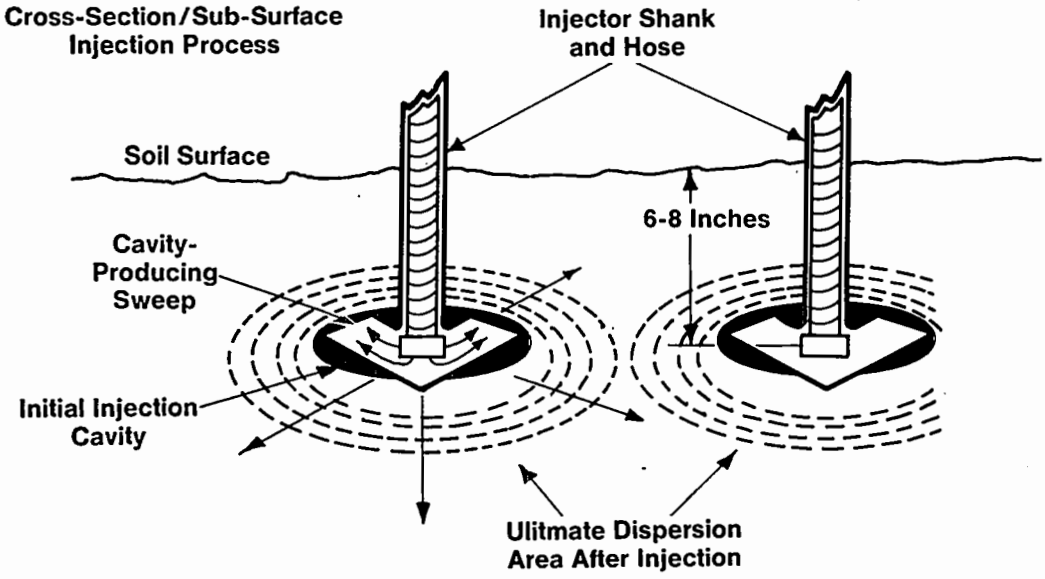
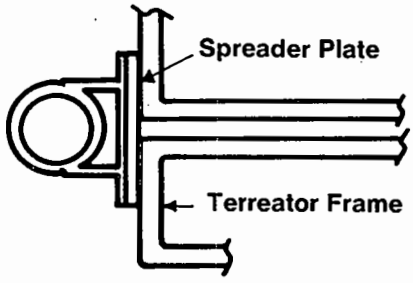
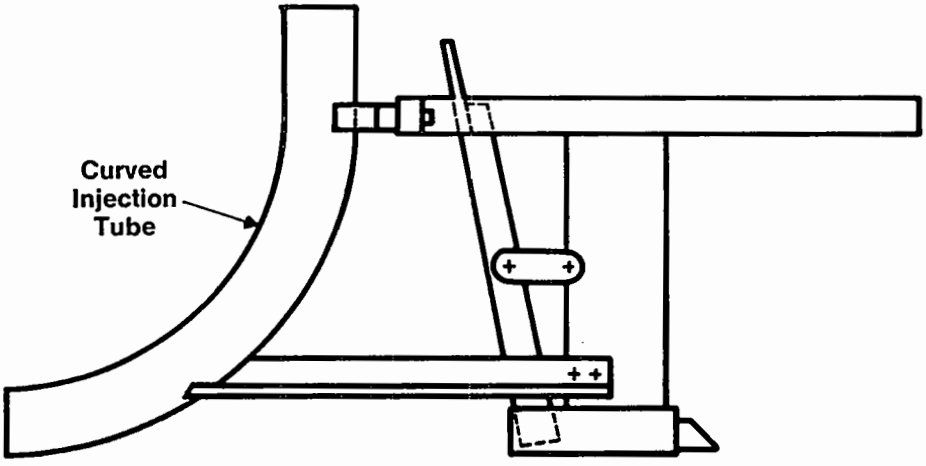


FIGURE 5-6
TERREATOR APPARATUS FOR SUBSURFACE INJECTION (1)





dosed with septage, and with 0.6 m (2 ft) of final cover within one week after the placement of the final lift. Generally, this is not an economical method of disposal and is not normally recommended.

5.4 Project Development

Certain basic planning elements are common to all land disposal projects, no matter how or where septage is to be applied. These elements include preliminary planning, site availability analysis, process design (which includes determination of sludge application rates), and facility management and operation. Figure 5-7 presents an overview of this process. The following sections provide a sequential description of the planning elements that are characteristic of a septage land application project.

5.4.1 Preliminary Planning

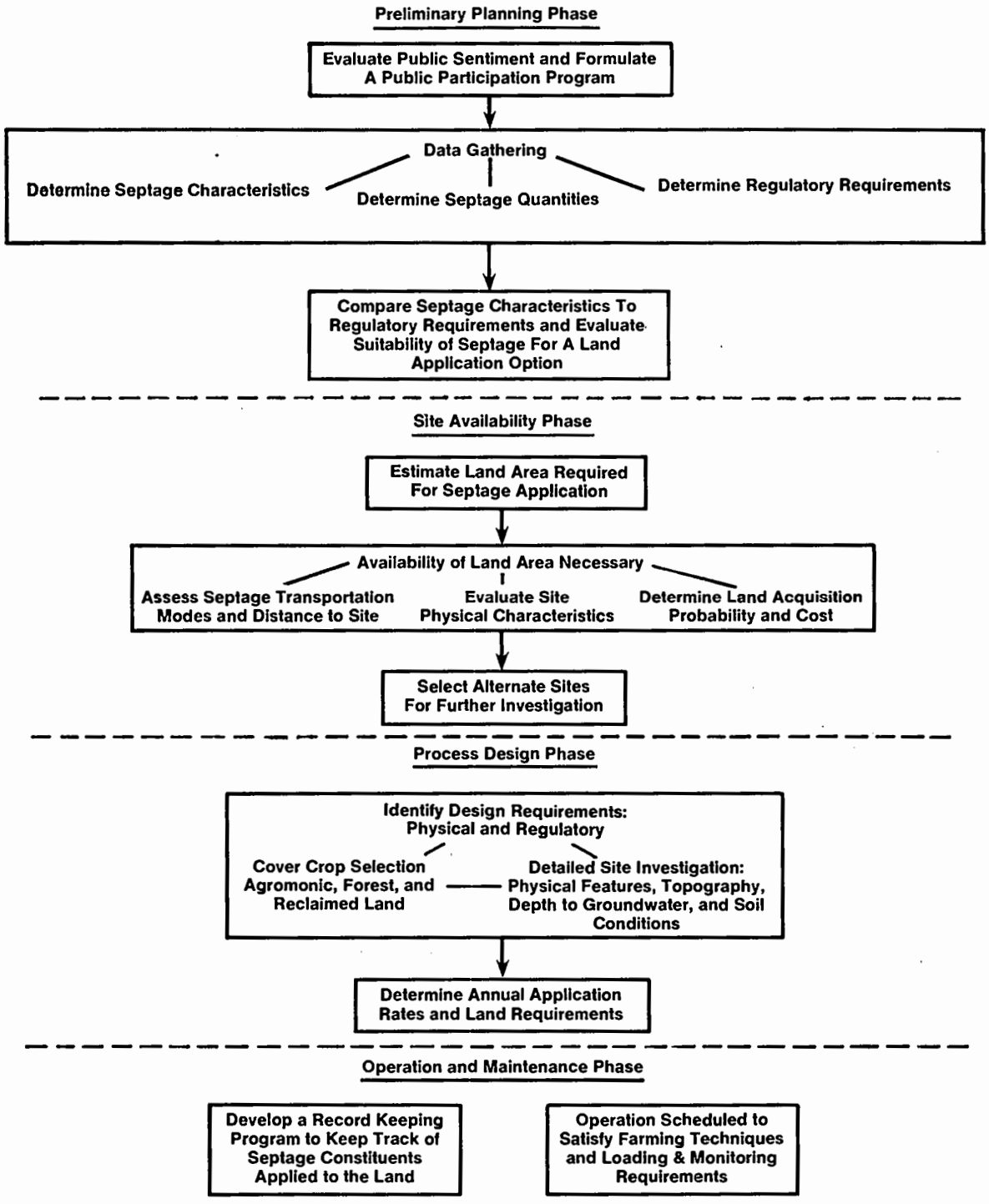
Once a program of land disposal has been proposed, a project team should be assembled and should consist of interested individuals and technical advisors. Soliciting public support for the project should be a major activity of the project team. The importance of obtaining public support cannot be overemphasized, since many land disposal projects experience stiff opposition from concerned and often misinformed citizens. A second activity is the collection of basic data necessary for a thorough examination of the project, including septage quantities and characteristics, climatic conditions, and local, state, and Federal regulations.

5.4.2 Site Availability Analysis

A three-phased approach to site selection is proposed as follows:

1. <u>Preliminary Screening</u> - Based on the basic data collected during the preliminary planning, a rough estimate of the total acreage required can be determined by dividing the total septage quantity by an assumed application rate. (Based on crop N uptake rates, typical annual application rates range from 280 m^3/ha [30,000 gal/acre] to 1,880 m^3/ha [200,000 gal/acre].)

FIGURE 5-7
TECHNICAL EVALUATIONS INVOLVED IN IMPLEMENTING A LAND DISPOSAL PROJECT



2. Preliminary Site Analysis - Sites identified by the preliminary screening process are characterized as to topography, land use, soil characteristics, geology, and average distance from the septage district. The initial characterization is done using published and readily-available information, such as soil surveys and topographic maps. Sites can be ranked by this initial characterization, and the top two or three can be investigated further with site-specific information during the process design element.

3. Site Acquisition - Sites can be acquired by purchase or by a contractual agreement for the right to use private land for septage utilization. The identified sites should be preliminarily evaluated for these criteria.

5.4.3 Process Design

Once it has been determined that a septage land disposal project is acceptable to the public and technically feasible, a process design phase can be undertaken. The design requirements and constraints associated with land disposal of septage are dependent on the type of crop grown, soil condition, and the septage characterization, including pathogens, organics, N, Cd, Pb, Zn, Cu, and Ni. Since state regulations vary in different regions, the constraints discussed in the following sections below are based on Federal regulations presented in 40 CFR 257, "Criteria for Classification of Solid Waste Disposal Facilities and Practices," Federal Register, 13 September 1979 (Criteria) (4). It should be noted that many state and local requirements are more restrictive than the Federal Criteria.

5.4.3.1 Pathogens

Untreated septage contains a variety of potential pathogens, including bacteria, protozoa, parasites, and viruses. Chapter 3 presented a bacteriological characterization of septage. The "Criteria" states that septage applied to the land or incorporated into the soil must be treated by a "process to significantly reduce pathogens" (PSRP) prior to application or incorporation, unless public access to the facility is restricted for at least 12 months, and unless grazing by animals whose products are consumed by humans is prevented for at least 1

month. PSRP's include aerobic digestion, air drying, anaerobic digestion, composting, lime stabilization, or other techniques that provide equivalent pathogen reduction. These pretreatment processes are discussed in Chapter 7. The "Criteria" also require septage to be treated by a "process to further reduce pathogens" (PFRP) prior to application or incorporation if crops for direct human consumption are grown within 18 months subsequent to septage application or incorporation where contact between the septage applied and the edible portion of the crop is possible. PFRP's include composting, heat drying, heat treatment, thermophilic aerobic digestion, or other techniques that provide equivalent pathogen reduction.

The potential for groundwater contamination by land treatment disposal of septage can be minimized by proper design and management techniques. It is important to demonstrate to the public that every managerial precaution has been taken, and that the chance of contamination is extremely remote.

5.4.3.2 Nitrogen

Nitrogen is the nutrient in septage that is required in the largest amounts by potential crops selected for the disposal site. However, N application in excess of the amount required for crops results in the potential for nitrate (NO_3) contamination of groundwater supplies. Elevated NO_3 levels in water supplies could result in health risks for infants and livestock. Because nitrogen requirements vary significantly from crop to crop, and due to the fact that some nitrogen may carry over from year to year, close monitoring of nitrogen application is required. Nitrogen requirements for different crops are given in Table 5-2.

5.4.3.3 Cadmium

An additional constraint that limits the rate at which septage can be applied to land used for crop production is the health risk associated with cadmium (Cd). Cadmium contained in the diet accumulates in the kidneys and may cause a chronic disease called proteinuria (increased excretions of protein in the urine). It is difficult to predict the effect of septage application on Cd in the human diet for the following reasons:

TABLE 5-2

ANNUAL NITROGEN, PHOSPHORUS, AND POTASSIUM UTILIZATION BY SELECTED CROPS[a] (3)

Crop	Yield[b] per ha	Nitrogen kg per ha	Phosphorus kg per ha	Potassium kg per ha
Corn	6 m^3	207	28	199
	7.2 m^3	269	49	223
Corn Silage	72 mt	224	39	339
Soybeans	1.8 m^3	288[c]	23.5	112
	2.1 m^3	376[c]	32.5	134
Grain Sorghum	9 mt	280	45	186
Wheat	2.1 m^3	140	24.5	102
	2.8 m^3	208	27	150
Oats	3.5 m^3	168	27	140
Barley	3.5 m^3	168	27	140
Alfalfa	18 mt	504[b]	39	446
Orchard Grass	13.5 mt	336	49	348
Brome Grass	11.2 mt	186	32.5	236
Tall Fescue	7.9 mt	151	32.5	172
Bluegrass	6.8 mt	224	27	167

[a]Values reported above are from reports by the Potash Institute of America and are for the total above-ground portion of the plants. Where only grain is removed from the field, a significant proportion of the nutrients is left in the residues. However, since most of these nutrients are temporarily tied up in the residues, they are not readily available for crop use.

[b]Yields expressed as either cubic meter (m^3) or metric tons (mt). 1 mt = 2,205 lb.

[c]Legumes get most of their nitrogen from the air, so additional nitrogen sources are not normally needed.

1. Crops vary markedly in Cd uptake (e.g., leafy vegetables are significantly higher in Cd than cereal crops).

2. Cd uptake by crops is dependent on soil properties and the amount of Cd applied.

3. The Cd content of the current human diet is not accurately known and varies with each individual's diet preferences.

4. Projected increases in dietary Cd are influenced by the amount of cropland affected, the properties of sludge and septage applied, types of crops grown, and soil properties.

The "Criteria" (4) specify the limits for annual amounts of Cd applied to different crops, as given in Table 5-3. It is also required that the septage and soil mixture pH be maintained at 6.5 or above.

5.4.3.4 Heavy Metal Lifetime Loadings

The lifespan of an application system is limited, based on the cumulative amounts of lead (Pb), copper (Cu), nickel (Ni), zinc (Zn), and cadmium (Cd) applied to the soil. Maximum application loadings suggested by the U.S. EPA are listed in Table 5-4. It should be noted that those loadings are cumulative loadings and are a function of the soil's cation exchange capacity. When one of the trace elements is loaded to its maximum allowable limit, septage and/or other sludge disposal at the site should be terminated. For septage with the mean characteristics presented in Chapter 3, zinc would be the limiting metal based on these loading factors.

5.4.3.5 Site Selection

During the site-selection phase, prospective sites should have been identified. Further investigation is required during the process design phase to determine the suitability of the site. The following sections identify restrictions and types of investigations required.

TABLE 5-3

ANNUAL CADMIUM LIMITS (4)

Type of Crop	Kg/ha/yr	(lb/acre/yr)
Tobacco, Root Crops, Leafy Vegetables	0.5	(0.45)
Other Food Chain Crops (e.g., corn, small grains, forages)	2.0	(1.78)[a]
	1.25	(1.11)[b]
	0.5	(0.45)[c]
Animal Feed Only	None[d]	

[a]to 30 June 1984.

[b]1 July 1984 to 31 December 1986.

[c]After 1 January 1987.

[d]A facility plan must be prepared showing the distribution of the animal feed to preclude human consumption.

TABLE 5-4

SUGGESTED TOTAL AMOUNT OF SEPTAGE METALS TO BE APPLIED TO AGRICULTURAL LAND (3)

	Maximum Amount of Metal in kg/ha/yr (lb/acre/yr) Soil Cation Exchange Capacity (meq/100 g)[a]					
Trace Element	0 to 5		5 to 15		15	
Pb	560	(500)	1121	(1000)	2242	(2000)
Zn	280	(250)	560	(500)	1121	(1000)
Cu	140	(125)	280	(250)	560	(500)
Ni	140	(125)	280	(250)	560	(500)
Cd	6	(5)	11	(10)	22	(20)

[a]Determined by the pH 7 ammonium acetate procedure.

5.4.3.6 Site Location/Land Requirements

Some states have guidelines or regulations for buffer zones to restrict the minimum setback distances between an area receiving septage and the adjacent site facilities, such as residential developments, inhabited dwellings, ponds and streams, and wells and public areas (parks, schools, roads). Figure 5-8 presents typical minimum setback requirements for a septage disposal site which are adopted from the State of Maine (5). The potential contaminants being carried from the site by surface runoff is the primary reason for these guidelines. Therefore, flat slopes or the application of dewatered septage may justify reduced setback requirements.

5.4.3.7 Slope Requirements

The slope of the land determines the potential for contaminated runoff to leave the application site. The method of land application is dictated to some extent by the slope of the site. The volumes of liquid septage applied are typically less than the natural annual rainfall in nearly all regions of the United States. Since these volumes are not excessive, use of appropriate septage application techniques and runoff control measures for different soil types and slopes will minimize the potential for contamination of surface waters. General slope criteria for sludge are presented in Table 5-5. The measures used to control surface runoff from soils treated with septage are generally the same as those designed to prevent soil erosion. These practices include strip cropping, terraces, grassed waterways, and minimum tillage systems (e.g., chisel plowing, no-till planting).

5.4.3.8 Depth to Groundwater

The primary concern regarding the depth to groundwater is the potential for contamination due to nitrate/nitrogen leaching through the soil. Essentially, all of the applied metals, pathogens, phosphorus, and organics remain in the upper 12 to 25 cm (5 to 10 in.) of soil. The ideal septage application site would be a previously-worked agricultural field with deep and well-developed soils to protect the integrity of the groundwater sources. Greater depth of soil above groundwater usually reduces the potential for contamination. Local or state guidelines often specify a minimum distance to groundwater of at least 1 m (3.3 ft) during those periods when septage is being applied. However, it is prudent to specify a minimum distance to the seasonal high groundwater level of 1 m (3.3 ft) or more to assure groundwater protection.

FIGURE 5-8
TYPICAL SEPTAGE DISPOSAL SITE (5)

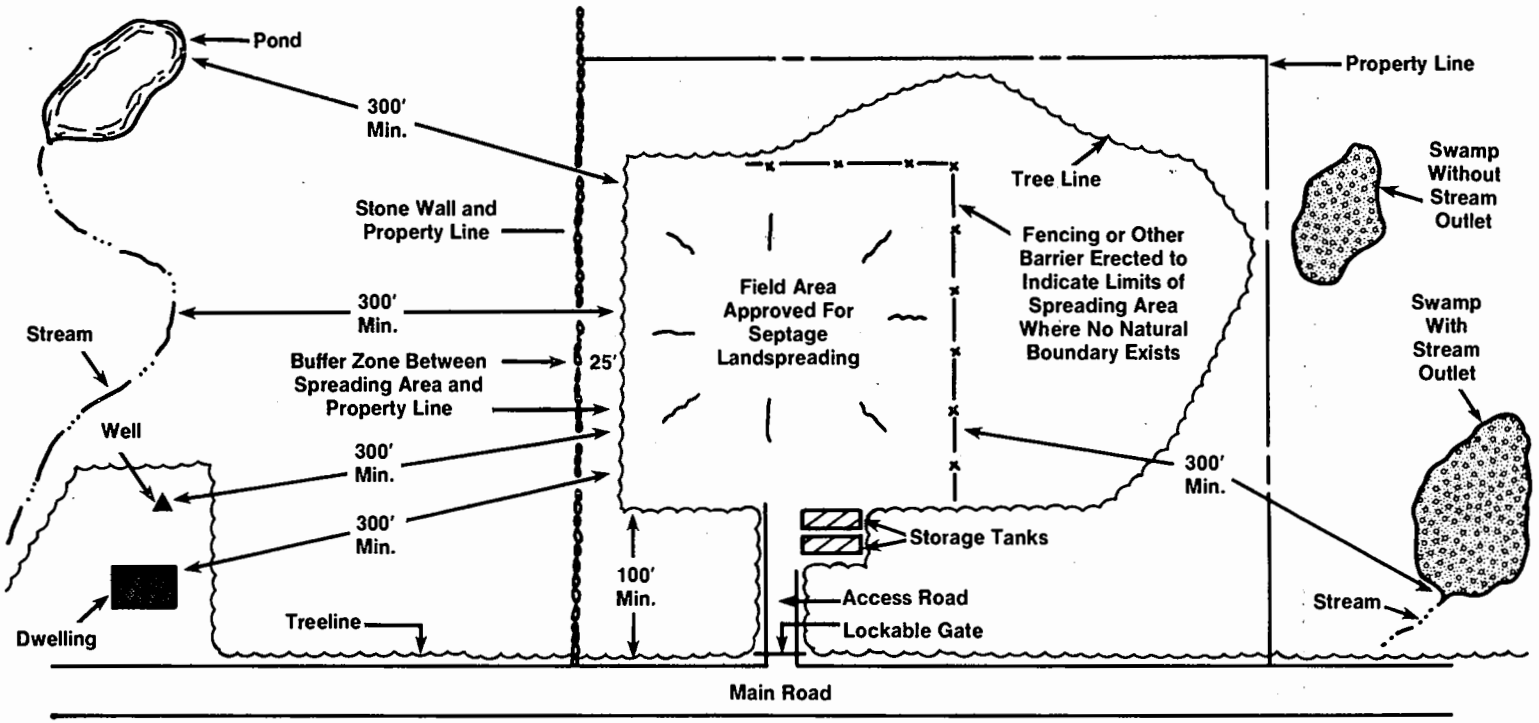


TABLE 5-5

RECOMMENDED SLOPE LIMITATIONS FOR LAND APPLICATION OF SLUDGE (COMPILED FROM EXISTING STATE REGULATIONS REVIEWED) (6)

Slope	Comment
0 to 3%	Ideal; no concern for runoff or erosion of raw septage or dewatered septage.
3 to 6%	Acceptable; very slight risk of erosion; surface application of raw septage or dewatered septage is acceptable.
6 to 12%	Injection of raw septage required for general cases, except in closed drainage basin and/or extensive runoff control. Surface application of dewatered septage is usually acceptable.
12 to 15%	No raw septage application without positive runoff control; surface application of dewatered septage acceptable, but immediate incorporation recommended.
Over 15%	Slopes greater than 15% are only suitable for sites with good vertical permeability (deep, well-drained soils) where the slope is short and is a minor part of the total application area.

5.4.3.9 Soil Conditions

A detailed soil sampling and analysis program is important to determine appropriate loading rates for septage. The amount of available nutrients must be known in order to determine how much additional nutrients can be added via septage application. Soil pH and cation exchange capacity influence the uptake of metals by crops. Soil sampling methods should also be established as part of a long-term monitoring program to determine when the soil has reached the maximum level of a particular nutrient or trace element.

5.4.3.10 Cover-Crop Selection and Nutrient Requirements

The basic design goals are maximization of crop yield and quality, and minimization of environmental damage. These remain constant regardless of projected land use. Nutrient requirements and regulatory constraints differ, however, for application to agricultural, forested, and reclaimed land.

5.4.4 Land Disposal Options

5.4.4.1 Application to Agricultural Land

It is advantageous to maintain or utilize the normal cropping patterns found in the community. The types of crops grown and crop rotation patterns have developed over the years in response to local soil conditions, climate, and economic conditions. The nutrient value of the septage should be utilized as a replacement for commercial fertilizers, while altering farming practices as little as possible.

Interest has developed in recent years regarding the timing and methods used to apply septage to cropland to maximize yield and minimize potential health risks. However, the crops selected essentially dictate the scheduling and methods of application (see Table 5-6). Since septage application rates are typically controlled by the nitrogen required by the crop, crops requiring large amounts of nitrogen (e.g., corn, forages, sorghum) will minimize the amount of land required and the operation costs. However, corn and sorghum actively grow from May to November, thereby limiting the time available for septage applications to a few months (i.e., the non-growing season). Although forage crops, legumes, and grasses consume large quantities of nitrogen and permit access during most of the growing season, surface application of septage is feasible only after crops have been mown and baled for animal feed.

TABLE 5-6

GENERAL GUIDE TO MONTHS AVAILABLE FOR SEPTAGE APPLICATION TO DIFFERENT CROPS IN NORTH CENTRAL STATES (6)

Month	Corn	Soybeans	Small Grains[a] Winter	Small Grains[a] Spring	Cotton[b]	Forages[c]
January	N	N	C	N	S/I	N
February	N	N	C	N	S/I	N
March	S/I	S/I	C	S/I	S/I	S
April	S/I	S/I	C	P, S/I	P, S/I	C
May	P, S/I	P, S/I	C	C	C	C
June	C	P, S/I	C	C	C	H, S
July	C	C	H, S/I	H, S/I	C	H, S
August	C	C	S/I	S/I	C	H, S
September	C	H, S/I	S/I	S/I	C	S
October	H, S/I	S/I	P, S/I	S/I	S/I	H, S
November	S/I	S/I	C	S/I	S/I	S
December	N	N	C	N	S/I	N

N = Surface application may not be allowed due to frozen or snow-covered soils in some states;
S/I = Surface or incorporated application;
S = Surface application;
C = Growing crop present;
P = Crop planted;
H = Crop harvested.

[a]Wheat, barley, oats, or rye.

[b]Cotton, only grown south of southern Missouri.

[c]Established forages, legumes (alfalfa, clover, trefoil, etc.), grass (orchard grass, timothy, brome, reed canary grass, etc.), or legume-grass mixture.

The amount of fertilizer recommended for different crops is determined by the nutrients required for optimum yield. Septage application rates are generally determined by using the same technique. The amounts of nitrogen, phosphorus, and potassium required to obtain a given crop yield have been determined experimentally for different crops and soil types in each region of the country. Table 5-2 lists a variety of crops that might be grown on sites where septage has been applied, along with their respective nutrient requirements. For all crops, yield potential and soil fertility are controlled by such factors as the amount and distribution of rainfall; soil physical properties (drainage, crusting, water-holding capacity, and compaction); length of growing season; available heat units; and incidence of weed, insect, and disease problems. These factors are integrated with the available nutrients to determine the yield level observed for each crop.

5.4.4.2 Application to Forested Land

As with agronomic crops, the harvesting of a forest stand removes the nutrients accumulated during growth. However, the amounts removed annually in forest harvesting are generally lower than in agronomic crop harvesting (see Table 5-7). Uptake by vegetative cover will affect the uptake of N; i.e., plush understory vegetation markedly increases N uptake. Forest systems also rely on soil processes (denitrification) to minimize nitrate leaching into groundwater. In general, nutrient loadings on forested lands should be less than those on agricultural sites. No annual limitations are set for cadmium, since no food-chain crops are grown. Lifetime metal limits used for agricultural sites are suggested for forested land; this would minimize metal toxicity to trees and allow growth of other crops if the area were cleared at a future date.

5.4.4.3 Application on Reclaimed Land

Septage is usually applied to impoverished lands at rates sufficient to satisfy the nutrient requirements of the cover crop.

TABLE 5-7

ESTIMATED ANNUAL NITROGEN UPTAKE BY FOREST SPECIES[a] (7)

	Tree Age, years	Average Annual Nitrogen Uptake kg/ha
Eastern Forests		
Mixed Hardwoods	40 to 60	200
Red Pine	25	100
Old Field with White Spruce Plantation	15	200
Pioneer Succession	5 to 15	200
Aspen Sprouts	---	100
Southern Forests		
Mixed Hardwoods	40 to 60	280
Southern Pine with No Understory	20	200[b]
Southern Pine with Understory	20	260
Lake State Forests		
Mixed Hardwoods	50	100
Hybrid Poplar[d]	5	150
Western Forests		
Hybrid Poplar[c]	4 to 5	300
Douglas Fir Plantation	15 to 25	200

[a]Uptake rates shown are for wastewater-irrigated forest stands.
[b]Principle southern pine included in these estimates is loblolly pine.
[c]Short-term rotation with harvesting at 4 to 5 years; represents first growth cycle from planted seedlings.

5.4.5 Application Rates

Annual application rates are typically controlled by the nutrient requirements of the crop grown and the cadmium limits established by regulation. One method establishes nutrient requirements of the selected crop; however, a more conservative method is to select an application rate based on the phosphorus requirements of the crop. Since the P requirements of most crops are approximately 25 percent of the N requirement, the nitrogen and cadmium applied is considerably less than under the previous approach. Lifetime loading rates are determined based on regulatory limits established for the cumulative metal additions. Septage, or any other sludge applications cease when any one of the metal limits is reached. The following sections present methodologies for determining the amounts of nutrients and metals applied, along with a design example of how to apply the methodologies to determine application rates and land requirements.

5.4.5.1 Calculation of Nitrogen Applied

The application of septage introduces nitrogen in two different forms: inorganic nitrogen (almost exclusively ammonia) and organic nitrogen. Inorganic nitrogen is available for plant uptake immediately upon application. The amount available for use by the plants is affected by the application method. For surface applications, as much as 50 percent of the ammonia-nitrogen will be volatilized. The amount of volatilization is influenced by many factors, including pH, soil water content, temperature, surface roughness, land cover and residue, air movement, and time elapse between application and next rainfall. If septage is incorporated immediately into the soil, all of the ammonia-nitrogen is available for use by the crops. The organic nitrogen in septage must first be mineralized; that is, converted to a plant-available form. The rate at which this takes place is a function of septage characteristics, soil characteristics, climatic conditions, and the time since application. The rate at which nitrogen decays is a function of the degree of treatment the septage has received, as shown in Table 5-8, which summarizes reported mineralization factors commonly used for wastewater sludge. These mineralization factors should be applicable to septage with equivalent treatment conditions. That is, mineralization rates for septage should be approximately the same as those for primary wastewater sludge, and anaerobically-digested septage should have the same mineralization characteristics as anaerobically-digested sludge.

TABLE 5-8

ORGANIC NITROGEN MINERALIZATION FACTORS[a]

Years After Application	Primary Wastewater Sludge (3)	Primary Wastewater Sludge (8)	Primary and Waste-Activated Sludge (6)	Aerobically-Digested Sludge (6)	Anaerobically-Digested Sludge (6)	Composted (6)
First Year	20	15 to 20	40	30	20	10
Second Year	3	6	20	15	10	5
Third Year	3	4	10	8	5	3
Fourth Year	3	2	5	4	3	3
Fifth Year	3	2	3	3	3	3
Five to Ten Years	3	2	3	3	3	3

[a]Factors represent the percent of remaining organic nitrogen in applied septage that is available for plant uptake in a given year.

In order to calculate the annual application rate of nitrogen in a particular year, the following sources must be included:

1. All of the nitrate (NO_3-nitrogen) present in the septage.

2. All or a fraction of the ammonia (NH_4-nitrogen) present in the septage, depending on the form applied and the type of application.

3. A fraction of the organic nitrogen (N_O) present in the septage that is mineralized the first year.

4. A residual fraction of the organic nitrogen (N_O) (applied previously either by adding septage, sludges, or commercial fertilizers) that is mineralized the current year.

For the first year of application, the amount of nitrogen applied can be calculated by the following equation:

$$C_N = S\ [(NO_3) + K_V(NH_4) + F_{(0-1)}(N_O)] \times A$$

where:

C_N	= Plant-available nitrogen in kg/ha (lb/acre).
S	= Raw septage application rate in m^3/ha (gal/acre).
NO_3	= Nitrate-N concentration in septage in mg/L.
NH_4	= Ammonia-N concentration in septage in mg/L.
N_O	= Organic-N concentration in septage in mg/L.
K_V	= Volatilization factor = 0.5 for surface-applied raw septage, or 1.0 for subsurface-applied raw septage and dewatered septage applied in any manner.
F_{0-1}	= Mineralization factor for organic-N in septage in the first year (from Table 5-8), expressed as a fraction.
A	= 1×10^{-3} -SI (8.34×10^{-6}-English)

For subsequent years, a three-step calculation is recommended to determine the amount of nitrogen applied each year:

Step 1: <u>Determine the amount of organic-N mineralized from previous applications of septage</u>.

From records of the septage applied, the organic-N applied each year can be determined. The amount mineralized each year can be determined using the factors in Table 5-8.

N_o applied in year 0-1	$= S_{0-1} \times N_o \times A$	$= N_{oA0-1}$
N_o mineralized in year 0-1	$= N_{oA0-1} \times F_{0-1}$	$= C_{NM0-1}$
N_o remaining in year 1-2	$= N_{oA0-1} - C_{NM0-1}$	$= N_{oA1-2}$
N_o mineralized in year 1-2	$= N_{oA1-2} \times F_{1-2}$	$= C_{NM1-2}$
N_o remaining in year 2-3	$= N_{oA1-2} - C_{NM1-2}$	$= N_{oA2-3}$
N_o mineralized in year 2-3	$= N_{oA2-3} \times F_{2-3}$	$= C_{NM2-3}$
etc.		

where:

A	$= 1 \times 10^{-3}$-SI (8.34×10^{-6}-English).
S	= Raw septage application rate in m^3/ha (gal/acre).
N_o	= Organic-N concentration in septage in mg/L.
N_{oA0-1}	= Organic nitrogen applied first year kg/ha (lb/acre).
F_{0-1}	= Mineralization factor first year.
C_{NM0-1}	= Plant-available mineralized-N first year kg/ha (lb/acre).
N_{oA1-2}	= Organic-N remaining second year in kg/ha (lb/acre).
F_{1-2}	= Mineralization factor second year.
C_{NM1-2}	= Plant-available mineralized-N second year in kg/ha (lb/acre).
N_{oA2-3}	= Organic-N remaining third year in kg/ha (lb/acre).
F_{2-3}	= Mineralization factor third year.
C_{NM2-3}	= Plant-available mineralized-N third year in kg/ha (lb/acre).

This calculation continues until each year since the time of application is considered. The procedure must be repeated for each previous year when septage was applied to the site. The amount of mineralized organic-N available for plant uptake in the current year (C_{NM}) is the sum of the residual amounts of organic-N that will be mineralized during the year.

Step 2: Determine the amount of nitrogen applied during the current year's application of septage. This can be done from the equation:

$$C_N = S[(NO_3) + K_v(NH_4) + F_{0-1}(N_o)]A$$

Step 3: The total amount of nitrogen available for plant uptake is the sum of the two sources:

$$C_{N\ Total} = C_N + C_{NM}$$

5.4.5.2 Calculation of Phosphorus Applied

In addition to the nitrogen, septage also provides the plant nutrient phosphorus. It is assumed that 50 percent of the phosphorus contained in septage is available for plant uptake as the phosphates normally applied to soils in commercial fertilizers. The amount of plant-available phosphorus applied to the soil can be calculated by the following equation:

$$C_P = (S)(0.5)(P) \times A$$

where:

C_P = Plant-available phosphorus in kg/ha (lb/acre).
S = Septage application rate in m^3/ha (gal/acre).
P = Phosphorus concentration in mg/L.
A = 1×10^{-3} - SI (8.34×10^{-6} - English).

5.7.3 Calculations of Metals Applied

Annual limits have been established for the amount of cadmium that may be applied to a site, and total cumulative limits have been established for Cd, Pb, Zn, Cu, and Ni. The amount of each metal applied to the site each year can be determined by using the same approach used for the nutrients:

$$M = S \times M_C \times A$$

where:

M = Amount of the metal of concern applied in a given year in kg/ha (lb/acre).

S = Amount of septage applied in a given year in m^3/ha (gal/acre).

M_C = Concentration of the metal of concern in the septage applied in mg/L.

A = 1×10^{-3} - SI (8.43×10^{-6} - English).

The total cumulative amount of metal applied can be determined by summing the annual amounts calculated using above equation.

5.4.5.3 Calculation of Additional Nutrient Requirements

Table 5-2 presented the relative amounts of N, P, and K required by a variety of crops for a projected yield. These yields will not result unless all the essential nutrients are available in the recommended amounts. Therefore, it may be necessary to add nutrients via commercial fertilizers to supplement the nutrients available in the septage applied. By subtracting the amount of nutrient applied in the septage (as calculated in the previous sections) from the amount of nutrient required for a desired yield, the amount of supplemental fertilizer required can be determined.

5.4.5.4 Application Rate Calculation

A community in the midwest with a population of 24,000 persons and an average household population of 3 persons/household is served by onsite septic systems. The town has adopted a septage management program and will pump septic tanks once every three years. An agreement has been made with a local farmer to apply raw septage to existing fields used to grow corn silage. During the first year, septage will be applied based on the crop N requirement, and, during the second year, the septage will be applied based on the crop P requirement. Determine the first and second year annual application rates and land requirements:

Septage Quantity

24,000 persons divided by 3 persons/household = 8,000 households (tanks)

Assume septic tank volume = 2.84 m^3 (750 gal)

Annual volume of septage = 8,000 x 2.84 m^3 divided by 3 (average pumping interval in years) = 7573.3 m^3 (2.0 million gal)

Septage Characteristics (from Tables 3-4 and 3-5)

1. TKN = 650 mg/L
2. NH_4-N = 120 mg/L
3. NO_3-N = 3 mg/L
4. N_O-N = 527 mg/L
5. Total P = 250 mg/L
6. Total K = 60 mg/L
7. Pb = 10 mg/L
8. Zn = 40 mg/L
9. Cu = 9.1 mg/L
10. Ni = 1.0 mg/L
11. Cd = 0.7 mg/L

Regulations

1. Annual septage applications cannot exceed either the N required for the crop grown or 2 kg Cd/ha (1.78 lb Cd/acre) for the first two years.

2. Soil must be maintained at pH 6.5 or above.

3. Annual monitoring is not needed other than routine soil testing to determine fertilizer and lime requirements.

4. Records are to be maintained on the amount of septage applied to each area.

Site Soil Properties

1. CEC = 10 meq/100g
2. Soil pH (in water) = 6.0
3. Available P = 15 kg/ha (13.1 lb/acre)
4. Available K = 75 kg/ha (67 lb/acre)
5. Lime (to pH 6.5) = 5.4 mt/ha (2.4 tons/acre)

Crop Nutrient Requirements

Corn silage is currently being grown on the land. Crop fertilizer requirements were obtained from Table 5-2.

Yield = 72 mt/ha (32 tons/acre)
N = 224 kg/ha (200 lb/acre)
P* = 24.4 kg/ha (21.8 lb/acre)
K* = 152.4 kg/ha (136 lb/acre)

*Recommendations based on soil test data shown above.

The septage will be applied to the soil by subsurface methods for the corn silage crop, making the K_v volatilization factor equal to 1. The mineralization factors for the first two years are $F_{0-1} = 0.4$ and $F_{1-2} = 0.2$.

Method 1: Calculation of First Year Septage Application Rate Using Nitrogen Basis

$$C_N = S\ [(NO_3) + K_v(NH_4) + F_{0-1}(No)] \times A$$

Solve for S knowing C_N = 224 kg/ha (200 lb/acre):

$$224\ \text{kg/ha} = S\ \text{m}^3/\text{ha}[(3\ \text{mg/L}) + 1.0(120\ \text{mg/L}) + 0.4(527\ \text{mg/L})] \times 10^{-3}$$

S = 671 m^3/ha (71,840 gal/acre)

Calculation of First Year Cadmium Applied Based on Nitrogen Loading

$M_{Cd} = S \times Cd \times A$

$M_{Cd} = 671\ m^3/ha \times 0.7\ mg/L \times 10^{-3} = 0.47\ kg/ha$ (0.42 lb/acre)

Calculation of Other Nutrients Applied Based On Nitrogen Loading

1. Phosphorus: Assume 50 percent of phosphorus in septage is available as phosphates.

$C_P = S[0.5(P)] \times A$

$C_P = 671\ m^3/ha \times 0.5\ (250\ mg/L) \times 10^{-3} = 83.9\ kg/ha$ (74.9 lb/acre)

Phosphorus required = 24.4 kg/ha, therefore more P is available than is required by the crop.

2. Potassium: Assume 100 percent availability.

$C_K = S \times K \times A$

$C_K = 671\ m^3/ha \times 60\ mg/L \times 10^{-3} = 40.3\ kg/ha$ (36.0 lb/acre)

Potassium required = 152.4 kg/ha, therefore more K will be needed in a supplemental form.

(152.4 - 40.3 = 112.1 kg/ha) (100 lb/acre)

Calculation of Metals Accumulation

The amount of all metals should be determined on an annual basis and recorded to determine when the lifetime limits are reached. For illustration purposes only, Zn (which will be the controlling metal) accumulation will be calculated.

$M_{Zn} = S \times Zn \times A$

$M_{Zn} = 671\ m^3/acre \times 40\ mg/L \times 10^{-3} = 26.8\ kg/acre$ (24.0 lb/acre)

Calculation of the Area Required

$A = 7{,}573.3\ m^3 - 671\ m^3/ha = 11.29\ ha$ (27.84 acres)

Method 2: Calculation of Second Year Septage Application Rate Using Phosphorus Basis

$C_P = S\ [0.5\ (P)] \times A$

$24.4\ kg/ha = S\ m^3/ha\ [0.5(250\ mg/L)] \times 10^{-3} = 195.2\ m^3/ha$ (20,910 gal/acre)

Calculation of Second Year Cadmium Applied

$M_{Cd} = S \times Cd \times A$

$M_{Cd} = 195.2\ m^3/acre \times 0.7\ mg/L \times 10^{-3} = 0.137\ kg/ha$ (0.12 lb/acre)

Calculation of Additional Nutrient Requirements

1. Nitrogen

   a. Calculate the fraction of the organic-N applied in the first year that will be mineralized in the second year:

      N_O applied in year 0 to 1 (N_{O0-1}) = $671\ m^3/ha \times 527\ mg/L \times 1 \times 10^{-3} = 353.6\ kg/ha$ (315.6 lb/acre)

      N_O mineralized in year 0 to 1 (C_{NM0-1}) = $353.6\ kg/ha \times 0.4 = 141.4\ kg/ha$ (126.3 lb/acre)

      N_O remaining in year 1 to 2 (N_{O1-2}) = $353.6\ kg/ha - 141.4\ kg/ha = 212.1\ kg/ha$ (189.3 lb/acre)

      N_O mineralized in year 1 to 2 (C_{NM1-2}) = $212.1\ kg/ha \times 0.2 = 42.2\ kg/ha$ (37.9 lb/acre)

b. Calculate nitrogen applied in second year:

$C_N = S[NO_3) + Kv(NH_4) + F_{0-1}(No)] \times A$

C_N = 195.2 m^3/ha [(3 mg/L) + 1(120 mg/L) + 0.4 (527 mg/L)] x 1 x 10^{-3} = 65.2 kg/ha (58.2 lb/acre)

c. Calculate the total plant-available nitrogen applied in the second year:

C_N Total = C_{NM} + C_N = 42.4 kg/ha + 65.2 kg/ha = 107.6 kg/ha (96.1 lb/acre)

Total N required for corn silage = 224 kg/ha (200 lb/acre)

Additional N required = 224 kg/ha - 107.6 kg/ha = 116.4 kg/ha (103.9 lb/acre)

2. Potassium

$C_K = S \times K \times A$

C_K = 195.1 m^3/ha x 60 mg/L x 1 x 10^{-3} = 11.7 kg/ha

Total K required for corn silage (yield = 72 mt/ha [32 tons/acre]) = 152.4 kg/ha (136 lb/acre)

Additional K required = 152.4 kg/ha - 11.7 kg/ha = 140.7 kg/ha (125.5 lb/acre)

Calculation of Metals Accumulation (Zn)

Year 1: M_{Zn} = 26.8 kg/ha (24.0 lb/acre)
Year 2: M_{Zn} = 195.2 m^3/ha x 40 mg/L x 1 x 10^{-3} = 7.8 kg/ha (6.9 lb/acre)

Cumulative total Zn = 26.8 kg/ha + 7.8 kg/ha = 34.6 kg/ha (30.9 lb/acre) (which is less than the limit of 560 kg/ha)

Calculation of Area Required to Apply 2.0 Million Gallons per Year

A = 7573.3 m^3 ÷ 195.2 m^3/ha = 38.8 ha (95.6 acres)

5.5 Management, Operations, and Monitoring

Once the system has been constructed, it must be made to run smoothly and efficiently according to the following:

1. Applications of septage must be scheduled to conform to the farming requirements. If crops are grown on the disposal area, tilling, planting, cultivating, and harvesting operations must all be scheduled. Scheduling is discussed in detail in references (6) and (8).

2. Operations must be monitored to assure that the system is operating as designed. Septage must be periodically analyzed to ensure its acceptability to the user and provide a record of nutrient and metal additions to the soil. Soil, crops, groundwater, and surface water need to be monitored periodically to determine if septage nutrients are applied at rates exceeding the uptake capacity of crops or soils, in a manner generally prescribed by local or state regulations. If the applied N equals crop N uptake, the potential groundwater contamination from septage is minimal.

5.6 References

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CHAPTER 6

CO-TREATMENT OF SEPTAGE AND SEWAGE

6.1 Introduction

The similarity in the characteristics of septage and municipal wastewater makes co-treatment an attractive method of septage treatment and disposal. However, appropriate facilities are needed at sewage treatment plants to receive, pretreat, and distribute the septage into the appropriate process units. Septage, which may be considered a high strength wastewater, can be either dumped into an upstream sewer or added directly into various unit processes in a sewage treatment plant. In both cases it is essentially a slug load of concentrated waste resulting from unloading of septage by tank trucks. For example, a 3.8-m^3 (1,000-gal) tank truck emptying its contents in 10 minutes represents a hydraulic surge of 6.3 L/sec (100 gpm). Such a hydraulic surge, when coupled with the concentrated suspended solids, BOD, and other pollutants contained in septage, could produce a shock load on the sewage treatment facility and can be overpowering in the case of small sewage treatment plants.

6.2 Feasibility of Co-Treatment

The ability of a treatment plant to accommodate septage depends on the following factors:

1. Plant type, layout, and location.
2. Plant design capacity.
3. Current wastewater flow.
4. Plant effluent limitations, including BOD, suspended solids, nitrogen, and phosphorus.
5. Septage receiving and pretreatment facilities.
6. Sludge handling facilities, including ultimate sludge disposal practices.

The quantity of septage that a plant can handle is governed by two major factors: 1) quantity and nature of flow and 2) aeration capacity and solids handling capacity of the plant. The volume of septage relative to sewage is important since it determines the additional organic solids load on the STP. The loading limits on the unit processes are significantly influenced by the nature of the flow of septage, which could be in the form of either slug loads or continuous loadings. In general, when septage is fed in as slug loads to aeration basins in sewage treatment plants, the loading should be about half of that under continuous loadings (1).

The aeration capacity, solids retention time, and organic loading will limit the amount of septage that can be handled in the aeration basins. Any remaining portion of septage could be diverted to the solids handling facilities of the plant if adequate capacity is available there.

Septage is about 50 times as concentrated as domestic sewage in terms of organic and solids loading (1). A constant 2 percent addition of septage approximately doubles the organic input to an aeration basin at an extended aeration facility, and doubles the solids loading on a primary clarifier in a conventional activated sludge facility (1). Secondary aeration basins at conventional plants receive about one fifth of the influent septage organic loading since the major fraction of organics in septage is usually associated with suspended solids that are effectively removed in primary clarification.

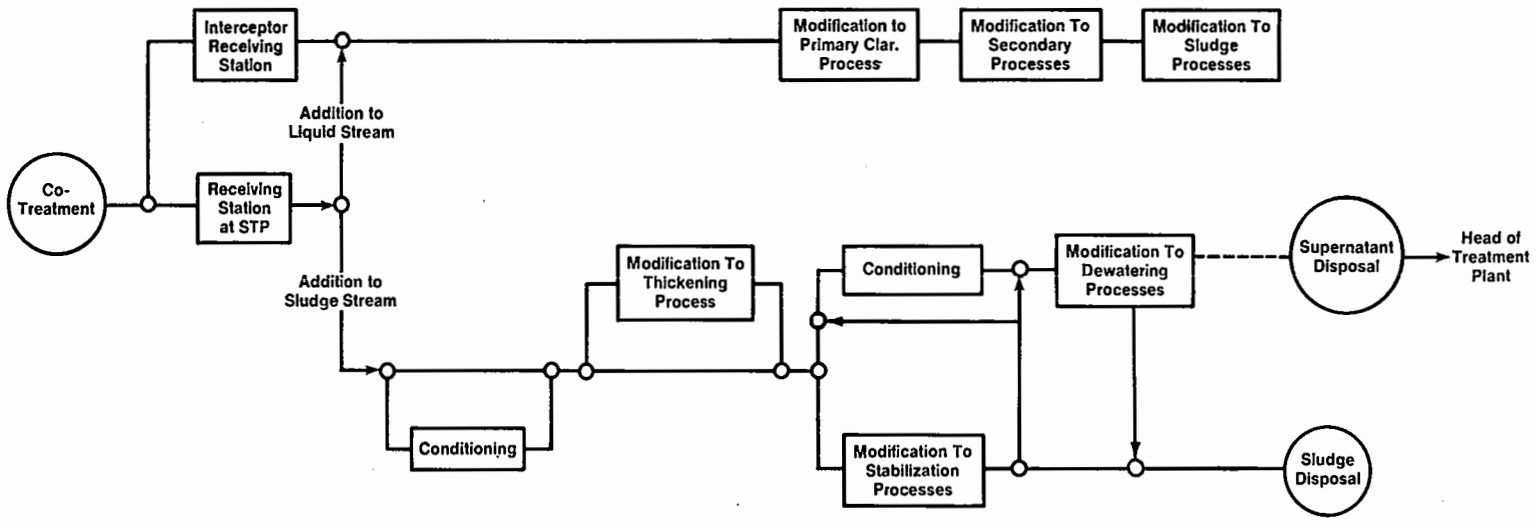
6.3 Modes of Septage Addition

6.3.1 Pretreatment Requirements

There are two options available for treating septage in a treatment plant. It could be treated either as a part of the liquid stream or as part of the solids handling and treatment system, as illustrated in Figure 6-1. Since septage usually contains hair, grit, plus stringy and plastic materials (in addition to the very high concentration of organic solids), it is recommended that septage undergo some form of pretreatment (e.g., screening and degritting) before being introduced into a liquid or solids stream. Another problem associated with septage treatment is the large variability in flow. For this reason, a septage receiving station is recommended to accomplish the following objectives:

1. Allow easy and safe transfer of septage from the hauler truck to the septage storage tank at the plant.

FIGURE 6-1
TECHNICAL OPTIONS FOR CO-TREATMENT OF SEPTAGE



2. Prevent clogging/fouling and excessive wear and tear on plant equipment.

3. Allow controlled flow of septage from a holding/equalization tank into the desired process unit, if required.

4. Prevent fouling of biological treatment processes due to floating inert materials.

Detailed discussion and design recommendations regarding receiving stations were given in Chapter 4. The following discussions on co-treatment of septage and sewage in an STP are based on the consideration that only screened and degritted septage (preliminary treatment) will be introduced into a primary or secondary treatment process.

6.3.2 Liquid Stream Addition

Screened and degritted septage can be added to the liquid stream of an STP at several points at the STP, as well as directly to the interceptor, as shown in Figure 6-2. Septage may be discharged directly from hauler trucks in slug loads, or it can be gradually fed into the system using some form of equalization. The point of addition chosen must take into account a variety of factors, not the least of which are the locations of plant bypass lines, organic and hydraulic loadings (design and actual), and physical capacity of unit processes directly and indirectly affected by septage addition.

Adding septage to a sewer can create the following maintenance problems in the sewer system:

1. Deposits in the sewers.

2. Clogging of pumps at pumping stations.

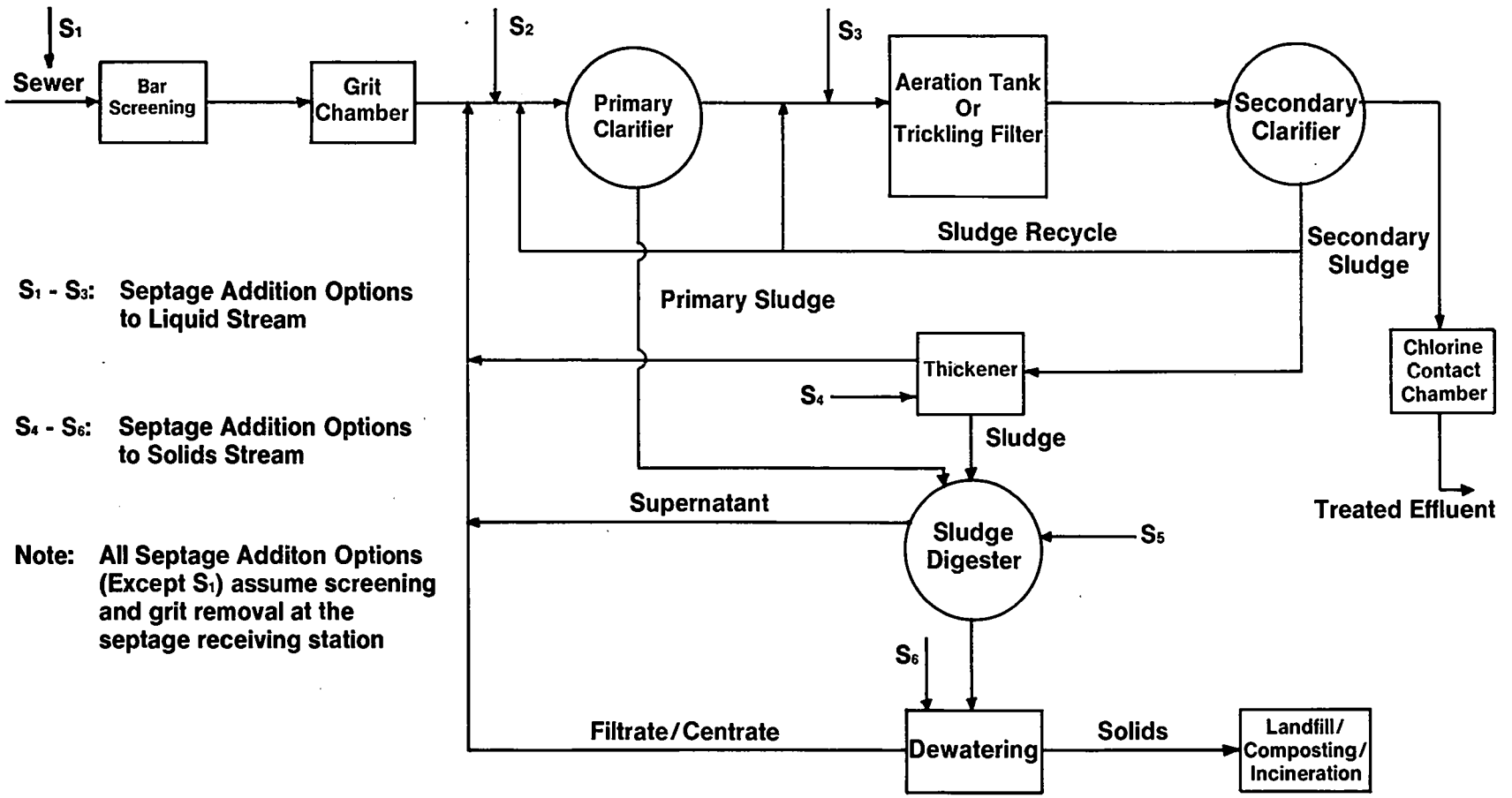
3. Increased corrosion of sewer pipes.

4. Odor problems at the point of discharge and at downstream locations.

Germany has developed guidelines for the addition of septage to the sewer mains (32):

1. The municipal treatment plant must have a biological step with enough excess capacity to treat the additional load from the septage.

FIGURE 6-2
POINTS OF SEPTAGE ADDITION IN A TYPICAL SEWAGE TREATMENT PLANT



2. The effluent quality requirement for the treatment plant must be kept during periods with addition of septage.

3. At the point of discharge the septage must be diluted at least 10 times with the municipal wastewater. The time of discharge must be regulated according to this. Generally septage should not be added at points in the sewer system where the municipal wastewater flow is less than the average flow from 30,000 persons.

4. If the sewer system has overflow weirs downstream from the point of discharge of septage, no septage must be added during or soon after rainfall periods.

5. Septage must only be added at the point that is especially set aside for septage addition.

6. Due to odor problems point of discharge must be located at least 100 meters from the nearest house.

7. Point of discharge of septage requires regular maintenance. Quantities and time of discharge must be recorded.

Septage addition to a treatment plant without screening, degritting, and equalization is not recommended since it produces shock loads on the plant's hydraulic and organic load-carrying capacity. The impact of slug loads on performance is, to a certain extent, dependent on the point of addition of the septage. If trucks discharge directly into the influent stream of primary clarifiers, little or no control can be exerted over amounts or timings of loads. Density currents caused by incomplete mixing of septage and sewage interfere with solids separation in primary clarifiers. Inefficiencies in suspended solids removal in primary clarifiers can cause serious malfunctioning of secondary process units. If septage is to be added before primary treatment and no equalization facilities are available, one method of minimizing shock loads is to discharge the septage into a "controlled" manhole upstream of the plant headworks. By this method, septage is diluted in the sewers. However, some control may be required to avoid septage loadings during low flow periods. Addition of septage during low flows can exert shock loading on the process units in smaller plants and may also result in the settling of grit in the manhole due to low flow velocities.

Slug loading of raw septage directly into secondary treatment units is not recommended. Biological treatment units are very sensitive to increased organic and solids loading and are especially sensitive to slug loads (2). Shock loads from septage can cause upsets in secondary process units including oxygen depletion, low BOD removals, and poor settling of sludge in secondary clarifiers.

The preferred method of septage addition to most plants is continuous feed at a rate proportional to sewage flow. In this way it is possible to introduce septage into the sewage flow stream at considerably higher flow rates than that possible with slug loading. In order to ensure continuous controlled addition of septage, equalization and metering facilities are required. Such facilities could be part of a septage receiving station at the headworks of an STP and should include provisions for mixing, odor control, and controlled rate feeding of septage. Bar screens and grit chambers are also recommended to protect the primary and/or secondary unit processes.

Continuous feed of septage after receiving station flow equalization provides better control of hydraulic and organic loading on primary and secondary process units, which improves overall performance of the treatment processes and ensures more uniform effluent quality. It is recommended that continuous feed systems be utilized for treatment of septage in small- to medium-sized plants whenever possible.

In large STP's the effects of septage loadings are generally expected to be low, because the ratio of septage to sewage is generally low and large STP's are capable of handling shock loads better than smaller plants. In such cases it may be possible to introduce small quantities of septage without equalization into an interceptor sewer upstream of the STP.

6.3.3 Solids Stream Addition

Based on the concept that septage is essentially a mixture of settled sludge and raw sewage, with very high solids content, it is logical to consider the option of treatment with primary and/or secondary sludges.

Septage addition to the solid stream may be made either at the entrance to the sludge stabilization system or to the dewatering system, as shown in Figure 6-2. Addition to the stabilization system (e.g., anaerobic/aerobic digestion) has the advantage that septage may be added after only screening and degritting, and without equalization. The characteristics of septage do not significantly interfere with the digestion process. Moreover, septage is biologically stabilized during digestion and could be disposed of along with the digested sewage sludge.

If septage is added directly to the sludge dewatering process, chemical conditioning is required, in addition to screening and degritting, in order to enhance its dewatering characteristics. Since the septage does not undergo any biological stabilization when added directly to the dewatering process, the high concentration of organic matter still present after dewatering could create odor and nuisances in the disposal of residuals. Chemical conditioning with lime prior to dewatering septage reduces odor problems. However, if composting or incineration are available methods of ultimate disposal, unstabilized, dewatered septage sludge can be handled with little concern for odor and nuisance problems.

Based on practical experience from plants mostly located in Norway, the following guidance is offered by Eikum (31):

1. Septage must undergo separate screening, grit, and sand removal prior to adding it to the sludge handling facility.

2. The sludge handling facility must have enough capacity to handle the additional volumetric and solids load (thickening, stabilization, and dewatering capacity).

3. The sludge return liquor added to the municipal plant must not reduce the effluent quality of the treatment plant below the requirements set by authorities.

4. Addition of sludge return liquor from the sludge treatment facility must enter a basin with 24 hours detention time.

5. The addition of septage must be managed by the treatment plant operators.

6. Quantities and time of discharge of septage must be recorded.

7. Plants with septage addition must be located at least 100 meters from nearest house unless the discharge takes place inside a building and odor reduction equipment is installed.

6.4 Co-Treatment of Septage in the Liquid Stream

Septage addition to the liquid stream of a sewage treatment plant is one of the most common methods of septage treatment and disposal. While

the similarity in characteristics of septage and sewage makes joint treatment a compatible option, the performance of an STP accepting septage is dependent on many factors. Design considerations for combined treatment of septage and sewage vary, depending on:

1. Type of process units in the STP.
2. Design capacity of the plant.
3. Location of septage input to the plant.
4. Volume of septage added daily.
5. Mode of septage addition (i.e., slug or continuous loading).
6. Ratio of current loading of plant to its design loading.

The impact of septage addition to process units in an STP should be evaluated based on the following considerations:

1. Increased hydraulic loading on primary and secondary treatment units.
2. Increased loading on sludge treatment units (thickeners, dewatering equipment, etc.).
3. Increased sludge volume in clarifiers.
4. Increased organic loading to biological process units.
5. Scum buildup in clarifiers and other facilities.
6. Odor and foaming problems in aeration units.
7. Potential toxic or incompatible substances present in septage causing inhibition to biological processes.
8. Effluent limitations.

Germany has developed specific guidelines (32) that seek to minimize operational problems associated with the addition of septage to the liquid stream in an STP. These guidelines contain the following suggestions:

1. The municipal treatment plant must have a biological step designed for minimum 10,000 persons.

2. The biological step must have enough excess capacity to treat the additional organic load from the septage. During periods with high hydraulic load on the plant (rainfall/infiltration) no septage must be added.

3. Effluent quality requirements for the plant must be kept at all times. During normal operation this can be achieved by estimating maximum volumes of septage that can be added to the plant (see Figure 6-3).

4. The septage volume determined from Figure 6-3 must be added in at least two batches with several hours in between, and outside the normal peaking periods at the plant.

5. The septage must be diluted at least 20 times with the municipal wastewater.

6. Detention basins for septage must be used in those cases where the truck capacity exceeds the allowable volume that can be added to the plant in one batch. The same is true if the trucks arrive at the plants too often to allow the necessary time between discharge of each truck load.

7. If the septage can be added from a detention basin during several hours and outside peaking periods at the plant, the volumes estimated from Figure 6-3 can be multiplied by a factor of 4.

8. The septage must be added upstream from the plant screen.

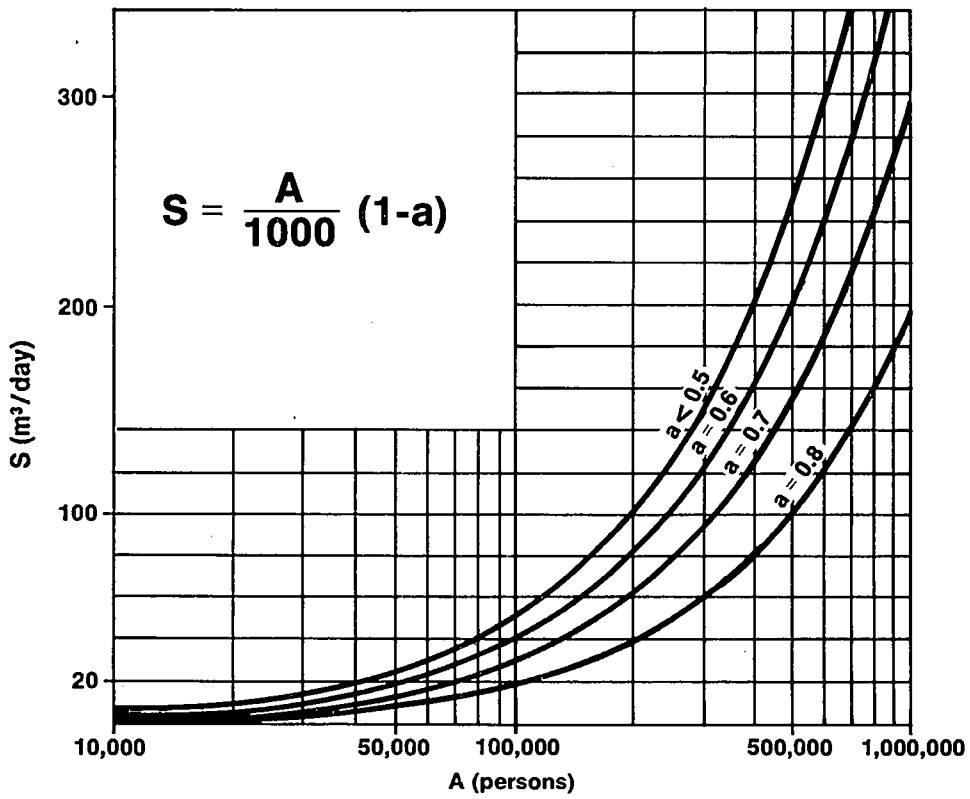
9. The addition of septage must be managed by the treatment plant operators.

10. Quantities and time of discharge must be recorded.

6.4.1 Septage Addition to Primary Process Units

The first option for introduction of septage to the liquid stream is at the entrance of the primary clarifier. This impacts both the primary and secondary treatment processes.

FIGURE 6-3
ALLOWABLE SEPTABE VOLUME TO BE ADDED TO MUNICIPAL TREATMENT PLANT PER GERMAN GUIDELINES (32)



S = Allowable septage volume to be added (m³/day)
A = Design capacity of municipal treatment plant (persons)
a = Loading factor = $\frac{\text{No. of equivalent users (edu's) connected to plant}}{\text{design capacity (edu's)}}$

6.4.1.1 Impact on Primary Treatment Process

Screened and degritted septage may be added to the influent of primary clarifiers to remove suspended solids. Although some plants add raw septage at this point and degrit the primary sludge from this process, this approach is not recommended. Septage usually contains very high concentrations of suspended solids (10,000 to 20,000 mg/L) compared to sewage (150 to 300 mg/L). Numerous studies have shown that raw septage has poor settling characteristics (3)(4)(5). One of these studies has noted suspended solids removals as low as 10 percent after 30 minutes of settling (5). The same study determined the average suspended solids removal to be 25 percent after 30 minutes. One reason for this poor performance is that septage contains extremely high concentrations of grease which has been well mixed with other solids during the pumping, transport, and discharge steps. The production of gas bubbles under anaerobic conditions, often found in septage, also tends to resuspend solids, thereby affecting settling behavior. However, the addition of septage, in combination with raw sewage, to primary clarifiers has been found to be successful in achieving acceptable suspended solids removal. Dilution of the suspended solids concentration in septage by sewage renders septage more easily settleable; also, the net increase in suspended solids in the liquid stream tends to improve overall settling efficiency. Studies by Smith and Wilson (6), Bennett, et al. (7), and Carroll (8) found an average of 55 to 65 percent suspended solids removal in primary clarifiers treating septage-sewage mixtures.

Segall and Ott (1) compared performance of a primary clarifier in an STP at Marlborough, Massachusetts with and without addition of septage. The results are given in Table 6-1. Under constant septage feed of 1.25 percent by flow volume, 56 percent of suspended solids were removed, compared to 52 percent removal without septage addition. Increasing septage loading to 2.14 percent resulted in a suspended solids removal of 75 percent. Further increase in septage addition did not appear to enhance removal efficiency of suspended solids. Based on limited data available it was assumed that an average of 55 to 60 percent suspended solids removal could be obtained in primary clarifiers treating septage-sewage mixtures. The increase in BOD removal efficiency was significant, with removals of 53 percent and 67 percent when septage was added to sewage, compared to 17 percent without septage addition. However, increased BOD removals were not expected with higher septage loadings. It would appear from these data that most of the additional BOD loading imposed by the septage addition is removed in primary clarification.

TABLE 6-1

CHARACTERISTICS OF PRIMARY CLARIFIER EFFLUENTS
AT MARLBOROUGH, MASSACHUSETTS (1)

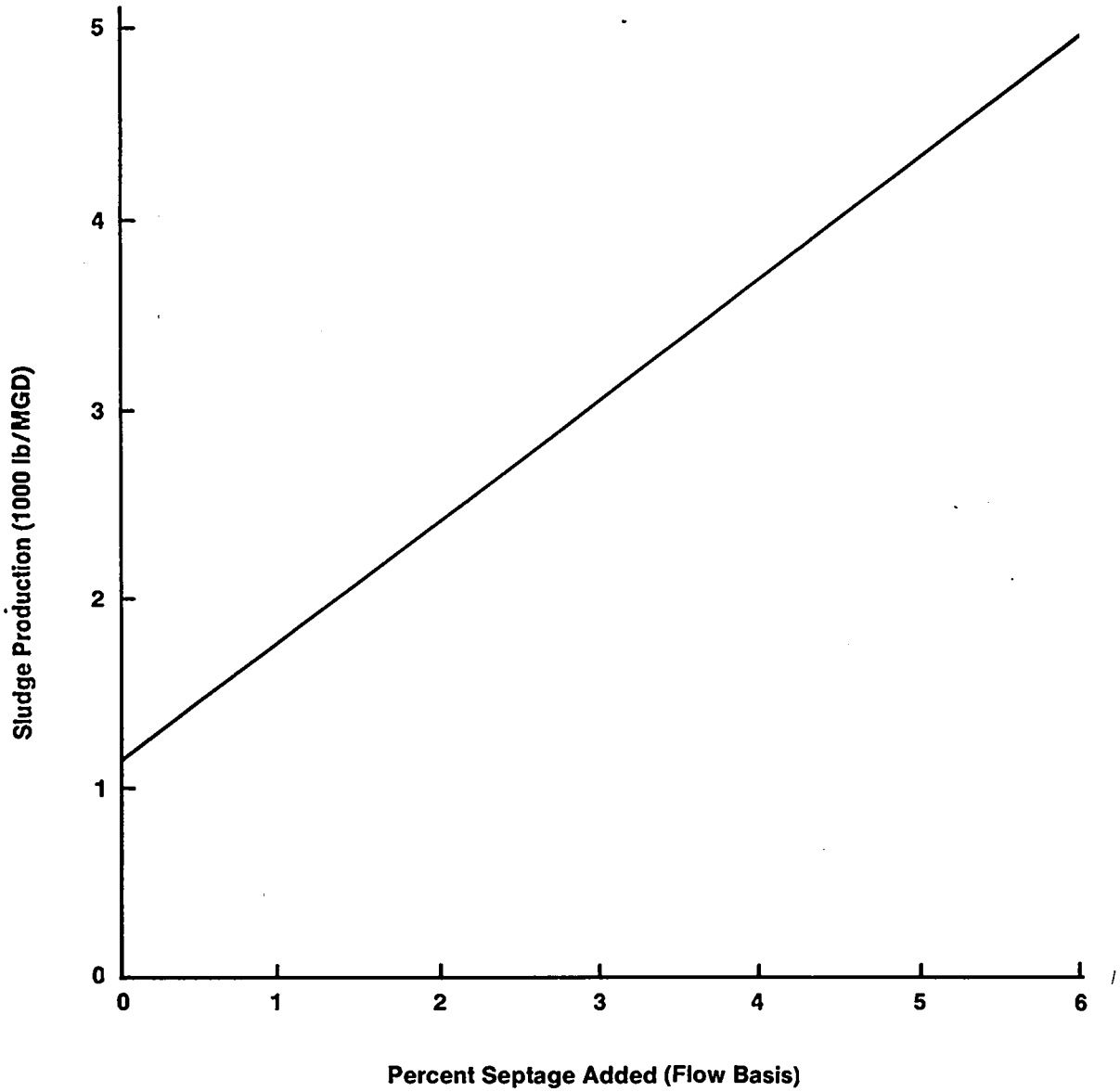
	Phase 1			Phase 2A			Phase 2B		
	Inf.	Eff.	% Reduction	Inf.	Eff.	% Reduction	Inf.	Eff.	% Reduction
Q Wastewater, m^3/s	0.1			0.1			0.1		
Q Septage, m^3/d	0			110			216		
Septage, % by Volume	0			1.2			2.1		
TS, mg/L	716	476	34	907	592	35	937	477	49
TVS, mg/L	468	193	59	683	298	56	595	206	65
TSS, mg/L	221	106	52	455	199	56	577	143	75
VSS, mg/L	200	72	64	363	137	62	488	101	79
BOD_5, mg/L	120	100	17	218	103	53	393	128	67
BOD_5-N Supressed, mg/L	87	73	16	183	69	62	289	76	74
COD, mg/L	317	247	22	602	310	49	905	255	72
COD-N Supressed, mg/L	90	78	13	---	98	---	---	80	---
TKN, mg/L	20	27	-35	35	33	6	66	---	---
NH-N, mg/L	16	17	-6	22	28	-27	15	20	-33
TP, mg/L	5.6	5.5	2	11	5.4	51	9.7	6.1	37
Alkalinity, mg/L	112	136	-21	142	192	35	115	156	-36
Grease, mg/L	129	211	64	189	135	29	268	914	-241

The impact of septage on primary effluent quality is also an important consideration for septage addition to primary clarifiers. Since high suspended solids removal can be successfully achieved in primary clarifiers loaded with septage-sewage mixtures, unduly high concentrations of organic matter would not be expected in primary effluent. The results of full-scale tests at Marlborough (1) (see Table 6-1) show that an approximate three-fold increase in organic loading of influent by septage produced only a 30 percent increase in the BOD of primary effluent, with almost no change in COD. This behavior also supports the hypothesis that a large fraction of organic material in septage is associated with suspended solids that can be readily removed in primary clarification. However, there is a relationship between primary effluent quality and the septage/sewage volumetric ratio which must be considered in design.

The addition of septage ahead of primary clarifiers not only helps to remove a substantial quantity of suspended solids present in septage, but also minimizes the additional organic load on secondary treatment units created by septage addition; however, it will increase the quantity of sludge produced in primary clarifiers. Estimated sludge production due to septage addition in primary clarifiers is given in Figure 6-4 assuming an average of 60 percent suspended solids removal and typical septage characteristics given in Table 3-4. Since septage sludges often contain anaerobic solids, its accumulation at the bottom of primary clarifiers may cause problems including resuspension of bottom sludge, short circuiting, and impaired settling in primary clarifiers. Primary sludge containing septage solids should be removed at a faster rate than with conventional domestic sewage. The excess sludge generated will create additional loading on sludge handling facilities.

Skimmers designed to remove grease in primary clarifiers treating sewage may not be able to handle the additional grease load caused by septage addition. Increased grease loads may result in spreading of the grease-scum layer over the entire surface of a clarifier and cause nuisance (odorous) conditions, clogging of inlet port of the scum tank, and removal difficulties due to the limited sweeping radius of the skimmer blade. Manual water hosing may be required to sweep the scum to an area suitable for removal with the wiper blade of the skimmer. High grease concentrations in primary effluent will affect the performance of secondary biological process units. Excess grease carried over to the mixed liquor of activated sludge aeration units decreases oxygen transfer, inhibits microbiological activity, and could be toxic to microorganisms. It may also inhibit settling in subsequent clarifiers and reduce final effluent quality.

FIGURE 6-4
ESTIMATED WASTE SLUDGE PRODUCTION IN PRIMARY CLARIFIER TREATING SEPTAGE AND SEWAGE



The following solutions are recommended to prevent problems arising from excessive grease:

1. Limit grease content of septage-sewage influent to primary clarifiers to 300 mg/L by controlling the rate of septage addition to sewage flow (proportional control). Although this would still impose higher oil and grease loads than that commonly found in sewage (see Table 3-8), it should be possible to accommodate the additional load by incorporating minor modifications in the oil and grease removal mechanism of the clarifier.

2. Modify skimming mechanisms as required to handle extra grease, and remove grease from scum tanks at shorter intervals. Increased width of scum tank with appropriate extension of wiper blade could enhance sweeping radius for better removal of grease. Increasing the speed of skimmer arm may also accomplish this. Although aimed at the primary clarifier, these improved scum control arrangmenets might be necessary for the secondary clarifier and chlorine contact units, as well.

Grease removed from septage pretreatment units or primary clarifiers can be landfilled or added to certain sludge treatment processes (e.g., anaerobic/aerobic digestion).

The following guidelines are to be considered in the design of primary clarifiers accepting septage:

1. Design primary clarifiers for handling septage on the basis of detention time or surface loading criteria used for domestic wastewater. Typical hydraulic loadings for primary settling range from 32 to 48 $m^3/m^2/d$ (800 to 1200 gpd/ft^2) for average flows. Detention times of 1.5 to 2.5 hours are normal (29).

2. Screen and degrit raw septage before addition to the primary clarifier. In STPs where grit removal is accomplished with primary clarification followed by degritting primary sludge, it may be feasible to add septage after just screening.

3. Mix septage with sewage prior to primary settling to achieve achieve satisfactory removals of suspended solids.

4. Ensure frequent removal of excess grease and scum due to septage addition. Modifications of skimmer mechanisms may be considered. The rate of septage addition should be controlled with relation of sewage flow to effect a maximum grease content of the grease in the primary clarifier of 300 mg/L.

5. The grease content of the primary sludge will be increased, with potential additional mixing problems for anaerobic digesters. Any treatment plant must consider this problem when contemplating acceptance of septage.

6.4.1.2 Impact on Suspended Growth Secondary Biological Processes

Although a considerable fraction of the organic matter in septage is removed with suspended solids in the primary clarifiers, the soluble BOD and remaining suspended organic matter exert a significant additional organic load on secondary biological process units.

If the form of secondary treatment is activated sludge, aeration capacity and mixed-liquor suspended solids are the two critical items to be considered for evaluating the impact of adding septage to the primary clarifier. Activated sludge plants require additional oxygen (i.e., additional aeration capacity) to accept the increased organic loading due to septage. The rate of septage addition, measured as a percentage of total sewage flow, will determine the additional organic load that is exerted on the activated sludge process after accounting for removals in primary clarification.

Recommended volumetric feed rates of septage on a constant, equalized loading basis have been developed by Rezek and Cooper (8), based on field investigations and earlier findings by Caroll (9), and are shown in Figure 6-5. The loading rates indicated here are higher (roughly by an order of magnitude) than those suggested by the earlier cited German guidelines (see Figure 6-3). This is most likely due to conservative assumptions on the part of the Germans regarding the degree of primary treatment and equalization provided in order to account for the worst case condition.

The amount of septage that can be added to a plant is a function of plant capacity and the ratio of present flow to design flow. Additional oxygen requirements as a function of the amount of septage added (with and without primary clarification) are given in Figure 6-6 (8). For septage added prior to primary clarification, the additional

FIGURE 6-5
ALLOWABLE RATES OF EQUALIZED SEPTAGE ADDITION (8)

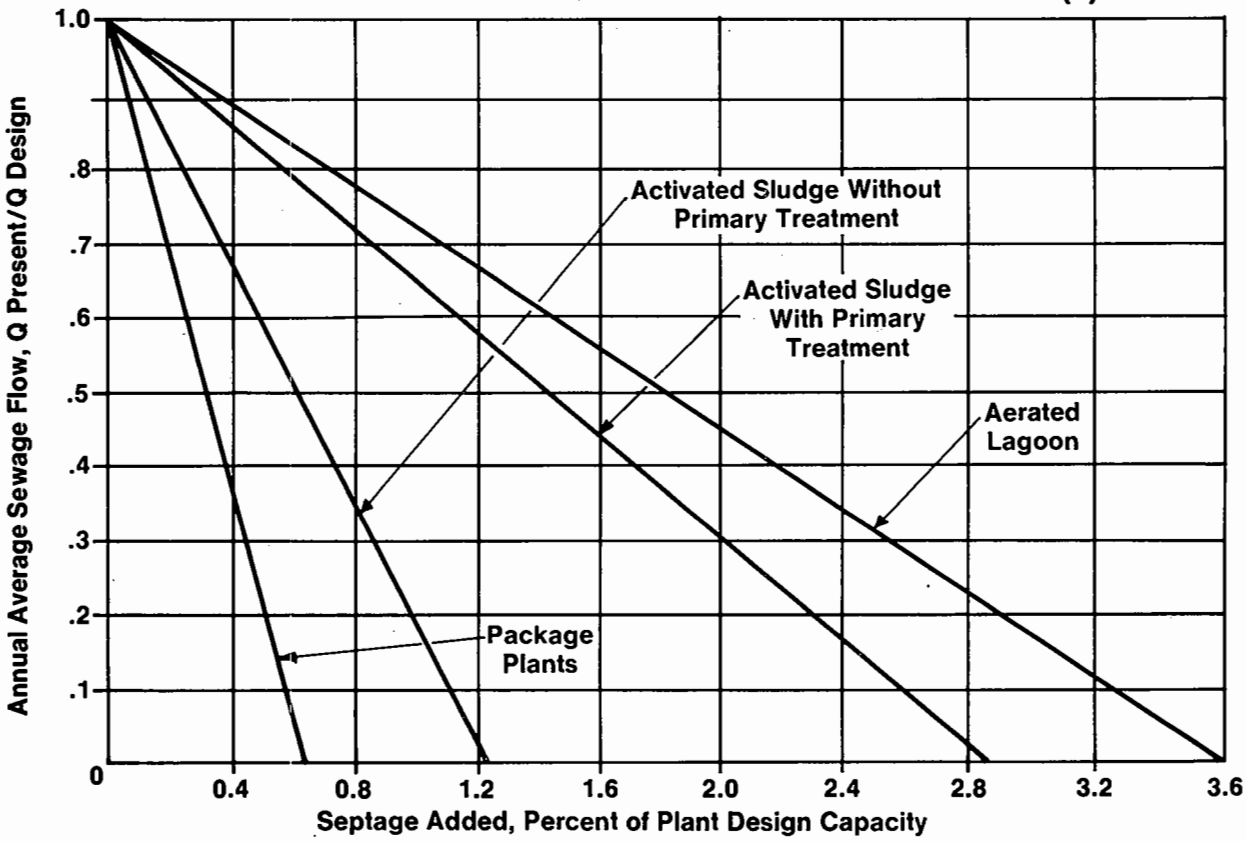
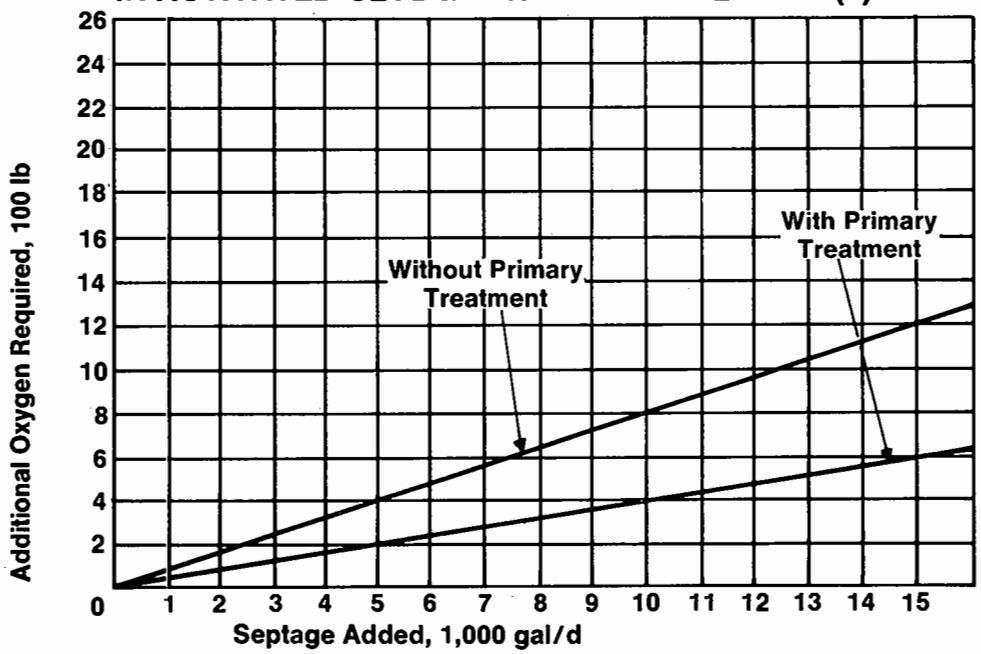


FIGURE 6-6
ADDITIONAL OXYGEN REQUIRED FOR SEPTAGE ADDITIONS IN ACTIVATED-SLUDGE TREATMENT PLANTS (9)



oxygen requirement is about 4.8 kg O_2/m^3 of septage added (40 lb O_2/1000 gal). Studies on a full-scale STP at Marlborough, Massachusetts indicate an average oxygen requirement of 0.7 kg O_2/kg of BOD in septage (1). This value is very close to that determined from Figure 6-6 for septage with a BOD of 7000 mg/L.

The organic loading rate to an activated sludge unit is also a very critical design consideration. Conventional activated sludge units have successfully operated with continuous septage additions (ahead of primary unit) of less than 5 percent of flow volume at loadings of 0.33 to 1.1 kg BOD_5/kg MLVSS/d and COD loadings of up to 3 kg COD/kg MLVSS/d. The full-scale STP at Marlborough, Massachusetts was operated at a loading of 0.42 kg BOD_5/kg MLVSS/d without septage addition which increased to 0.45 and 0.54 kg BOD_5/kg MLVSS/d for respective septage addition rates of 1.25 and 2.14 percent of sewage flow (1). In those studies, no significant deterioration in secondary effluent quality was found compared to that without septage addition (see Table 6-2). Secondary effluent suspended solids concentration increased to 18 mg/L with septage addition, but did not exceed discharge limitations.

A study conducted on a pilot-scale activated sludge unit at septage loadings of 2 to 13 percent of sewage flow determined that BOD and suspended solids concentrations of the secondary clarifier effluent ranged from 20 to 40 mg/L and 11 to 13 mg/L, respectively, and were not significantly different from that of the control unit receiving no septage. However, COD concentrations in the effluent increased with rise in influent COD (7).

Sludge production in secondary clarifiers following the activated sludge process is increased due to septage addition. The amount of sludge produced, depending on the percentage of septage added, is shown in Figure 6-7 (24).

6.4.1.3 Impact on Fixed Film Secondary Process Units

Fixed film or attached growth systems such as trickling filters and rotating biological contactors are commonly used for sewage treatment, particularly in small communities, and have been used to a relatively limited extent for combined septage-sewage treatment. In general, attached growth systems have been found to be more suitable for handling variations in hydraulic and organic loads than suspended growth systems. Some of the advantages of attached growth systems include economy in capital and operation costs, ability to recover from shock loads, and operation with minimal supervision.

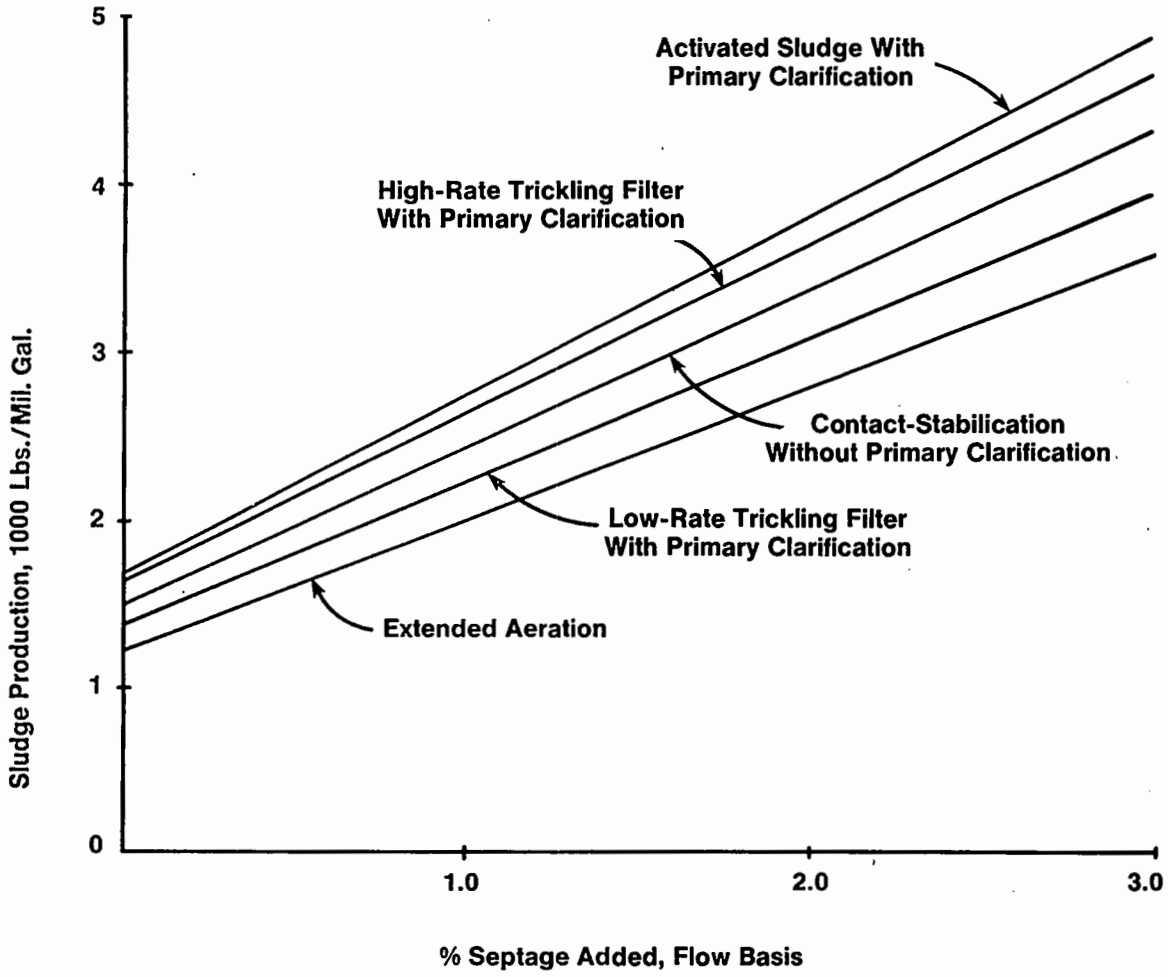
TABLE 6-2

CHARACTERISTICS OF INFLUENTS AND EFFLUENTS AT MARLBOROUGH, MASSACHUSETTS (1)

Characteristic	Sewage Only				Sewage + 1.25% Septage			Sewage + 2.14% Septage		
	Influent		Secondary Effluent		Influent*	Secondary Effluent		Influent*	Secondary Effluent	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	$\bar{X}$	S	$\bar{X}$	$\bar{X}$	S
COD - Total, mg/L	317	75	55	17	602	62	24	905	46	4.5
COD - Soluble, mg/L	90	24	37	12		52	18	---	33	15
BOD_5 - Total, mg/L	120	40	11	5.1	218	8.7	6.9	393	7.8	3.4
BOD_5 - N - Suppressed mg/L	87	37	4.1	3.0	183	2.6	0.6	289	1.9	0.4
Total Solids, mg/L	716	506	358	108	907	395	54	937	364	22
Total Volatile Solids mg/L	468	493	111	68	683	158	23	595	82	57
Suspended Solids, mg/L	221	376	10	4.6	455	18	4.4	577	10	0.6
Vol. Susp. Solids, mg/L	200	366	7.6	3.8	363	9	6	488	7.3	1.2
Total Kjeldahl-N, mg/L	20	6.5	17	4.1	35	18	0.5	66	---	---
Ammonia-N, mg/L	16	2.8	13	2.8	22	17	2.1	15	13	6
Nitrate-N, mg/L	1.0	0.3	3.2	1.0	---	4.4	0.5	---	2.7	0.7
Total Phosphorus, mg/L	5.6	2.1	1.0	0.5	11	0.8	0.1	9.7	0.9	0.6
Grease, mg/L	129	11	52	19	189	35.2		268	51.2	
Alkalinity, mg/L as $CaCO_3$	112	21	89	31	142	106	30	115	98	8
pH	6.8	0.3	6.8	0.3	6.9	7.1	0.2	6.7	6.7	0.2
Dissolved Oxygen, mg/L	3.3	1.0	4.4	1.6	---	2.1	1.4	---	3.0	1 2
Temperature	10	1.4	10	2.9	---	13	0	---	14	0.6
Metals, mg/L										
Cadmium	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0	0.03	
Chromium	0.04	0.09	0	0	0.02	0	0	0.02	0.50	
Copper	0.20	0.05	0.75	1.78	0.41	0.06	0	0.48	0.09	
Nickel	0.04	0.03	0.05	0.04	0.01	0.05	0.03	0	0.11	
Lead	0.07	0.06	0.14	0.06	0.08	0.08	0.11	0.22	0.07	
Zinc	0.27	0.09	0.72	1.43	0.35	0.12	0.11	0.59	0.21	

Note:
$\bar{X}$ = Mean
S = Standard Deviation
* = Calculated concentration from sewage and septage characteristics.

FIGURE 6-7
ESTIMATED WASTE SLUDGE PRODUCTION FROM BIOLOGICAL TREATMENT PROCESSES RECEIVING SEPTAGE (24)



a. Trickling Filters

Although trickling filters have been used for combined treatment of septage and sewage in some plants, performance and design data are limited. A 83.1-L/s (1.9-mgd) trickling filter plant at Huntington, Long Island (New York) treats 1.3 L/s (30,000 gpd) of septage with BOD reductions of 85 to 90 percent and suspended solids removals of 85 percent (8).

Treatment of septage-sewage mixtures in trickling filters should only be considered in plants where the trickling filter is preceded by primary treatment. This is because high concentrations of suspended solids (1 to 3 percent) could cause plugging of the filter media if septage were added directly to the trickling filter. Although a 55 to 75 percent removal of suspended solids can be obtained (1), the suspended solids concentration in the primary effluent is a critical factor to be considered when applying septage-sewage mixtures to a filter process.

The design of trickling filters is based on hydraulic and organic loading. Trickling filters can be designed as 1) low-rate systems with organic loading varying between 0.08 and 0.32 kg BOD/m^3-d (5 to 20 lb BOD/1000 ft^3/d) or 2) as high-rate systems with organic loadings ranging from 0.32 to 0.96 kg BOD/m^3-d (20 to 60 lb BOD/1,000 ft^3/d). In the case of septage-sewage treatment, organic content of primary effluent may be too high, even for a high-rate trickling filter. It may be possible to operate at a lower hydraulic loading in order to maintain the desired organic load on the trickling filter. However, this would increase the problem of filter flies associated with low-rate trickling filters. There are empirical models available for design of trickling filters on the basis of organic loading and other parameters (2). These have been designed for sewage treatment applications, and modifications required for septage-sewage combined treatment are not available. However, with due consideration to the increased strength of trickling filter influent, these models can be used in designing co-treatment systems.

Sludge production will increase in secondary clarification due to septage addition. The rate of sludge production is a function of septage-sewage flow characteristics, hydraulic and organic loading, type of filter media, and temperature. For example, for a septage input of 1 percent of sewage flow, a low-rate trickling filter would produce about 0.24 kg sludge/m^3 (2,000 lb/million gallons) of flow, which would increase to 0.3 kg sludge/m^3 (2,500 lb/million gallons) for high-rate trickling filters. Figure 6-6 gives the estimated production of sludge from treatment of septage-sewage mixtures by trickling filters (24).

b. Rotating Biological Contactors

Rotating biological contactors (RBC's) feature a microbial biomass attached to rotating discs that aerobically break down organic matter in wastewater flowing over the disc surface. Although RBC systems have been used for sewage treatment, very few examples of combined treatment of septage and sewage have been reported. Combined treatment of septage and sewage at the Ellsworth, Maine RBC treatment plant was not very successful (25). Addition of less than 1 percent septage to a sewage flow of 2460 m^3/d (0.65 mgd) caused several problems. Roto strainers used for primary treatment were consistently clogged, and concentrations of BOD and TSS in the final effluent after RBC treatment were high. This, however, could be in part due to the poor performance of the preliminary treatment unit.

RBC plants should be capable of adequately co-treating septage and sewage provided accepted design guidelines are followed. Organic loading rate is a particularly important factor. In studies at 24 facilities with mechanical drive units, first stage organic loadings above 6 lb total $BOD_5/d/1{,}000\ ft^2$ or 2.5 lb soluble $BOD_5/d/1{,}000\ ft^2$ resulted in an increased frequency of process and mechanical problems (34). These problems included excessive biofilm thickness, nuisance organism growths, and deterioration of process removal efficiency.

Soluble BOD loading is a critical parameter in the design of RBC units and should be verified by influent sampling whenever possible. Organic loading considerations during design must include contributions from in-plant sidestreams, septage dumps, etc.

It is recommended that septage addition to RBC plants be limited to those incorporating primary clarification, unless the sustained loading of pretreated septage combined with incoming sewage is less than the loading rates suggested above. Temporary high organic loadings during septage loading may be accommodated to some degree with supplemental aeration of the first stage. Flow equalization should be incorporated if possible to mitigate the highly fluctuating organic loadings which may result from random septage dumping.

Control of excessive biological growth and nuisance growths may also require special attention when septage is added to RBC plants. High influent H_2S concentrations can impede RBC performance and accelerate nuisance growths (27).

Other more specific guidance pertaining to the design of RBC systems can be found in recent EPA publications (27) (34).

6.4.1.4 Impact on Sludge Handling and Treatment Systems

Addition of septage to primary clarifiers in STP's results in an increased quantity of primary sludge. Typical additional sludge production will be approximately 7.8 kg/m^3 of septage (60 lb/1000 gal). Removal of a large proportion of suspended solids in septage in primary clarifiers substantially reduces solids and organic loading on secondary treatment units of the liquid stream. However, this form of septage treatment could create problems in sludge handling and treatment. The concentration of organic matter increases considerably in primary sludge due to septage addition. This increase would have to be considered in determining the organic loading to sludge digestion units. It may be necessary to adjust the flow of sludge to the digesters to maintain the desired organic loading.

6.4.2 Septage Addition to Suspended Growth Secondary Process Units

Extended aeration plants do not normally have primary clarification, so that septage is introduced directly into the aeration basin. In such cases, septage may be mixed with the sludge recycle stream entering the aeration basin to ensure a well-mixed influent. Septage pretreatment in the form of screening and degritting is required prior to septage addition to secondary biological treatment processes.

The following factors are to be considered for septage addition to activated sludge units:

1. Available aeration capacity.
2. Available hydraulic loading capacity.
3. Excess sludge handling capacity available.
4. Method of septage addition.
5. Septage pretreatment facilities.

The performance of an activated sludge plant is significantly influenced by the method of septage addition, i.e., slug or continuous. Slug loading to an activated sludge unit should be limited so as not to increase the MLSS concentration by more than 10 to 15 percent per day in order to maintain a stable sludge quality. Studies also indicate that loss of the system's biomass may result if the change in MLSS exceeds this range (9). Maintaining loadings below this recommended limit did not cause upsets at the Weaverville wastewater treatment plant in Trinity County, California (6). Loadings for septage addition to activated sludge plants with no equalization facilities have been developed and are shown in Figure 6-8 (8) (9).

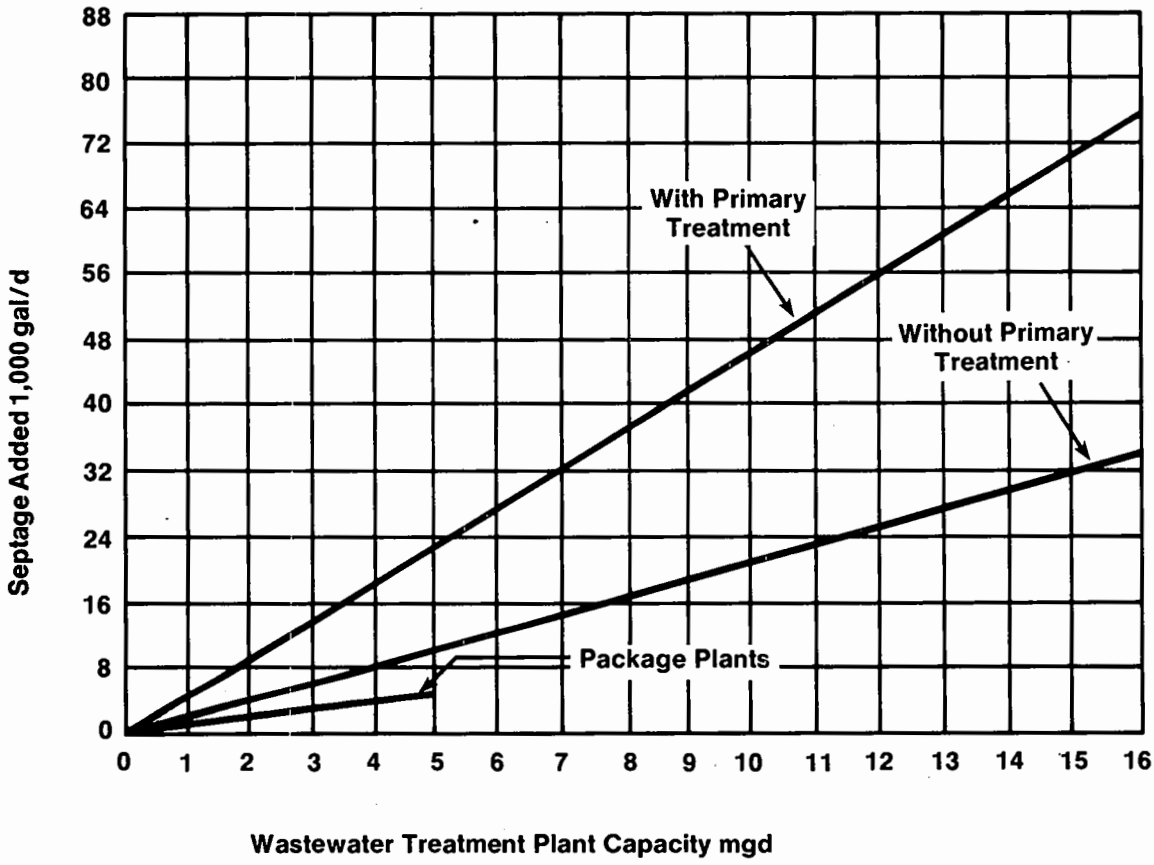
The loadings given in Figure 6-5 are for a fully-acclimated biomass in the aeration basin. When initiating septage feed to an unacclimated biomass, about 10 percent lower loadings should be used. Septage flows can be increased rather quickly thereafter until the recommended loading is accomplished because of the rapid increase in dissolved oxygen uptake normally experienced when domestic septage addition is initiated (22). Dissolved oxygen should be checked frequently, and gradual changes made in sludge age for optimum performance (8).

Additional oxygen requirements for activated sludge plants are higher when septage is added directly to aeration basins without primary clarification. From Figure 6-6, it can be seen that about 9.6 kg O_2/m^3 (80 lb O_2/1,000 gal) septage are required when septage is added directly to an activated sludge aeration system, which is approximately twice that required if septage addition is made to a primary clarifier. The higher oxygen requirement is for metabolizing the high concentration of organic matter in the suspended solids. A large fraction of the suspended solids are removed when septage undergoes primary clarification; hence the oxygen requirement in the aeration basin is lower.

Extended aeration systems can also accept septage for co-treatment; however, this means adding the septage directly to the aeration basin without primary clarification. The design of extended aeration systems is based primarily on a low ratio of BOD to MLSS (F/M) in the aeration basin. The microorganisms undergo partial auto-oxidation, which results in lower sludge production than in conventional activated sludge processes.

In extended aeration systems, oxygen requirements are higher than for conventional activated sludge processes. This is because nitrification usually occurs in extended aeration processes, which requires additional oxygen over that required for removal of carbonaceous BOD. Bowker

FIGURE 6-8
ACCEPTABLE SEPTAGE FLOWS AS FUNCTION OF PLANT CAPACITY (WITHOUT EQUALIZATION FACILITIES) (8) (9)



(11) estimated that septage addition of 3 percent by volume of influent wastewater increased TKN and NH_3-N concentrations by 48 percent and 2 percent, respectively. Actual NH_3-N concentrations are higher due to both hydrolysis of organic nitrogen and release of NH_3-N during auto-oxidation of cellular material. At the full-scale extended aeration plant in Medfield, Massachusetts, treating septage and sewage, oxygen utilization was approximately 0.59 to 0.74 kg O_2/kg BOD (1). Estimated oxygen requirements for extended aeration plants receiving septage are given in Figure 6-9 for combined treatment of septage and sewage.

The food-to-microorganism ratio of extended aeration plants is much lower than for conventional activated sludge plants. Addition of septage increased F/M ratios in STP's. Studies conducted at Medfield show that up to 3.6 percent addition of septage was possible without any deterioration of effluent quality when the F/M was maintained between 0.033 and 0.055 (1). The STP was operating at about 20 percent of hydraulic design capacity. The results of studies at Medfield are given in Table 6-3.

Mean cell residence time (θ_c) for extended aeration plants treating sewage range between 20 to 30 days (2). The STP at Medfield, treating septage at rates of 2 and 3.6 percent of sewage flow, was successfully operated at mean cell resident times of 36 and 59 days, respectively (1). The recirculation ratio of sludge return was about 1.7.

Volumetric loadings at Medfield STP for septage-sewage treatment were 0.16 to 0.24 kg BOD/m^3-d (10 to 15 lb BOD/1000 ft^3/d), which is similar to that provided in extended aeration type sewage treatment plants (0.16 to 0.4 kg BOD/m^3-d [10 to 25 lb BOD/1000 ft^3/d]).

The characteristics of secondary effluent from the extended aeration plant at Medfield are given in Table 6-3. An analysis of the variance of secondary effluent quality indicates that total and soluble COD appear to increase with septage addition. BOD, total solids, suspended solids, and volatile suspended solids are relatively unaffected.

Based on the various studies reviewed, extended aeration appears to be a feasible process for combined treatment of septage and sewage. However, more information based on full-scale plant operation is required to establish criteria for design of extended aeration co-treatment systems.

FIGURE 6-9
ESTIMATED OXYGEN REQUIREMENTS FOR BIOLOGICAL TREATMENT PROCESSES RECEIVING SEPTAGE (24)

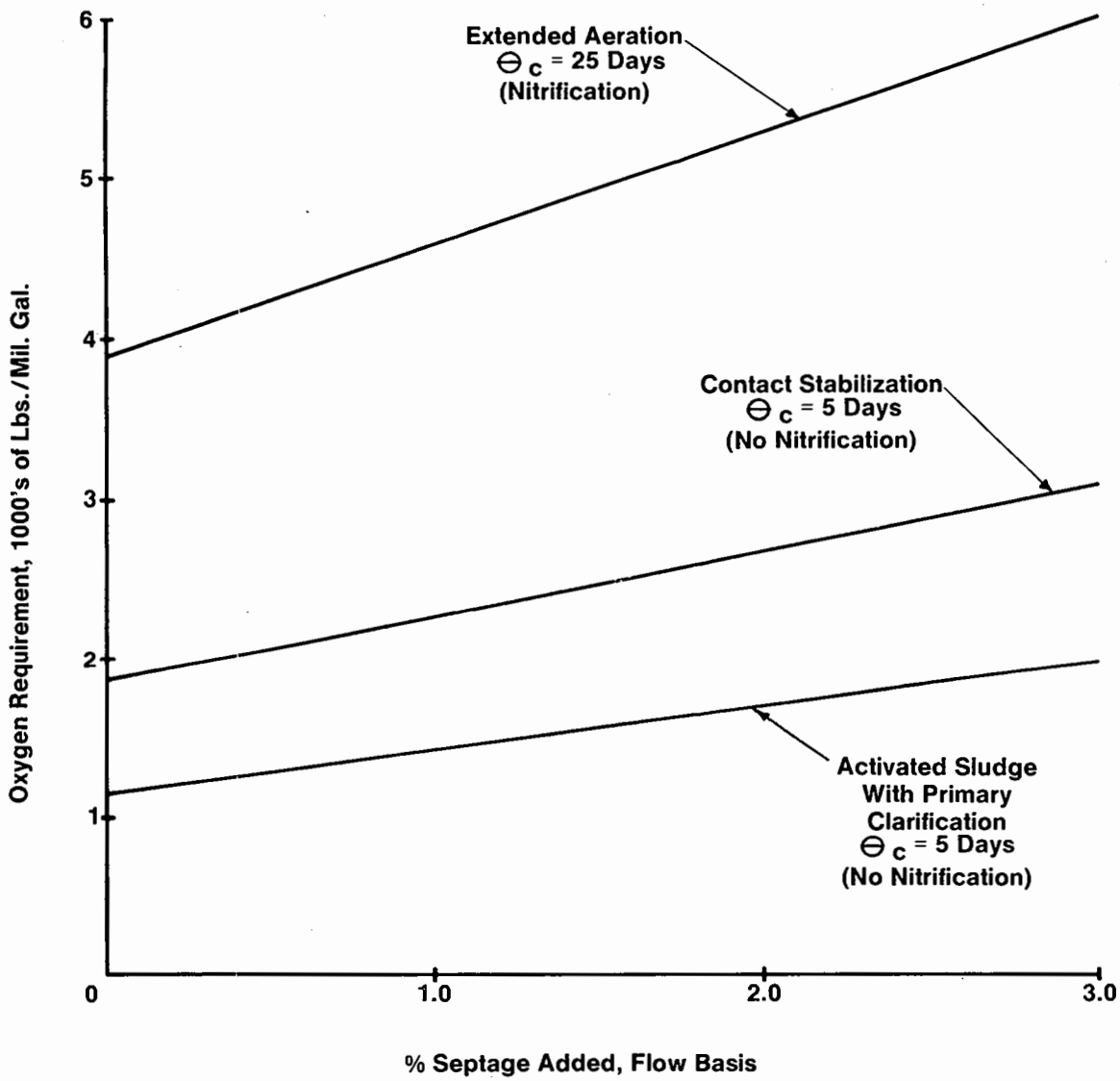


TABLE 6-3

CHARACTERISTICS OF INFLUENTS AND EFFLUENTS AT MEDFIELD, MASSACHUSETTS (1)

Characteristic	Sewage Only			Sewage + 1.25% Septage			Sewage + 2.14% Septage		
	Influent		Secondary Effluent	Influent*	Secondary Effluent		Influent*	Secondary Effluent	
	$\bar{X}$	S	$\bar{X}$	$\bar{X}$	$\bar{X}$	S	$\bar{X}$	$\bar{X}$	S
COD - Total, mg/L	276	78	19.5	558	27	11	887	31	5.0
COD - Soluble, mg/L	87	23	17	150	20	7.3	142	26	7.4
BOD_5 - Total, mg/L	141	22	4	238	3.7	2.7	246	2.5	1.0
BOD_5 - N - Suppressed mg/L	93	24	1	180	1.0	0.9	140	1.4	0.8
TOC, mg/L	75	10	13	---	6.3	4.2	---	---	---
Total Solids, mg/L	446	64	336	558	326	45	855	316	68
Total Volatile Solids mg/L	185	43	78	265	68	22	538	115	42
Suspended Solids, mg/L	108	56	4	201	3.2	2.7	505	1.4	1.4
Vol. Susp. Solids, mg/L	85	48	3	150	2.0	1.9	388	2.1	1.4
Ammonia-N, mg/L	13	1.7	0.2	16	2.7	2.0	18	0.4	0.2
Nitrate-N, mg/L	0	0	7.2	0	4.1	3.5	---	12.8	1.8
Total Phosphorus, mg/L	10.6	3.7	0.7	13	1.4	0.7	---	---	---
Grease, mg/L	74	72	4.5	144	3.9	0.6	---	---	---
pH	7.1	0.2	7.3	7.0	7.1	0.3	7.3	7.4	0.3
Temperature, °C	18	1.0	19	17	18	1.3	15	14.1	0.9
Heavy Metals, mg/L									
Cadmium	0.04	0.02	0.03	0.02	0.02	0.01	0.05	0.01	0.01
Chromium	0.20	0.28	0.15	0.13	0.13	0.04	0.08	0.05	0.04
Copper	0.13	0.03	0.06	0.30	0.14	0.09	0.16	0.03	0.01
Nickel	0.10	0.04	0.10	0.18	0.11	0.01	0.05	0.01	0.01
Lead	0.59	0.10	0.15	0.21	0.03	0.05	0.30	0.08	0.02
Zinc	0.37	0.28	0.22	1.71	0.70	1.40	0.41	0.41	0.46

Note:
$\bar{X}$ = Mean
S = Standard Deviation
* = Calculated concentration from sewage and septage characteristics.

Aeration basins are an essential part of any suspended growth systems used for treatment of septage and sewage. Foaming problems commonly occur in such aeration basins. For control of foaming, several methods have been explored at various treatment plants, with some degree of success. The most common are the use of commercial defoamers and aeration tank spray water systems. Increased aeration tank freeboard has also been considered as a means of containing the foam within the aeration basin.

6.5 Co-Treatment of Septage in the Solids Stream

Addition of septage to the sludge stream, as opposed to the liquid stream, will have less impact on forward flow treatment processes. This is true since only the return flows, such as digester supernatants, thickener overflows, and dewatering filtrates, are recirculated through the major liquid treatment processes. In contrast, during liquid stream addition of septage, both the direct septage input and return-flow impacts may be significant.

Septage could be added to the sludge stream in an STP at several points. It is generally recommended that septage be chemically conditioned or biologically stabilized (aerobic or anaerobic digestion) prior to dewatering and ultimate disposal. However, in cases where sludge is to be buried or disposed of at a landfill, it may be more feasible to add septage directly to the thickening or dewatering processes.

6.5.1 Addition to Stabilization Processes

6.5.1.1 Addition to Anaerobic Digestion

Stabilization of sewage sludge is commonly accomplished in anaerobic digesters in STP's. Septage added to sewage sludge could also be treated by anaerobic digestion for stabilization. In addition to stabilization through reduction of volatile solids in sludge, anaerobic digestion produces methane gas, which is used as a supplemental source of energy for heating, mixing, and generation of electricity in STP's.

Few studies have been conducted by researchers on the anaerobic digestion of septage and septage-sewage sludge mixtures. The long detention time (1 to 2 years) in septic tanks before septage is collected for disposal allows anaerobic decomposition of septage to take place. Since

very little control is available in septic tank operation, organic matter in septage is only partially stabilized by anaerobic decomposition. The anaerobic characteristic of septage makes it an ideal candidate for anaerobic digestion. Section 7.2.2 discusses the separate treatment of septage by anaerobic digestion.

Small-scale studies on anaerobic digestion of septage-sewage sludge mixtures have recommended a limit of about 15 percent septage, loadings of 1.28 kg VSS/m^3-d (0.08 lb VSS/ft^3/d), and a detention time of 30 days (15). The design of septage-sewage sludge anaerobic digestion units can be based on design criteria used for sewage sludge; however, the quantity of septage to be added should be determined on the basis of total organic loading of the combined septage-sewage sludge mixture. Recommended total loading is normally between 0.5 and 1.6 kg VSS/m^3-d (0.03 to 0.1 lb VSS/ft^3/d).

The operation of anaerobic digesters should be monitored for pH, volatile solids reduction, volatile acid concentration, alkalinity, and gas production. Lowering of pH could result due to buildup of volatile acids, which would severely affect performance of digesters. Overloading of digesters by increased organic loading is one of the reasons for enhanced volatile acids production and should be avoided. It is recommended that septage be screened, degritted, and equalized before it is added to anaerobic digesters. In the case of multiple digesters operating in parallel, equal distribution of septage among the digesters is recommended. Recycling digested sludge up to 50 percent of raw feed per day has been found helpful (8). Mixing of digester contents is important for maintaining homogeneous conditions in the digester and to prevent settling of digester contents. This is especially important with septage-sewage sludge mixtures.

6.5.1.2 Addition to Aerobic Digestion

Aerobic digestion can also be used to treat septage. Septage can be introduced to the aerobic digesters along with primary and secondary sludges. Aerobic digestion of septage and septage-sewage sludge mixtures has been found to be feasible based on experiences at pilot- and full-scale treatment plants (see Chapter 7).

Aerobic digestion of septage-sewage sludge mixtures has been successfully applied in several cases. Septage addition to sewage sludge at rates up to 20 percent has resulted in average BOD removal as high as 98 percent, with 6 days of hydraulic retention time (HRT) (16). In Orange County, Florida, good BOD and VSS reductions were reported in aerobic digesters treating septage-sewage mixtures (5 percent septage)

at an organic loading of 2.4 kg VSS/m^3-d (0.15 lb VSS/ft^3/d) (16). At Bend, Oregon, 13 percent septage addition to aerobic digesters provided good reductions at a loading of 0.3 kg VSS/m^3-d (0.02 lb VSS/ft^3/d) at a 15- to 18-day HRT (18). In addition to good BOD and VSS reductions achieved with aerobic digestion, improved dewatering and settleability characteristics were reported by Jewell (17).

Foaming and odor problems are common with aerobic digestion of septage-sewage sludge mixtures (5)(14)(15)(16)(17). Foaming is dependent on the amount of detergents present in septage; however, most investigators report that foaming is usually diminished after about 24 hours (8). Methods to minimize foaming problems in aerobic digestion are similar to those applied to activated sludge systems.

Based on studies at pilot- and full-scale facilities, it is clear that aerobic digestion is feasible for septage treatment in STP's. Screening, degritting, and equalization of septage is recommended before addition to aerobic digesters. As a design guideline, organic loading of 8 to 16 kg VSS/m^3-d (0.05 to 0.1 lb VSS/ft^3/d) are recommended. VSS and BOD removals of 35 to 40 percent and 70 to 80 percent may be expected.

6.5.2 Addition to Thickening/Dewatering Processes

6.5.2.1 Addition to Thickeners

Thickening is a process often used to reduce the volume of sludge prior to digestion and/or dewatering operations. Reduction in volume decreases capital and operating costs of subsequent sludge processing systems. Field experience has indicated that thickening also improves the dewatering characteristics of sludge. Common methods of thickening used for treatment of sewage sludge are gravity thickening and dissolved air flotation. In some cases, chemicals are added to condition the sludge prior to thickening.

The impact of septage addition to thickening units is dependent on the type of process used for thickening. Due to poor solids-liquid separation characteristics of septage, addition to gravity thickeners would not thicken the septage much further and could create severe odor problems due to septic conditions. It is recommended that septage be added directly to sludge digestion units in plants that use gravity thickening. If dissolved air flotation units are used for thickening, septage could be added to the unit along with plant generated sludges. Septage could be thickened in this process unit and then the thickened

septage-sewage sludge mixtures added to sludge digesters or other sludge stabilization systems. Since large quantities of air would be added in the dissolved air flotation process, severe odor problems are not expected. Unfortunately, there are no field-scale data on the addition of septage to thickeners, primarily because septage is generally thickened separately from the STP sludges.

6.5.2.2 Addition to Dewatering Systems

Dewatering of sewage sludge can be accomplished using several methods, including sand drying beds, filtration (e.g., belt and vacuum filters), centrifugation, and presses. Capillary suction time (CST) is a parameter commonly used to determine dewatering characteristics of sludge for process control purposes.

Septage has poor dewatering properties compared to sewage treatment plant sludges. The CST of raw (~4 percent TS) septage has been shown to vary from 120 to 825 seconds (19). Studies conducted on dewatering characteristics of septage conclude that septage needs to be chemically and/or biologically conditioned prior to dewatering in order to achieve satisfactory performance levels. This means that direct addition of septage to conventionally used dewatering systems is not recommended.

The recommended method of adding septage to the dewatering facilities of the receiving STP is to first pretreat the septage to make the entire septage mass or (when solids separation is employed) the septage solids amenable to dewatering either with the STP sludge or separately (22). Although most septage dewatering studies have dealt with separate dewatering (see Subsections 7.9 and 7.10), some work has been carried out with mixed septage solids and sludges (20) (22) (23) (33).

Crowe (20) successfully dewatered mixtures of raw septage and digested sludge (up to 20 percent septage by volume) with a laboratory vacuum filter apparatus. The dewatering characteristics of these chemically treated mixtures were similar to those of the chemically treated digested sludge. Pilot vacuum filter studies of 90 percent (aerobically digested sludge) and 10 percent (acid/lime treated septage solids) by volume showed that marginal yields and marginal cake release characteristics could not be significantly enhanced by a wide variety of chemical additions prior to vacuum filtration (23). Similar studies with the same volumetric ratio using screened raw septage instead of conditioned septage solids yielded almost identical results. Ott and Segall found that conditioned septage solids and thickened waste activated sludge dewatered better by full-scale coil vacuum filtration than did the latter by itself (22). These mixtures were made up of up

to 50 percent by weight of conditioned septage solids. Ott and Segall also found that chemical usage could be reduced by up to 50 percent by first conditioning the septage and mixing with the thickened activated sludge before final chemical dosing prior to the vacuum filter, as opposed to conditioning the entire mass without preconditioning the septage.

Condren (23) also investigated the dewaterability of 90/10 volumetric mixtures of aerobically digested sludge and acid/lime-conditioned septage solids by solid bowl centrifugation and filter pressing at pilot scale. The centrifuge gave poor results with and without polymer addition ahead of the unit, while the filter press yielded an excellent cake (46 percent solids), filtrate (6 mg/L SS), and suspended solids capture (>99.99 percent).

In Norway, full-scale experience has generally been with mixtures of screened and degritted septage and primary alum sludges (33). Solid-bowl centrifuge dewatering of these mixtures are reported to yield cakes of 20 to 25 percent solids and centrate suspended solids of <2,000 mg/L with 2 to 4 g of polymer per kg of mixture SS. Eikum (33) indicates that higher septage/sludge ratios increase cake solids content without increasing centrate SS, but the BOD content of centrate does increase. He also indicates that belt filters give similar results to the centrifuges when testing these mixtures.

Based on full-scale as well as laboratory and pilot-plant data, the following recommendations are given for the design of dewatering systems receiving septage and treatment plant sludges:

1. Screen and degrit septage prior to its addition to dewatering systems. Degritting may not be warranted if sand drying beds are being used for dewatering.

2. For mechanical types of dewatering systems, chemically condition septage before mixing with digested primary or secondary sewage sludge.

3. An application rate of about 25 kg/m^2-hr (5 $lb/ft^2/hr$) should be used for vacuum filtration of chemically conditioned septage-sludge mixtures.

6.5.3 Impact on Ultimate Sludge Disposal Practices

The method of ultimate disposal of the treated septage/sludge mixture is influenced to a certain extent by the method of septage treatment. If septage is added to the liquid stream, significant impact on the current ultimate disposal method is not expected since septage undergoes secondary biological treatment along with sewage, and characteristics of the wasted sludge should not be greatly affected. However, additional sludge will be generated.

If septage is added to the solid stream, it is recommended that septage be added prior to digestion (i.e., stabilization). The septage, after undergoing biological stabilization, can be disposed of along with treated sewage sludge. Addition of septage to the dewatering process would have to be evaluated for its suitability for ultimate disposal unless lime stabilization is used. If the high organic matter in septage is not stabilized, ultimate disposal on land might be restricted. However, composting or incineration could be alternative methods for ultimate disposal of the dewatered septage-sewage sludge mixture where dewatering without stabilization is provided.

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CHAPTER 7

INDEPENDENT TREATMENT OF SEPTAGE

7.1 Introduction

This chapter presents information on the treatment of septage at a facility dedicated exclusively to that purpose. Many of the independent septage facilities in the U.S. are lagoons, which are often favored, particularly in rural areas, due to their low capital and operating costs. However, there are examples of mechanical septage treatment facilities that have been applied in more developed areas. In such areas, the premium on land discourages the use of land-intensive methods, and the higher density and larger numbers of septic systems create certain economies of scale that make the more capital-intensive mechanical treatment systems cost-effective.

This chapter describes the following processes typically used for septage treatment:

1. Lagoons.
2. Composting.
3. Biological secondary treatment processes.
4. Aerobic digestion.
5. Anaerobic digestion.
6. Lime stabilization.
7. Chlorine oxidation.

Other supplemental treatment processes are also addressed. These include:

1. Conditioning.
2. Dewatering.
3. Disinfection.
4. Odor control.
5. Ultimate disposal.

Finally, the relatively new concept of mobile dewatering, as currently practiced in Scandinavia (1) is briefly discussed.

Figure 7-1 depicts the various process alternatives for independent septage treatment. Raw septage can be delivered to a receiving/pretreatment facility or directly to a lagoon. The pretreatment step can also include flow equalization and/or thickening. The pretreated sludge then typically undergoes some form of stabilization - partial or complete - and is then conditioned and dewatered.

Septage is stabilized in order to eliminate odors, reduce pathogens, and reduce the potential for putrefaction. Stabilization is a relative term that refers to the degree of decomposition that limits further biological activity and renders the product satisfactory for further handling or utilization. In general, there are four ways to stabilize septage:

1. Biological reduction of volatile content.

2. Chemical oxidation of volatile matter.

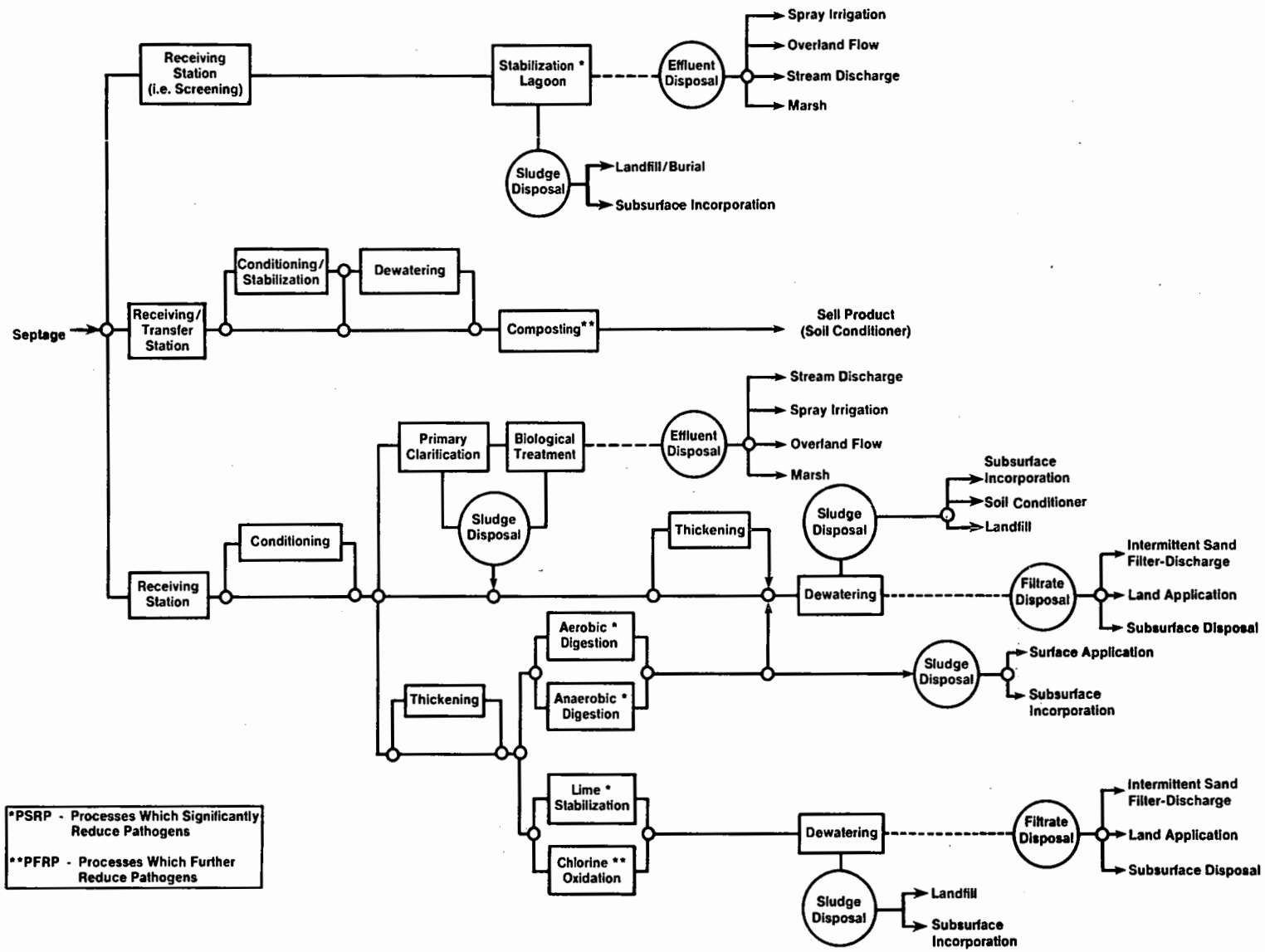
3. Sterilization by heat.

4. Chemical addition to render the septage unsuitable for microorganism survival.

The liquid stream can be disposed of by direct discharge after treatment or by discharge to groundwater via percolation, etc. Although an acceptable land application site and sufficient accessible STP capacity were previously assumed not to exist, Figure 7-1 shows these options of disposal. This is to accomplish a complete array of options for illustrative purposes, recognizing that if these limitations exist prior to choosing independent treatment, it would be a rare occurrence that independent septage processing would then allow their use for liquid fraction processing. Similarly, the solids residuals can be disposed of with sludge to land, composted, or incinerated.

If composting is chosen as the stabilization method, the septage is usually dewatered first, although composting of liquid septage has been successfully practiced. The stabilized compost can be used for gardening and soil conditioning and, in some cases, sold as a fertilizer product. It is also possible to go directly from pretreatment to conditioning and dewatering, especially if the solids are to be incinerated.

FIGURE 7-1
TECHNICAL OPTIONS FOR INDEPENDENT TREATMENT OF SEPTAGE



7.2 Lagoons

Lagoons are widely used for the treatment and disposal of septage, most notably in the northeast region of the U.S. (2). Properly designed and sited lagoons are easy to operate, and they perform consistently. They can be operated year-round and are relatively easy and inexpensive to build and operate.

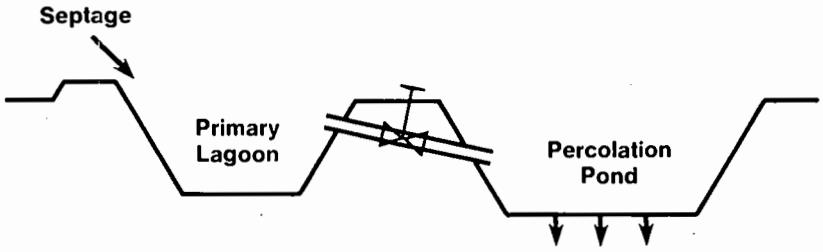
The simplest septage lagoon systems consist of two earthen basins arranged in series. The first, or primary, lagoon receives raw septage. It may be lined or unlined, depending on the geological conditions of the site. The supernatant from the primary lagoon, which has undergone some clarification and possibly anaerobic digestion, is drawn off into the second lagoon, or percolating pond, where it is allowed to infiltrate into the ground (2). It is also possible to have multi-celled lagoon systems with either surface discharge or land application of effluent. One option involves subsurface disposal of limed lagoon sludge and use of liquid decant as soil top dressing for sod farming (33).

7.2.1 Process Considerations

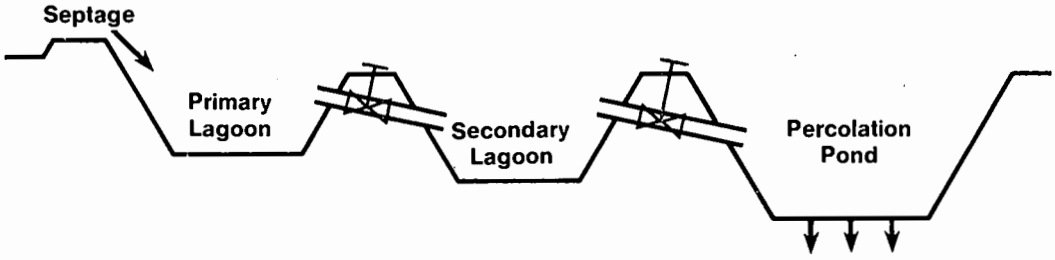
Figure 7-2 shows a number of variations of septage lagoon systems. A septage receiving facility should be employed at the site to help eliminate the odors associated with septage. Typically, this would consist of a concrete chamber with a tight-fitting hatch or manhole designed to allow the septage to be discharged below the liquid level of the primary lagoon. For further design considerations concerning receiving facilities, refer to Chapter 4.

Where groundwater separation distances or geological conditions are unfavorable, septage lagoons should be lined to avoid infiltration. The liner should be impermeable to liquids, durable, and able to withstand heavy equipment used for cleaning and removal of accumulated solids. Concrete, asphalt, or clay liners are recommended over membranous rubber or plastic liners due to the limited ability of the rubber and plastic to withstand the stresses of heavy equipment and their susceptibility to laceration, abrasion, or puncture from sharp objects such as stones, tree branches, or roots. Lagoons are normally built above grade with earthen embankments to minimize construction costs.

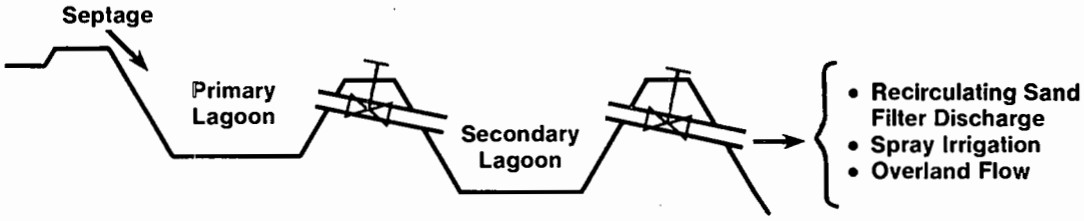
FIGURE 7-2
SEPTAGE LAGOON VARIATIONS



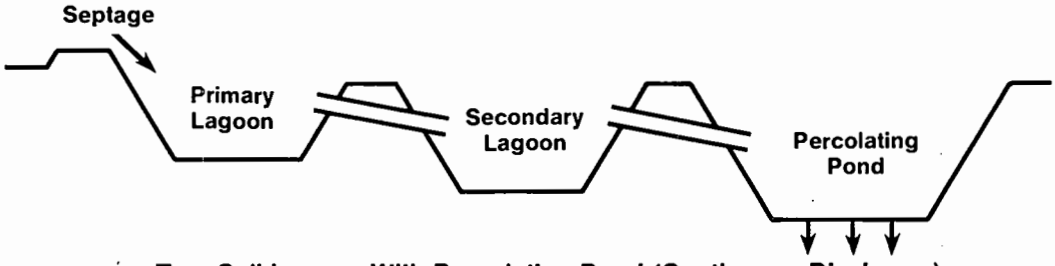
One Cell Lagoon With Percolation Pond (Controlled Discharge)



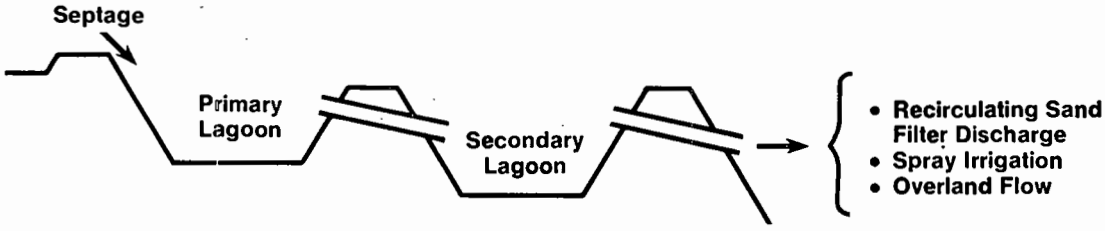
Two Cell Lagoon With Percolation Pond (Controlled Discharge)



Two Cell Lagoon With Surface Discharge or Land Application (Controlled Discharge)



Two Cell Lagoon With Percolation Pond (Continuous Discharge)



Two Cell Lagoon With Surface Discharge or Land Application (Continuous Discharge)

Septage lagoons can be operated with a continuous discharge (i.e., through an overflow outlet structure) or with a controlled discharge using a gate or valve to regulate periodic discharges of effluent. When actual septage flows are less than design flow, controlling discharges (i.e., minimizing number and frequency of discharges) will increase detention time and should improve treatment efficiency. Continuous discharging systems, on the other hand, require less manual adjustment. The appropriateness of controlled discharge versus continuous discharge may depend on the type of effluent disposal method used. Spray irrigation and overland flow, for example, would be more suitable with controlled discharge, whereas discharges to percolation ponds or sand filters should be continuous in order to minimize the effective loading rate.

A percolating pond can be used to receive the supernatant from lagoons which, in turn, is allowed to infiltrate into the ground, undergoing further treatment before entering the groundwater table. The outlet from the lagoon should be designed to prevent flotable materials, grease, and algae from overflowing into the percolating pond. This can be done by submerging the outlet pipe or by using a baffle structure. The pH in a septage lagoon must be maintained at 8.0 or greater to control odors. This is usually accomplished by adding lime to the septage before it is discharged to the lagoon (i.e., add bag of lime to septage in hauler truck) or as it is discharged (i.e., add lime to receiving chamber).

A major operating consideration with this septage disposal method is the accumulation of suspended solids. Solids will eventually accumulate to the point where the lagoon no longer acts as a clarifier. If solids accumulate in the percolating pond the infiltrative surface may become clogged and no longer accept effluent. For this reason, it is recommended that two parallel systems be constructed to allow for draining, solids drying, solids removal, and resting in alternate lagoons as illustrated in Figures 7-3 and 7-4.

Performance data for septage lagoons are limited. Average influent and effluent concentrations for the Acton septage lagoon facility are presented in Table 7-1(3). Although these data indicate high removal percentages for all parameters measured, the effluent concentrations are comparable to high strength raw domestic sewage. This indicates that secondary lagoons should be used to polish the effluent before disposal. Certainly, surface water discharge of lagoon effluent should not be contemplated without sand filtration or overland flow.

FIGURE 7-3
ALTERNATING LAGOONS IN BATCH TREATMENT
(CONTROLLED DISCHARGE) MODE

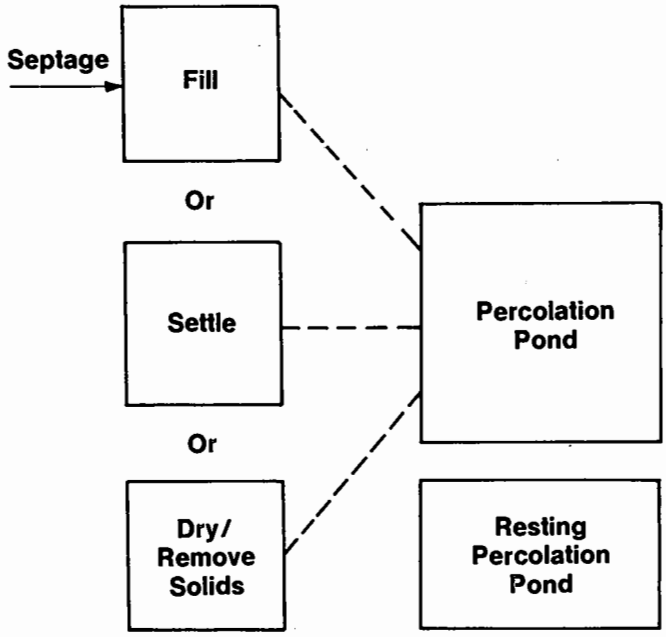


FIGURE 7-4
PARALLEL OPERATION OF CONTINUOUS DISCHARGING LAGOONS

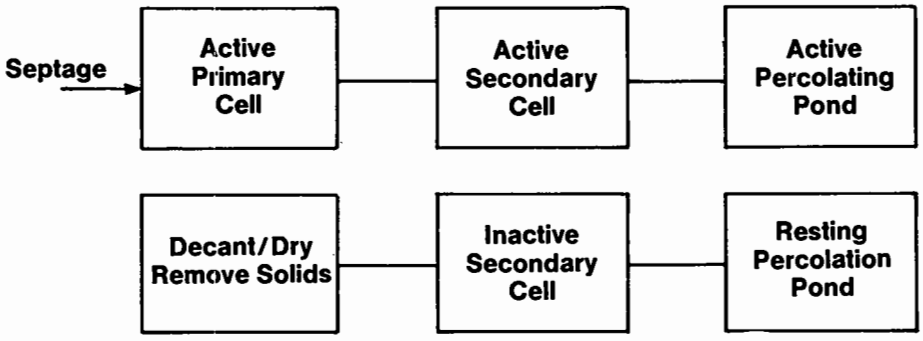


TABLE 7-1

LAGOON PERFORMANCE DATA, ACTON, MASSACHUSETTS (3)

	Influent (mg/L)	Effluent (mg/L)	Percent Removal
COD	19,500	1,870	90
BOD	5,890	450	92
Total Solids	11,600	1,610	86
Suspended Solids	9,500	610	94
Total Volatile Solids	8,170	910	89

The most serious environmental consideration with lagoon systems is the potential for groundwater contamination. Little control is available concerning the application rates of nitrogen, phosphorus, organics, pathogenic bacteria and viruses, and potential heavy metals, as compared to land application methods. The Commonwealth of Massachusetts recommends the use of percolation beds (not percolation ponds) preceded by a two-cell lagoon system in order to maximize the renovation of the effluent before it leaches into the soil (2). At a lagoon site in Acton, Massachusetts (3), percolation beds were constructed using 15 cm (6 in.) of coarse sand on top, followed by 15 cm (6 in.) of fine sand, 46 cm (18 in.) of coarse gravel, and 15 cm (6 in.) or more of medium and coarse gravel.

A study done by the New England Interstate Water Pollution Control Commission (NEIWPCC) recommends that percolation beds use a thicker subsurface (0.6 to 0.9 m, or 2 to 3 ft) layer of fine sand to increase the removal of bacteria and other pollutants (3).

Where the risk of groundwater contamination justifies the elimination of the percolation pond or percolation bed option, surface discharge and land application alternatives should be seriously considered. Surface discharges should be preceded by some form of polishing, such as intermittent sand filtration, while land application designs should follow guidelines provided in available documents addressing land application of wastewater effluent (4) (5) (6).

7.2.2 Design Guidelines

Design guidelines pertaining to the construction, siting, and operation of septage lagoons vary from state to state. Table 7-2 presents recommended guidelines from the NEIWPCC. Although these guidelines suggest a detention time of at least 20 days, considerably longer detention times may be necessary to achieve more acceptable treatment efficiencies. Applying an area loading rate for facultative sludge lagoons of 0.84 kg VS/day/1,000 m^2 (20 lb VS/day/1,000 ft^2) (34) results in a detention time requirement of approximately 500 days for a 2.5-m (8-ft) deep lagoon. This should provide greater than 95 percent reduction of BOD and volatile solids. Other aspects of facility siting and operation are discussed in Chapter 8.

TABLE 7-2

SEPTAGE LAGOON DESIGN GUIDELINES AS SUGGESTED BY THE NEW ENGLAND INTERSTATE WATER POLLUTION CONTROL COMMISSION (7)

Parameter	Guidelines
• Configuration	A minimum of two lagoons in series, with control of discharge to the second lagoon by release during quiescent periods to minimize the carryover of suspended solids into the second lagoon. A parallel series of similar lagoons should also be installed to facilitate proper maintenance of each series of lagoons. or A minimum of two lagoons installed in parallel, followed by at least six percolation beds with a total effective area of 23.6 $m^2/m^3/d$ (1 sq ft/gal/d) of design flow. The soil in the percolation bed shall provide a percolation rate of not over 2 minutes per inch. The base of the percolation facilities shall be at least 1.8 m (6 ft) above maximum groundwater.

TABLE 7-2 CONTINUED

Parameter	Guidelines
● Design Siting	
- Minimum height above maximum groundwater table	1.2 m (4 ft) for both primary and secondary lagoons.
- Groundwater monitoring	Monitoring wells recommended as well as surface water sampling.
- Buffer zone	90 m (300 ft).
- Lining (percolation bed)	Minimum 0.3 m (1 ft) of good filterable sand.
- Access	All-weather roads.
- Fencing and signs	1.8 m (6 ft) fence with locking gate-warning signs posted on all sides.
- Grading	Adequate to prevent surface run-off water from entering lagoons.
● Receiving Station	Concrete chamber with provisions to discharge septage beneath the liquid level of the lagoon.
● Odor Control	Lime.
● Sludge Disposal	Not specified - refer to individual state requirements.
● Design Sizing	
- Volume	Each lagoon system should provide a retention time of no less than 20 days
- Basis	Total of: 1. Domestic flow 0.19-0.27 m^3/cap/d (50-70 gal/cap/d) 2. Commercial flow 3. Industrial flow
- Minimum Depth	0.9 m (3 ft)
● pH Control	6.8 - 7.2 using lime

7.3 Composting of Septage

Composting is the stabilization of organic material through the process of aerobic, thermophilic decomposition. It is an alternate septage treatment technique that offers the potential for good bactericidal action while achieving up to 25 percent reduction in organic carbon (8). Septage is transformed into a humus-like material that can be used as a soil conditioner. The composting of sludge has been successfully demonstrated at Beltsville, Maryland (8); Bangor, Maine (9); Durham, New Hampshire (10); and Windsor, Ontario (11). Also, a description of U.S. composting facilities has been published (72). Composting characteristics of septage have been found to be the same as sewage treatment plant sludge.

The composting of liquid septage is accomplished by adding additional bulking agents (e.g., woodchips, sawdust, bark chips, etc.), or by dewatering the septage prior to composting. The purpose of the bulking agent is to decrease the moisture content of the mixture, increase the porosity of the septage, and to assure aerobic conditions during composting. Liquid septage composting has been demonstrated in several instances (18) (34) (73).

Composting is generally classified into three types of operations, which differ primarily by the aeration mechanism they employ. Each are described briefly in the following sections.

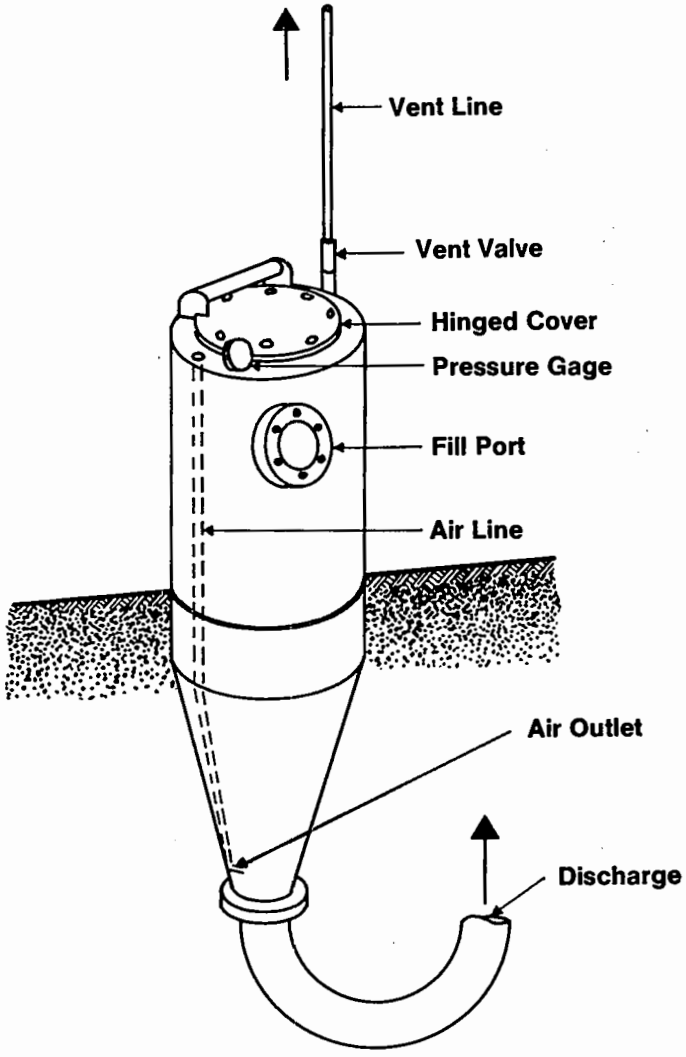
7.3.1 Windrow Composting

In the windrow process, the septage and bulking agent are stacked in long parallel rows called "windrows." The cross-section of the windrows is either trapezoidal or triangular, depending on the equipment used for mixing and turning the compost material.

Convective air movement within the windrows is essential for providing oxygen for the microorganisms. The heat produced by the aerobic reactions warms the air in the windrow, causing it to rise, producing a natural chimney effect. In order to expose all the organisms within the pile to oxygen, it must be turned, varying from once a day to several times per week. This method is highly equipment- and labor-intensive.

A variation of the windrow process, the Lebo process, is perhaps the first composting process designed specifically for the treatment of septage. The Lebo composting process consists of two steps: aeration and composting. The aeration deodorizes the liquid waste. Figure 7-5 illustrates the patented Lebo aerator. It is installed mostly underground, with only the top exposed. Septage is held in a storage tank

FIGURE 7-5
THE LEBO AERATOR (15)



prior to being pumped to the aerator. Septage flows by gravity into the aerator where it is aerated under a pressure of 69 to 103 kPa (10 to 15 psi) for approximately 10 minutes (15). At the end of 10 minutes, the vent valve on the aerator is closed and the discharge valve is opened, forcing the septage through the U-tube and a discharge hose into a sawdust/sludge mixer. After mixing, a front-end loader is used to transfer the wet mixture to a compost pile. Alternating layers of septage-sawdust are used until a pile height of 2.5 to 3.0 m (8 to 10 ft) is attained. Pile configuration is generally square with a flat top to prevent excess heat loss. Provisions for the collection of leachate are necessary because the material is relatively wet. The leachate may be collected and recycled or, if the facility is located at a treatment plant, the leachate may be with the liquid waste stream.

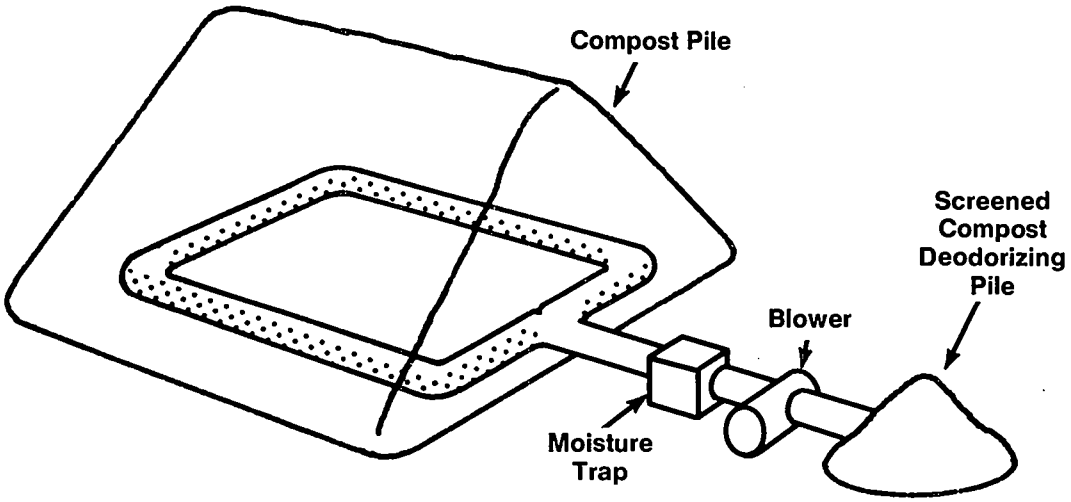
The material in the compost pile is left for 90 to 180 days during which time the piles reach sufficient temperature (e.g., 50°C or 120°F) to dry the material (15). Then it is moved to a finished pile for at least 30 days. The outer layer may then be removed and used as a bulking agent. Although the process appears to be effective, little data are available. Since the piles are not mixed, it is questionable as to whether uniform distribution of adequately high temperatures is consistently achieved to provide complete pathogen destruction.

7.3.2 Aerated Static Pile Composting

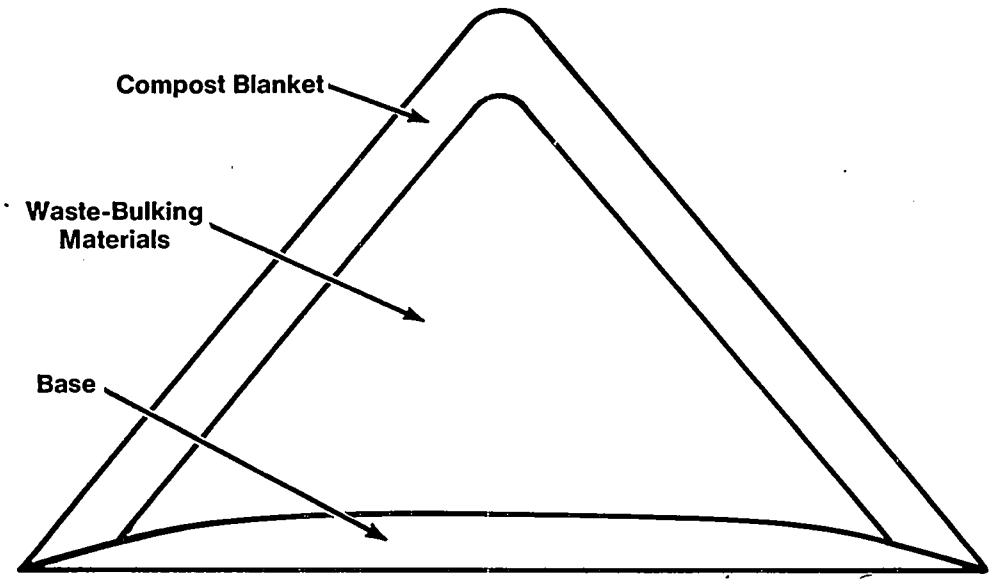
One composting technique that appears to offer potential as a septage treatment alternative is the Beltsville "static pile method." Septage composting by this technique has been performed at a small National Park Service facility, which has also used this approach for composting liquid wastes pumped from portable toilets and vault privies (18). Some pilot studies have been reported on the static pile composting of dewatered septage solids, which would not be expected to differ significantly from the many studies of dewatered sludge composting (8) (9) (10) (11) (73).

The aerated static pile system was developed to eliminate many of the land requirements and other problems associated with windrow composting, and to allow for the composting of raw sludge. The essential elements of the static pile method are shown in Figure 7-6. An aeration header consisting of perforated pipe is placed on the ground and covered with approximately 30 cm (12 in.) of woodchips or unscreened, previously-composted material. This base acts as an absorbent for liquids, prevents clogging of pipe holes, and allows air circulation below the raw material mixture. A front-end loader or some mixing device is used to blend the bulking agent (sawdust, woodchips, or other material) and raw sludge in the appropriate proportion. The mixture is then placed on the base in the configuration illustrated in Figure 7-6. The pile is covered with a 30-cm (12 in.) layer of screened compost to provide insulation (minimizing loss of generated heat) and to

FIGURE 7-6
FORCED AERATION STATIC PILE COMPOSTING SYSTEM (17) (18)



General Layout



Blanket and Base — Woodchips & Previously Composted Material

Bulking Material — Woodchips, Sawdust and Previously Composted Material

Septage Pile Dimensions
2.7 m (9 ft.) High
4.6 m (15 ft.) Diameter
30 cm (12 in.) Base
50 cm (18 in.) Blanket

Cross Section

prevent odors from escaping. Vacuum is applied to the header by the use of a blower. Between the pile and blower, a moisture trap is generally installed to collect water that condenses in the piping. The discharge from the blower is operated on a timer, allowing an operator to adjust the cycle to maintain oxygen concentrations in the pile of between 5 and 15 percent. A three-week composting period is usually provided, during which time temperatures and oxygen levels in the pile are monitored. The composted material is then moved to a stockpile for a four-week or more curing period. Screening of the material to recover the woodchips may be effected before or after curing. The compost is then ready for distribution. Health risks relating to the fungi A. fumigatus are not usually a problem in septage compost operations due to their small size and rural locations.

Results of the NPS study indicated that this process is capable of producing a stabilized compost product when appropriate ratios of liquid waste and organic bulking agents are achieved prior to the initiation of the composting process. Approximate volumetric requirements for the total compost pile per 3,790 L (1,000 gal) of waste were: base - 5.4 m^3 (7 yd^3) woodchips; absorbant organic mixture - 7.4 m^3 (9.7 yd^3) woodchips, 7.4 m^3 (9.7 yd^3) sawdust, 3.2 m^3 (4.2 yd^3) compost; and insulation blanket - 7.7 to 15.3 m^3 (10 to 20 yd^3) compost (18).

7.3.3 Mechanical Composting

The mechanical composting method is substantially different from other methods. Instead of a batch mode of composting, mechanical composting is a continuous process. Organic material and the bulking agent are introduced daily into the influent end of the reactor. Mixing to ensure adequate aeration can be done by tumbling, by movement with an endless belt that lifts and drops the material, or by movement with an auger. Additional aeration is provided by externally supplying air to the reactor. This method is popular in Europe for composting municipal refuse and wastewater sludge (62). It has not found wide-scale application in this country. Application to septage composting is limited by the size of available equipment, which is generally applicable only to facilities handling greater than 115 m^3 (30,000 gal) of septage per day.

7.3.4 Process Considerations

Composting represents the combined activity of a succession of mixed populations of bacteria, actinomycetes, and other fungi associated with a diverse succession of environments (12). The principle factors that affect the biology of composting are moisture, temperature, pH, nutrient concentration, and availability and concentration of oxygen (12). Table 7-3 presents generally recommended operating parameters for septage composting.

7.3.4.1 Moisture

Organic decomposition is dependent upon moisture. The lowest moisture content at which bacterial activity takes place is from 12 to 15 percent; however, less than 40 percent may limit decomposition. The optimum moisture content is in the range of 50 to 60 percent. Beyond 60 percent, the proper structural integrity will not be obtained.

Normally the moisture content of septage is in excess of 90 percent. In order to optimize the composting process, septage should be dewatered and/or blended with a bulking agent, whichever is more economical.

7.3.4.2 Temperature

For the most efficient operation, composting processes depend on temperatures of from 55° to 65°C (130° to 150°F) but not above 80°C (176°F). High temperatures are also required for the inactivation of human pathogens in the sludge. Moisture content, aeration rates, size and shape of pile, atmospheric conditions, and nutrients affect the temperature distribution in a compost pile. For example, temperature elevation will be less for a given quantity of heat released if excessive moisture is present, as heat will be carried off by evaporation. On the other hand, low moisture content will decrease the rate of microbial activity and thus reduce the rate of heat evolution.

TABLE 7-3

OPERATIONAL PARAMETERS FOR SEPTAGE COMPOSTING

Parameter	Optimum Range (12) (13) (14)	Control Mechanisms
Moisture Content of Compost Mixture	40-60%	Pretreatment of septage by dewatering to 10-20% solids Addition of bulking material (woodchips, sawdust), 3:1 bulking agent: dewatered septage (by volume)
Oxygen	5-15%	Periodic turning/natural convection (windrow, Lebo composting) Forced aeration (static pile) Mechanical agitation with compressed air (mechanical)
Temperature (must reach)	55-65°C	Natural result of biological activity in piles Too much aeration can reduce temperature
pH	5-8	Generally occurring in septage, no adjustment necessary
C/N Ratio	20:1 to 30:1	Addition of bulking material

7.3.4.3 pH

The optimum pH range for growth of most bacteria is between 6 and 7.5, and between 5.5 and 8.0 for fungi (13). The pH varies throughout the pile and throughout the composting operation, but it is essentially self-regulating. A high initial pH resulting from the use of lime for dewatering will solubilize nitrogen in the compost and contribute to the loss of nitrogen by ammonia volatilization. It is difficult to alter the pH in the pile for optimum biological growth, and this has not been found to be an effective operation control.

7.3.4.4 Nutrient Concentration

Both carbon and nitrogen are required as energy sources for organism growth. Thirty parts by weight of carbon (C) are used by microorganisms for each part of nitrogen (N); a C/N ratio of 30 is, therefore, most desirable for efficient composting, and C/N ratios between 25 and 35 provide the best conditions. The carbon considered in this ratio is biodegradable carbon. Lower C/N ratios increase the loss of nitrogen by volatilization as ammonia, and higher values lead to progressively longer composting times as nitrogen becomes growth-rate limiting (12). No other macro-nutrients or trace nutrients have been found to be rate-limiting in composting municipal wastewater sludge.

7.3.4.5 Oxygen Supply

Optimum oxygen concentrations in a composting mass are between 5 and 15 percent by volume (60). Increasing the oxygen concentration beyond 15 percent by air addition will result in a temperature decrease because of the greater air flow. Although oxygen concentrations as low as 0.5 percent have been observed inside windrows without anaerobic symptoms, at least 5 percent oxygen is generally required for aerobic conditions (12).

7.4 Biological Secondary Treatment Processes

Since the basic composition of septage is very similar to domestic sewage, it is reasonable to assume that processes used in treating sewage should be suited to the treatment of septage. Although the great variability in waste strength and characteristics of septage may present operational problems for low-SRT activated sludge processes, extended aeration processes should be more capable of handling such conditions. Fixed growth biological systems at low loadings may be well suited to septage treatment due to their relative ease of operation.

Unfortunately, there is limited documented experience with full-scale applications of these processes to septage treatment. However, such designs may represent a cost-effective method of treating septage when the generally less costly options of land application, lagoons, and composting are not applicable. One example where a biological secondary septage treatment process was selected was in Wayland and Sudbury, Massachusetts, where a system employing RBC treatment of septage was determined to be more cost-effective than two other alternatives incorporating anaerobic digestion and chlorine oxidation (addressed later in this chapter) (19). The Wayland-Sudbury treatment facility provides screening, grit removal, equalization, chemical conditioning, primary clarification, and secondary treatment using rotating biological contactors, followed by sand filtration. The layout of the plant is illustrated in Figure 7-7.

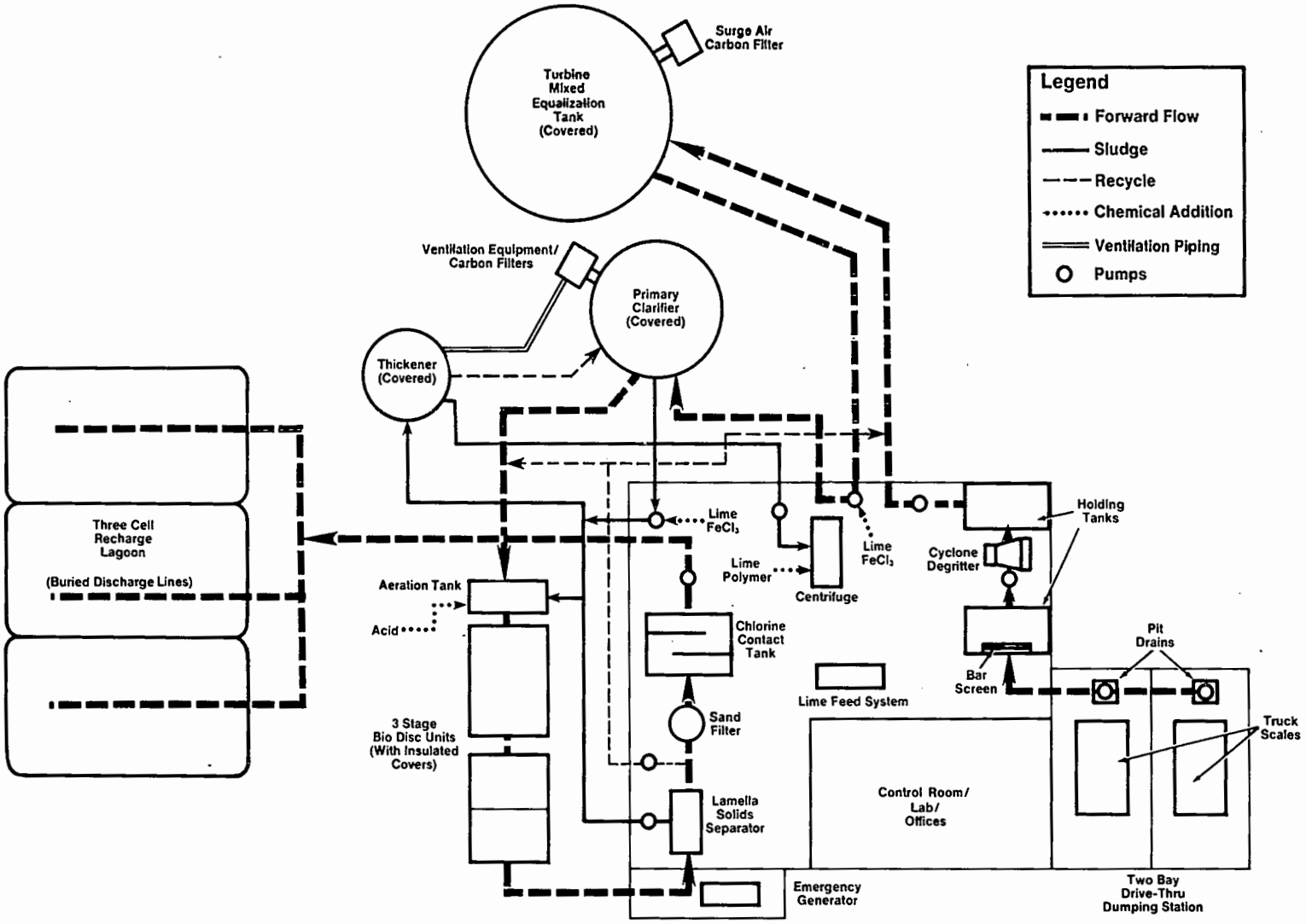
Given that septage generation is erratic and in many areas seasonal, secondary treatment processes which are minimally upset by this variability are more desirable. Condren (29) applied acid/lime treated supernatant (neutralized) to intermittent sand filters at pilot scale. Although hydraulic loadings were high (1,400 $m^3/d/ha$ (150,000 gal/d/acre)), BOD was reduced by more than 50 percent and effluent SS averaged 31 mg/L.

The performance of biological septage treatment processes is yet to be fully demonstrated; however, such systems may offer economic and operational advantages in many situations. The design of a biological septage treatment system should follow the same basic principles of design that apply to sewage treatment, by simply taking into account the higher organic and solids loadings. Other special design and operational requirements, such as the need for increased scum removal capacity, are identified in Chapter 6 in discussing the co-treatment of septage at sewage treatment plants.

7.5 Aerobic Digestion

Aerobic digestion operates in the endogenous respiration phase. Cell matter is oxidized to carbon dioxide, water, and other inert materials. Aerobic stabilization of septage-sludge mixtures has been widely used in Europe at small plants (1), although for digestion of septage alone, the process has not been adopted at full scale (20). Compared with anaerobic stabilization processes, aerobic processes are easier to operate and maintain, have lower capital costs, and produce an odorless, biologically stable residual that dewaters easily (21).

FIGURE 7-7
RBC SEPTAGE TREATMENT FACILITY - WAYLAND - SUDBURY, MASSACHUSETTS



Aerobic digestion qualifies as a Process to Significantly Reduce Pathogens (PSRP) as per 40 CFR 257. Kuchenrither and Benefield (22) found that fecal coliform and fecal streptococci concentrations decreased with time during aerobic digestion, and that the rate of decrease tended to increase as the temperature increased. Figures 7-8 and 7-9 illustrate these findings.

7.5.1 Research on Aerobic Digestion of Septage

Aerobic digestion of septage has been shown to be reasonably effective in full-scale operations as well as in laboratory and pilot-scale studies. A common problem, however, has been the control of both foam and odors. Foam problems have been controlled by increased freeboard, up to 1.2 meters (4 feet) or more (23); laboratory experiments have used foam-retardant devices or chemicals. Table 7-4 presents a summary of research involving aerobic digestion of septage.

Bowker (20) has provided a summary of available data on the aerobic digestion of septage. He noted that Jewell, et al. (24) investigated bench-scale batch and continuous-feed aerobic digestion of septage at detention periods of 1 to 30 days and noted high removals of soluble organics, but limited reduction of particulate organic material. Removal efficiencies varied widely. Jewell stated that odor and foaming were eliminated in the batch units in 5 and 11 days, respectively. Foaming persisted in the continually-fed reactors, but odors were not a problem in these units after an acclimation period of 3 to 4 days. Zone settling velocity and CST (capillary suction time), indicators of settleability and dewaterability, respectively, were improved considerably after aerobic stabilization at loadings of 0.5 to 21 $kg/m^2/day$ (0.03 to 1.3 lb VSS/cu ft/day), and a detention time of greater than 30 days (24).

Aerobic digestion is commonly used in Norway for sludge and septage stabilization because of the large number of small wastewater treatment plants in that country. Eikum and Paulsrud (25) reported on studies conducted at the Norwegian Institute for Water Research (NIVA) to determine the solids retention time necessary to produce a fully-stabilized sludge. They studied primary sludge and mixed primary/chemical (alum) sludge, as well as septage. They defined a fully-stabilized sludge as that in which the Odor Intensity Index (OII) (ASTM D 1292) does not exceed 11 at any time during 14 days of storage (i.e., without aeration) at 20°C (68°F), unless the odor can clearly be classified as a typical "soil" odor. They found that septage required a minimum solids retention time (aerated) of 44 days at 18°C (64°F) before it could meet the requirements for full stabilization. Primary sludge and mixed primary-chemical sludge required 37 days and 40 days, respectively, at 18°C (64°F) to be considered fully stabilized.

FIGURE 7-8
FECAL COLIFORM COLONIES REMAINING FOLLOWING AEROBIC DIGESTION (22)

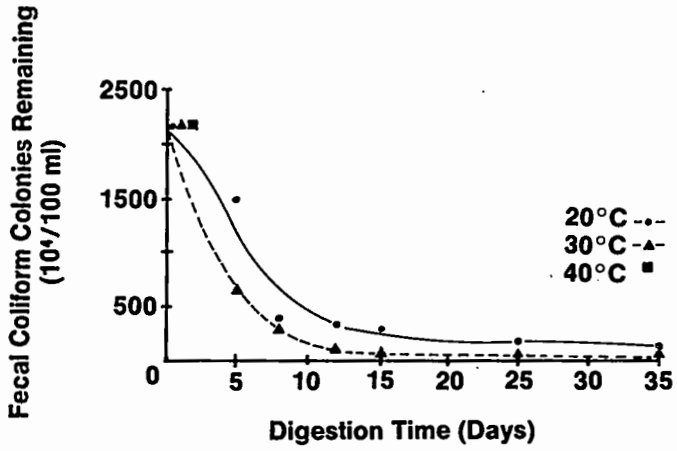


FIGURE 7-9
FECAL STREPTOCOCCI COLONIES REMAINING FOLLOWING AEROBIC DIGESTION (22)

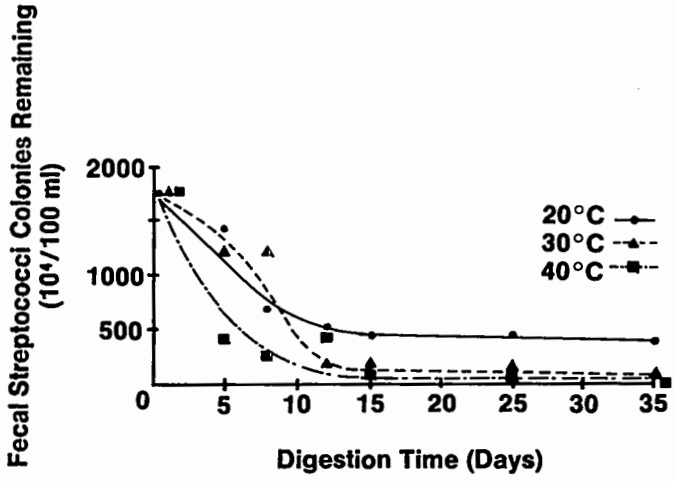


TABLE 7-4

SUMMARY OF RESEARCH OF AEROBIC DIGESTION OF SEPTAGE

Time of Aeration days	Raw Septage Characteristics mg/L	Supernatant Characteristics mg/L	Remarks	Reference
44	TSS - 33,240 VSS - 26,200 COD - 33,820		Aeration time required to produce fully stabilized sludge @ 18°C; max. O_2 uptake rate for fully stabilized sludge @ 18°C: 0.7 mg O_2/g VSS/hr	25
10	TSS - 21,400 VSS - 14,100 BOD_5 - 8,600 COD - 24,000	TSS - 9,550 VSS - 5,800 BOD_5 - 6,900 COD - 13,100	Bench scale using 6-liter reactors	26
Batch - 22 to 40	TSS - 39,100 VSS - 30,100 COD - 3,360	TSS - 40% Red. VSS - 43% Red. COD_s - 75% Red.	Batch size - 3 to 6 liters D.O. maintained at 1 mg/L Raw septage CST = 223 sec	24
Lagoon - 1 to 30		TSS - 16% Red. VSS - 20% Red. COD_s - 74% Red.	Lagoon size - 1.75 to 10 liters semi-continuous feed	
1	TSS - 7,734 BOD_5 - 4,004 COD - 14,655	TSS - 1,063 BOD - 661 COD - 3,361	Pure oxygen atmosphere in a closed reactor; supernatant reported after settling	27
1	TS - 19,262* BOD_5 - 7,990 COD - 25,880	TS - 480 BOD - 1,030 COD - 3,310	Pure oxygen atmosphere in a closed reactor; supernatant reported after settling	28
4	TSS - 8,680 BOD_5 - 5,850 (screened)	TSS - 1,480 BOD_5 - 295	Supernatant reflects 2 hours of settling; improvement in settling characteristics noted; 90% NH_3-N removal and 93% removal noted in supernatant also	29

*Digested Sludge Characteristics: TS-37,500 mg/L; TVS-28,100 mg/L

A pilot study at the U.S. EPA Lebanon pilot plant was hampered by serious foaming problems during batch aerobic digestion of septage (20). Odors were eliminated and settleability improved in 7 to 13 days, respectively, at air flow rates of 500 L/min/m^3 (0.5 scfm/cu ft). Supernatant quality improved sharply from COD values of 31,200 and 26,830 mg/L on days 1 and 12, respectively, to 2,270 mg/L on day 13. However, supernatant quality did not improve after a 31-day batch aeration study at 250 L/min/m^3 (0.25 scfm/cu ft). At the latter air flow rate, 55 percent reductions of volatile solids were observed, while 70 percent reductions were achieved at 500 L/min/m^3 (0.5 scfm/cu ft), over the same 31-day period. Perrin (30), in his bench-scale study on chemical treatment, concluded that the use of short-detention aerated lagoons for odor reduction and partial stabilization, followed by chemical conditioning and sand-bed dewatering, may be a workable alternative to full stabilization by long-term (approximately 40 days) aerobic digestion of septage. Tilsworth (26) noted 80 percent BOD_5 reductions and 41 percent VSS reductions after 10 days of aeration.

7.5.2 Equipment

Conventional aerobic digesters are open-topped tanks or earthen basins and are affected by ambient temperatures. To avoid excess heat losses, tanks have been covered or placed below grade. The mixing and aeration requirements can be provided by either mechanical mixers or diffusers. The equipment (basins, aerators, etc.) used for aerobic digestion of septage is the same as that used for other sludges (1): Because the solids retention time is generally longer for septage than for other sludges, the size of the equipment may differ.

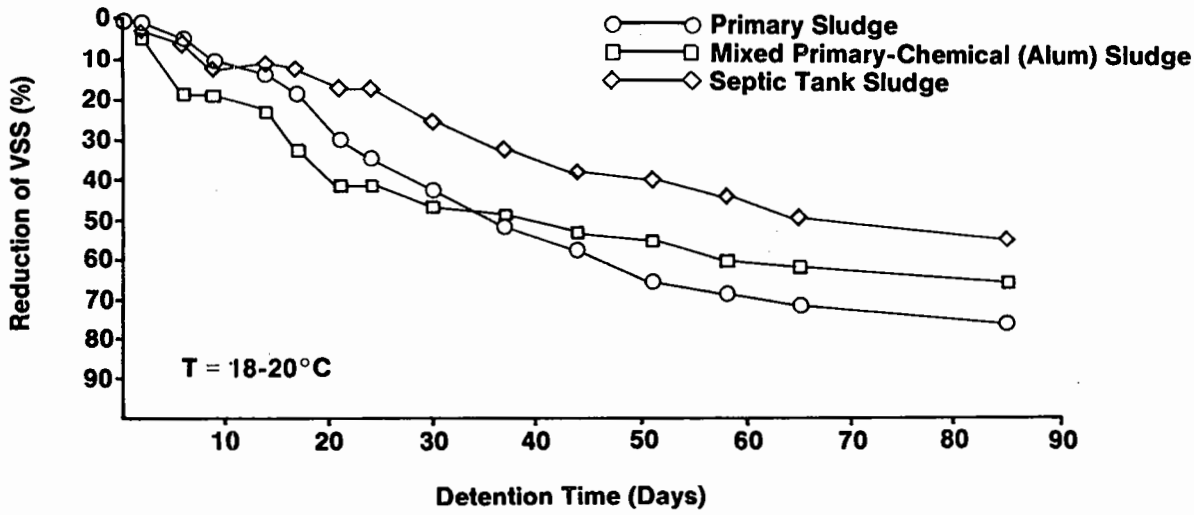
7.5.3 Design Criteria

The design of aerobic digestion systems for septage should be based on the following criteria: solids retention time, VSS loading, aeration capacity, minimum dissolved oxygen concentration, and operating temperature.

7.5.3.1 Solids Retention Time (SRT)

Figure 7-10 shows the reduction of VSS with time in a batch aerobic digestion system study by Eikum (31). The solids retention time (SRT) required for a particular case depends on the degree of septage stabilization required, the characteristics of the septage, and the operating temperature. If complete stabilization is required, then the SRT

FIGURE 7-10
REDUCTION OF VSS IN BATCH AEROBIC DIGESTION WITH TIME (31)



should be 30 to 40 days at a temperature of about 18 to 20°C (64 to 68°F). If complete stabilization by aerobic digestion is not required (e.g., the partially stabilized septage will be land applied), then the SRT can be proportionally lower.

7.5.3.2 Solids Loadings

VSS loadings ranging from 0.5 to 21 kg VSS/m^3/d (0.03 to 1.3 lb VSS/ft^3/d) for batch aerated lagoon studies have been reported (32). Researchers have recommended that the organic loading for aerobic digestion be in the range of 1.6 to 21 kg VSS/m^3/d (0.1 to 1.3 lb VSS/ft^3/d) (25). Although these volatile suspended solids loadings are somewhat higher than volatile solids loadings typically reported for aerobic digestion of sewage sludge [1.6 to 3.2 kg VSS/m^3/d (0.1 to 0.2 lb VS/ft^3/d)] (21), it should be kept in mind that the recommended values for septage are derived from a much smaller data base. Septage loadings should conform to sludge loading recommendations until further experience in gained. Therefore, septage loadings for aerobic digestion should be 3.2 kg VS/m^3/d (0.2 lb VS/ft^2/d) or less for design purposes.

7.5.3.3 Air Requirements

Aeration serves two purposes in aerobic digestion: it maintains a positive dissolved oxygen (D.O.) level, and it keeps the solids in suspension. The air requirements should ideally be based on oxygen uptake rate measurements, but the air requirement based on uptake alone is not sufficient to keep septage solids in suspension (1). An air flow rate of 50 m^3/min/1,000 m^3 has been successful at the U.S. EPA Lebanon pilot plant, with VSS reductions of greater than 70 percent after 30 days of aeration (39). Eikum (1) recommends 80 to 100 m^3/min/1,000 m^3 based on Norwegian experience. Since Norwegian septage is heavily concentrated with sand and other heavier organics, a lower value of 50 to 80 m^3/min /1,000 m^3 of digester capacity is recommended for design.

7.5.3.4 Dissolved Oxygen

The aerators must be able to maintain a minimum D.O. level of 1 mg/L for efficient operation. Experience with wastewater sludges indicates that aerobically-digested sludge dewaters most efficiently if the D.O. during digestion is maintained at a level of at least 1 mg/L (34).

7.5.3.5 Operating Temperature

One of the major variables affecting the rate of aerobic digestion is the operating temperature of the digester. It has been observed that, for sewage sludge, aerobic digester operation is temperature-dependent, especially at temperatures below 20°C (68°F) (21). At higher temperatures, the biological activity - and therefore the oxygen uptake rate - would increase (25). It was proposed that the oxygen uptake rate (OUR) be adjusted for the temperature as follows:

$$OUR_{T1} / OUR_{T2} = \Phi^{(T_1 - T_2)} \quad (1)$$

OUR_{T1} = Oxygen uptake rate at temperature T_1

OUR_{T2} = Oxygen uptake rate at temperature T_2

Φ = Streeter-Phelps temperature sensitivity coefficient (Eikum and Paulsrud (25) assumed a value of 1.10)

Eikum (1) also noted that the SRT's for aerobic stabilization of septage increased dramatically with decreasing temperatures. Bowker and Hathaway (20) noted that for average annual temperatures lower than 20°F (68°F), longer SRT's will be required for good VSS reduction. In extremely cold climates, consideration should be given to heating the septage or the air supply, and covering and insulating the tanks. Table 7-5 contains a summary of the design criteria for aerobic stabilization of septage.

7.5.4 Limitations

Two major problems associated with aerobic digestion of septage are odors and foaming. In batch aerobic digestion pilot tests, it was found that odors were reduced after approximately 3 to 4 days of aeration, and that foaming would dissipate after about 10 days (32). Foaming was caused by washing machine detergents and could be controlled in the digester by foam fractionation or use of commercial antifoamers. In addition, aerobic digestion requires constant monitoring and operator attention, can be sensitive to toxic substances in the septage, and requires further handling (e.g., dewatering, transportation, etc.) prior to ultimate disposal (20).

Because of these limitations, long detention times required for stabilization, and high capital and operating costs (compared with land treatment, lagooning, etc.), it is unlikely that aerobic digestion would be attractive or justifiable for any but large or land-limited independent septage treatment facilities.

TABLE 7-5

AEROBIC STABILIZATION OF SEPTAGE
TYPICAL DESIGN CRITERIA

Parameter	Value	Remarks
Solids Retention Time, Days	20 - 40	For septage characteristics similar to Table 3-4, design for 20 - 30 days SRT; for stronger septage, use longer SRT. For operating temperatures > 20°C (68°F), use 20 - 30 days SRT; for lower temperatures, use longer SRT.
VSS Loading, $kg/m^3/d$	1.6 - 21	Loading increases with increasing SS concentration, decreases with increasing SRT.
Requirements for Mixing		
Air mixing, $m^3/1000\ m^3/min$	25 - 50	To maintain minimum D.O. of approximately 1 - 2 mg/L and to keep solids in suspension.
Mechanical Aerators, $kw/1000\ m^3$	26 - 33	
Oxygen Requirements $kg\ O_2/kg$ VSS	1.8	
D.O. Level in Liquid, mg/L	1 - 2	
Operating Temperature, °C	>18	
Tank Design		Aerobic digestion tanks are open and generally require no special heat transfer equipment or insulation in warmer climates. However, in cold climates, heating influent septage or air supply, and/or covering and insulating tanks should be considered. For small treatment systems, the tank design should be flexible enough so that the digester tank can also act as a thickening unit. If thickening is to be utilized in the aeration tank, sock-type diffusers or mechanical aerators should be used to minimize clogging.

7.5.5 Monitoring - Aerobic Digestion of Septage

Temperature, pH, total solids, volatile solids, dissolved oxygen, settleable solids, BOD_5, and alkalinity must be monitored regularly for process control of aerobic digestion.

A study was conducted to determine which parameters can be used as a measure of the degree of stability of aerobically-digested sludges (25). Of the parameters studied, including ATP (adenosine triphosphate) levels, pH, TSS and VSS reduction, and oxygen uptake rate (OUR), it was concluded that OUR is a reliable indicator of sludge and septage stability, as defined in Section 7.2.1.1. OUR decreases and levels off with increased detention time, as shown in Figure 7-11. It was also concluded that aerobically-digested septage could be considered stabilized as long as the OUR remained less than 0.7 mg O_2/g VSS/hr at 18°C (25). Thus, OUR can be corrected for temperature using Equation 1.

7.6 Anaerobic Stabilization of Septage

Anaerobic stabilization or digestion is a biological process in which organic matter is decomposed in the absence of molecular oxygen. The primary products of anaerobic digestion are methane and carbon dioxide; however, some unusable intermediate organics and a relatively small amount of cellular protoplasm are also produced. The major applications of anaerobic digestion have historically been in the stabilization of concentrated sludges produced from the treatment of wastewater and in the treatment of some industrial wastes (21). Because septage is such a concentrated waste, it follows that anaerobic digestion would be an appropriate stabilization technique. Only limited data exist on anaerobic digestion of septage at independent septage treatment facilities, although anaerobic digestion of septage at a treatment plant (co-treatment) has been well documented, as discussed in Chapter 6.

This section presents available design and operating data for anaerobic digestion of septage. A complete discussion of the design of municipal sludge digestion facilities is given in Subsection 7.2 of the EPA Manual for Sludge Treatment (36). The basic design approach presented in the manual can be applied to the design of independent septage digestion facilities. Anaerobic digestion is classified by EPA as a process to significantly reduce pathogens (PSRP). Table 7-6 shows levels of pathogenic bacteria reduction that can be expected during anaerobic digestion.

FIGURE 7-11.
OXYGEN UPTAKE RATE VERSUS DETENTION TIME IN AEROBIC DIGESTER. (25)

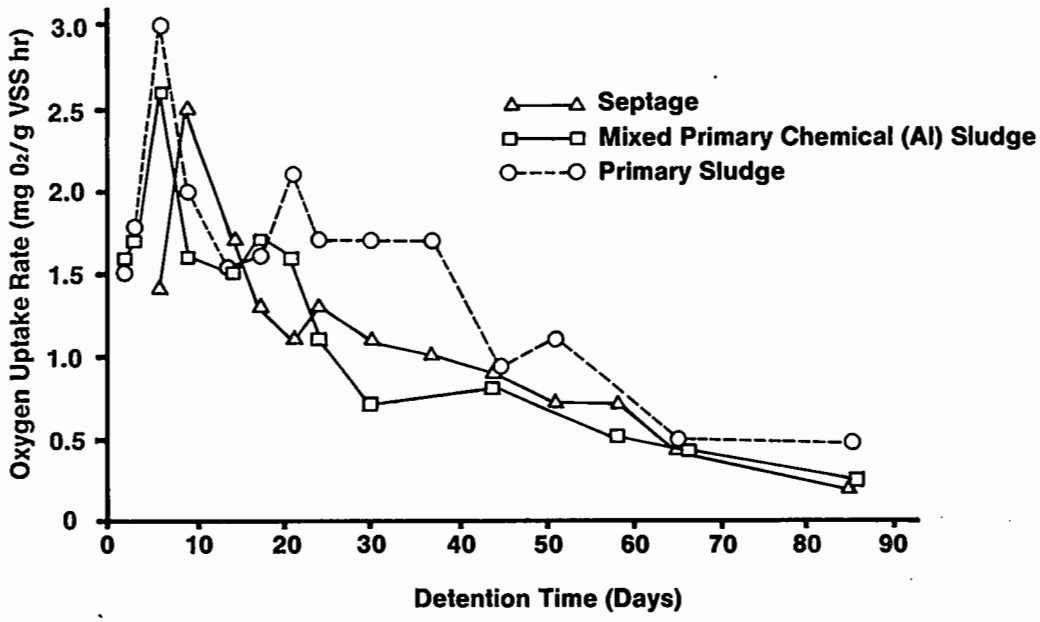


TABLE 7-6

REMOVAL OF PATHOGENIC BACTERIA
DURING ANAEROBIC DIGESTION OF SEWAGE SLUDGE (34)

Bacteria	Digestion Period (days)	Removal (%)	Remarks
Endamoeba hystolytica	12	<100	Greatly reduced populations at 68°F (20°C)
Salmonella typhosa	20	92	85% reduction in 6 days detention
Tubercle bacilli	35	85	Digestion cannot be relied upon for complete destruction
Escherichia coli	49	<100	Greatly reduced populations at 99°F (37°C)

7.6.1 Research - Anaerobic Digestion of Septage

Table 7-7 is a summary of five studies in which septage was stabilized by anaerobic digestion. All five studies operated in the mesophilic range, 32 to 35°C (90 to 95°F). The results and conclusions of the studies are varied. Two studies had limited success with anaerobic digestion of septage. Kolega, et al. (37) experienced very poor gas production; the gas that was produced was of very low quality.

Kolega, et al. (44) sampled for the presence of detergent surfactants in the form of linear alkyl sulfonate (LAS) because foaming was noticed. LAS concentrations ranged from 3 mg/L to 61 mg/L in 30 samples, indicating the presence of detergent products. Jewell, et al., (24) experienced digester failure, but the laboratory test was inadequate to draw any conclusions.

A U.S. EPA study performed at Lebanon, Ohio (39) attempted to determine the effectiveness of anaerobic digestion of septage alone, as well as mixtures of septage and primary wastewater sludge. The conclusion of the study was that septage mixed with primary sludge had no adverse effect on the digestion process. The study also revealed the effectiveness of anaerobically digesting septage alone. With an SRT of 30 days, the gas production from anaerobic digestion of the septage averaged 9 percent lower than that for primary sludge. Volatile solids

TABLE 7-7

SUMMARY OF RESEARCH ON ANAEROBIC DIGESTION OF SEPTAGE

	Loading kg VS/m^3/d	Average Total Solids %	HRT days	% Reduction VSS	% Reduction TS	Gas Production m^3/kg VS	References
Septage	0.16	0.23	10	---	---	---	38
Septage	0.48	2.84	15	---	---	---	37
Septage	0.48-2.6	2.8	10-30	40	26	0.46-0.70	39
Primary Sludge	0.71-1.8	3.2	10-30	56	37	0.52-0.87	
Septage	0.77	4.2	48	47	35	0.44	24
Septage	1.6	---	---	30	---	---	40
Primary Sludge	1.9	---	---	35	---	---	

destruction of septage was also 25 percent less than that of primary sludge during the test period. Since septage is partially stabilized (due to anaerobic processes in the septic tank) and contains more grease than primary sludge, less gas production and less volatile solids reduction are expected from septage digestion.

A German study also showed that the volatile solids reduction of digested septage (29.5 percent) was less than that of digested primary sludge (38.5 percent) (40). In this same study there was a BOD_5 reduction of 53 percent for digested septage, compared to a 72 percent reduction for primary sludge.

The results from these tests cannot be considered conclusive; however, the data indicate that septage can be anaerobically digested. In the U.S. EPA study, batches of septage were stored for long periods. Thus, the digesters were not subject to daily shock loads but were, instead, fed the same septage over long time periods. This study also shows that good results were obtained using standard rate digester loadings in a high rate (i.e., completely mixed and heated) environment.

7.6.2 Equipment

Anaerobic digestion of septage can proceed either in airtight tanks or in anaerobic and facultative stabilization ponds. Stabilization ponds were discussed in Section 7.2, which specifically addresses septage lagoons. The equipment discussed in this section is limited to that for anaerobic digestion in tanks. The three most commonly used types of anaerobic digestion are standard-rate (or conventional), high-rate, and two-stage. Thorough discussions of equipment for anaerobic digestion are available in standard references (21)(34)(36).

7.6.3 Design Criteria

The design of anaerobic digestion systems for septage should be based on the following criteria: solids retention times, VSS loading, pH control, mixing, heating requirements, and operating temperature.

7.6.3.1 Loading

As shown in Table 7-7, the VS loading range that produced a VSS reduction of 40 percent or more was 0.5 to 2.6 kg VS/m^3/day (0.03 to 0.16 lb VS/ft^3/day). This loading is roughly within the same range as for standard rate mesophilic (25 to 40°C or 77 to 104°F) anaerobic digestion of wastewater sludge, and is lower than the typical high-rate loading for sludge, as shown in Table 7-8.

TABLE 7-8

COMPARISON OF SLUDGE DIGESTION DESIGN CRITERIA
WITH REPORTED VALUES FOR
MESOPHILIC ANAEROBIC DIGESTION OF SEPTAGE

Parameter	Primary and Waste Activated Sludge[a,b] Standard Rate	Primary and Waste Activated Sludge[a,b] High-Rate	Reported Values for Septage Digestion[c]
Solids Loading, kg VS/m^3/day	0.5 - 1.6	1.6 - 6.4	0.5 - 2.6
Solids Retention Time, days	30 - 60	10 - 20	10 - 30
Expected Gas Production, m^3/kg VS added	0.5 - 0.75	0.5 - 0.75	0.25 - 0.62

[a]EPA, 1974 (34).
[b]Tchobanoglous, 1979 (21).
[c]Table 7-6.

7.6.3.2 Solids Retention Time (SRT)

Although the septage SRT values listed in Table 7-7 are within the range of high-rate digestion of sewage sludges, it should be kept in mind that the septage values are those reported for laboratory and pilot-scale studies. The criteria listed for sewage sludge digestion are based on full-scale operations and have been used successfully in many facilities.

7.6.3.3 pH Control

Based on sewage sludge experience, it is good practice to provide for pH control of the anaerobic digestion process. The pH in an anaerobic digester should be maintained in the range of 6.6 to 7.6 for a proper growth environment for the methane-forming organisms (21). Therefore, pH control of the septage feed to the digester should be provided. With a high pH, the production of ammonium increases and the production

of methane slows down (42). Lime, soda ash, sodium bicarbonate, etc., can be used to adjust the pH of the septage as required. Sufficient alkalinity should be present to ensure that the pH will not drop below 6.2, since the methane bacteria cannot function below that level (21). The alkalinity of undigested primary sludge ranges from 500 to 1500 mg/L (average 600 mg/L) as $CaCO_3$ (21). As discussed in Chapter 3, septage alkalinity typically ranges from 500 to 4000 mg/L (average 1000 mg/L) as $CaCO_3$; therefore pH depression due to insufficient alkalinity should not be a common problem during anaerobic digestion of septage.

7.6.3.4 Mixing

Proper mixing is one of the most important considerations in achieving optimum process performance (21). Draft tubes, mechanical mixers, and gas recirculation mixers are most commonly used in anaerobic digesters. Mixer sizing and design criteria depend on the type of digester tank and on the type of mixing system selected.

The researchers whose work was summarized in Section 7.6.1 report no difficulties in mixing septage, compared with sewage sludge, during anaerobic digestion. General design guidelines applying to treatment of sewage sludge (21)(34)(36) should also apply to the treatment of septage with the exception of grease interference with mixing. The major concern which designers must deal with is the high grease concentration of septage, which can interfere with proper digester mixing.

7.6.3.5 Heating Requirements

Digester heating requirements consist of the amount needed to: raise the incoming septage to digestion-tank temperature; compensate for the heat losses through digester walls, floor, and roof; and make up for heat losses in external piping (21). The requirements for heating septage and for insulating against heat losses have not been reported to be different from those of sewage sludge. Tchobanoglous (21) presents an excellent procedure for calculating energy requirements for raising influent temperature and for computing heat losses through the tank itself and through external piping. This calculation procedure illustrates the benefits of insulating and/or burying tankage and piping to minimize heat losses.

7.6.3.6 Operating Temperature

Optimum temperature ranges for anaerobic digestion are the mesophilic, 30 to 38°C (85 to 100°F) and the thermophilic, 49 to 57°C (120 to 135°F). These higher temperatures provide more rapid pathogen destruction (as was shown in Figures 7-8 and 7-9) and require shorter detention times.

7.6.3.7 Typical Design Criteria

Table 7-9 is a summary of the typical design criteria for anaerobic stabilization of septage.

7.6.4 Limitations

The limitations of anaerobic digestion include its relatively high capital cost (compared with aerobic digestion), sensitivity to upset, monitoring requirements, poor quality supernatant (high oxygen demand and high concentrations of nitrogen and suspended solids), and relatively long detention time required for stabilization (34).

7.6.5 Monitoring

The following parameters must be monitored for control of anaerobic digestion: pH, temperature, and presence of toxic materials.

7.6.5.1 pH

Close pH control is necessary because methane-formers are extremely sensitive to slight changes in pH. The pH should be monitored within the range of 6.6 to 7.6 (36). Methods for maintaining the pH in this range are discussed briefly in Section 7.6.3.3, and in more detail elsewhere (21) (34).

7.6.5.2 Temperature

More important than maintenance within a particular temperature range is maintenance of the chosen temperature for operation at a constant value. Based on experience with sewage sludge, a temperature change of

TABLE 7-9

TYPICAL DESIGN CRITERIA FOR
ANAEROBIC STABILIZATION OF SEPTAGE

Parameter	Value	Remarks
Solids Retention Time, days	10 - 30 (heated)	High-rate: 10 days minimum Low-rate: 30 days minimum Higher temperatures require shorter SRT
VSS Loading, $kg/m^3/d$	0.5 - 1.6	For VSS reduction >40%
pH Control	6.6 - 7.6	Sufficient alkalinity required to maintain pH > 6.2; otherwise, methane-formers cannot function.
Operating Temperature		
Mesophilic °C	30 - 38	
Thermophilic °C	49 - 57	

2 or more degrees can be sufficient to disturb the dynamic balance between the acid and methane formers. Such a disturbance can lead to an upset because the acid formers are able to respond more rapidly to changes in temperature than are the methane bacteria (34).

7.6.5.3 Toxicity

Toxicity can be due to an excessive quantity of any material, even a substance normally considered a nutrient. The concentration at which a substance starts to exert a toxic effect is difficult to define because it can be modified by antagonism, synergism, and acclimation. In addition, the organic loading and biological solids retention time can cause a stress on the process, and this stress can affect toxicity. The substances that can produce toxicity when present in municipal sludge or septage in an excessive concentration include heavy metals, sulfides, surface active agents, light metals, and certain organics. General information on some potentially toxic substances is given in Table 7-10 (34) (36). Compared with sewage sludge, the septage concentrations of heavy metals are generally lower, while sulfide and surfactant concentrations are generally higher. It can, therefore, be assumed that any potential for toxic effects during anaerobic digestion would more likely be associated with sulfides and surfactants rather than heavy metals if septage is purely domestic. However, the problem of industrial waste contamination and lack of control at the receiving station could create a significant risk if anaerobic digestion were chosen as the stabilization method.

7.6.6 Process Modifications

The two most common modifications of the anaerobic digestion process are thermophilic anaerobic digestion and the anaerobic contact process. Thermophilic anaerobic digestion operates in the temperature range of 49 to 57°C (120 to 135°F). The advantages of thermophilic over mesophilic anaerobic digestion include faster reaction rates (which permit lower detention times), improved dewatering of digested septage, and increased destruction of pathogens (36). The last advantage places thermophilic digestion into the PFRP category (Process to Further Reduce Pathogens). Disadvantages of thermophilic digestion include higher energy requirements for heating; lower quality supernatant containing larger quantities of dissolved materials; and poorer process stability. Thermophilic organisms are particularly sensitive to temperature fluctuation (36).

TABLE 7-10

SUBSTANCES AND CONCENTRATIONS CAUSING TOXICITY IN WASTEWATER SLUDGE DIGESTION (34) (36)

Substance	Concentration (mg/L)
Volatile Acids	6,000 - 8,000
Sulfides	200
Soluble Heavy Metals	> 1
Sodium	5,000 - 8,000
Potassium	4,000 - 10,000
Calcium	2,000 - 6,000
Magnesium	1,200 - 3,500
Ammonium	1,700 - 4,000
Free Ammonia	150

The anaerobic contact process is the anaerobic equivalent of the activated sludge process. The unique feature of this variation is that a portion of the active biomass leaving the digester is concentrated and then mixed with the raw feed. This recycling allows for adequate cell retention time to meet kinetic requirements while operating at a significantly reduced hydraulic retention time. This process modification has not been widely applied for sewage sludge because of the difficulty in achieving the necessary concentration within the return stream (36), and its use has not been reported for septage.

7.7 Lime Stabilization of Septage

Lime stabilization is a low capital cost, simple technology. Addition of lime to septage in sufficient quantities to maintain a high pH (>12) for 30 minutes creates an environment that is not conducive to microorganism survival. This criterion (pH > 12 for 30 minutes) has been found to correlate well with dewaterability and odor conversion in U.S. practices. As a result, the septage will not putrefy, cause odors, or pose a health hazard as long as the pH is maintained at a high enough level (21)(35). Actual dosage may require adjustment due to local conditions and the period of stability required.

Lime stabilization may be followed by a dewatering step, or the stabilized liquid septage may be spread on the land directly (20). Since lime stabilization, unlike aerobic or anaerobic digestion, does not destroy the organics necessary for bacterial growth, the septage must be disposed of before the pH drops significantly or it can become reinfested and putrefy (21). Lime addition to septage may reduce nitrogen concentration through volatilization of ammonia if conditions permit this stripping, often enabling greater quantities of stabilized septage to be applied per unit of land area, since such applications are often limited by nitrogen loading (see Chapter 5). Lime stabilization is, therefore, only a temporary stabilization which enables further handling and disposal to take place prior to the onset of destabilization.

7.7.1 Research - Lime Stabilization of Septage

It has been shown that achieving a high pH is not as important as maintaining a high pH for a certain period of time (1)(45). Enough lime must be added to provide a sufficient degree of stabilization to permit a storage/handling time period of about 14 days so that the septage can be ultimately disposed of in an environmentally-sound manner. A 14-day time period has been used by researchers to allow for odor control during storage (46). Paulsrud and Eikum (46) found that the lime dosages necessary to reach a high initial pH (10.0, 10.5, 11.5)

were not sufficient to maintain a high pH during storage. They further found that lime dosages to raise the pH to initial values of 12.5 or higher produced the most stabilized septage samples. These dosages were sufficient to prevent pH reduction within four weeks of storage, as shown in Figure 7-12. They concluded that a lime dosage of 100 to 300g lime/kg SS (200 to 600 lb lime/ton SS) would be necessary to prevent pH reduction and odor production within 14 days of storage. These dosages are to maintain pH $>$ 11 at 20°C (68°F) during the 14-day storage period. These researchers found that thickening does not alter the lime dosage necessary to prevent pH reduction during storage, that both microbial activity (measured by ATP) and CO_2 uptake from the air are responsible for the pH reduction during storage, and that higher storage temperatures result in greater pH reductions.

Some investigators have commented on the change in odor intensity during lime stabilization. Eikum (1) noted that, during storage of lime stabilized septage, as soon as the pH fell below 11.0, the odor increased considerably. In addition, an increase in the Odor Intensity Index (OII) (ASTM Method D 1292) was normally experienced during storage, regardless of the amount of lime added. This increase took place during the first eight days of storage, but was slowed by higher lime levels, as shown in Figure 7-13.

Although the odor intensity generally remains the same, the type of odor changes as a result of lime addition (1)(45). During full-scale operations at the Lebanon plant (49) it was noted that odor was intense when raw septage was first pumped to the lime stabilization mixing tank. Odor intensity increased when diffused air was used for mixing. When lime was added, the septic odor was masked by the odor of ammonia, which was stripped from the septage by the air bubbled through it. As mixing proceeded, the treated septage acquired a musty, humus-like odor. Lime stabilization studies conducted at the Lebanon plant for both septage and sewage sludge showed that odor reduction was significantly greater for sewage sludge than for septage.

High pH not only reduces odors but also inhibits pathogen growth. Work by Farrell, et al. (47) and Counts, et al. (48) has shown that lime stabilization will reduce pathogens in sludges. However, most work has been based on 24-hour storage after lime addition. Since the stability concept is based on several days of storage after lime addition, it is necessary to look at the removal of pathogens with respect to lime dosage and storage period.

FIGURE 7-12
CHANGE IN pH DURING STORAGE OF SEPTAGE AT 20°C (68°F)
USING DIFFERENT LIME DOSAGES (46)

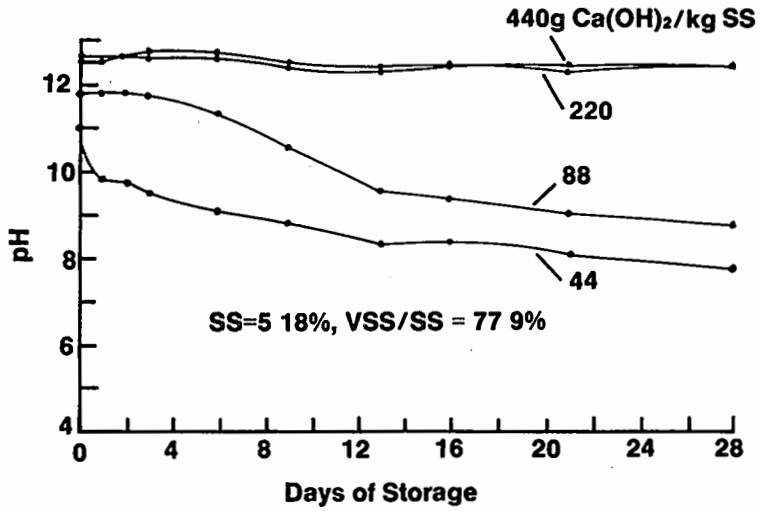
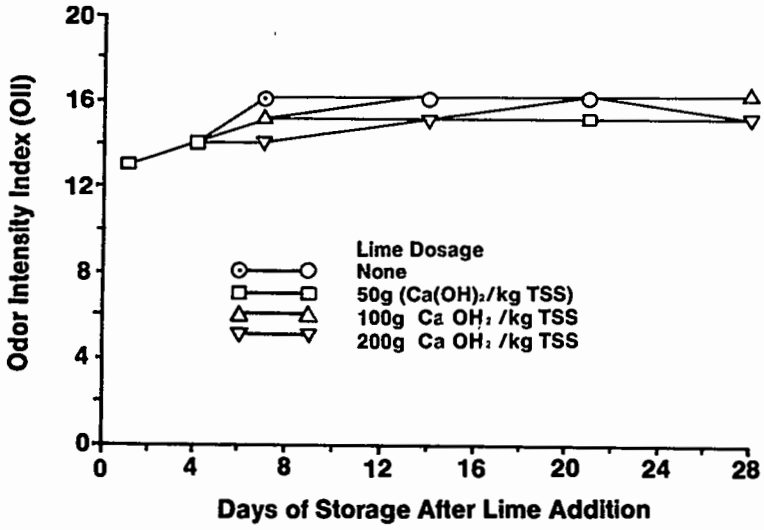


FIGURE 7-13
CHANGE IN ODOR INTENSITY INDEX DURING STORAGE
OF LIME STABILIZED SEPTIC TANK SLUDGE AT 68°F (20°C) (1)



Work done at the Norwegian Institute for Water Research (1) shows that a reduction of coliforms and fecal streptococci takes place during storage of sludges (primary, primary/alum, biological/alum) even without lime addition. However, this was not found to be true for septage. Anaerobic spore formers were not affected by storage period alone. At a lime dosage of 50g lime/kg SS (100 lb lime/ton SS), it was found that the concentrations of the organisms investigated were not reduced. This was true for all types of sludges. With septage, this dosage of lime even indicated an increase in the number of organisms in some cases. A lime dosage of 200g/kg SS (400 lb lime/ton SS) used during the investigation clearly showed that the pathogen concentration can be reduced below the detectable limit of 200 organisms per 100 ml for septage as well as for sludges. In many cases, it took approximately 2 hours of contact time to get below the detectable limit.

Noland, et al. (45) added lime to septage to maintain pH 12 for 30 minutes. Pathogens were reduced significantly as shown in Table 7-11. In addition, total COD, phosphate, TKN, and VSS were reduced by lime stabilization, while alkalinity, soluble COD, ammonia nitrogen, and TSS increased, as shown in Table 7-12.

7.7.2 Equipment

Two process trains most applicable to the lime stabilization of septage are shown in Figure 7-14 (1). Lime stabilization facilities should consist of at least a method of lime feeding, a mix tank, and pH monitoring. Mixing can be accomplished by either diffused aerators or mechanical mixers. Thickening, if desired, can occur in a separate tank or batchwise in the mix tank after shutting off the mixing device.

7.7.3 Design Criteria

The two most important criteria for design of a septage lime stabilization facility are lime dosage/pH and mixing/contact time. Detailed discussion of the design procedure for lime-handling facilities can be found elsewhere (36).

TABLE 7-11

BACTERIA IN RAW AND LIME-STABILIZED SEPTAGE AT LEBANON, OHIO (45)

Parameter	Bacterial Density, Number/100 ml	
	Raw Septage	Lime-Stabilized Septage[a]
Total Coliform[b]	2.9×10^8	2.1×10^3
Fecal Coliform[b]	1.5×10^7	265
Fecal Streptococci	6.7×10^5	665
Salmonella[c]	6	<3
Ps. Aeruginosa[c]	754	<3

[a]To pH $\geqslant$ 12 for at least 30 minutes.
[b]Millipore filter technique used.
[c]Detection limit = 3.

TABLE 7-12

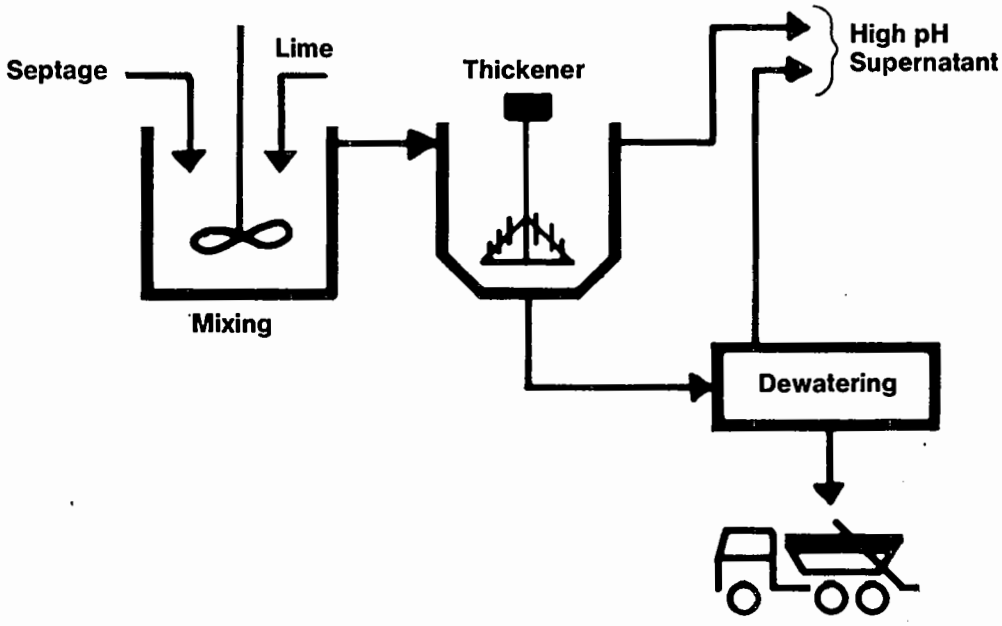
CHEMICAL COMPOSITION OF RAW AND LIME STABILIZED SEPTAGE AT LEBANON, OHIO (45)

Parameter	Concentration, average, mg/L	
	Raw Septage	Lime-Stabilized Septage[a]
Alkalinity	1,897	3,475
Total COD	24,940	17,520
Soluble COD	1,223	1,537
Total Phosphate	172	134
Soluble Phosphate	25	2.4
Total Kjeldahl Nitrogen	820	597
Ammonia Nitrogen	92	110
TSS	21,120	23,190
VSS	12,600	11,390

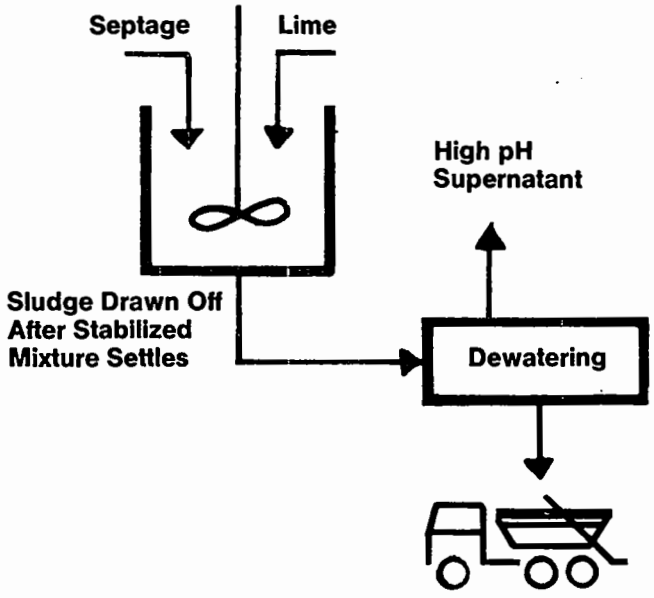
[a]To pH $\geq$12 for at least 30 minutes.

FIGURE 7-14
COMMON LIME STABILIZATION PROCESS TRAINS

Alternative 1 - Continuous Feed



Alternative 2 - Batch Treatment



7.7.3.1 Lime Dosage/pH

The amount of lime required to stabilize septage depends primarily on its chemical composition and solids concentration. Dosages reported by various investigators are summarized in Table 7-13. A relationship between pH and lime dosage at various initial SS concentrations is shown in Figure 7-15 (45). Noland, et al., (45) examined the effects of excess lime addition above the levels necessary to reach pH 12. They found that there was a negligible drop in pH over a 10-day period, and concluded that significant pH decay should not occur once sufficient lime has been added to maintain the sludge pH at 12.0 for at least 30 minutes. Their conclusion was based on studies with primary sludge. EPA considers lime stabilization an accepted PSRP (Process to Significantly Reduce Pathogens). The definition given in 40 CFR 257 calls for the addition of "sufficient lime to produce a pH of 12 after 2 hours of contact." Based on the findings of Paulsrud and Eikum (46), lime addition at a rate sufficient to maintain pH 11.0 for at least 14 days of storage at 20°C also would fulfill the PSRP requirement.

The lime dosages predicted by the "Counts Equation" were compared with the actual lime dosages required at the Lebanon plant (45). The Counts Equation (Equation 2) was developed to predict lime dosages for primary and secondary sludges from the trickling filter plant in Richland, Washington (48).

$$\text{Lime Dose} = 4.2 + 1.6\ (TS) \qquad (2)$$

where:

Lime dose = Grams lime/liter of sludge
TS = Total solids fraction in sludge

It was found that with increasing solids concentrations, the Counts Equation results in lower than actual required lime dosages (45).

7.7.3.2 Mixing/Contact Time

The design objective is to maintain pH above 12 for about 2 hours and to provide enough residual alkalinity so that the pH does not drop below 11 for at least 14 days to ensure pathogen destruction, thereby allowing sufficient time for disposal or use without the possibility of renewed putrefaction.

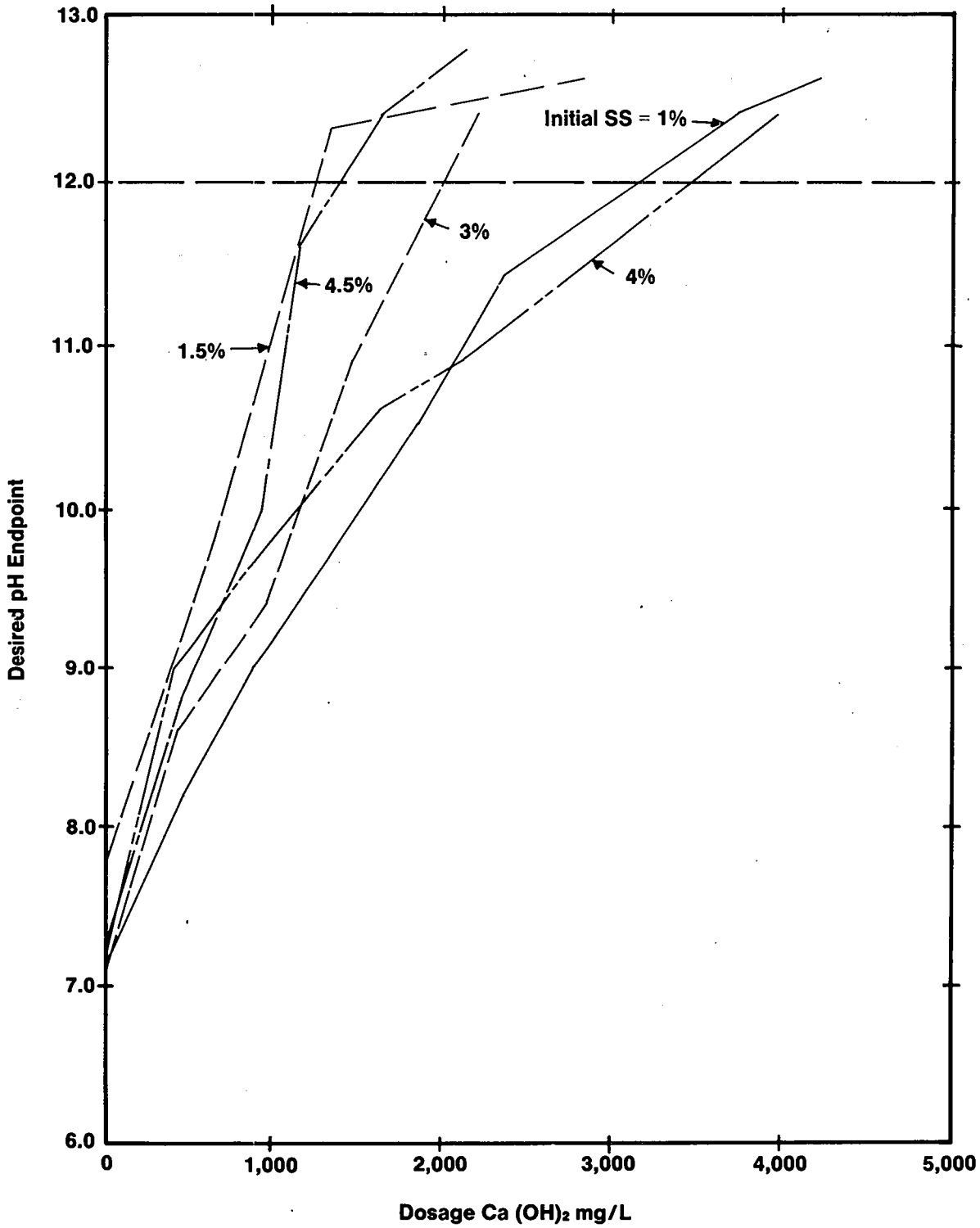
TABLE 7-13

REPORTED VALUES OF LIME REQUIREMENTS FOR SEPTAGE STABILIZATION

Reference	Total Solids Concentration Percent	Lime Dosage, kg lime/kg dry solids Average	Range
45	1 to 4.5	0.20	0.09 to 0.51[a]
46	5.1	0.125	0.10 to 0.30[b]
49	3.1 to 4.5	0.10	0.053 to 0.11[c]

[a]Lime required to maintain pH $\geq$12.0 for 30 minutes.
[b]Lime required to maintain pH $>$11 for 14 days.
[c]Lime required to raise pH to 11.5.

FIGURE 7-15
LIME DOSAGE VERSUS pH (45)



The lime mixing tank should be sized to provide a minimum of 30 minutes' contact time at peak flow. In the case of a small treatment facility, where batch processing is most attractive, the mix tank should be sufficiently large to treat the maximum-day septage production in one batch, particularly if the treatment facility is to be operated only one shift per day. Norwegian guidelines call for a minimum of 15 minutes detention in the mixing tank if followed by thickening or aerated storage, with 30 minutes being otherwise required (1).

Mixing can be provided by either diffused air or mechanical mixers, but the former is preferred both in the United States (45) and Norway (1). Air requirements of 150 to 250 m^3/min/1000m^3 (150-250 cfm/ 1000 ft^3) of mixing tank volume for coarse bubble diffusers have been suggested (45). The diffusers should be mounted such that a spiral roll is established in the mixing tank away from the point of lime slurry application. In addition, the diffusers should be accessible, and piping should be kept against the tank wall to minimize the collection of rags, etc.

Mechanical mixer sizing should be based on the following two criteria (36):

- Maintaining the bulk fluid velocity (turbine agitator pumping capacity - cross sectional area of the mixing vessel) above 7.9 m/min (26 ft/ min).
- Using an impeller Reynolds number greater than 1000.

Noland, et al. (1978) (45) reported that mechanical mixing has been used by previous researchers for lime stabilization, but only on the pilot scale. Section 9 of the report by Noland (45) discusses selection of mixer horsepower.

Although lime may be added in the slurry or dry form, the former is generally preferred for larger installations. Dry lime addition for batch processing at smaller facilities is less efficient, but far easier for operators.

A summary of the design criteria for lime stabilization of septage is presented in Table 7-14.

TABLE 7-14

TYPICAL DESIGN CRITERIA - LIME STABILIZATION OF SEPTAGE

Parameter	Value	Remarks
Lime Dosage		
kg lime/kg dry solids	0.1 - 0.3	Dosage must be sufficient to maintain pH of 12.0 for at least 2 hours or above 11.0 until further processing[a]
Contact Time, min	30	At peak flow
Mixing Requirements		
Air, $m^3/1000\ m^3/min$	150 - 250	
Mechanical		
Bulk fluid velocity m/min	4.6 - 7.9	
Impeller Reynolds Number	>1000	

[a]Specific dosage must be adjusted to the purpose of lime stabilization and site conditions.

7.7.4 Limitations

Limitations of lime stabilization of septage are:

1. Lower fertilizer value (soluble phosphate, ammonia nitrogen, TKN, etc.) than comparable digested sludge (45).

2. O&M problems due to scaling in the lime addition system.

3. No reduction of organics.

4. Potential for fecal streptococci to remain viable, although regrowth of other bacteria is minimal (45).

5. Lime addition significantly increases the quantity of material for disposal.

6. High pH sludge liquor to treat or dispose of, if separation or dewatering follows this process.

7.7.5 Monitoring

As discussed above, the requirements for lime stabilization include maintaining the pH at 12.5 or greater for at least 30 minutes. This can be accomplished in a batch system by monitoring the pH throughout the lime addition, and for a minimum of 30 minutes thereafter.

In continuous flow systems, automated control of lime feeding may be required. The pH is normally measured in the exit line from the mix tank. The pH and volume of septage in the mix tank are held constant. Entering raw septage displaces an equal volume of treated septage. Lime is added continuously, in proportion to the flow of incoming raw septage; therefore, the holding time can vary. If the pH of the limed septage appears to fall too rapidly upon standing, the pH controller for the lime feed rate can be adjusted to a higher set point.

7.8 Chlorine Oxidation (Purifax TM)

The BIF-Purifax™ process utilizes chlorine gas in solution to oxidize various types of waste sludges, including septage. Chlorine oxidation stabilizes sludges and septage both by reducing the number of organisms present and by making organic substrates less suitable for bacterial metabolism and growth (36).

The Purifax™ process involves oxidation of several septage constituents with high dosages of chlorine gas, which is applied directly to the septage in an enclosed reactor for a short time. Because of the reaction of chlorine gas with the septage, significant quantities of hydrochloric acid are formed, and the stablilized septage has low pH (about 2). The reactor vessel is moderately pressurized (207 to 275 kn/m^2 or 30 to 40 psi) to ensure more complete absorption of the chlorine gas as well as adequate chlorination penetration into the larger particles in the sludge (51). At these pressures, the gases formed are supersaturated in the treated septage. When discharged from the reactor vessel at atmospheric pressure, these gases come out of solution as fine bubbles that float the septage solids. The process is followed by dewatering, generally on sand beds.

Chlorine oxidation, like lime stabilization, does not completely destroy organic matter or solids during septage treatment. It can, however, produce a relatively biologically stable end-product, which is dewaterable and which does not have an offensive odor. Because chlorine reactions with sludge and septage are very rapid, reactor volumes are relatively small; therefore, compared with biological digestion processes, Purifax™ system sizes are generally smaller, and capital costs may be lower, depending on the site-specific circumstances. In addition, Purifax™ systems can be run intermittently (unlike biological processes) so long as sufficient storage volume is available both upstream and downstream of the reactor. As a result, operating costs are more directly dependent on septage production rates. Septage treatment facilities utilizing Purifax™ include Babylon, New York; Ventura, California; Putnam, Connecticut; and Bridgeport, Connecticut.

7.8.1 Research

Pilot testing of the Purifax™ process was conducted at the Lebanon, Ohio treatment plant which addressed chlorine requirements, dewatering rate, and sand bed underdrainage quality (51). The study concluded the following:

1. The chlorine oxidation process, in conjunction with sand bed dewatering, was an effective septage treatment method.

2. The sand bed underdrainage quality, compared with untreated septage, indicated the following removals: COD, 98 percent; BOD, 95 to 97 percent; total phosphorus, 99 percent; ammonia, 55 to 75 percent.

3. Mass balance calculations indicate that the sand dewatering beds following the Purifax™ process were the site of the majority of the organic and nutrient removal. It is possible that after repeated application, the removal capacity of the sand would be exhausted.

4. Large dosages of chlorine (1000 to 3000 mg/L) were required for the process to operate satisfactorily.

5. Chlorinated organics formed during processing appeared to be tied up in the sludge solids. The ultimate fate of these organics and their effects on the environment are not well documented.

The pilot testing also showed that Purifax™ treatment of septage produced a solids fraction with greatly reduced total and fecal coliform concentrations, although coliform concentrations in the sand bed underdrainage were quite high, as summarized in Table 7-15 (20). Analyses of the dried solids for bacteriological regrowth were not performed. The average chlorine dose used during the pilot testing was 0.0021 kg Cl_2/L septage or 0.115 kg Cl_2/kg dry solids.

TABLE 7-15

BACTERIOLOGICAL DATA[a]
PURIFAX™ TREATMENT OF SEPTAGE (20)

	Total Coliform (counts/100 ml)	Fecal Coliform (counts/100 ml)
Raw Septage	4.4×10^7	5.3×10^6
Purifax™ Treated Septage[b]	200	200
Sand Bed Underdrainage	6.9×10^6	3.2×10^4

[a]Values are averages of four runs.
[b]Dewatered solids.

7.8.2 Equipment

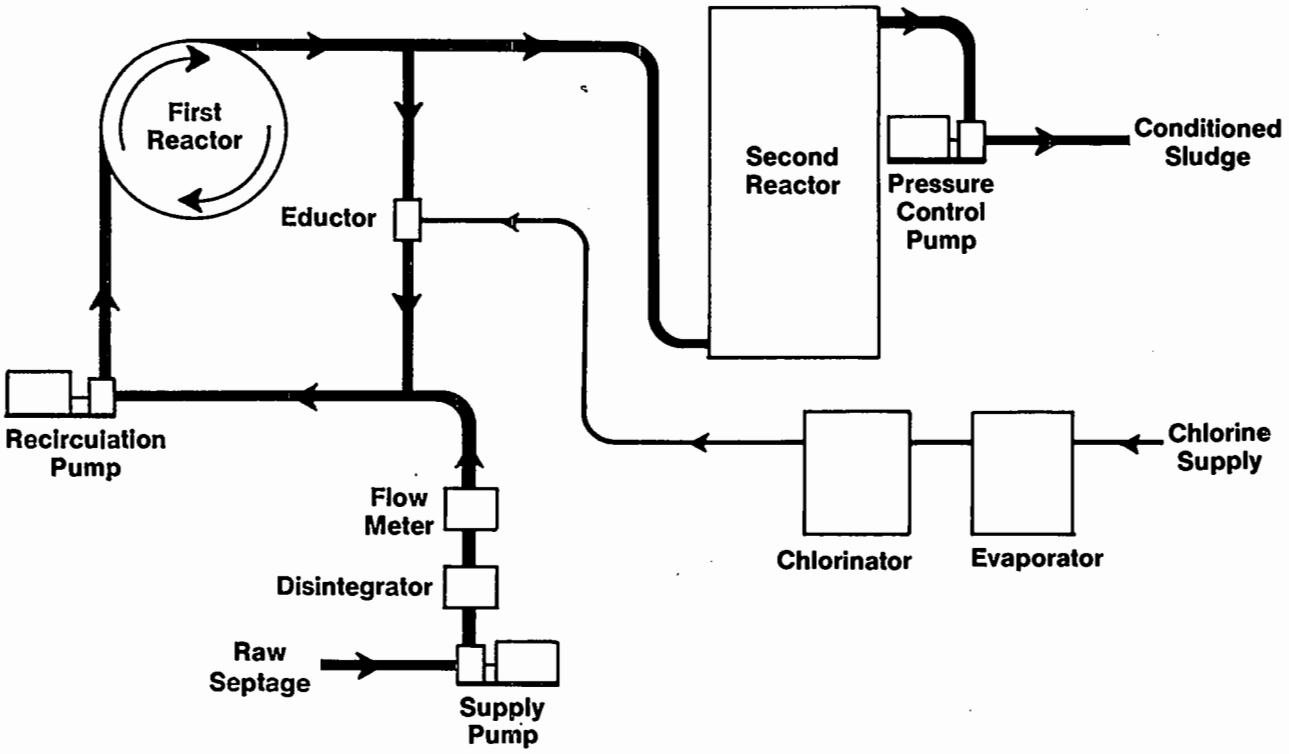
A schematic diagram of a chlorine oxidation system is shown in Figure 7-16 (36). The heart of the Purifax™ system consists of a disintegrator, a recirculation pump, two reaction tanks, a chlorine eductor, and a pressure control pump. The chlorine can be fed to the system through a chlorinator and/or evaporator. An influent feed pump and flow meter should also be provided.

Raw septage is pumped through the disintegrator to reduce particle size and increase particle surface area for contact with the chlorine. Chlorinated septage from the first reactor is mixed with raw septage just prior to reaching the recirculation pump. The combined flow then passes through the first reaction tank. Chlorine is added to the system by means of an eductor in the recirculation loop. Recirculation aids mixing and efficient chlorine use. The ratio of recirculated reacted product to raw septage is normally about 7 to 1. System pressure (210 to 275 kn/m^2 (30 to 40 psi) is maintained by a pressure control pump located at the discharge of the second reactor tank, which has been provided to increase system detention time to allow for a more complete reaction between septage and chlorine.

A holding/equalization tank should be provided upstream of the oxidation system. Mechanical mixing can be used, although air mixing is preferable because it enhances aerobic conditions and reduces odors (36). A particular benefit of Purifax™ treatment of septage is that odor can be controlled in the holding tank by returning a portion of the filtrate or supernatant from the dewatering process. Ventilation of such tanks must be provided.

A downstream holding tank is beneficial in that it ensures optimum functioning of subsequent processes, and it allows the chlorine residual to drop from approximately 200 mg/L to about 0, and the pH to rise to between 4.5 and 6.5 (36). Lombardo (33) has noted that this process takes approximately 48 hours.

FIGURE 7-16
CHLORINE OXIDATION SYSTEM (36)



7.8.3 Design Criteria

7.8.3.1 Size

The Purifax™ unit is available over a wide range of flow capacities, from 55 m^3/d (10 gpm) to a theoretically unlimited maximum. Sizing information is available from BIF, the manufacturer of Purifax™ (33). BIF suggests that the system be dimensioned such that the daily volume of septage can be treated in 4 to 6 hours (42). Most chlorine-oxidation units are of a prefabricated, modular design, completely self-contained and skid-mounted (21).

7.8.3.2 Chlorine Requirements

Chlorine dosages vary from 700 to 3000 mg/L, depending on the solids content of the septage and the amount of chlorine-demanding substances present (20). These substances include ammonia, amino acids, proteins, carbonaceous material, hydrogen sulfide, etc. The Babylon, New York septage treatment facility uses about 0.6 kg Cl_2/L influent (5 lb /1000 gal) (52).

BIF recommends a chlorine dosage of approximately 0.7 kg Cl_2/L influent (6 lb/1000 gal) for septage with a suspended solids concentration of 1.2 percent. The chlorine demand varies in proportion to the solids concentration. For example, if the solids concentration were to double, the chlorine concentration would double as well (36).

7.8.3.3 Typical Design Criteria

A summary of the typical design criteria for chlorine stabilization of septage is presented in Table 7-16.

7.8.4 Limitations

Limitations of the chlorine stabilization process center on chemical, operational, and environmental factors. From a chemical standpoint, the low pH of chlorine-stabilized septage may require neutralization prior to mechanical dewatering or before being applied to acid soils. Costs of neutralization are in addition to chlorine costs. Chlorine stabilization does not reduce sludge mass nor produce methane gas as a by-product for energy generation. The process consumes relatively large amounts of chlorine. Special safety and handling precautions must be

used when employing this system. If high alkalinity wastes are processed, CO_2 generated during chlorination may promote cavitation in downstream pumps (36). The potential for production of carcinogenic compounds by the chlorine-oxidation process has been a major concern, since these compounds may leach into the ground or contaminate surface waters as a result of sludge or liquid effluent disposal.

TABLE 7-16

TYPICAL DESIGN CRITERIA FOR CHLORINE STABILIZATION OF SEPTAGE[a]

Parameter	Value	Reference
System Size	To treat daily septage volume within 4 to 6 hours	42
Chlorine Dosage	0.7 kg/L for 1.2% TS - chlorine demand varies directly with TS	36

[a]BIF - Purifax Process.

The effluent (filtrate, supernatant) from the dewatering step is not suitable for direct discharge into surface waters. Infiltration/percolation beds have been used for effluent disposal (33). Alternative disposal methods have included direct recycle to a treatment plant or direct discharge following activated carbon adsorption (36).

7.8.5 Monitoring

The major parameters used to control the Purifax™ process are treated septage color, effluent pH, and effluent chlorine residual. The chlorine dose can be adjusted until the effluent stream is a light buff color with a pH of 2 to 2.5, and a chlorine residual of 150 to 200 mg/L (51).

7.9 Conditioning

Septage is conditioned primarily to improve its solids separation and/or dewatering characteristics. The most commonly used method of septage conditioning is chemical addition. Chemicals are added to coagulate septage solids and to release bound water. The chemicals most commonly used for septage conditioning are ferric chloride, lime, alum, organic polymers, and, less frequently, acids. These chemicals can be used alone or in combination. Table 7-17 summarizes the advantages and disadvantages of each of these septage-conditioning chemicals. Chemical selection should be based on several factors, including the following: ultimate disposal method for the dewatered sludge; local chemical costs and availability; required operator training and experience; specific site restrictions and requirements; and conditioning efficiency, based on laboratory studies.

7.9.1 Research

Many studies have shown that untreated septage neither thickens well (see Table 7-18) nor filters well. Table 7-19 summarizes conditioning studies with $FeCl_3$ alone and with lime. Tables 7-20 and 7-21 summarize conditioning with alum and with acid/lime, respectively.

Tawa identified three types of septage (53). Type I septages are watery, settle well, and have relatively low solids contents. Type III septages settle very little (if at all) and have high solids levels. Between these two extremes are Type II septages, which evidence some settling and have characteristics in the median range. Tawa found that $FeCl_3$ and alum are equally effective in treating septage, and that a cationic polymer (Calgon ST-266, which is no longer manufactured) achieved noticeably better solids settling than inorganic salts, while at the same time removing more solids from the supernatant portion and enhancing dewatering.

TABLE 7-17

SUMMARY OF THE CHARACTERISTICS OF SEPTAGE-CONDITIONING CHEMICALS

Chemical	Advantages	Disadvantages	Remarks
Ferric Chloride ($FeCl_3$) with or without lime	Cost may be less than alum.	Iron compounds are corrosive.	Dosages determined by jar tests.
	Precipitates solids and phosphorus.	Increases amount of solids for disposal.	$FeCl_3$ reduces alkalinity; may need supplemental source of alkalinity.
			Depresses pH; phosphorus, etc., can resolubilize if pH drops too low (pH 4) (53).
Aluminum Sulfate (Alum) $Al_2(SO_4)_3 \cdot 14\ H_2O$	Precipitates phosphorus and solids.	Somewhat corrosive when exposed to humidity.	Dosages determined by jar tests.
			Alum reduces alkalinity; may need supplemental source of alkalinity.
		Increases amount of solids for disposal.	Depresses pH; phosphorus, etc., can resolubilize if pH drops too low (pH 5) (53).
Sulfuric Acid (H_2SO_4) with or without lime	Some researchers noted improved phase separation over both $FeCl_3$ and alum.	Highly corrosive to equipment.	Dosages controlled by pH measurements.
	Simplified dosage control (no jar tests).	Must readjust pH to neutral to protect subsequent processes and equipment.	
Lime ($Ca(OH)_2$)	Precipitates phosphorus and solids.	Greatly increases solids for disposal.	Dosages determined initially by jar tests, but pH generally used.
	Precipitates some heavy metals.		
	Provides some pH control, odor reduction, disinfection, filter aid effect.		
Polymer(s)	Improves settleability, dewaterability.	Most polymers are considerably more expensive than inorganic conditioners.	Dosages determined by jar tests.
	Preferred conditioning chemical for dewatering prior to incineration - does not lower fuel value of solids.	Does not remove phosphorus.	Cationic polymers shown to be most effective with septage.
	Dosage of other conditioning chemical(s) can be lowered when polymer is used.		

TABLE 7-18

SUMMARY OF STUDIES ON THICKENING RAW SEPTAGE

Raw Septage mg/L	Supernatant mg/L	Settling Time	Reference
TS - 18,300 TVS - 11,530 TSS - 14,000 BOD_5 - 12,400 COD - 62,500	Average Settleable Solids 24.7% Nine of 21 samples showed no separation	30 minutes	26
TS - 11,800 TVS - 9,280 TSS - 8,680 BOD_5 - 5,850 COD - 20,400	TS - 9,630 TVS - 8,310 TSS - 4,880 BOD_5 - 4,900	48 hours	29
TS - 41,900 TVS - 31,800 SS - 39,100 COD - 3,360	No settling observed	1 hour	54
TS - 22,400 TVS - 15,200 BOD_5 - 4,794 COD - 26,162	TSS - 2,350 VSS - 1,819 BOD_5 - 1,948 COD - 6,343	1 hour	44
TS - 39,500 TVS - 27,370 COD - 60,582	23 of 26 samples showed no separation	24 hours	49
TS - 29,840 TVS - 19,910 COD - 36,770	TS - 3,800 TVS - 2,510 COD - 23,660	1 hour	55

TABLE 7-19

SUMMARY OF FERRIC CHLORIDE AND FERRIC CHLORIDE/LIME CONDITIONING STUDIES

Study Type Ref	Influent Septage mg/L	Overflow Quality mg/L	Dosage and Mixing	Comments
Lab Study $FeCl_3$ Only (29)	TSS - 9,790 VSS - 7,990 BOD - 7,980 COD - 26,100 Alk. - 293 as $CaCO_3$	TSS - 271 VSS - 240 BOD - 664 COD - 5,480 Alk. - 135 as $CaCO_3$	$FeCl_3$ - 400-600 mg/L Rapid Mix - 30 min Slow Mix - 90 min Settling Time - 22 hr	Difficult to define phase separation. Testing performed on finely-screened septage
Pilot Study $FeCl_3$ plus Lime (29)	TSS - 9,220 VSS - 7,960 BOD - 4,290 COD - 11,300 Alk. - 743 as $CaCO_3$	TSS - 108 VSS - 7,960 BOD - 610 COD - 5,480 Alk. - 1,780 as $CaCO_3$	$Ca(OH)_2$ - 4,000 mg/L $FeCl_3$ - 400 mg/L Rapid Mix - 30 min Slow Mix - 90 min Settling Time - 22 hr	Difficult to define phase separation. Phosphorous removal 77%. Testing performed on fine-screened septage.
Lab Study $FeCl_3$ Only (55)	TS - 29,000 TVS - 20,000 COD - 36,800	TS - 2,160 TVS - 1,180 COD - 2,500	$FeCl_3$ - 400-1,000 mg/L Mix and settling times not given	
Pilot Study $FeCl_3$ plus Lime and Polymer (56)	TS - 2,390 SS - 250 VSS - 2,070 COD - 2,886	TS - 3,525 TSS - 23 VSS - 22 COD - 334	$FeCl_3$ - 409 mg/L $Ca(OH)_2$ - 9,595 mg/L Polymer - 10 mg/L Clariflocculator	
Lab Study $FeCl_3$ Only (30)	TSS - 17,440 - 52,700	No data	$FeCl_3$ - 360-2,140 mg/L Mix Time - 30 sec Settling Time - 60 min	Dosages necessary to reduce CST to 50 seconds.
Lab Study $FeCl_3$ Only (53)	TS - 5,000 - 35,000 COD - 10,000 - 30,000 BOD - 5,000 - 15,000	TS - 500 - 2,500 COD - 250 - 2,500 BOD - 100 - 1,500	Type I. $FeCl_3$ - 400-800 mg/L Rapid Mix - 2 min Slow Mix - 30 min Settling Time - 30 min	Type I septage - easily treated, good settling characteristics, 35-75% volume reduction after settling.
Lab Study $FeCl_3$ Only (53)	TS - 15,000 - 45,000 COD - 15,000 - 45,000 BOD - 7,500 - 25,000	TS - 500 - 2,500 COD - 250 - 2,500 BOD - 100 - 1,500	Type II. $FeCl_3$ - 1,000-2,000 mg/L Rapid Mix - 2 min Slow Mix - 30 min Settling Time - 30 min	Type II septage - fair settling characteristics, 10-40% volume reduction after settling, limited success using chemicals.
Lab Study $FeCl_3$ Only (53)	TS - 45,000 - 75,000 COD - 45,000 - 75,000 BOD - 25,000 - 50,000	No supernatant	Type III. $FeCl_3$ - 3,000 mg/L Rapid Mix - 2 min Slow Mix - 30 min Settling Time - 30 min	Type III septage - very poor settling characteristics, 0-15% volume reduction.
Lab Study $FeCl_3$ plus Lime (53)	TS - 15,000 - 45,000 COD - 15,000 - 45,000 BOD - 7,500 - 25,000	TS - 500 - 2,500 COD - 250 - 2,500 BOD - 100 - 1,500	Type II. $FeCl_3$ - 1,250 mg/L $Ca(OH)_2$ - 2,000 mg/L Rapid Mix - 2 min Slow Mix - 30 min Settling Time - 30 min	Type II septage - as above
Lab Study $FeCl_3$ plus Lime (53)	TS - 45,000 - 75,000 COD - 45,000 - 75,000	No supernatant	Type III. $FeCl_3$ - 2,000 mg/L $Ca(OH)_2$ - 3,000 mg/L	Type III septage - as above

TABLE 7-20

SUMMARY OF ALUM CONDITIONING STUDIES

Study Type Ref	Influent Septage mg/L	Overland Quality mg/L	Dosage and Mixing (Alum as Al^3)	Comments
Pilot Study (29)	TSS - 13,400 VSS - 10,600 BOD_5 - 5,250 COD - 13,500	TSS - 183 VSS - 139 BOD_5 - 293 COD - 407	Alum - 355-950 mg/L Rapid Mix - 30 min Slow Mix - 90 min Settling Time - 22 hr	Pilot plant - 4 cubic meter (1,000 gal) batch process. Data obtained using finely-screened raw septage. Range of alum does given is the range tested, not an optimum dose.
Pilot Study (55)	TSS - 9,950 TVS - 7,450 COD - 16,730 CST - 169 sec	TS - 950 TVS - 490 COD - 750 CST - 40 sec	Alum - 80 mg/L Mix Time - 30 min Settling Time - 24 hr	Study performed using 12,000 gal(45 cubic meters)
Lab Study (55)	TSS - 29,000 TVS - 20,000 COD - 37,000	TS - 2,500 TVS - 764 COD - 2,000	Alum - 100-200 mg/L Mixing/settling times not given	Alum dosage range for optimizing septage CST.
Lab Study (30)	TSS - 17,400-52,000 Avg.TSS - 33,800	No data	Alum - 40-210 mg/L Avg. - 132 mg/L Mix Time - 30 sec Settling Time - 60 min	Dosage ranges are those required to reduce CST to 50 seconds.
Lab Study (53)	TS - 15,000-45,000 COD - 15,000-45,000 BOD_5 - 7,500-22,500	TS - 500-2,500 COD - 250-2,500 BOD_5 - 10-1,500	Alum - 45-90 mg/L Rapid Mix - 2 min Slow Mix - 30 min Settling Time - 30 min	Dewatering characteristics poorer than $FeCl_3$, $Ca(OH)_2$, or polymer conditioning. Type II septage, as defined in Table 7-19.
Lab Study (53)	TS - 45,000-75,000	No separation observed	Alum - >135 mg/L	Type III septage, as defined in Table 7-19.

TABLE 7-21

SUMMARY OF ACID AND ACID/LIME CONDITIONING STUDIES

Study Type Ref	Test Parameters	Initial Septage Characteristics	Results
Pilot Study H_2SO_4 Only (29)	Acidified to pH 2 (H_2SO_4 dose = 3,000 - 4,000 mg/L[a] Mixing Time = 2 hr Settling Time = 22 hr	Screened Septage: TSS = 2,140 - 22,600 mg/L (Average = 8,690 mg/L Coliform Count: 4-6 million/100 ml	Supernatant: Vol = 59-92% of initial septage (Average = 78%). TSS = 83 - 190 mg/L (Average = 393 mg/L) Sludge: Vol = 8-41% of initial septage (Average = 22%). TSS = 9,440 - 52,650 mg/L (Average = 37,300 mg/L) Effective phase separation requires minimum 6-8 hr settling time Coliform count septage 30,000/100 ml after 4 hr; 20/100 ml after 16 hr Lime neutralization of overflow to pH 7 resulted in formation of minor precipitate
Pilot Study H_2SO_4 plus Lime (29)	Overflow from the acid conditioning described above was used for the feed to lime conditioning step. TSS = 83 - 1,900 mg/L (Average = 393 mg/L) Overflow adjusted to pH 11 ($Ca(OH)_2$ dose = 3,500 - 4,500 mg/L). Mixing Time = 30 min. Settling Time = 2 hr	Same as above	Supernatant: Vol = 74-95% of acidified supernatant (Average = 89%). TSS = 0 - 100 mg/L (Average = 69 mg/L) Sludge: Vol = 5-26% of acidified overflow (Average = 11%) TSS = 76 - 5,260 mg/L (Average = 3,020 mg/L) Very clear phase separation
Lab Study H_2SO_4 Only (57)	To pH 2-3		Acidification released an oily scum to the surface of the overflow Acidified overflows were more turbid than alum conditioned overflows Acidified sludges settled slower than alum Less defined interface than with alum

[a]Pilot studies showed that amount of acid necessary to lower septage pH to 2 was significantly greater than theoretical amount based on initial alkalinity.

Tawa also concluded that lime was the most unpredictable of all chemicals tested; there seemed to be no characteristics of a particular septage that would allow one to predict the effectiveness of lime for clarification, and lime was inferior to alum, ferric chloride, and polymer in improving supernatant quality. In addition, lime used in conjunction with ferric chloride, while greatly improving the dewatering characteristics of the settled solids, gave poorer supernatant quality than ferric chloride used alone. If, however, lime was added in a two-step process (i.e., lime added to the settled solids of a $FeCl_3$-treated sample), the dewatering characteristics of those solids could be conditioned to a level comparable with that achieved using ST-266.

Perrin studied the effects of conditioning on sand bed dewatering (30). The conditioning methods studied included freezing, aerobic digestion, and chemical conditioning. The study determined that freezing aerobically-digested septage improved the filterability but suggested that freezing not be used for conditioning, since it does not reduce the septic odor and since the dewaterability decreases after thawing as oxygen again enters the septage. Perrin's criterion for good dewaterability was a CST (capillary suction time) of 50 seconds or less, which resulted in total drainage of the septage on sand beds within 48 hours. The CST techniques employed in this study cannot be directly converted for use by others. Correlations of CST with dewaterability are functions the CST test procedure employed, mixing time and total solids content. Conditioning the septage with ferric chloride, alum, Purifloc C-31, and Purifloc C-41 resulted in a direct linear relationship between initial CST (i.e., CST of unconditioned septage) and the chemical dosage required to reduce CST to 50 seconds or less. Perrin recommended that this relationship be used by sand drying bed operators to determine the amount of chemical conditioner required to provide maximum drainage within 48 hours. The dosages of synthetic polyelectrolytes were found to be at least as high as those required for alum and ferric chloride for equivalent dewaterability.

Laboratory studies have been conducted to optimize the dosages of ferric chloride, ferric chloride/lime, and Calgon WT-2640 (cationic polymer) to dewater septage by vacuum filtration (58). Septage dewaterability was compared to municipal sludge dewaterability and found to be more rapid than both unconditioned and optimally-conditioned digested municipal sludge.

Addition of 1,260 to 1,360 mg/L of ferric chloride, alum, or cationic polymer improved the dewaterability of septage sufficiently to allow proper dewatering (20). Laboratory studies show similar improvement in dewaterability of septage by addition of either 10 to 20 g lime/100 g dry solids, 5 to 26 g ferric chloride/100 g dry solids, or 1 to 2 g cationic polymer/100 g dry solids (20).

Pilot-scale evaluations of septage conditioning using alum, ferric chloride, ferric chloride-lime, and acid-lime coagulation resulted in improved dewatering characteristics (23). High doses (480 to 3,600 g/m^3 [4 to 30 lb/1,000 gal]) of chemicals were required however.

Sand drying beds have been used to dewater septage. Anaerobically-digested septage required 2 to 3 times the drying period of similarly digested sewage sludge (21). Studies have showed that addition of about 82 kg lime/ton (180 lb lime/ton) dry solids of septage resulted in 25 percent solids after sand bed drying for 6 days. Solids increased to 38 percent after drying for 19 days. Use of sand drying beds for dewatering of septage is feasible with chemical conditioning prior to drying. It is recommended that depth of application of septage be limited to a maximum of 20 cm (8 in.), since more depth has been shown to slow the drying process (3).

Experience indicates that chemical conditioning of septage is necessary before vacuum filtration. In Islip, New York, 95 kg lime/mt (190 lb lime/ton) dry solids and 190 liters (50 gal) of standard concentration ferric chloride/ton dry solids were used at a now abandoned facility for chemical conditioning of septage. The conditioned and settled septage solids were added to the vacuum filter at a rate of 24 kg/m^2-hr (5 $lb/ft^2/hr$), and found to dewater satisfactorily (14).

7.9.2 Conditioning with Metal Salts and Lime

The inorganic chemicals used in sludge and septage conditioning include compounds of iron, aluminum, and calcium. Ferric sulfate, ferric chloride, and aluminum sulfate (alum) are the most commonly used inorganic chemicals, with calcium hydroxide (lime) often serving auxiliary functions (53). The trivalent metal species in ferric chloride and sulfate (Fe^{+++}) and in alum (Al^{+++}) form hydroxometal complexes when added in excess of solubility limits to aqueous systems(59). The hydrolyzed salts possess a significant charge and some polymeric properties as well. Therefore, they provide charge neutralization and enmeshing capabilities toward dispersed material. Hydrated lime is often used in conjunction with metal salts.

Although lime has some slight dehydration effect on colloids, its use in conditioning is also for pH control, odor reduction, disinfection, and filter aid effect (34).

Colloid destabilization by metal salt addition to septage is achieved by adsorption of positively-charged hydroxometal polymers to produce charge neutralization (59). Because the alkalinity of septage is high (see Table 3-4), charge neutralization is relatively difficult since high alkalinity keeps the pH in the neutral region where the hydroxometal polymers are not highly charged. Destabilization, therefore, can be accomplished either by using a higher coagulant dosage or by elutriating the septage first to remove alkalinity and then destabilizing with a lower coagulant dosage at a lower pH (59). Due to solubility considerations, however, the pH should not be reduced below 5 for aluminum salts, or below 4 for ferric salts (53).

7.9.2.1 Design Criteria: Dosage

The required dosage of inorganic coagulants, particularly ferric chloride, is a function of the "solids demand" and the "liquid demand" (60). The solids demand is the amount of coagulant required by the solids fraction in the suspension and is dependent on the organic or volatile matter in the sludge. The liquid demand, on the other hand, is a function of the alkalinity and solids content of the sludge or septage. For systems free of chemical reducing agents, oil emulsions, and a large percentage of fines, the $FeCl_3$ dose can be determined from the following equation:

Total dose (as % $FeCl_3$) = Liquid demand + solids demand

where:

$$\text{Liquid demand} = \frac{\%\ H_2O \times \text{alkalinity (ppm)} \times .000108}{\%\ \text{solids}}$$

$$\text{Solids demand} = \frac{\%\ \text{volatile matter in dried sludge}}{\%\ \text{ash in dried sludge}}$$

Crowe reported the following optimum chemical dosages (58):

$FeCl_3$: 6.5% of total septage solids

$FeCl_3$/Lime: $FeCl_3$: 2% of total septage solids
Lime: 9% of total septage solids

Crowe found that the CST at the $FeCl_3$ dosage was 32 seconds, and the vacuum filter cake solids content was 16 percent. At the $FeCl_3$/lime dosage, the CST was 25 seconds, and the cake solids concentration was over 17 percent. In both cases, the filtrate COD reduction was 98 percent. Again, the CST values are not universally applicable, but provide a useful correlation for specific conditions at the study site.

Perrin reported that the conditioner dose required to reduce the initial septage CST to 50 seconds ranged from 1.8 to 7.8 percent of TSS for $FeCl_3$, and from 1.3 to 7.3 percent of TSS for alum (30).

Ott and Segall (1982) (55) found that septage conditioned with an alum [as Al^{+++}] dosage of 0.8 percent of TSS did not vacuum filter well. They concluded that vacuum filtration of alum-treated septage without the addition of thickened waste activated sludge and without polymer was not feasible at the facilities they studied.

7.9.2.2 Design Criteria: Mixing/Contact Time

Chemical mixing thoroughly disperses coagulants or their hyrolysis products so the maximum possible portion of influent colloidal and fine solids are absorbed and destabilized. Flocculation processes increase the natural rate of contacts between particles. This makes it possible, within reasonable detention times, for destabilized colloids and fines to aggregate into particles large enough for effective separation by gravity processes or media filtration (61). Controlling parameters in mixing and flocculation processes are time (seconds) and velocity gradient (m/sec/m or fps/ft, or simply sec^{-1}). Chemical mixing and flocculation differ primarily in intensity (i.e., velocity gradient) and duration, although flocculation may also be affected by the total solids concentration.

Chemical mixing facilities should be designed to provide a thorough dispersal of chemical(s) throughout the septage being treated to ensure uniform exposure to pollutants that are to be removed. The intensity and duration of mixing the coagulants with the septage must be controlled to avoid overmixing or undermixing. Overmixing excessively disperses newly formed floc and may rupture existing septage solids. Undermixing, on the other hand, inadequately disperses coagulants, and uneven dosing results. This may, in turn, reduce solids removal efficiency while requiring unnecessarily high coagulant dosages (61).

The mixing and flocculation equipment used in wastewater treatment has been "borrowed" from water treatment practice. The water treatment units that have been successful for chemical mixing applications in sludge and septage treatment are high-speed mixers and variable-speed mixers. Where flows must be pumped just prior to coagulation, chemical addition at the pumps is an option. However, if velocity gradient values are too high, organic solids may be sheared (61).

The design criteria for high-speed mixers usually include a 10- to 30-second detention time and a velocity gradient of about 300 m/sec/m (300 fps/ft). In some plants, variable-speed mixers allow for varying requirements for optimum mixing (61).

The proper measure of flocculation effectiveness is the performance of subsequent solids separation units, in terms of both effluent quality and operating requirements. Design requirements for flocculation include a maximum detention time of 15 minutes and paddle speeds of 0.15 to 0.30 m/min (0.5 to 1.0 fpm) (61). Flocculation units should have multiple compartments and should be equipped with adjustable-speed mixers to permit meeting changed conditions. In spite of simplicity and low maintenance, non-mechanical baffled basins are undesirable because of inflexibility (i.e., G cannot be changed to meet requirements, but is instead a function of flow rate through the units), high head losses, and large space requirements (61).

When lime is used, flocculation parameters may be quite different. Lime precipitates are granular and do not benefit much from prolonged flocculation times or very low terminal G values. Detention times should range from a minimum of 5 minutes to a maximum of about 10 minutes. G values of 100 sec^{-1} or more are desirable (61).

Batch treatment systems can be designed so that chemical addition and flocculation can take place in the same tank. It is unlikely that both flash mixing and flocculation could be accomplished by the same mixer. Therefore, the following mixing systems can be designed to accomplish both flash mixing and flocculation in the same tank:

1. Chemical addition at pump discharge; flocculation by paddles or low-speed mixer in tank.

2. Chemical addition upstream of in-line static mixer; flocculation as above.

3. Chemical addition in tank with rapid mixing by recirculation of tank contents; flocculation as above.

4. Chemical addition in tank with rapid mixing by coarse bubble diffusers; flocculation as above.

Design criteria (dosage, contact time) for batch systems would be the same as for continuous systems.

7.9.2.3 Typical Design Criteria

Table 7-22 summarizes the design criteria for conditioning with metal salts and lime.

TABLE 7-22

TYPICAL DESIGN CRITERIA
CONDITIONING WITH METAL SALTS AND LIME

	Dosage	Reference
CHEMICAL DOSAGE		
Metal Salts	Equation 3	60
$FeCl_3$	6.5% of TS	58
$FeCl_3$/Lime	$FeCl_3$: 2% of TS Lime: 9% of TS	58
$FeCl_3$	1.8 to 7.8% of TSS	30
Alum (as Al)	1.3 to 7.3% of TSS	30
Iron Salts (as Fe)	2 to 6.25% of dry solids	36
Lime (as $Ca(OH)_2$)	10 to 30% of dry solids	36
MECHANICAL MIXING CRITERIA		
Metal Salts High-Speed Mixing	Detention Time: 10 to 30 sec Velocity Gradient: 300 sec^{-1}	61
Flocculation	Detention Time: 15 minutes maximum Paddle Speed: 0.15 to 0.30 m/min	61
Lime High-Speed Mixing	Detention Time: 5 to 10 min Velocity Gradient: 100 sec^{-1}	61
COARSE-BUBBLE MIXING CRITERIA		
Air Requirements $m^3/1000\ m^3/min$	150 to 250	45

7.9.3 Conditioning with Polyelectrolytes

Some inorganic chemicals used for conditioning septage, such as ferric chloride, alum, lime, and sulfuric acid, are difficult to handle due to their corrosive nature. Use of organic polymer coagulants, by contrast, has developed partially due to the ease of handling and simple facility requirements, effectiveness in operation, and the limited resultant increase in sludge mass.

There is such a wide variety of polymers, along with continuing development of new ones, that the selection of a polymer requires a designer to work with an individual polymer supplier to obtain specific information on polymers (relative to the dewatering equipment and processes to be used, as well as to pilot-test available polymers on several septage samples).

There are three basic types of polymers: anionic, cationic, and nonionic. Anionic polymers carry a negative charge and are often used with aluminum sulfate and ferric chloride additions to increase rate of flocculation, size, and toughness of particles when conditioning sludges. Anionic polymer addition to septage in laboratory experiments did not improve dewatering in one experiment (53), but, in another case, dewatering was enhanced (49).

Cationic polymers carry a positive charge and often serve as primary coagulants alone or in combination with inorganic coagulants such as aluminum sulfate. Septage conditioned with various cationic polymers (53)(26)(58)(49) has shown increased dewatering properties when studied under some laboratory conditions. Results were not always consistent due to the variability of septage sources. Eikum (1) reported on septage conditioning with the cationic polymer Praestol 444 K manufactured by Chemische Fabrik Stockhausen, a West German firm, which is used in Europe as a standard polymer for measuring the relative conditionability of sludges (1). Dosages of about 0.5 percent of TSS were required for satisfactory conditioning of untreated septage. He also reported that aerobic stabilization (20 to 25 days) enhanced conditionability of septage, and that polymer dosages in the range of 0.135 to 0.5 percent of TSS were required. Perrin reported that cationic polymer dosages of 1.1 to 7.2 percent of TSS (Dow Purifloc C-31), and 3.1 to 12.8 percent of TSS (Dow Purifloc C-41) were required to reduce the CST to 50 seconds or less, as discussed previously (30).

Nonionic polymers carry no net electrical charge in aqueous solutions, but, under some conditions and with some solids, the polymer can be sufficiently surface-active to perform as a flocculant (36). There are few data on nonionic polymer addition to treat septage independently; however, there may be facilities that treat septage in the sludge train with other wastewater sludges using such polymers.

Design dosages for polymer additions to various wastewater sludge combinations range from 7.5 to 15 kg/metric ton dry solids (15 to 30 lb/ton dry solids). Actual dosages for septage sludges may vary from these figures and should be confirmed by pilot testing. Manufacturer's recommendations should be sought on the mixing conditions that optimize their effectiveness, and these must be supplemented by jar tests. When coagulant aids are employed, provisions for multiple addition points should be made at the rapid mixing basin and in the flocculator to optimize the performance of the coagulant (61).

Septage variability is such that it is doubtful that a consistently effective polymer can be found for any batch treatment operation. Although the use of continuous flow treatment systems may improve chances for a relatively consistent polymer, data on successful application of this treatment concept in the United States is scarce. Based on the presently available U.S. data, conditioning by polymer alone is not a viable alternative, although polymer alone has been used for centrifuges and belt presses in Europe. However, polymer use as an adjunct to improve the performance of inorganic conditioning chemicals may be considered quite economically feasible if pilot studies provide consistently positive results.

7.10 Dewatering

Dewatering is generally required for ultimate disposal of treated septage. There are two options available for dewatering; namely, gravity dewatering systems and mechanical dewatering systems. Gravity dewatering includes sand drying beds; mechanical dewatering systems include vacuum filters, filter presses (including belt filters), centrifugation, and vacuum-assisted drying beds.

Septage has poor dewatering characteristics (26)(49)(53)(57), which warrants the need for conditioning prior to dewatering. Biological conditioning of raw septage by digestion or use of heat conditioning followed by dewatering may not be economical at an independent septage treatment facility due to high capital and operating costs. A summary of several studies on chemical conditioning of septage is given in Table 7-23. Chemical conditioning followed by dewatering results in average cake solids content of approximately 20 to 40 percent, which

TABLE 7-23

SUMMARY OF SEPTAGE DEWATERING STUDIES

Equipment	Chemical Addition	Remarks	Reference
Vacuum Filtration (Full-Scale Field Studies)	Alum, Ferric Chloride, Acid, Lime, Polymers, and Combinations	Conditioned septage with thickened waste activated sludge; achieved cake solids from 10 to 20%.	55
Vacuum Filtration (Pilot Studies)	Alum, Ferric Chloride, Acid, Lime, Polymers, and Combinations	Conditioned screened septage alone or combinations of screened septage and aerobically-digested sludges; cake solids 9 to 35%.	29
Vacuum Filtration (Laboratory Studies)	Ferric Chloride, Lime and Polymers	Conditioned septage and combinations of septage and digested sludges; cake solids 6 to 15%.	58
Solid Bowl Centrifugation (Pilot Studies)	Alum, Ferric Chloride, Lime and Acid	Dewatering of conditioned screened septage, and dewatering of septage and aerobically-digested sludges; cake solids 17 to 23%.	29
Solid Bowl Centrifugation (Field Studies)	Lime	Centrifuge optimal performance with equal parts of septage and primary chemical wastewater sludges; resulting sludge total solids cake was approximately 25%.	62
Filter Press (Pilot Studies)	Alum, Ferric Chloride, Lime and Acid	Cake solids 26 to 46% with acid-conditioned screened septage and up to 55% solids with ferric chloride/lime and alum-conditioned screened septage.	29
Sand Beds	Alum	Alum enhanced dewatering on sand beds.	57
Sand Beds	Alum, Ferric Chloride, Lime and Acid	Screened raw septage dewatered to 6%; $FeCl_3$/lime dewatered to 11% cake solids; alum-treated dewatered to 15%; and acid/lime conditioned septage dewatered to cake of 24% cake total solids in two days.	29
Sand Beds	Alum and Aluminum Potassium Sulfate	Conditioning septage to a CST of <50 seconds enabled dewatering on sand beds in 48 hours with cake solids of 20%.	30
Sand Beds	Lime	Lime added to pH >10; septage then dewatered on sand beds to 25% cake solids in 6 days.	49

should be suitable for mechanical or manual methods of cake removal for ultimate disposal. Details on chemicals used and optimum doses were discussed in Section 7.9. It is recommended that septage be chemically conditioned prior to dewatering. The degree of dewatering accomplished is a function of conditioning chemicals, admixtures of other sludges with septage, and the dewatering process used.

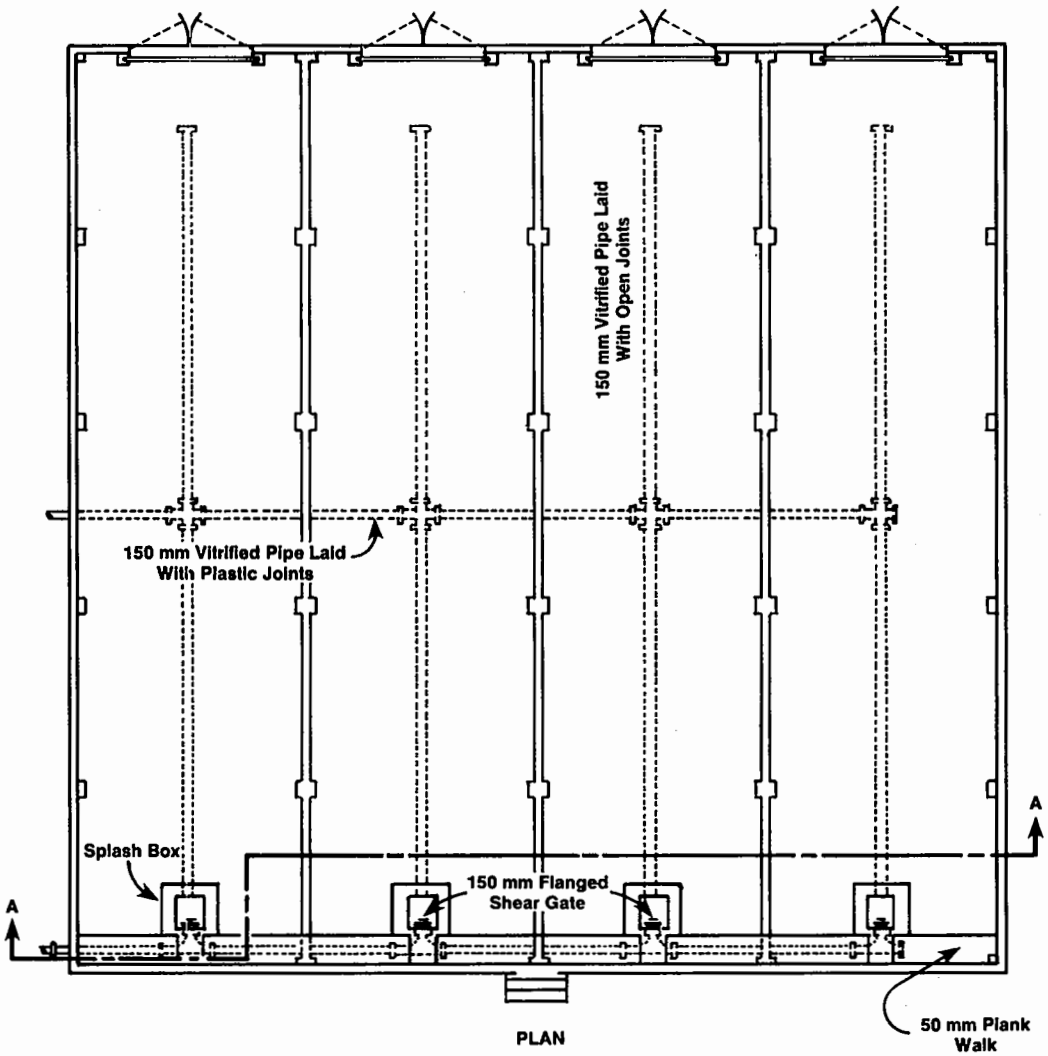
7.10.1 Sand Drying Beds

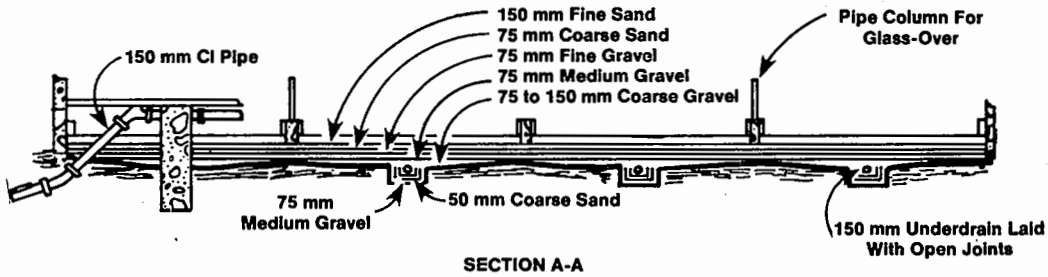
Dewatering of septage using sand drying beds is a convenient method for small communities in areas where land availability is not a major constraint. Septage is placed on drying beds of sand and gravel and allowed to dry. Dewatering occurs by drainage through the sand bed and also by evaporation. As the septage dries, cracks develop on the surface allowing further evaporation and drying in the lower layers. The filtrate draining through the sand is collected in a perforated, open-jointed piping system below the sand beds and can either be returned to the head of the septage treatment plant or treated separately as an effluent before ultimate disposal. The sludge cake is removed from the sand bed either by front loaders or by hand shoveling, and it is trucked to an ultimate disposal site. A typical sand bed drying system is shown in Figure 7-17. Considerations for design of sand drying beds include type of conditioning, depth of application, and drying time.

With regard to the effect of conditioning on sand bed performance, Feige noted that the addition of approximately 90 kg lime/metric ton (180 lb lime/ton) dry solids of septage resulted in 25 percent solid cake in 6 days and 38 percent in 19 days (49). Condren's studies (29) showed that alum-conditioned septage dewatered to 15 percent cake solids after one day, whereas ferric chloride-/lime-conditioned septage produced 10 to 11 percent cake solids after 2 days. In comparison, acid lime conditioning of septage resulted in a cake of 24 percent solids after 2 days. Perrin (30) evaluated dewatering characteristics of septage in laboratory-scale studies using capillary suction time (CST) as the parameter for comparison. Perrin found that septage with a CST of 50 seconds would cease free drainage on a sand drying bed within 48 hours or less, resulting in about 20 percent cake solids content. Studies by Crowe (58) indicated that a CST of 50 seconds can be achieved by conditioning septage with 0.1 to 0.2 kg lime/kg dry solids. However, there is no basis to compare these two CST values due to differences in total solids and test methods.

Since evaporation is a contributing factor to the performance of sand bed dewatering, depth of application of septage is an important design/operation consideration. One study indicated that chemically-conditioned septage dewatered more readily at a 15-cm (6-in.) depth of application than at a 30-cm (12-in.) depth (57). Based on this and other pilot-scale and full-scale dewatering plants, a septage application depth of 20 cm (8 in.) is recommended.

FIGURE 7-17
TYPICAL SAND DRYING BED CONSTRUCTION (21)





Drying time is a function of drainage and evaporation. The predominant function of sand bed dewatering is drainage, most of which usually occurs within about 7 to 10 days. However, depending on weather conditions, evaporation also contributes significantly to dewatering, particularly in the latter part of the drying period. Average drying time for sewage sludge is about 2 to 4 weeks. Since conditioning significantly improves dewatering characteristics of septage, it is possible that the average drying time for conditioned septage may be reduced to approximately 10 to 15 days. Table 7-24 provides a summary of findings of some studies on sand bed dewatering of septage. Although bench scale and pilot plant studies indicate drying time for septage between 2 and 6 days, full scale operations are estimated to require longer drying time.

Sand bed drying is one of the simplest systems that can be used for dewatering of conditioned septage. The advantages of this system are: 1) its simple construction; 2) the minimal operator training and attention required; and 3) its low capital and operation costs. The disadvantages are: 1) large sand area required; and 2) potential problems with operation during cold and wet weather seasons unless the beds are covered.

One of the variations in sand drying bed construction relates to the choice between asphalt and concrete paved drying beds. Use of mechanical equipment for cleaning unpaved sand beds has resulted in damage to underdrain pipes. Paved drying beds permit the use of mechanical equipment without damaging underdrains and thereby reduces the cost of labor and sand replacement. Paved drying beds are usually constructed with a 1.5 to 2 percent slope toward the center. A perforated drainage pipe is located in the center beneath a sand drainage strip at a level below the paved bed. Operation of paved drying beds is economical since use of mechanical equipment allows removal of sludge with a higher moisture content in shorter drying time intervals than in the case of manual cleaning. The main disadvantage of paved beds is higher capital cost. The feasibility of using paved drying beds for dewatering digested sewage sludge has been demonstrated elsewhere (63) (64) (65).

7.10.2 Vacuum Filtration

Vacuum filtration is a common method of dewatering wastewater sludges in the United States. It has also been used to dewater chemically-conditioned septage, as well as mixtures of septage and wastewater sludge.

TABLE 7-24

SUMMARY OF STUDIES ON SAND BED DEWATERING OF SEPTAGE

Type of Study Ref	Feed Septage mg/L	Conditioning Chemical	Conditioning Dosage mg/L	Drying Time days	Cake Solids mg/L	Filtrate mg/L	Comments
Pilot Study (29)	TSS - 7,700	None	---	2	TSS - 59,500	TSS - 319	0.2 m^3 batches were placed on 1 m^2 sand beds
	TSS - 21,000	$FeCl_3$ $Ca(OH)_2$	400 4,000	2	TSS - 105,000	TSS - 46	Conditioned septage was settled for 22 hours
	TSS - 30,600	Alum	355 - 955	1	TSS - 153,000	TSS - 79	0.2 m^3 screened septage was placed in 20 cm layers on a 30.5-cm deep bed with an area 0.93 m^2
	TSS - 21,100	Acid (H_2SO_4) $Ca(OH)_2$	3,000 - 4,000 3,500 - 4,500	2	TSS - 241,000	TSS - 53	
Pilot Study (49)	TS - 37,200 COD - 58,000	$Ca(OH)_2$	83,000	6 19	TS - 247,500 TS - 380,000	--- COD 186 - 1,660	$Ca(OH)_2$ dosage is that required to raise septage pH to 11.5, an average of 4 tests Sand beds of a 6 m^2 area are covered with septage to a depth of 20 cm
Bench Scale (30)	TSS - 32,000	Aerated	---	3-4	TS - 200,000	---	Added 0.5 L of septage to sand drying column
		$FeCl_3$ Alum Polymer	640 - 1,280 70 - 135 640 - 1,280	3-4 3-4 3-4	TS - 200,000 TS - 200,000 TS - 200,000	--- --- ---	
Bench Scale (57)	TS - 34,500 VS - 14,300 COD - 17,000	Alum	100	1.5	TS - 150,000	---	

Vacuum filtration is generally accomplished on cylindrical vacuum drums. These drums have a filter medium that may be a cloth of natural or synthetic fibers, coil springs, or a wire mesh fabric. The drum is suspended above and rotates through a vat of conditioned septage (Figure 7-18). As the drum rotates, part of its circumference is subject to an internal vacuum that draws the septage to the filter medium. In this section of the circumference, the water is drawn through the porous filter cake. The piping arrangement within the filter permits the suction to be maintained until the release point, at which time compressed air may be blown through the medium to release the cake, or a scraper assembly may be used to aid discharge. The yield of the filter, usually expressed in kilograms per square meter per hour (pounds of dry solids per square foot per hour), may be changed by varying the suction, the speed of rotation, the portion of the cycle time during which suction takes place, or the conditioning chemicals that are added to the septage.

The auxiliary equipment for vacuum-filter operations include: sludge conditioning tank with mixer, sludge cake conveyor, vacuum pump, and filtrate receiver and pump.

Chemical conditioning of septage is strongly recommended prior to vacuum filtration in order to achieve satisfactory dewatering operation (29) (23) (55) (58).

At an independent facility in Islip, New York, septage solids conditioned by the addition of lime and ferric chloride were fed to a vacuum filter at a rate of 24 kg/m^2-hr (5 lb/ft^2-hr) and were dewatered satisfactorily (17). Other studies have indicated that vacuum filtration of septage after chemical conditioning with lime, ferric chloride, and a polymer yielded 15 to 17 percent cake solids (58). Another study (29) demonstrated that good solids capture and cake solids consistencies were achieved with vacuum filtration of septage. However, it was difficult to obtain consistent release of the cake. Coil spring vacuum filtration of chemically conditioned septage has been investigated in laboratory and field studies (55). Chemical conditioning consisted of either alum, ferric chloride, or sulfuric acid. These studies showed that chemically conditioned septage produced very low cake yield ranging from 1 to 3 $kg/m^2/hr$ (0.2 to 0.6 $lb/ft^2/hr$). However, significantly higher cake yields of about 20 $kg/m^2/hr$ (4 $lb/ft^2/hr$) were achieved when conditioned septage was mixed with thickened waste activated sludge. Although vacuum filtration of septage may be technically feasible, due consideration would have to be given to its high cost when evaluating its feasibility in an independent septage treatment system. Table 7-25 summarizes the results of studies conducted on vacuum filtration of septage.

FIGURE 7-18
VACUUM FILTRATION PROCESS (58)

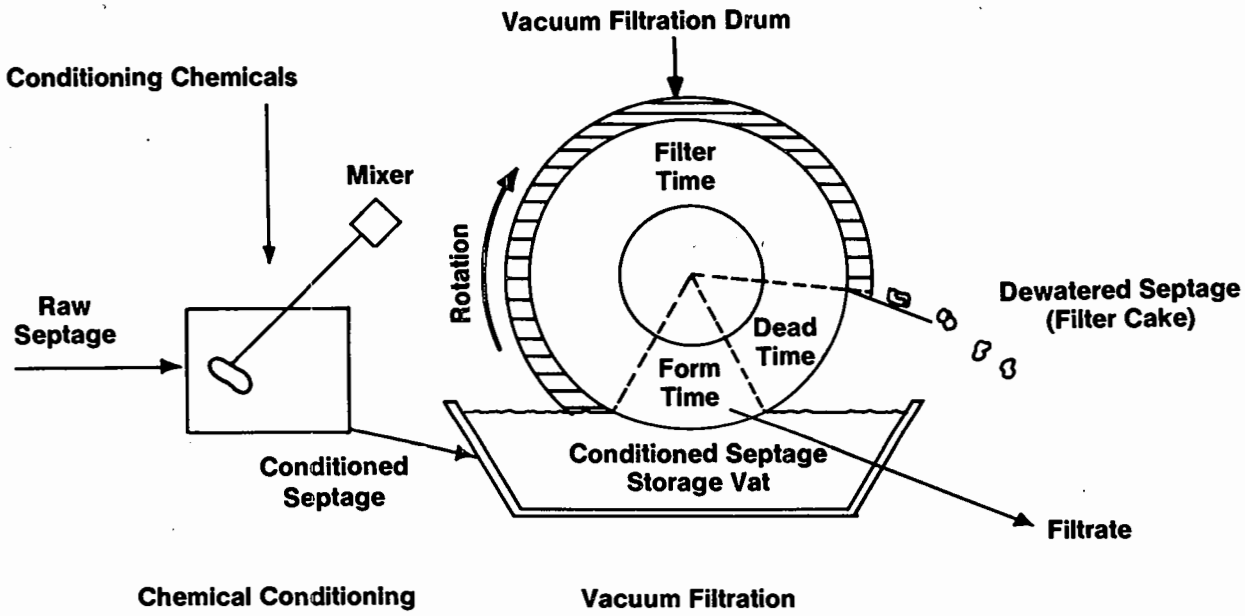


TABLE 7-25

VACUUM FILTRATION OF SEPTAGE

Type of Study Ref	Feed Septage Characteristics	Conditioning Chemical	Conditioning Dosage mg/L	Yield kg/m²/hr	Cake	Filtrate mg/L	Remarks
Full-Scale Study (55)	TS - 37,180 mg/L TVS - 27,190 mg/L	$Al_2(SO_4)_3$	80 as Al^{+++}	1.0	TS - 20% TVS - 76.2% of TS	TS - 14,234 TVS - 10,230	Tests performed on 47 m^3 batches of thickened septage.
	TS - 51,160 mg/L TVS - 36,100 mg/L pH - 2.6	H_2SO_4	---	3.0	TS - 16.8% VS - 75.6% of TS pH - 4.4	TS - 10,430 TVS - 6,957	Tests performed on 19 m^3 batches of thickened septage.
	TS - 52,770 mg/L TVS - 35,135 mg/L	$Al_2(SO_4)_3$	130 as Al^{+++}	26.5	TS - 12.5% VS - 65% of TS	TS - 1,910 VS - 940	Filter feed was 55% septage, 45% TWAS
	TS - 51,468 mg/L TVS - 35,755 mg/L	$FeCl_3$	220 as Fe^{+++}	20.5	TS - 12.2% VS - 65% of VS	TS - 2,372 TVS - 1,388	Filter feed was 44.8% septage, 55.2% TWAS
Pilot Scale (29)	TSS - 22,200 mg/L	$FeCl_3$ and $Ca(OH)_2$	400 4,000	2.5	TS - 35%	TSS - 117	Pilot Vacuum Filter - Diameter - 0.9 m Length - 0.5 m
	TSS - 33,000 mg/L	$Al_2(SO_4)_3$	355 - 955	2.0	TS - 28%	TSS - 80	Vacuum - 406 mm Hg
	TSS - 33,000 mg/L	$Al_2(SO_4)_3$ Anionic Polymer	315 25	7.5	TS - 27%	TSS - 56	Drum Speed - 16 min/rev
	TSS - 30,700 mg/L	H_2SO_4 $Ca(OH)_2$	3,000 4,000 3,500 4,500	4.0	TS - 27%	TSS - 44	

TWAS - Thickened waste activated sludge.

7.10.3 Filter Press

The plate and frame filter press is another mechanical dewatering system that has been used for sewage sludge applications. Most independent septage treatment units are expected to be generally small in size, perhaps located in relatively remote areas, and subjected to wide variability in flow conditions. Considering the high cost of the equipment, the use of plate and frame filter presses to dewater septage would be highly uneconomical unless very large septage treatment systems are considered.

Characteristics of filter cake and filtrate from belt filter pressing of septage were evaluated by Condren (29) using different types of chemical conditioning (29). Chemicals used for conditioning included 1) ferric chloride and lime, 2) alum, and 3) acid and lime. Norwegian practice always includes polymer with or without these chemicals. In all cases, filter press dewatering yielded high cake solids (26 to 55 percent) with run times of about 45 minutes. However, the feasibility of using belt filter presses at an independent septage treatment facility would be determined by economics.

7.10.4 Centrifugation

Centrifugation of wastewater/septage sludges is carried out using either solid bowl centrifuge or basket centrifuge. The use of solid bowl centrifuges to dewater septage, mixtures of septage, and aerobically-digested sewage sludge yielded acceptable cake solids in the range of 16 to 23 percent (29). However, prior chemical conditioning of septage was necessary to obtain these levels of cake solids. Results of these studies are given in Table 7-26. The flow rate used for the study was 4 L/min (1 gpm). Grit removal is essential before centrifugation to prevent severe wear and tear and damage to centrifuges.

Solid bowl type centrifugation of septage has been investigated in Europe at laboratory and full-scale plants. A summary of data from these studies is given in Table 7-27. Eikum (1) reported that average cake solids concentration of about 25 percent and solids capture of 90 to 95 percent are possible with centrifugation of screened and degritted septage. Polymer requirements for conditioning prior to centrifugation are about 2 to 4 g/kg TSS (0.4 to 0.8 lb/lb).

TABLE 7-26

SEPTAGE DEWATERING BY SOLID-BOWL CENTRIFUGATION (29)

Feed Source	TSS, mg/L Influent	TSS, mg/L Centrate	Cake % Solids	Capture % of TSS
Ferric Chloride/Lime Septage Sludge	31,000	3,970	16.5	90.5
Alum Septage Sludge	33,000	14,000	20.6	62.4
Acid/Lime Septage Sludge	30,700	17,600	23.0	45.0
90/10 Mixture[a]	23,400	18,400	20.0	25.7

[a]Volumetric ratio of aerobically digested STP sludge to acid/lime conditioned septage.

7.10.5 Vacuum-Assisted Drying Bed

This is a relatively new system for dewatering water/wastewater/chemical sludges. It is comprised of a drying bed of permeable media to which polymer-treated sludge is applied to depths of about 30 cm (1 ft) and allowed to drain by gravity. A vacuum is then applied and held until the sludge surface cracks. It is then ready for removal by front-end loaders specially equipped with rubber-bottomed buckets. After a washing step, the process can again be initiated. The process is schematically illustrated in Figure 7-19. Proprietary systems of three different manufacturers are available. These systems are quite similar and are designed on the concept that a vacuum applied to a permeable mat loaded with sludge significantly improves the dewatering efficiency. Figure 7-20 outlines the steps involved in the operation of a typical vacuum-aided drying bed.

This system of dewatering septage may have several advantages, as follows:

1. Simplicity in construction.
2. Minimal operator training and attention.
3. Able to produce truckable sludge cake in 24 hours.

TABLE 7-27

SUMMARY OF SEPTAGE CENTRATE WATER QUALITY (25) (46) (66) (67)

Parameter		Quality of Centrate from: Untreated Septage, Laboratory Centrifuge	Untreated Septage, Full Scale Centrifuge	Lime Stabilized Septage, Laboratory Centrifuge	Lime Stabilized Septage, Full Scale Centrifuge	Aerobic Stabilized Septage, Laboratory Centrifuge	Aerobic Stabilized Septage, Full scale Centrifuge
TSS (mg/L)	Range	70-2155	723-11,790	194-1424	8,150-14,520	41-102	30-434
	Median	645	1,710	380	11,430	59	146
VSS (mg/L)	Range	45-1943	597-10,430	119- 896	4,920- 9,945	19- 54	16-231
	Median	475	1,270	214	6,870	29	69
BOD_7 (mg O_2/L)	Range	206-3195	515- 2,865	---	---	5- 37	9- 36
	Median	1120	886	---	---	10	15
COD_{total} (mg O_2/L)	Range	378-7998	1,285- 9,480	3050-8700	9,776-28,810	79-282	140-632
	Median	3373	3,605	4670	19,200	202	181
$COD_{soluble}$ (mg O_2/L)	Range	280-5277	563- 1,525	2854-5228	2,117- 4,586	100-246	80-212
	Median	2791	846	4220	3,411	183	159
Total-P (mg P/L)	Range	11- 107	15- 56	3.4- 20	39.5- 116	1.1- 6.0	0.9- 4.7
	Median	47	33	5.7	54	2.7	1.5
PO_4-P (mg P/L)	Range	0.4- 83	0.2- 49	0.1- 1.9	0.1- 3.1	0.4- 2.5	0.2- 1.3
	Median	30	16	0.3	0.2	1.1	0.2
Total-N (mg N/L)	Range	37- 529	140- 228	221- 368	323- 770	10.8- 42.4	12.4- 34.0
	Median	199	180	288	553	20	24
NH_4-N (mg N/L)	Range	35- 288	65- 128	128- 203	100- 160	0.3- 8	0.2- 6.4
	Median	147	80	150	120	0.4	0.5
pH	Range	5.5- 7.8	---	9.8- 12.5	9.7- 12.4	7.8- 8.1	7.6- 7.7
	Median	6.3	---	12.3	12.4	7.9	7.6
Number of samples		23	6	9	6	7	6

FIGURE 7-19
VACUUM ASSISTED DRYING BED SYSTEM (69)

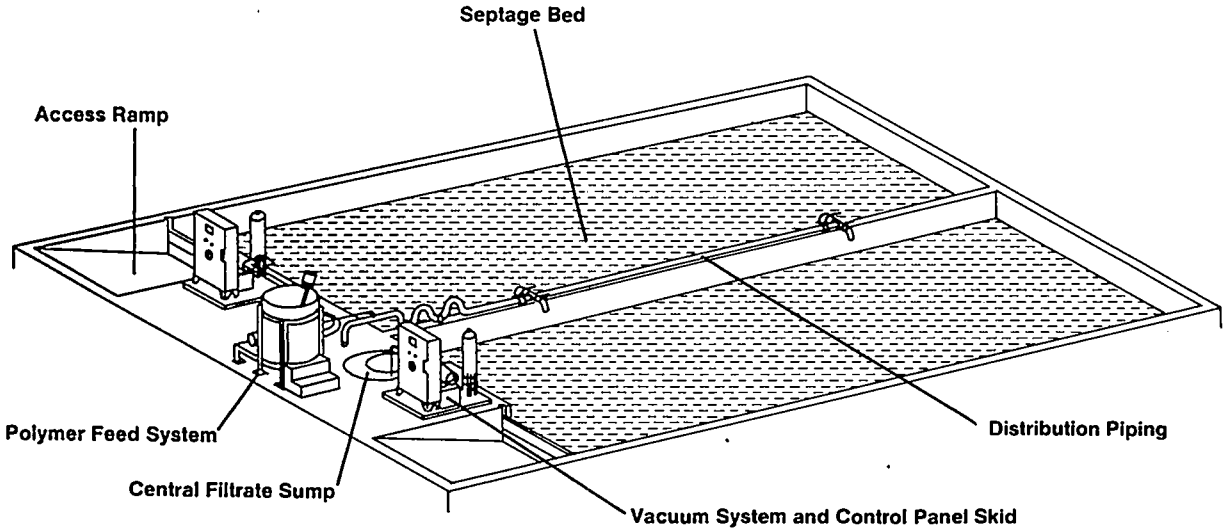
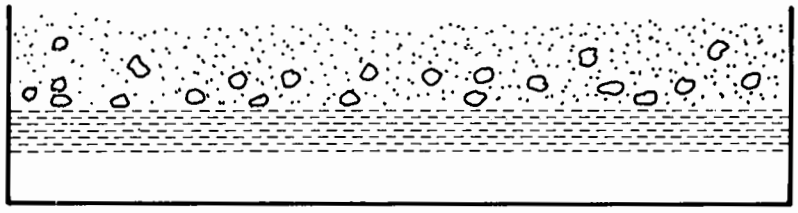
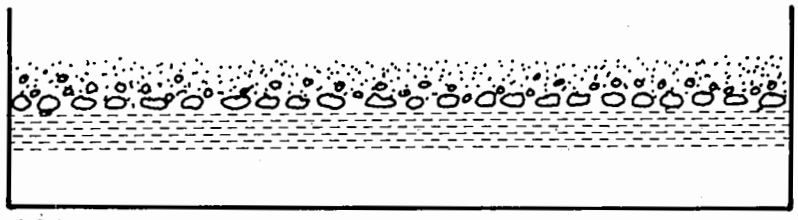


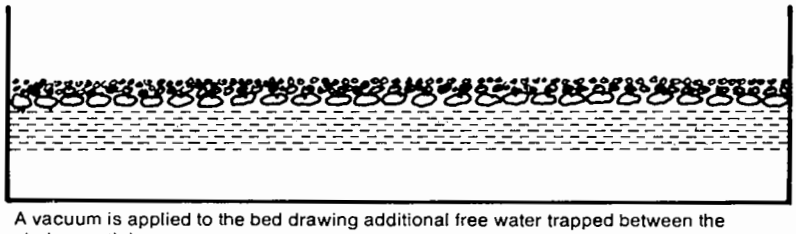
FIGURE 7-20
SEQUENCE OF OPERATIONS IN VACUUM ASSISTED DRYING BED SYSTEMS (69)



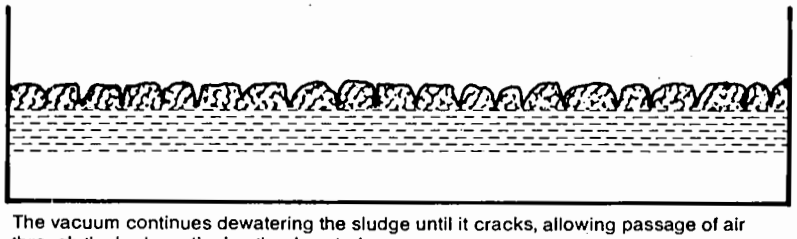
(1) Conditioned sludge is distributed on the permeable mat. Immediately large particles begin to settle onto the mat as free water drains.



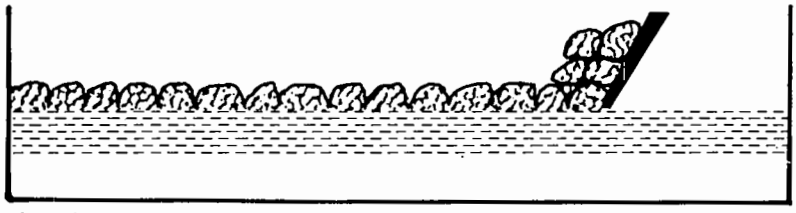
(2) A Cohesive layer of large particles formed on the mat traps finer sludge particles as free water continues to drain.



(3) A vacuum is applied to the bed drawing additional free water trapped between the sludge particles.



(4) The vacuum continues dewatering the sludge until it cracks, allowing passage of air through the bed, continuing the dewatering process.



(5) Once the sludge has been dewatered to a truckable condition it is removed from the mat.

4. Porous blocks generally resist clogging and blinding and require only hosing down for cleaning.

5. High loading rate capability.

Although open air drying beds may require large areas, the provision of the vacuum significantly reduces the area requirement over that for conventional sand drying beds. Moreover, the ability to remove sludge cake in 24-hour or less cycles reduces the total bed area requirements. As with other dewatering systems for septage, conditioning is required prior to application on the bed. The level of septage conditioning required prior to bed application is not yet tested, but experience with STP sludge would indicate that lime stabilization or aerobic or anaerobic digestion would suffice prior to polymer treatment.

Cake solids ranging from 15 to 25 percent are claimed to be achieved in 24 hours or less for sewage sludge, which is a very high yield compared to gravity sand drying beds (69).

This system of dewatering appears to be well-suited for independent septage treatment since it combines the simplicity of a gravity dewatering system with the rapid dewatering rates of a mechanical system. Since, in many cases, independent septage treatment systems may be small in size and may be located in relatively remote areas, a simple, efficient system with low maintenance requirements is highly desirable. Depending on the pattern of septage generation and climatic conditions, these beds will generally require heated enclosures in northern regions. No performance data on application of this system for septage treatment are currently available. Conventional sand drying beds may be loaded from 10 to 270 kg dry solids/m^2/yr (2 to 55 lb/ft^2/yr) depending on type of sludge, weather, dryness required, and whether the bed is covered or uncovered. Loading for operating vacuum-assisted sludge drying beds has ranged up to 950 kg dry solids/m^2/yr (195 lb/ft^2/yr), with typical polymer additions between 2 and 6 kg/metric tons of dry solids (4 and 12 lb/ton) (69). Manufacturers claim that significantly higher loadings are possible (68).

7.11 Disinfection

Septage disinfection or the destruction or inactivation of pathogenic organisms in the septage is carried out principally to minimize public health risks. Destruction is the physical disruption or disintegration of a pathogenic organism, while inactivation is the removal of a pathogen's ability to infect. This section will identify certain pathogenic organisms found in septage, briefly describe their characteristics, and discuss methods for reducing the number of pathogenic organisms in septage.

7.11.1 Applicability of Disinfection

Disinfection of septage is most applicable when there is a potential risk of humans coming into contact with the septage during the disposal process. The most common disposal process and the one with the largest potential for human contact is application of raw untreated septage or pretreated septage to the land. Federal, state, and/or local regulations may require some form of disinfection prior to land application.

At the present time in the United States, the use of a process to significantly reduce pathogens (PSRP) is required for land application of septage unless public access is controlled for 12 months, and grazing animals whose products are consumed by humans is prohibited for one month after application. In addition, production of crops for direct human consumption are prohibited for 18 months after the application of septage, unless the edible portion in no way touches the wastes or the septage has been treated by a process to further reduce pathogens (PFRP) (50). This section will briefly describe the pathogens of concern, and will present a brief description of many of the accepted PSRP's and PFRP's that might be applied to reduce the risk of pathogen contamination.

7.11.2 Characteristics of Pathogenic Organisms

A pathogen or pathogenic agent is any biological species that can cause disease in the host organism. This section will limit discussion to pathogens that produce disease in man and complete their life cycles

in climates typical of the United States. There are four broad categories of pathogenic organisms: viruses, bacteria, parasites, and fungi. Viruses, bacteria, and parasites enter the septic systems of typical homes by several sources:

1. Human wastes, including feces, urine, and oral and nasal discharges.

2. Food wastes.

3. Domestic pet feces and urine.

Fungi are secondary pathogens and are only numerous in septage when given the opportunity to grow during some treatment or storage process.

7.11.2.1 Viruses

Viruses depend on host cells to perform most of the metobolic functions necessary for replication. Viruses are small particles whose protein surface charge changes in magnitude and sign with pH. Most viruses have a negative surface charge in the pH range typical of most septage. Some viruses demonstrate considerable resistance to environmental factors such as heat and moisture.

The major virus subtypes transmitted in human excrement are listed in Table 7-28, together with the disease they cause. Viruses are excreted by man in numbers up to 10^{10} per day. However, little information is reported on the survival of viruses in septage.

7.11.2.2 Bacteria

Bacteria are able to reproduce outside the host organism. They can grow and reproduce under a wide range of environmental conditions; however, low temperatures cause dormancy and high temperatures may result in inactivation. The major pathogenic bacteria are listed in Table 7-29. Man excretes up to 10^{13} coliforms and 10^{16} other bacteria in his feces every day.

TABLE 7-28

PATHOGENIC HUMAN VIRUSES POTENTIALLY IN SEPTAGE (36)

Name	Disease
Adenoviruses	Adenovirus infection
Coxsackie virus, Group A	Coxsackie infection; viral meningitis; AFRI[a]; hand, foot, and mouth disease
Coxsackie virus, Group B	Coxsackie infection, viral meningitis; viral carditis, endemic pleurodynia, AFRI[a]
ECHO virus (30 types)	ECHO virus infection; aseptic meningitis; AFRI[a]
Poliovirus (3 types)	Poliomyelitis
Reoviruses	Reovirus infection
Hepatitis virus A	Viral hepatitis
Norwalk agent	Sporadic viral gastroenteritis
Rotavirus	Winter vomiting disease

[a]AFRI is acute febrile respiratory illness.

TABLE 7-29

PATHOGENIC HUMAN BACTERIA POTENTIALLY IN SEPTAGE (36)

Species	Disease
Arizona hinshawii	Arizona infection
Bacillus cereus	Gastroenteritis; food poisoning
Vibrio cholerae	Cholera
Clostridium perfringens	Gastroenteritis; food poisoning
Clostridium tetani	Tetanus
Escherichia coli	Enteropathogenic E. coli infection; acute diarrhea
Leptospira spp	Leptospirosis (Weils disease)
Mycobacterium tuberculosis	Tuberculosis
Salmonella spp (over 1,500 serotypes)	Salmonellosis; acute diarrhea; paratyphoid fever; typhoid fever
Shigella spp	Shigellosis; bacillary dysentery; acute diarrhea
Yersinia	Gastroenteritis

7.11.2.3 Parasites

Common pathogenic parasites, including protozoa, nematodes, and helminths are listed in Table 7-30. Pathogenic protozoa enter the host organism as environmentally-insensitive cysts. Once in the host organism, the cysts transform into active organisms, mature and reproduce, releasing cysts in the feces.

Roundworms and hookworms are commonly recognized nematodes that may reach sizes up to 36 cm (14 in.) in the human intestine. Nematodes may migrate to other body tissue such as the eye, causing inflammation. Nematodes cannot be transmitted from one man directly to another, but must go through an embryonic stage - usually in the soil - for a period of about two weeks.

Helminths are flatworms, such as tapeworms, that may be more than 30 cm (12 in.) long. Helminths are ingested when man eats raw or inadequately cooked meats. Tapeworms usually develop in the intestine, causing minor diseases, but may locate in the ear, eye, heart, or central nervous system, causing a much more serious disorder.

7.11.2.4 Fungi

Fungi are single-celled plants that lack chlorophyll and therefore the ability to photosynthesize. They reproduce by developing spores, which, when released, cluster together to form colonies. Pathogenic spores are most dangerous when inhaled by someone already suffering from a disease such as diabetes. Spores are secondary pathogens that grow in stored or partially treated septage.

7.11.3 Disinfection Methods

The disinfection methods discussed in this section apply to raw septage or the solids fraction of treated septage. The liquid fraction of treated septage may be handled in a manner similar to that for effluent from a municipal wastewater treatment facility. Since the ultimate disposal method for most septage or septage sludge is land application, regulations have been promulgated to reduce the potential threat to public health. EPA regulations (40 CFR 257 "criteria") for land application of septage require that the septage be treated by a process to significantly reduce pathogens (PSRP), unless: 1) public access to the facility is controlled for at least 12 months; and 2) grazing by animals whose products are consumed by humans is controlled for at least 1 month after the last septage application. Crops for direct human consumption are prohibited for 18 months after septage application,

TABLE 7-30

PATHOGENIC HUMAN AND ANIMAL PARASITES POTENTIALLY IN SEPTAGE (36)

Species	Disease
A. Protozoa	
Acanthamoeba sp	Amoebic meningoencephalitis
Balantidium coli	Balantidiasis, Balantidial dysentery
Dientamoeba fragilis	Dientamoeba infection
Entamoeba histolytica	Amoebiasis; amoebic dysentery
Giardia lamblia	Giardiasis
Isopora bella	Coccidiosis
Naegleria fowleri	Amoebic meningoencephalitis
Toxoplasma gordii	Toxoplasmosis
B. Nematodes	
Ancyclostoma dirodenale	Ancylostomiasis; hookworm disease
Ancyclostoma sp	Cutaneous larva migrans
Ascaris lumbricoides	Ascariasis; roundworm disease; Ascaris pneumonia
Enterobius vermicularis	Oxyuriasis; pinworm disease
Necator americanus	Necatoriasis; hookworm disease
Strongyloides stercoralis	Strongyloidiasis; hookworm disease
Toxocara canis	Dog roundworm disease, visceral larva migrans
Toxocara cati	Cat roundworm disease; visceral larva migrans
Trichusis trichiura	Trichuriasis; whipworm disease
C. Helminths	
Diphyllobothrium latum	Fish tapeworm disease
Echinococcus granulosis	Hydated disease
Echinococcus multilocularis	Aleveolar hydatid disease
Hymenolepis diminuta	Rat tapeworm disease
Tymenolepis nana	Dwarf tapeworm disease
Taenia saginata	Taeniasis; beef tapeworm disease
Taenia solium	Cysticercosis; pork tapeworm disease

unless the edible portion in no way touches the waste or unless the septage has been treated by a process to further reduce pathogens (PFRP) (50).

Some stabilization processes that will significantly reduce pathogens are: aerobic and anaerobic digestion, composting, lime stabilization, air drying, and long-term storage. This section will highlight the disinfection capabilities of these processes. A more detailed description of these processes has been presented earlier in this chapter.

EPA has identified several processes that achieve a further reduction in pathogens as: high temperature composting, heat drying, heat treatment, and thermophilic aerobic digestion. Any of the following processes, provided they follow an acceptable PSRP process, may be considered as a PFRP: beta ray irradiation, gamma ray irradiation, and pasteurization. Disinfection methods that qualify as PSRP's and PFRP's will be discussed further in the following sections.

7.11.3.1 Pathogen Reduction During Digestion

Aerobic or anaerobic digestion are common methods for septage stabilization in the United States. Well-operated digesters can reduce virus and bacteria levels but are less effective against parasitic cysts. Sections 7.5 and 7.6 presented detailed discussions of aerobic and anaerobic digestion of septage.

7.11.3.2 Chemical Disinfection

A number of chemicals used for septage stabilization, including lime and chlorine, also reduce the number of pathogenic organisms. However, the high suspended solids conentrations of some septage may prevent adequate contact between the chemical and the pathogenic organisms.

a. Lime

Pathogenic bacteria reduction occurs at high pH (11 to 13) and improves with exposure time (EPA Process Design Manual - Sludge Treatment and Disposal). Virus studies on limed septages have not been reported, but a pH in excess of 11.5 should inactivate known viruses (70). Lime stabilization is described in more detail in Section 7.7.

b. Chlorine

Chlorine is a strong oxidizing agent used for disinfecting drinking water and wastewater effluent. Provided adequate mixing is achieved and application is in sufficient quantity to develop a free chlorine residual in the solution being treated, chlorine can be effective for bacteria and virus inactivation. However, cysts and ova of parasites are resistant to chlorine. Chlorine oxidation is discussed in Section 7.8.

c. Formaldehyde

Formaldehyde treatment of septage that had been adjusted to pH 10 has proved to be a successful disinfection procedure during studies conducted on the disinfection of septage (71). Formaldehyde at a concentration of 1000 mg/L was able to reduce bacteria to undetectable limits after 12 hours of contact time when the sludge was adjusted to pH 10.

d. Glutaraldehyde

Glutaraldehyde has the advantage over formaldehyde of being effective in the neutral pH range and of producing more rapid bacterial kills (71). As with formaldehyde, the recommended dosage concentration is 1000 mg/L.

e. Other Chemicals

Other strong oxidizing chemicals such as ozone have been successfully used to disinfect drinking water and wastewater effluent. Due to the high solids concentration, their applicability to septage may be suspect and is as yet untried.

7.11.3.3 Heat Disinfection

Sufficient temperatures and exposure times will inactivate most microorganisms as well as the eggs and cysts of parasites. Table 7-31 presents the exposure times and temperature levels required to reduce the population of some pathogenic viruses and bacteria to undetectable limits. Heat processes applicable to septage include: pasteurization, heat conditioning, heat drying, high temperature processes, and composting.

TABLE 7-31

TIME AND TEMPERATURE TOLERANCE
FOR PATHOGENS AND INDICATORS IN SEPTAGE (36)

Species	Exposure Time for Organism Inactivation, min				
	Temperature, °C				
	50	55	60	65	70
Viruses					25
Mycobacterium tuberculosis					20
Micrococcus pygogenes					20
Escherichi coli			60		5
Salmonella typhi			30		4
Fecal streptococci					60
Fecal coliforms					60
Corynebacterium diptheriae		45			4
Brucella abortus		60		3	
Cysts of *Entamoeba histolytica*	5				
Eggs of *Ascaris lumbricoides*	60	7			
Aspergillus flavus conidia			60		

a. Pasteurization

Pasteurization qualifies as a PFRP provided it follows an approved PSRP. The critical requirement for pasteurization is that all of the septage be held above a predetermined temperature for a minimum time period. Incomplete mixing of septage due to the non-homogeneous consistency of septage creates heating problems and reduces the efficiency of the process. The application of the pasteurization process to septage is not well documented.

b. Heat Conditioning

Heat conditioning includes processes where raw or partially-treated septage is pressurized with or without oxygen, and the temperature is raised to 177° to 240°C (350° to 400°F) and maintained for 15 to 40 minutes (36). These processes will destroy or inactivate all pathogens in septage. Heat conditioning of septage, although technically feasible, may not be practical on a large scale.

c. Heat Drying

Heat drying of septage could be accomplished in a flash drier or a rotary kiln. Heat drying would achieve sufficient temperatures and contact times to significantly reduce the number of pathogens; however, fuel costs may be prohibitive if applied to a full-scale septage facility.

d. High Temperature Processes

High temperature processes include incineration, pyrolysis, or a combination thereof (starved-air combustion). These processes raise the septage temperature above 500°C (930°F), thereby destroying the physical structure of all septage pathogens and effectively sterilizing the septage. The product of a high temperature process would be sterile unless shortcircuiting occurs within the process. The fuel cost for this type of system would still be high, but the volume of solids to be disposed of would be reduced significantly. No septage studies have been reported with these systems.

e. Composting

Composting, depending on the temperature levels and exposure times, can be considered as either a PSRP (40°C for 5 days or 55°C for 4 hours, using the within-vessel or windrow methods) or a PFRP (55°C for 5 days using the within-vessel method and 55°C for 15 days using the windrow method) (36). Composting is considered a heat process because a major aim of septage composting operations is to produce a pathogen-free compost by achieving and holding a thermophilic temperature. Greater detail on the process of composting is provided in Section 7.3.

7.11.3.4 Long-Term Storage

Pathogen reduction has been recognized for years as a side benefit of septage storage in lagoons. The U.S EPA has listed long-term storage (air drying) as an acceptable process to significantly reduce pathogens. Raw septage is allowed to drain and/or dry on under drained sand beds, or on paved or unpaved basins at an average depth of 23 cm (9 in.). A minimum of three months is needed, two months of which the average daily temperatures must exceed 0°C. Table 7-32 presents the results of a laboratory study on the number of days required to achieve a 99.9 percent reduction of pathogens in sludge.

7.11.3.5 Disinfection with High-Level Radiation

High-energy radiation has shown promise for the disinfection of wastewater sludges. Facilities in the U.S. and Europe are currently utilizing both beta and gamma rays to destroy or inactivate pathogenic organisms in municipal wastewater sludge. The same principles applied to sludge disinfection would also apply to septage. Beta rays are high-energy electrons, generated with an accelerator for use in disinfection, while gamma rays are high-energy protons released from atomic nuclei. Both beta and gamma ray irradiation are considered by U.S. EPA as PFRP's.

a. Beta Ray Irradiation

Accelerated electrons produce both biological and chemical effects as they scatter off material in the septage. Direct ionization by the electrons causes damage to the DNA in bacteria cell nuclei and the DNA or RNA of viruses. A second way beta irradiation destroys pathogens is by producing ozone and hydroperoxides. These compounds then attack organics in the septage, including pathogens, thereby promoting oxidation, reduction, dissociation, and other forms of degradation.

TABLE 7-32

LABORATORY STUDY ON DAYS OF STORAGE REQUIRED FOR 99.9% REDUCTION OF VIRUSES AND BACTERIA IN SLUDGE (22)

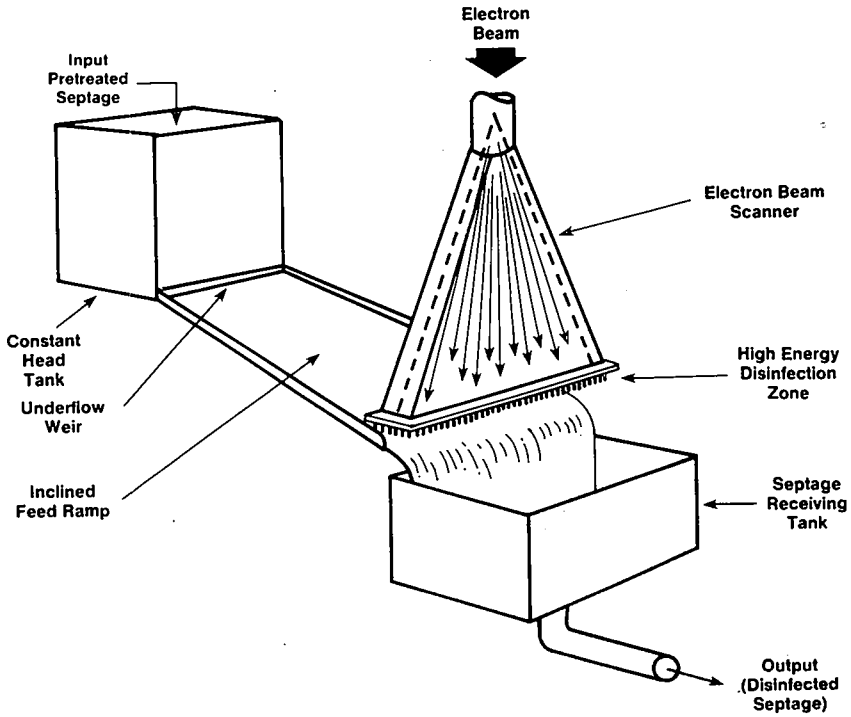
Organism	Number of Days		
	at 4°C	at 20°C	at 28°C
Poliovirus 1	110	23	17
Echovirus 7	130	41	28
Echovirus 12	60	32	20
Coxsackievirus A9	12	--	6
Aerobacter aerogenes	56	21	10
Escherichlia coli	48	20	12
Streptococcus faecalis	48	26	14

The disinfection power of the electron beam is limited because electron penetration is only about 0.5 cm (0.2 in.). Septage, which would require pretreatment, must flow past the electron beam in a thin uniform film. Figure 7-21 presents a typical configuration for an electron beam disinfection unit. This unit would require a minimum level of electron irradiation of 400,000 rads. This energy level would ensure penetration of 0.5 cm (0.2 in.). No septage studies have been reported with beta ray irradiation.

b. Gamma Ray Irradiation

Gamma rays' disinfection properties are very similar to beta rays; however, there are two major differences between the two. First, gamma rays are much more penetrating; a layer of water 64-cm (25 in.) deep is required to stop 90 percent of the rays from a cobalt-60 source; in comparison, a 1.MeV electron can only penetrate about 1 cm (0.4 in.) of water. Second, gamma rays are emitted from decaying radioactive isotopes. The decay is continuous and uncontrolled; it cannot be turned on and off as with the electron generator.

FIGURE 7-21
ELECTRON BEAM SCANNER AND SEPTAGE SPREADER (36)

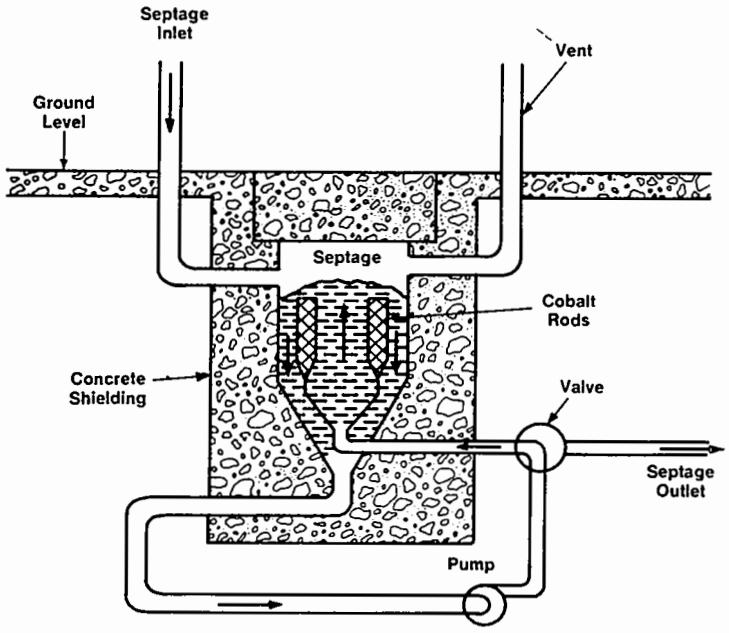


Two isotopes, Cs-137 and Co-60, have been used as fuel sources for disinfection processes. Cs-137 has a half life of 30 years but produces only half as much energy as does Co-60, which only has a half life of 5 years. Two general types of gamma ray irradiation systems have been proposed for septage disinfection. Figure 7-22 presents a typical design for a batch-type system for septage, where a volume of septage would be circulated in a closed vessel surrounding the gamma ray source. The second system is similar in design to the beta system illustrated previously. Dried septage would be carried on a conveyor belt past the gamma ray source. As of this date no such facilities are in operation.

7.12 Odor Control

Odor control is a critical element in the design of a septage treatment facility. As a general rule, all process units should be self contained, individually covered, or contained within buildings vented through an odor removal system. This is especially true for preliminary treatment processes, any process where the wastewater is mixed or aerated. The degree of odor control warranted at a particular facility will depend on the typical characteristics of the incoming septage, the location of the plant in relation to residential areas, the existence of natural buffers (i.e., wooded areas), and local microclimates (i.e., typical wind direction, potential for inversions, etc.).

FIGURE 7-22
COBALT-60 IRRADIATION FACILITY
AT GEISELBULLACH, WEST GERMANY (36)



The basic components of an odor control system are the process or building containment structure, the air collection and ventilation system, and the odor removal system (scrubber or filter). The design of containment structures is a function of equipment design, building design, and site layout. The design of the ventilation system should follow general heating, ventilation, and air conditioning design practice. Several odor removal systems are discussed in Chapter 4 under receiving station design.

7.13 Treatment and Disposal of Liquid Fraction

Methods that can be used for treatment/disposal of the liquid fraction from an independant septage treatment facility are: 1) land treatment; 2) direct discharge to surface water after further treatment; and 3) discharge to STP. Table 7-33 summarizes applicable processes for each method, as well as advantages, disadvantages, and general design criteria for each process. Land treatment is the most commonly practiced treatment/disposal method for solid and liquid fractions of septage. Table 7-34 summarizes the advantages, disadvantages, and general design criteria for several land disposal processes for raw septage and septage solids, as well as for incineration. Many fo the processes listed in these tables have been described elsewhere in this handbook. Descriptions of those processes not discussed in this handbook are available elsewhere (21) (35) (36). Tables 7-33 and 7-34 emphasize those processes that would most likely be considered for an independent septage treatment facility (because of plant location, operational requirements, funding, etc.).

TABLE 7-33

TREATMENT/DISPOSAL OF LIQUID FRACTION --
ADVANTAGES, DISADVANTAGES, AND DESIGN CRITERIA (21)(35)

Process	Advantages	Disadvantages	Design Criteria
Land Treatment			
Irrigation	• Effluent quality excellent	• Large land requirement • Limited by soil type, depth topography, climate, etc. • Sprinkler clogging, odors • Storage required for cold weather	• Area req'd: 300 to 3,000 ha/1,000 m^3/d • BOD loading: 0.2 to 5.6 kg/ha/d • Depth to Groundwater: 0.9 to 1.2 m (min) • Slope: 20% maximum • Soil Permeability: Mod. slow to mod. rapid
Rapid Infiltration	• Simple operation • Least land-intensive • Cold weather does not affect operation	• Nitrate, nitrite removals low • Limited by soil type, depth, hydraulic capacity, etc.	• Area req'd: 20 to 300 ha/1,000 m^3/d • BOD loading: 22.4 to 112 kg/ha/d • Depth to Groundwater: 3 m (min) • Slope: Not critical • Soil Permeability: Rapid (sands, loamy sands)
Overland Flow	• Soil clogging not a problem • Depth to groundwater not critical	• Limited by soil type, crop water tolerances, climate slope • Vegetation required • Potential odor, vector problems	• Area req'd: 200 to 500 ha/1,000 m^3/d • BOD loading: 5.6 to 56 kg/ha/d • Depth to Groundwater: Not critical • Slope: Finish slopes 2 to 8% • Soil Permeability: Slow (clays, silts, and soils with impermeable barriers)
Wetland Application	• Good for small flows • Low cost, simple	• In developmental stage - design information limited • Climate may be major limitation • Large area requirement • Potential for mosquito breeding	• Site and project specific

TABLE 7-33

(CONTINUED)

Process	Advantages	Disadvantages	Design Criteria		
Discharge to Surface Water					
Lagoons	• Simple operation • Low cost • High reliability • Long service life • Less solid residue generation than with other secondary processes	• Large land requirement • Cold weather problems • Potential for seepage to ground-water • Potential odor, vector problems • Effluent quality marginal		Aerobic	Facultative
			Detention, d	3-10	20-180
			Depth, m	2-6	1-2.5
			pH	6.5 to 8.0	6.5 to 9.0
			Temp., °C	0-40	2-32
			Opt. Temp., °C	20	20
			Organic loading: kg/ha/d	11-335	11-110
Attached Growth	• Process more controllable than lagooning, land treatment • Performance well-documented for wastewater treatment • Small land requirement	• Higher capital, operating costs than lagooning, land treatment	• Depends on selected method; available in literature		
Suspended Growth (Activated Sludge, Extended Aeration, etc.)	• Process more controllable than lagooning, land treatment • Performance well-documented for wastewater treatment • Small land requirement	• Higher capital, operating costs than lagooning, land treatment	• Depends on selected method; available in literature		
Discharge to STP					
	• Construction and maintenance of liquid stream treatment facility not required	• May have adverse impact on POTW, especially if flow equalization not provided, or if stream is high-strength	• Depends on POTW • Implications, design criteria, etc., discussed in Chapter 6		

TABLE 7-34

ULTIMATE DISPOSAL OF RAW SEPTAGE AND SEPTAGE SOLIDS -- ADVANTAGES, DISADVANTAGES, AND DESIGN CRITERIA (21)(35)(36)(7)

Process	Advantages	Disadvantages	Design Criteria
Land Disposal			
Spreading (Liquid Septage)	• Soil conditioning, fertilization • Dewatering not required • Inexpensive liquid transfer	• Septage should be stabilized to avoid problems from odors, vectors, etc. • Large area required • Wet-weather problems	• Ground slope: 5 to 8% maximum • Soil Permeability: 1.5 to 15 cm/hr (0.6 to 6 in/hr) • Soil pH: alkaline or neutral (pH 6.5)
Trench Fill (Liquid or Solids Fraction)	• Suitable for unstabilized septage • Low initial costs	• Daily soil cover required for vector control • Large land area	Narrow Trenches / Wide Trenches Width: <3 m / >3 m Septage Solids Content: 3 to 28% / >20% Application Rate: 2,270 to 10,580 m^3/ha / 6,050 to 27,400 m^3/ha Surface Soil Cover: 1.3 m / 1 to 1.5 m Depth to Groundwater: 0.6 to 1.5 m / 0.6 to 1.5 m
Area Fill Mound (Septage Solids)	• Suitable in shallow-watertable areas or where excavation not possible • Very reliable disposal method	• Stabilized septage required • Large land area required • Leachate must be controlled • High manpower and equip-requirements	• Septage Solids Content: 20% • Septage Characteristics: Stabilized • Ground Slope: No limitation if suitably prepared • Bulking Ratio: 0.5 to 2 soil: 1 septage solids • Septage Application Rate: 5,670 to 26,450 m^3/ha • Mound Height: 2 m • Soil Cover Height: 1 to 1.5 m
Area Fill Layer (Septage Solids)	• Solids content can be as low as 15% • Very reliable disposal method	• Wet-weather problems • Large area required • Requires relatively level ground • Stabilized septage required	• Septage Solids Content: ≥15% • Septage Characteristics: Stabilized • Ground Slope: Level preferred • Bulking Ratio: 0.25 to 1 soil: 1 septage solids • Septage Application Rate: 3,780 to 17,000 $m/^3$ha • Layer Height: 0.15 to 1 m • Soil Cover Height: 0.15 to 0.3 m

TABLE 7-34

(CONTINUED)

Process	Advantages	Disadvantages	Design Criteria
Diked Containment (Septage Solids)	• Stabilization not required • Bulking agent not required • Efficient land use	• Controls for leachate outbreaks required	• Septage Solids Content: > 20% • Septage Characteristics: Stabilized or unstabilized • Ground Slope: Level ground or steep terrain if suitably prepared • Bulking Ratio: 0 to 0.5 soil: 1 septage • Septage Application Rate: 9,070 to 28,300 m^3/ha • Interim Cover (Occasional): 0.3 to 1.0 m • Final Cover (Filling Discontinued): 1.0 to 1.5 m • Typical Dimensions: 15 to 30 m wide, 30 to 60 m long, 3 to 9 m deep
Lagooning (Septage)	• Simple operation • Economical • Stabilization, dewatering not required • Septage may be stored indefinitely	• Odor problems • Large area required • Treatment of supernatant may be required	• Depth: 1 to 1.5 m - other dimensions depend on design life of lagoon • Dike Slopes: 1:2 exterior, 1:3 interior • Bottom Separation from Groundwater: 1.2 m minimum • Cells: Minimum of two • Loading Rates: 35 to 38 kg solids/m^3/yr 0.8 to 1.5 kg solids/m^2 of surface/30 days of use • Solids Removal: 1.5 to 3 yr intervals
Incineration	• Very small quantities of solids for disposal • Stabilization not required • Total or partial conversion, primarily to CO_2 and water • Possibility for co-incineration with municipal refuse • Possibility for steam, electric generation, heat recovery, etc. • Small land area required	• Ash disposal required • High costs • Air pollution control devices normally required • Dewatering required • Complex operation	• Depends on method chosen (multiple-hearth, fluidized bed, etc.)

7.14 Mobile Septage Dewatering

A novel approach to septage treatment, which has had limited practice in Europe, is the use of a mobile septage processing unit where raw septage is lime-conditioned and dewatered in the same truck used for the pumpout operation. A proprietary mobile dewatering/hauler truck, which pumps out septic tanks and then dewaters the septage in transit, has been tested (1). After dewatering, the reject liquor is emptied into the next septic tank after it is pumped out. The dewatered sludge can be discharged to an STP sludge stream or applied directly to the land. Some of the advantages and disadvantages of this treatment scheme are as follows (see also Figure 7-23):

Advantages

1. The liquid volume of septage to be disposed of (i.e., after dewatering) is reduced considerably.

2. The septage sludge to be disposed of has a dry solids content consistently in the range of 16 to 23 percent. By producing a stabilized dewatered sludge, direct disposal at nearby landfills or directly on farmland is more feasible.

3. Mobile dewatering/hauler trucks could service more septic tanks before disposal is required since the bulk of the liquid volume is returned to empty septic tanks in the form of reject liquor. This minimizes the time and associated cost in traveling to and from disposal sites.

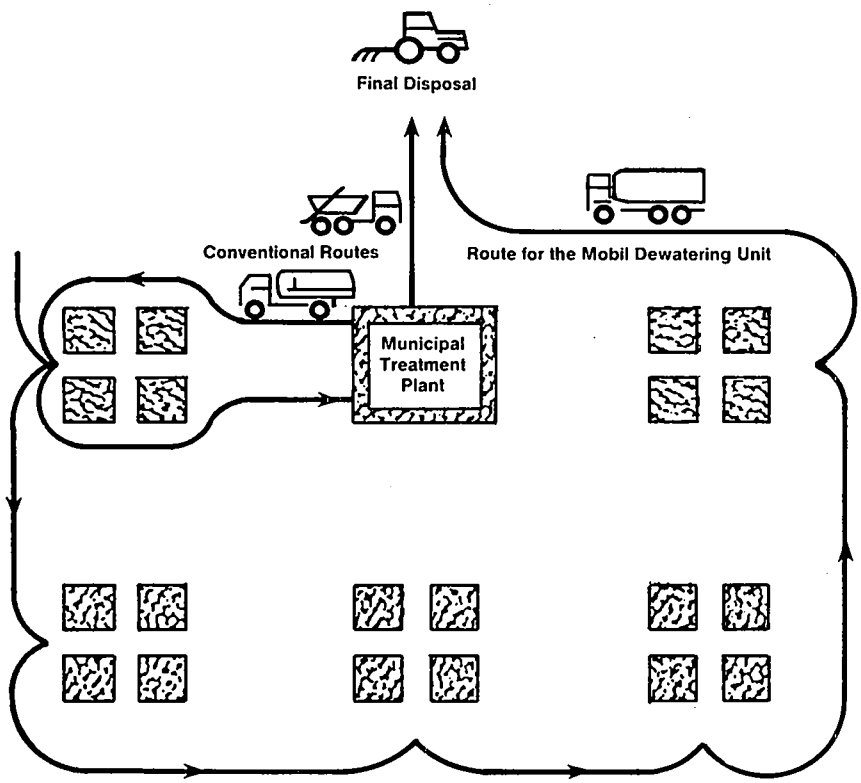
Disadvantages (for the Absorption Field)

1. The resting period which normally follows pump-out is eliminated and could affect the long-term performance of the absorption field.

2. High suspended solids effluent and high pH effluent to absorption field for a period after pumping.

3. Potential public health risk of transferring pathogens between residences even though lime use may minimize survival.

FIGURE 7-23
REDUCED TRAVEL DISTANCE THROUGH ON-THE-ROAD DEWATERING OF SEPTAGE (1)



7.14.1 Process Description

The proprietary mobile dewatering/hauler truck (see Figure 7-24) consists of the following components:

1. 90 m (295 ft) of hose on a motorized windlass.
2. A lime conditioning unit (storage and injection pump).
3. A 4.5 m^3 (1200 gal) holding tank for conditioned septage.
4. A sludge feed system to maintain appropriate levels in the dewatering unit.
5. Vacuum filter for dewatering.
6. A 3 m^3 (800 gal) sludge cake container.
7. A 4.5 m^3 (1200 gal) tank for reject liquor.
8. Reject liquor feedback pipe.

This equipment is mounted on a 22 metric ton (24 ton) truck and can be remotely operated by one man servicing the septic tank.

The sequential steps in the collection and dewatering of the septage from the septic tank are listed below:

1. Preparation of tank (includes gaining access to tank and preparing equipment).
2. Suction of contents from tank. Suction can be facilitated by periodically blowing air or reject liquor into the septic tank and scraping the sides of the tank to mix or liquify the contents.
3. The septage is conditioned with lime and injected in-line before it enters the storage tank.
4. After all the septage is removed from the septic tank, the reject liquor from the previous dewatering operation is pumped into the septic tank.

FIGURE 7-24
MOBILE DEWATERING/HAULER TRUCK (1)

1. Hose
2. Lime Conditioning Unit
3. Holding Tank, Conditioned Septage
4. Sludge Feed
5. Dewatering Unit
6. Sludge Tank
7. Reject Liquor Collection Tank
8. Reject Liquor Feed Back Tank

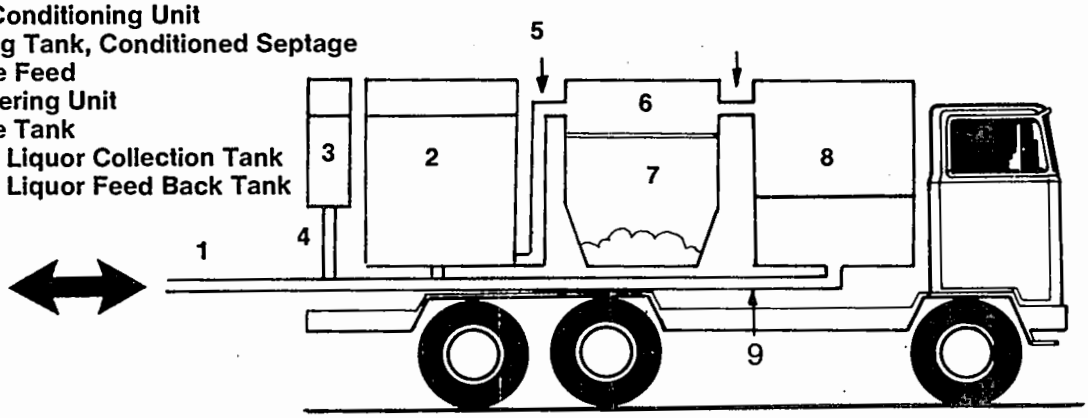
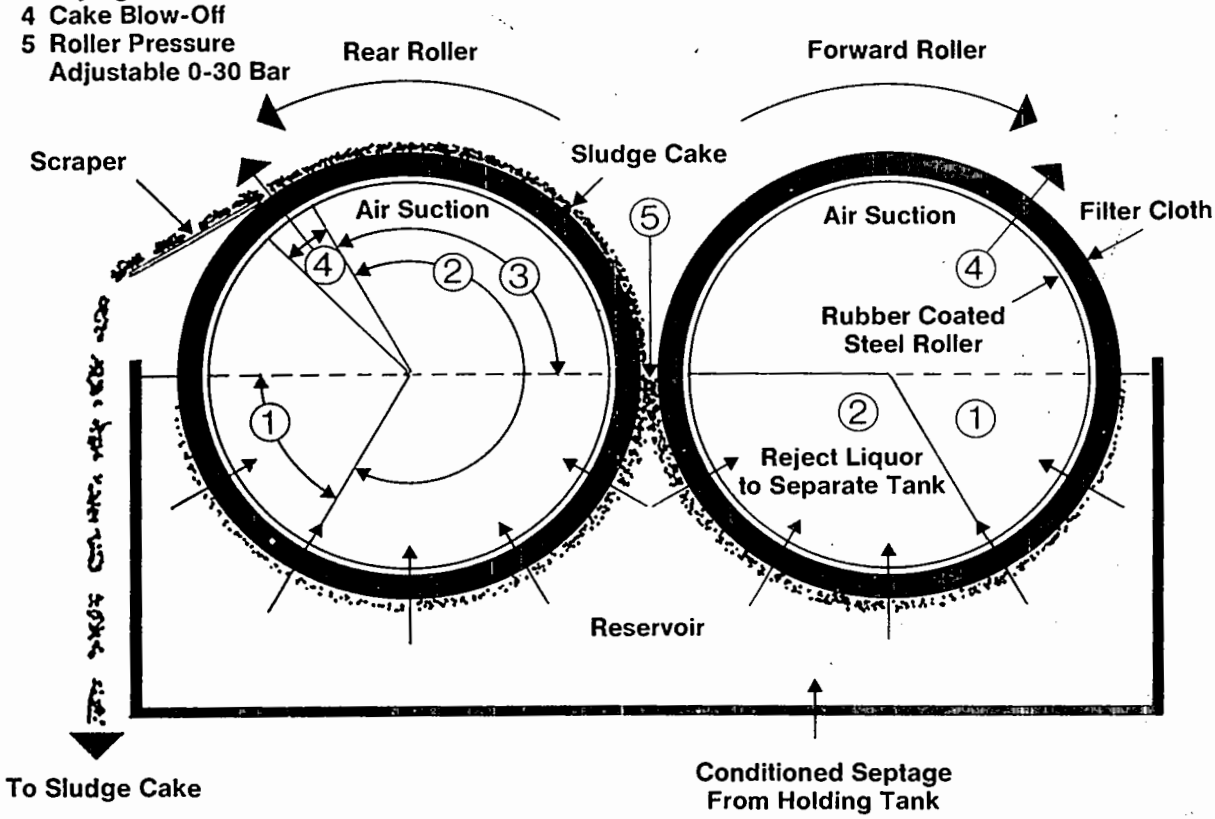


FIGURE 7-25
VACCUM FILTER FOR SEPTAGE DEWATERING (1)

1 Attachment Zone
2 Vacuum Zone
3 Drying Zone
4 Cake Blow-Off
5 Roller Pressure Adjustable 0-30 Bar



5. Dewatering of the conditioned septage from the storage tank can begin as soon as the reject liquor return operation is finished. The reject liquor tank is gradually filled as dewatering progresses, simultaneously emptying the septage storage tank. This process will continue until the next septic tank is ready for pumping.

6. Final maintenance check and septic tank closure.

7.14.2 Dewatering Equipment

The dewatering process is performed with a vacuum filter press designed to handle non-homogeneous septage. Figure 7-25 shows a typical press which consists of two parallel rollers partially submerged in the conditioned septage reservoir. The only additional time required is for the refilling of the septic tank (Step 4 above).

7.14.3 Mobile Dewatering Performance

The mobile dewatering/hauler truck has been used in Norway and Sweden (1). The time required for the septic tank cleaning operation is very similar to the time for conventional pumping (generally less than 1 hour).

The septage sludge has a dry solids content of 16 to 23 percent. A significant reduction in pathogenic microorganisms occurs due to the high pH levels from lime conditioning. If sufficient lime is added to produce a pH of 12 after 2 hours, the process could qualify as a process to significantly reduce pathogens (PSRP). PSRP treatment eliminates many restrictions placed on land application of septage sludge (see Chapter 5).

The reject liquor returned to the septic tanks has a suspended solids content in the range of 600 to 2000 mg/L. After three days the levels drop to an average of 200 to 500 mg/L, and to less than 200 mg/L within 16 days. The high pH (12 to 13) introduced with the reject liquor was reduced to approximately pH 8 after 7 days, and back to a normal value of 6 to 7 within 16 days. It is claimed that the disposal field should not be subject to any ill effect from the pumping/dewatering operation, provided reserved capacity is left when the reject liquor is returned to the septic tank and proper care is demonstrated in the use of the system immediately after pumping(1). However, the potential for impact on disposal field performance needs to be further investigated.

Eikum (1) did note that poor reject liquor quality was encountered in instances when septage quality was poor (i.e., septage age $>$3 years) when conditioning was insufficient, or when septage contained excessive grease, oil, or substances that interfere with filtration. The conclusions drawn from the NIVA studies (1) were that mobile dewatering with this machine is an attractive alternative in rural areas, provided that:

1. Pumping frequency is kept in the order of 1 to 3 years.
2. Septic tanks containing excessive grease or oil are avoided.
3. Operation is performed by skilled personnel.
4. Disposal sites for high pH sludge cakes can be found.
5. Transport distances to treatment facilities are unfavorable for conventional collection.

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CHAPTER 8

OPERATION AND MANAGEMENT CONSIDERATIONS

8.1 Overview of Management Concerns

Each of the major components of septage disposal, i.e., pumping and hauling, treatment, and final disposal, have certain operational requirements that require specific management responsibilities. Management, by definition, is the process of controlling, directing, and handling a resource, facility, or group of people. The management of septage disposal includes any actions taken to ensure the proper planning, design, and operation of facilities and equipment to handle this waste. Proper management is just as important to the success of a septage hauling and disposal program as is the design of the hauling, treatment, and disposal systems.

This chapter presents a review of the management activities involved in implementing a successful septage management program. The reader should recognize that the information presented in this chapter serves as input to the formulation of a septage management plan. A septage management plan is a strategy document that outlines the actions that are necessary for implementing proper controls on the hauling, treatment, and disposal of septage.

One of the first questions that should be asked by the individual who is interested in developing a septage management plan is "What are the management needs?" Management needs can be expressed as the services or activities that need to be provided to ensure proper design and operation of septage facilities. Once the needs are defined, the question then is, "Who is responsible for carrying out the management services?" Answering these questions requires that the appropriate management functions and institutional arrangements be specifically described. Management functions and institutional arrangements, as used in this context, can be defined as follows:

> <u>Management Functions</u> - The range of services and activities to be provided to ensure the proper design and operation of septage facilities.

Institutional Arrangements - The assignment of responsibilities to the principle participants in the management process.

The basic types of management functions and institutional arrangements that apply to septage management are discussed as follows.

8.1.1 Typical Septage Management Functions

A complete septage management program might include the following basic management functions:

On-Site System Management - Closely linked to any septage management program is the design, installation, and maintenance of onsite wastewater disposal systems. Onsite system maintenance involves the routine inspection and pumping of septic tanks. Since septage is generated from the maintenance of onsite systems, the relationship of onsite system maintenance and septage management is an important one.

Management of Pumping and Hauling Activities - There are several techniques that can be used to ensure the proper performance of the septage hauler; a key factor is a septage management program. The septage hauler is basically responsible for pumping septage and transporting the wastes to an acceptable location for treatment and disposal. The control techniques commonly used to regulate haulers include licensing, certification, and registration.

Treatment/Disposal Facility Operations - The actual operation of the treatment/disposal facility will require the provision of a variety of maintenance and repair services, depending on the type of technology involved.

Treatment/Disposal Facility Performance Monitoring - The purpose of performance monitoring is to assure regulatory agencies that a facility is meeting operating permit conditions and, if not, determine necessary corrective actions. These conditions provide the regulatory agency with the necessary authority to conduct onsite inspections and review performance data on a routine basis.

System Financing - Financing a septage facility and transport system involves securing grants and loans to cover capital expenditures (e.g., equipment, vehicles, and physical plant), and collecting revenues to support annual debt retirement and operating costs. The choice of financing methods will depend on the types of costs to be incurred and the entity that is responsible for the costs.

The number of management functions to be provided and the complexity of the services involved will vary from one program to another. Specific examples of the types of management functions that may be included in a management program are discussed later in this chapter.

8.1.2 Institutional Arrangements

Having defined the range of management functions to be provided, arrangements for implementing the various activities involved need to be made. This task requires the allocation of responsibilities between the public and private sectors and the designation of a management agency (i.e., the lead or principle institutional entity responsible for program implementation). The various entities that might take on different management responsibilities include:

State Agencies - Environmental protection agencies, health departments, and public utility commissions are involved in a variety of septage management tasks, particularly in regulating haulers and disposal facilities, enforcement, and financing. Each state is organized differently and has different sets of laws and regulations governing septage disposal.

Municipalities - Cities, towns, villages, etc. can provide a range of services to its constituents, including septage hauling and treatment. Municipalities can also adopt and enforce special rules and regulations concerning septage disposal. Cooperative agreements among municipalities enable several adjoining communities to participate in a septage management program.

Counties - A county can help coordinate municipal activities in septage disposal or provide a variety of planning and operational services on its own.

Special Purpose Entities - Single or multiple purpose entities such as special districts and public authorities (e.g., sewage authorities) can be established for the purpose of providing septage management services, either independently or in conjunction with other public service functions (e.g., sewage treatment of solid waste management). Special purpose agencies are legal governmental entities, but they operate outside the regular governmental framework for a specific purpose. State laws define the organizational characteristics, powers, jurisdiction, and financial authority of special purpose entities within each state.

Private Corporations - These include private enterprises such as small private firms (e.g., septage haulers, septic system contractors, plumbers, etc.). Private utilities can own and operate facilities and provide a variety of services in a septage management program. Such privately owned and operated facilities (which operate at a profit) are typically regulated by state public utility commissions.

Nonprofit Corporations - These can be public or private entities. A public nonprofit corporation can be formed by cooperating municipalities (e.g., a waste disposal utility). Typical private nonprofit corporations include rural cooperatives and property owners associations.

The choice of specific type of management agency for septage management depends on many factors, including legal authority, financing capability, service area flexibility, and willingness to provide septage management functions. Table 8-1 briefly summarizes the capabilities of each of the aforementioned institutional arrangements related to the provision of septage management functions.

The remainder of this chapter describes the key management considerations in developing a septage management plan, namely:

1. Management of onsite (septic) systems.
2. Management of septage pumping and hauling.
3. Monitoring of the quality and quantity of incoming septage.
4. Facility operation and maintenance.
5. Performance monitoring.
6. System financing.

These management concerns are basically consistent with the major management functions described previously.

8.2 Onsite Systems Management

A major concern in implementing a septage management program is the transport of septage from septic systems to the treatment/disposal facility.

TABLE 8-1

INSTITUTIONAL CAPABILITY MATRIX

Management Function	Implementing Entity					
	States	Counties	Municipalities	Special Purpose Agencies	Private Corporations	Nonprofit Corporations
Onsite Management System Inspections Septage Pumping		X	X	X	X	X
Management of Septage Pumping and Hauling Vehicle Inspections Hauler Regulation Recordkeeping		X	X	X		
Treatment/Disposal Facility Operations Receiving Stations Periodic Maintenance Process Control Recordkeeping		X	X	X	X	X
Treatment/Disposal Facility Performance Monitoring Facility Inspections Monitoring Reporting	X	X	X	X	X	X
System Financing Capital Financing Operations Financing Recordkeeping	X	X	X	X	X	X

The scheduling of septic tank pumping is a primary means of controlling the volume of septage received at treatment and disposal facilities. A number of approaches can be taken to directly or indirectly control septic tank pumping. Some examples, in increasing order of public agency involvement are:

1. Leaving septic tank system maintenance solely to the discretion of homeowners, with the need for pumping to be determined as they deem necessary. This is, in essence, no control, and is the predominant situation throughout the country.

2. Providing general public education material to septic tank system owners to acquaint them with their maintenance responsibilities.

3. Sending scheduled, personal "reminder cards" to homeowners to have their system inspected and pumped, if necessary. To be totally effective, such a system must have a response mechanism to determine which people have done so. This would allow for either a follow-up reminder card or scheduling of the next reminder for those who have acted on the recommendation.

4. Requiring septic systems to be inspected and pumped, if necessary, when a home is sold (i.e., before the transfer of title can take place). Homes are sold every five to seven years on the average.

5. Scheduling and arranging for septic tank inspection and maintenance (e.g., via an onsite wastewater management district). To effectively implement such a system, the onsite system management entity must have access to the onsite wastewater disposal system. This can generally be granted through an onsite wastewater management district ordinance.

Also involved in the management of septage generation is the concern for septage characteristics. Public education programs aimed at the homeowner should address the proper use of a septic system; that is, elimination of the use of chemicals, degreasers, or other additives to the septic tank.

It is obvious that the greater the degree of public control of onsite system maintenance, the greater can be the control of the quantity and quality of septage that must be "managed." Left totally to homeowner discretion, septage flow has a tendency to be crisis-generated; that is, need being determined by occurance of problems. Since problems can often be seasonal or climate-related (e.g., more problems during wet

periods), the quantity of septage generated can vary greatly from day to day, and from month to month. Greater public control can minimize the difference between extremes in septage flow. Otherwise such irregularities must be compensated for at the treatment and disposal facilities by constructing relatively large equalizing facilities, or by over-designing all processes to handle peak volumes. Both of these can add significantly to the cost of the facilities. Unless septage is treated at a facility with built-in capacity to handle peak volumes, the scheduling of septic tank maintenance should be considered as an integral part of the septage management program.

Many communities have instituted programs which attempt to control the practice of septic tank pumping. In Marin County, California, the County Health Department requires the renewal of septic tank maintenance permits every two years (1). Renewal of the permits involved inspection of the septic tank and pumpings of the tank if deemed necessary by the inspector (i.e., County Sanitarian). Inspections and tank pumping are scheduled evenly throughout the year. A similar program was implemented in Santa Cruz, California, with the exception that a specially created County Septic Tank Maintenance District actually peformed the necessary maintenance, including tank pumping, on a schedule where tanks were generally pumped once every three years on the average (2).

Two communities in Massachusetts have created a joint on-site systems management program under which homeowners are required to have their septic tanks pumped every three years (3). The towns notify homeowners when the tank pumpings must take place, and the pumpings must be confirmed by submission of a receipt to the towns.

8.3 Management of Septage Pumping and Hauling Activities

The pumping of septage from individual septic tanks and hauling to disposal sites is done primarily by private septage haulers. Since the pumping and hauling of septage is a key aspect of a septic management program, some degree of public control of this activity is important. Such a program should address the regulation of hauler activities, as well as the regulation of adequate disposal facilities. Specific activities involved include:

1. Regulation of individuals involved in the design, installation, cleaning, or repair of septic systems.

2. Regulation of individuals involved in the transport of septage for treatment.

3. Recording of septage pumping events, volume of residuals transported, and location of disposal.

4. Establishment of hauler vehicle specifications.

5. Mandatory periodic inspection and approval of all vehicles used to transport residuals.

6. Prohibiting of industrial waste hauling trucks from pumping out domestic tanks.

7. Restricting the disposal of septage to approved sites.

The regulation of haulers can be accomplished through licensing, certification, and registration. Licensing is the most restrictive of these three control techniques. Licensing regulates the haulers by imposing certain limitations or conditions on their activities. Licenses can be an effective regulatory tool, especially if the licenses are revoked when the performance of the individual (or firm) is not satisfactory. (Vehicles can also be licensed. In fact, the management agency should decide who or what to regulate, i.e., the hauler, the firm, or the vehicle.)

Many states license septage haulers (Delaware, Florida, Illinois, and Wisconsin) (2). However, state licensing programs generally are not effective at controlling the practices of individual haulers. Some local licensing programs, such as the one in Fairfax County, Virginia require haulers to display color-coded decals, issued by the County, on their trucks (4). The haulers can not use County-operated septage treatment facilities without a valid license decal.

Certification and registration, on the other hand, are typically voluntary mechanisms. Certification is a confirmation or assurance that the individual (or firm) is competent and qualified to provide hauling services (or that the vehicle meets all specifications). A qualification exam (or vehicle inspection) may be a prerequisite to certification. Registration is the least restrictive technique, merely requiring the individual (or firm) to register (i.e., "sign up") for a particular activity.

Certification or registration allows the operator of a septage treatment facility to limit use of the facility to recognized and approved haulers. In Acton, Massachusetts, for example, haulers must be registered with the town, and must purchase coupons from the town in order to discharge septage at the Acton septage lagoon facility (1)(4). Coded registration numbers or decals such as used in Fairfax County, Virginia (4) can also serve to identify currently registered or certified haulers.

Whichever techniques are chosen to control hauler activities, periodic inspections of hauler vehicles and equipment, as well as a manifest (i.e., recordkeeping) system, should be instituted for quality assurance. These conditions can, in fact, be linked to a mandatory licensing requirement.

Maintaining accurate files of septage pumping events and disposal locations can be ensured by the implementation of a trip ticket or manifest system. An additional benefit of such a system can be its built-in monitoring or recordkeeping mechanism. This system can take on many forms, but it basically requires the written documentation of the origin of each load of septage brought to the treatment and disposal facilities. All manifest systems use some type of onsite system maintenance form (also called manifest, trip tickets, and septic tank pumping permit) on which pertinent information (i.e., pumping and hauling firm, date, property location and owner, volume, etc.) relative to a particular load of septage is recorded. Verification of the report is by means of a signature of the representative of the firm and the owner or resident of the property from which the septage was pumped. The form is provided in multiple copies, which can be left with or sent to the owner, the operator of the treatment and disposal facilities, the management entity, and the pumping and hauling firm.

In Marin County, California (1) the hauler provides a receipt to the homeowner who in turn must submit the receipt to the County Health Department as proof that the septic tank was pumped. A record of septic tank pumpings is kept with the individual permit file. In Acton, Massachusetts (1) the hauler must purchase coupons from the town in order to use the town septage facility. Upon discharging septage at the facility, the hauler must submit a filled out coupon indicating name of hauler, quantity of septage, and origin of septage. The Town of Somersworth, New Hampshire issues coupons to individual homeowners. The coupons are given to the hauler when a tank is pumped, and the hauler turns in the coupon at the treatment plant as payment for treatment. The coupon, which indicates the origin of the load (i.e., homeowner's name or address) is maintained on file.

An innovative approach to hauler regulation is the requirement for the submission of hauler plans as a condition to the issuance of hauler licenses or permits to operate within a jurisdiction or service area. The hauler plans would essentially:

1. Identify the disposal sites permitted to be used.

2. Show proof of use of these sites.

3. Set forth the operational provisions for septage, nondomestic septage.

4. State provisions for disposal during cold and wet weather.

5. Identify reporting and recordkeeping procedures.

6. Show general service areas of operation.

7. Identify standard service contract-type agreements made with homeowners and industries for septage hauling services.

The maintenance of a septage hauler plan with a manifest system (to record each pumping event) is a beneficial management tool in that it not only identifies septage pumping events, but also assists in scheduling septage disposal facility operations.

8.4 Monitoring the Quantity and Quality of Incoming Septage

The next phase of septage management programs is the delivery of septage to a facility for final treatment and disposal. As discussed in previous chapters, some type of receiving station will need to be provided at a treatment/disposal facility to hold or store the waste until it can be treated. Regardless of the type of receiving station that is chosen, a system for checking the quantity and quality of incoming septage is necessary to ensure the smooth, efficient operation of the septage treatment and disposal facility.

The following is a suggested sequence of activities to be accomplished in monitoring the volume and characteristics of incoming septage flows to its treatment/disposal destination:

1. Record the name of the hauler, the origin of the septage, and the time of arrival. This can be done at the facility entrance or at the receiving station by a plant operator or clerk. The coupon systems mentioned earlier can serve this purpose, or more sophisticated credit card type systems can be used.

   One system administered by the Seattle METRO Public Authority involves the use of magnetically coded credit cards (5). The credit cards, which are issued to haulers, provide access to approved disposal sites and automatically record a hauler identification code and time of arrival. A computerized interceptor receiving station in Germany (see Figure 4-8) uses a credit card to provide access and record hauler identification (6). The computerized receiving station also records septage volume, and takes a representative sample which is held for future testing if an inappropriate discharge is suspected.

2. Record the septage volume of the incoming vehicle. Septage quantity can be monitored by requiring site glasses on the trucks or by directly measuring the volume of septage delivered.

   This can be done roughly by estimating capacity of truck, or can be directly determined by flow measurement or by weighing the truck.

   The computerized receiving station discussed earlier (6) incorporates an in-line flow meter. Such equipment will be expensive and will require routine calibration and maintenance. The use of truck scales also involves considerable capital investment, but should require considerably less routine maintenance and calibration. The Wayland-Sudbury septage facility utilizes a pair of truck scales which provide digital readouts and print-outs of truck weight and corresponding septage amount (7). The Tryon Creek Plant in Portland, Oregon uses a system where the operator manually records the time, load volume, pH, source of load, and hauled identification on the payment receipt, a copy of which is maintained on file (8).

3. Sample septage quality prior to discharge or during discharge. This can be done for individual truck loads where there is a concern for the identification and elimination of harmful industrial and hazardous waste discharges to the treatment facility that may cause an upset to the treatment processes and/or cause a violation of permit requirements. A grab sample could be taken of the incoming waste for each and every incoming truck load, for truck loads where odors or other suspicious indicators identify a potential problem, or

on a simple random basis. As a routine maintenance activity, random samples should be performed from time to time to establish a trend analysis of septage quality characteristics or to adjust for pH. Samples could then be analyzed immediately (delaying septage discharge) or stored for a length of time equal to the flow-through time of the incoming septage through the treatment facility. If a problem arises with the facility operations (per this latter option), individual samples could be analyzed accordingly and traced back to the individual hauler.

This procedure is practiced at the computerized German interceptor receiving stations discussed earlier (6). The same procedure is carried out manually at the Ocean County, New Jersey sewage treatment plant (9) where samples are taken from each truckload and stored in a refrigerator for at least 24 hours. The septage is held in storage tanks where oxygen uptake rate (OUR) is constantly monitored. (A significant decrease in OUR indicates toxic effects or non-biodegradability). If plant upset results from introducing septage from a given storage tank, all samples representing loads dumped to that tank are tested to determine which load contributed the incompatible waste.

4. Supervise hauler activities during discharge. Visual inspections during the unloading process are all that is necessary to make sure that the wastes are properly discharged to the facility.

5. Keep the unloading area clear of debris and residue. This will help control odors and improve the access of hauler vehicles to the tipping area. Haulers who disregard this requirement might be fined, or their disposal privileges may be revoked for repeated violations.

6. Maintain a manifest ("trip-ticket") system. This involves the maintenance of a hauler billing schedule and origin-destination report on the volume, source, and quality of incoming septage. Coordination with another agency, such as a local municipality, a septic tank management district, or a health department, may be necessary to support septic system maintenance program activities.

Manpower requirements for this phase of septage management can be minimal. The sampling and laboratory analysis activities, however, could significantly add to the manpower requirements in conducting these tasks.

8.5 Facility Operation and Maintenance

The operation and maintenance activities of a septage treatment and disposal facility are similar in many ways to those typically performed at conventional wastewater treatment plants or land application sites for wastewater and sludges. This section outlines the general requirements for proper operation and maintenance of a septage treatment and disposal facility.

Many of the operational concerns of a septage treatment and disposal facility are related to the fact that septage is a highly concentrated waste as compared to sewage. Septage characteristics dictate greater attention to the operation of screening and grit and grease removal facilities at the receiving station and primary treatment systems. For example, bar screens at a septage receiving station are designed to handle larger quantities of screenings and heavier material than for a sewage treatment facility. This will result in more material to be disposed of, in addition to increased cleaning of the equipment to maintain proper working order.

The overall effectiveness of a septage treatment and disposal facility is dependent upon the skill of the operator. No matter how well a facility is designed, it may not live up to its capability if the operator is not thoroughly familiar with the function of each process in the plant, how each process accomplishes its function, how to evaluate the operation of each process, and how each process fits in the overall treatment scheme. This includes being familiar with the characteristics of the septage received for treatment (as discussed in Section 8.4) and monitoring the treatment processes to make the necessary adjustments to plant operations. Of particular concern to operators at sewage treatment plants which accept septage is maintaining a proper blending rate of incoming septage with sewage to avoid both hydraulic and organic overloads of treatment processes.

In addition to the proper operation of a septage facility, it is important to provide proper maintenance. A proper maintenance program will help reduce breakdowns, extend equipment life, and provide more efficient manpower utilization and performance. Any maintenance program should follow these few simple rules:

1. Start with good housekeeping, and keep a clean, neat, and orderly facility.

2. Make sure that personnel are familiar with each piece of equipment (how it works, and what function it is to perform). They will then be able to spot possible failures or, if and when failures do occur, they can pinpoint the trouble and act to correct the failure in the shortest possible time.

3. Establish a routine service and maintenance schedule for each piece of equipment.

4. Keep manufacturers' catalogs, manuals, blueprints, etc. available and stored in an indexed file for ready reference. Care must be taken in handling this information because it may have to last throughout the life of the equipment.

5. Maintain operating and maintenance records on each piece of equipment, with emphasis on lubrication frequencies and unusual incidents or faulty operating conditions.

6. Procure and maintain an adequate stock of the tools required to perform maintenance, with due consideration of accessibility and security.

7. Maintain a spare parts inventory for each piece of equipment. Consult manufacturers' recommendations for a listing of spare parts required.

8. Observe good safety procedures.

These rules may be applied to any of the methods previously discussed for the treatment and disposal of septage. Establishing effective operation and maintenance procedures at the onset will ensure effective treatment over the expected lifetime of the project.

Although the basic operation and maintenance requirements of a septage facility are similar to those of a typical sewage treatment plant, special attention should be given to certain aspects of septage handling and treatment. Increased labor will be necessary to operate and maintain the receiving station and preliminary treatment processes (i.e., supervision of dumping operations, cleaning of dump area, disposal of screenings and grit, sampling and testing of septage, etc.). Increased sludge and scum production in the primary treatment process will also require greater operator attention (i.e., process control, maintenance of clarifier equipment, pumps, and transport equipment, etc.). Fluctuating aeration requirements as a function of septage loading will necessitate greater process control flexibility and operator attention. Finally, additional administrative and clerical labor may be required to administer hauler billings and maintain manifest system records.

These special management requirements should be considered when estimating the cost of operating independent treatment facilities or when determining the incremental additional cost of handling septage at a sewage treatment facility.

8.6 Performance Monitoring

Monitoring the performance of septage treatment and disposal facilities is an important aspect of overall septage management. As discussed in the previous section, performance monitoring aids the facility operator in evaluating the overall effectiveness of the septage treatment and disposal facility. This information will indicate to the operator whether any adjustments or changes to the treatment and disposal processes have to be made in order to ensure that the minimum requirements are met.

Where treatment processes result in a liquid effluent discharge to surface waters, conventional water quality monitoring is used to check conformance with applicable effluent discharge requirements. Facilities employing land application, either surface or subsurface, must also include groundwater monitoring. Individual states have specific requirements for performance monitoring that should be consulted before establishing a monitoring protocol.

8.7 Financial Arrangements

The final consideration with regard to septage management is the financing of the septage transport and treatment process. Financing basically involves the raising of revenue to cover debt service (from capital investments) and operation and maintenance expenses. There are many conventional and alternative financing techniques that can be used by the public and private sectors to provide funding for capital projects and to fund their subsequent operations, maintenance, and replacement. These techniques will generally fall into the categories shown in Table 8-2.

In the financing of septage management facilities, the appropriate financing mechanism will depend upon:

1. Who owns and operates the transport vehicles.

2. Who owns and operates the treatment and disposal facility.

TABLE 8-2

CONVENTIONAL AND ALTERNATIVE FINANCING TECHNIQUES FOR SEPTAGE (10)

Conventional Financing	Private Financing	Privatization	Risk Reduction and Cost Reduction of Debt	Revenue Sources
Property taxation (i.e., general funds) as the primary source of revenue	Sale and leasebacks	Contracting for operations and maintenance	Bond pooling, State infrastructure banks, and loan	Treatment fees
	Conventional leasing		Bond banks, bond insurance, and letters of credit	Handling fees
General obligation bonds	Limited partnership financing	Private (tax-exempt financing	Zero-coupon bonds, floating interest rate bonds, etc.	User charges
Revenue bonds				Alternative taxes (luxury goods, local income tax, etc.)
Short-term notes used as interim financing before bonds are issued				

3. Whether septage pumping is mandatory (i.e., part of a formalized onsite management program) or voluntary (i.e., at the homeowner's discretion).

As discussed in the overview of management concerns (Section 8.1), and as was shown in Table 8-1, both public and private entities can become involved in the transport, treatment, and disposal of septage. The precise financing arrangement to be applied, therefore, will depend on the ownership-operational status of the facility (i.e., whether it is publicly or privately owned) and the type of facility (i.e., transport vehicle, receiving station, treatment plants, etc.).

Regardless of the financing methods chosen and the ownership-operational status of the facilities, there are several different financing options by which revenues could be collected to finance capital and operating costs. These options are described below, as they apply to the financing of septage pumping and hauling, and septage treatment and disposal. Some of the alternatives include the provision for a "trip ticket" system, which is part of a manifest program to identify the source of the septage. The manifest program can also be part of a formal onsite management program (as described in Section 8.2). Figure 8-1 illustrates how a trip ticket operation works in the financing of septage disposal costs for a municipally-owned septage treatment facility in Acton, Massachusetts.

The following options could serve as possible methods for funding septage pumping and hauling, and treatment and disposal:

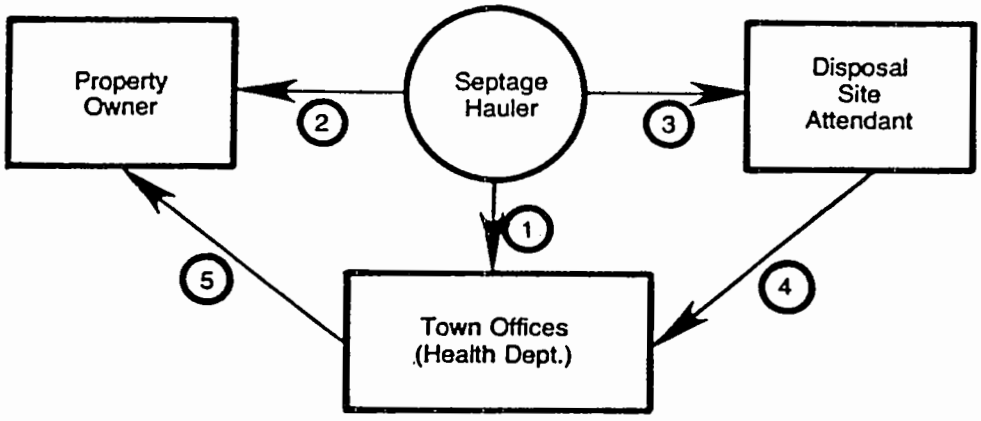
<u>Septage Pumping and Hauling</u>

1. The hauler would simply bill the homeowner for the costs of septage pumping and hauling.

2. Costs for pumping and hauling would be raised through an annual user charge levied by an onsite management district. Included in the user charge would be one tank pumping every five years. (The precise interval between pumpings can be determined by each management agency.)

3. The homeowner could enter into a septic system service contract with a hauler. One of the provisions of the contract would be to have the system pumped periodically (e.g., once every five years) or when necessary (as determined by the hauler and homeowner).

FIGURE 8-1
SEPTAGE MANAGEMENT SYSTEM FOR ACTION, MASSACHUSETTS (2)



NOTES:

1. Haulers purchase coupons (usually coupon booklets) from town offices (one coupon for each 500 gallons pumped). This entitles the hauler to dispose of septage at the town-owned disposal site at no extra cost.

2. Haulers pump septage from property owner on request. (The town's biennial pumping requirement is not actively enforced.) Property owner pays the hauler for pumping.

3. A trip ticket is filled out by the hauler in triplicate. Hauler gives one copy of the ticket to the disposal facility operator. The ticket shows the name of the pumper, the location of the septic tank pumped, the quantity pumped, and the date of pumping. One copy remains with the hauler, and the third with the property owner.

4. The disposal facility attendant submits daily receipts to the town offices, where daily and monthly log summaries are tabulated.

5. A copy of the trip ticket is placed in a file kept for each system installed or repaired in the town. This file contains: a copy of the original percolation tests results, the installation permit, copies of the system design drawings, an as-built drawing, any repair permits, correspondence concerning the system, and any septage pumping trip tickets. Files that collect a large number of trip tickets within a short period of time are noted as potential problems and visited by a Town Health Department Officer.

Septage Treatment and Disposal

1. The hauler would be charged for septage treatment services by the plant operator on a per-event basis.

2. The hauler would purchase a coupon from the plant operator (or representative). The cost of the coupon would reflect the treatment charge per septic tank. The hauler would present this prepaid ticket to the plant operator prior to the unloading of the truck contents.

3. The coupon could be sold directly to the homeowner by the plant operator (or representative). The homeowner would give the coupon to the hauler, who would then present it to the plant operator as proof of purchase for septage treatment services.

4. The cost of septage treatment would be included as part of an annual user fee paid by the homeowner (e.g., from an onsite management program or from a private service contract arrangement).

5. The plant operator could assess each hauler (based on the number of vehicles he operates) a flat fee for vehicle registration and septage treatment. The flat fee would entitle the hauler to an unlimited use of the facility for septage treatment. (Or a ceiling could be established with a surcharge payment for truck loads delivered to the site beyond the ceiling limit.)

The choice of the actual financial arrangement will depend on whether a manifest system is to be used (i.e., incorporated as part of the trip ticket concept), and the degree of control desired by the plant operator over the origin of wastes and the haulers utilizing the facility. These are important considerations to be made in designing a septage management program.

8.8 References

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4. Ciotoli, P.A. and K.C. Wiswall. Management of On-Site and Small Community Wastewater Systems. U.S. EPA Report No. 600/8-82-009, NTIS No. PB 82-260829, July 1982.

5. Rezek, J.W. and I.A. Cooper. Septage Management. U.S. EPA Report No. 600/8-80-032, NTIS No. PB 81-142481, August 1980.

6. Eikum, A.S. Treatment of Septage - European Practice. Norwegian Institute of Water Research, Report No. 0-80040, February 1983.

7. Roy F. Weston, Inc. Preliminary Draft Operation and Maintenance Manual for Wayland Sudbury Septage Treatment Facility, 1982.

8. Bowne, W.C. An Engineering Study of Septic Tank Content Disposal in Douglas County, Oregon. County Engineer's Office, Roseburg, March 1972.

9. Roy F. Weston, Inc. Concept Engineering Report - Septage Management Facilities for Ocean County Utilities Authority. October 1980.

10. Peterson, J.E. and W.C. Hough. Creative Capital Financing for State and Local Governments. Government Finance Research Center, Municipal Finance Officers Association, March 1983.

Chapter 9

Fact Sheets

9.1 Introduction

In order to provide a summary of technical guidelines pertaining to the design of septage treatment facilities, brief fact sheets addressing selected processes are presented. The fact sheets presented represent technologies which are considered to be most applicable to septage treatment, and are intended to provide specific guidance relevant to septage treatment applications which is generally lacking in currently available guidance documents. The cost information provided is somewhat limited due to the lack of cost data for full-scale operating facilities. In some cases, rough estimates of capital and operating costs are provided in the form of unit costs or cost curves. These estimates should be used only for general planning purposes to determine order-of-magnitude costs.

The fact sheets presented include:

- Receiving Stations (Dumping Station/Storage Facilities)
- Receiving Stations (Dumping Station/Pretreatment/Equalization Facilities)
- Land Disposal
- Lagoons
- Composting
- Lime Stabilization
- Odor Control (Soil Filters)

A more detailed discussion of technical considerations for each of these processes is presented in the respective design chapters:

- Chapter 4 Receiving Station Design
- Chapter 5 Land Application
- Chapter 6 Independent Septage Treatment

The co-treatment of septage at sewage treatment facilities is not addressed in fact sheet form because design criteria and most information cannot be generalized considering the wide range of facility designs and operational conditions that are possible. The reader is referred to Chapter 6 for specific technical guidance pertaining to the impact of septage co-treatment on individual unit processes.

The following common assumptions apply unless otherwise noted on individual fact sheets:

- Labor (including fringe benefits, etc.) $12.10/hr
- Electrical Energy - $.05/kwh
- Construction and O & M costs based on average design flow.
- Construction costs do not include external piping, electrical, instrumentation, land and site work cost, contingencies, or engineering, legal, and administrative fees.

Receiving Station (Dumping Station/Storage Facility) Fact Sheet 1

Description
A septage receiving station with dumping station and storage facilities provides for the transfer of septage from hauler trucks to a temporary holding tank from which it can be drawn at a controlled rate. With such a facility, septage can be discharged to an interceptor sewer or directly to the headworks of a treatment plant. The dumping station should provide for both direct hose connections (preferred) and open pit discharges. The dumping pit should be equipped with a coarse bar screen, and should be covered and preferably locked when not in use. A manual-controlled or timer-controlled pump discharge facilities feeding septage at a predetermined rate over specific periods of time in order to maximize the dilution of septage by sewage.

Common Modifications
Where septage is to be transferred from haulers' trucks to other vehicles (e.g., large tanker trucks for transport to centralized treatment facilities, or specialized land application equipment), the same basic facilities as described above could be used, with the exception that tanker trucks or trailers would replace the permanent storage tanks. Where land application is involved longer term storage may be required during adverse weather conditions. lagoon storage facilities should be considered in such cases. If septage is to be discharged to an interceptor sewer where flows are high, storage facilities might not be required. Odor control may be required depending on station location.

Pretreatment and Post-Treatment Requirements
No pretreatment of the septage is required before discharge to a receiving station. Post-treatment requirements will be determined based on the location of the station and the specific treatment method to be applied.

Technology Status
Widespread use of septage receiving stations is documented in Europe, specifically Germany, Sweden, and Norway; relatively fewer operating examples exist in the United States.

Typical Equipment
Dumping pit with cover; coarse bar screen; holding tank(s); solids handling pump(s); piping, valves, and hose connections.

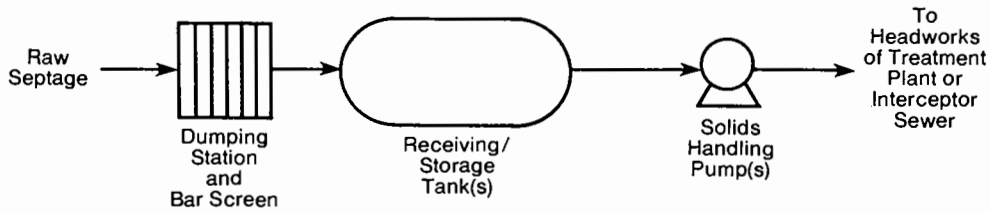
Residuals Generated
Grit and solids which may accumulate in holding tank must be cleaned out periodically. This can be accomplished by removing the solids using vacuum truck equipment, or by flushing the solids out of the tank using high pressure water. Periodic removal of screenings will also be required.

Design Criteria
- Bar Screen - ½ in. x 1½ in. bar stock, ½ in. - ¾ in. spacing
- Hauler Truck Hose Connection - 4 in. diameter
- Piping and Valves - 8 in. diameter
- Holding Tank Capacity - 1 day peak flow (not including supplemental storage requirements associated with land application systems etc.)

Unit Process Reliability
Extremely reliable with properly designed connections and tank sizes.

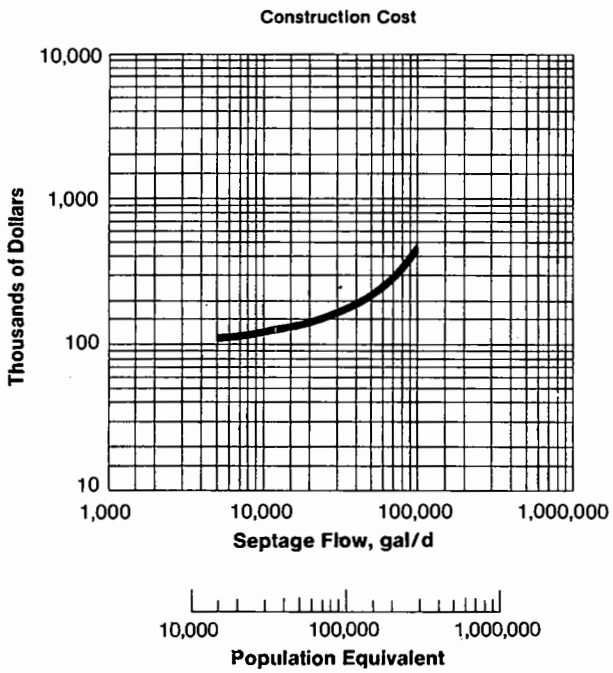
Environmental Impact
Land requirements are generally minimal; small energy requirement; odor problems with spillage.

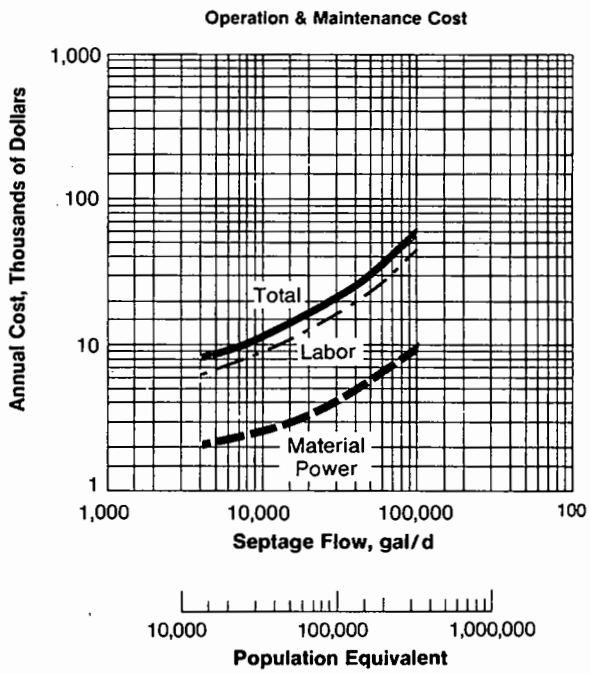
References
1, 2, 3, 4, 5.



Energy Notes - only energy requirements is for electrical power to operate pumps. Power consumption would be a function of motor horsepower and run time which will be determined by design flow and operational period (i.e. 8-hour shift vs. 24 hour operation.)

Costs - Assumptions: ENR Index = 3875
Construction cost includes equipment, materials, and installation.
Operating labor costs based on a minimum manpower requirement of 1 hour/day plus 1 hour/day every 10,000 gpd of septage received.
Electrical power costs based on pumping intermittently to meet design flow over 24 hour period on a 5-day week.
Does not include cost of accessory buildings, access roads, or grit and screenings disposal.





Receiving Station (Dumping Station, Pretreatment, Equalization) Fact Sheet 2

Description
When septage is to be ultimately treated at a wastewater treatment plant or independent septage treatment facility, a receiving station is required in order to provide preliminary treatment and equalization. This normally consists of a dumping pit with screening, grit removal, and flow equalization. Features which should be provided include: sloped ramp and hose-down facilities at unloading location; channel in front of bar screen for more uniform flow and to avoid direct discharge of septage onto screen; manually or mechanically cleaned bar screens; solids handling pumps; sampling/monitoring capability; ventilation system and odor control.

Pretreatment and Post-Treatment Requirements
No pretreatment of the septage is required prior to discharge to a receiving station. Post-treatment requirements will be determined based on the specific treatment method to be applied.

Technology Status
The pretreatment processes involved have been widely used since the origins of municipal wastewater treatment. Application to septage is widespread in Europe and more recently is being employed in the United States.

Typical Equipment
Bar screens or racks (mechanically cleaned screens are preferable, but may be impractical due to cost); receiving tank/pit; aerated grit chamber; flow equalization tanks; pump(s); odor control equipment (ventilation systems, blowers, filters, etc.).

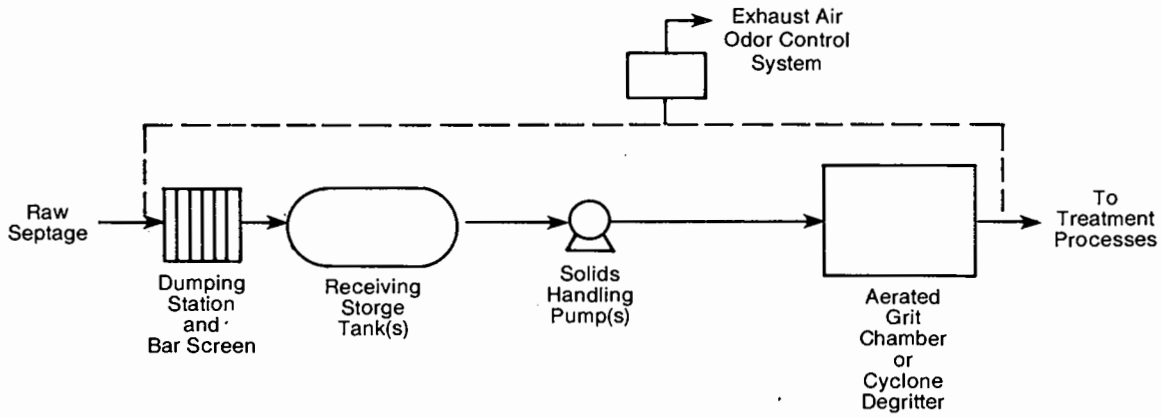
Residuals Generated
Screenings and grit, plus accumulated solids which settle out in flow equalization tanks. Provisions must be made for removal and disposal of these residuals. Landfilling is the most common method of disposal

Design Criteria
- Bar Screen - ½ in. x 1½ in. bar stock, ½ in. - ¾ in. spacing
- Hauler Truck Hose Connection - 4 in. diameter
- Piping and Valves - 8 in. diameter
- Degritting Equipment - per manufacturer's specifications for design flow
- Equalization Tanks - multiple tanks, total capacity twice peak daily flow
- Pumps - sized according to average design flow and operational schedule

Environmental Impact
Requires land; energy use for pumping, mechanically cleaned bar screens and aerated grit chambers. Solids will be generated, requiring disposal; odors may be associated with dumping, pretreatment, and residuals disposal operations.

Reference
1, 2, 3, 4, 5, 6, 7.

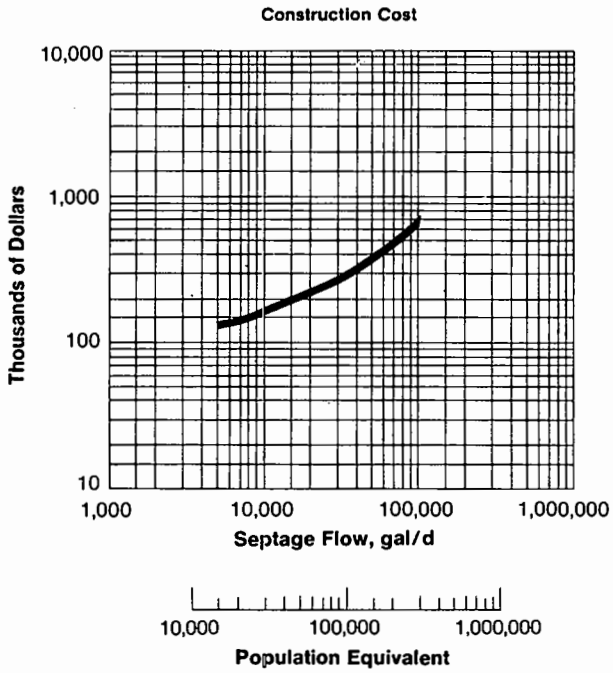
Common Modifications
Grit removal can either precede storge and equalization or follow it. If a grit chamber precedes equalization, it must be designed to handle the discharge of individual or multiple truckloads of septage as they come. If storage and equalization precede grit removal the grit removal process can be designed to handle the average flow, and can be operated according to a set schedule coinciding with subsequent treatment operations. Cyclone degritters may be substituted for aerated grit chambers if average septage solids concentration is less than 2 percent.

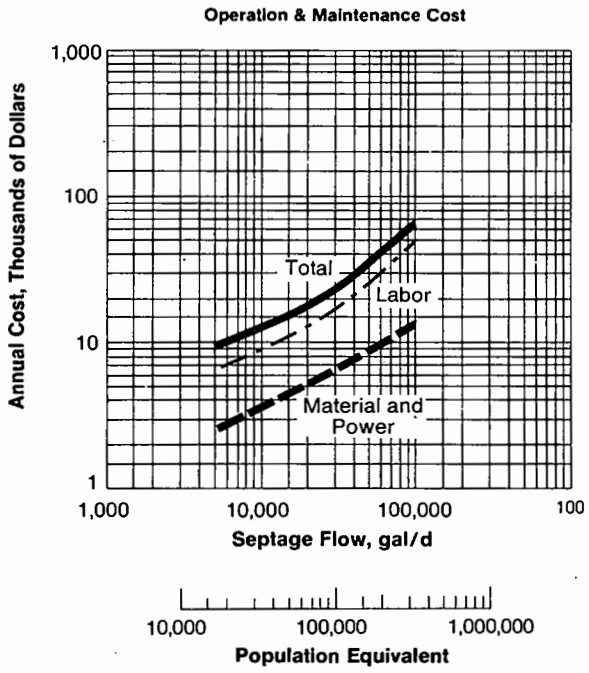


Energy Notes - Electrical power required for pumps, as well as operation of mechanical screening and degritting equipment. Power requirements for specific equipment to be specified by manufacturer.

Costs - Assumptions: ENR Index 3875

- Facility includes dumping pit, manually cleaned bar screen, equalization storage tanks, pumping station, and aerated grit chamber.
- Construction cost includes equipment, materials, and installation.
- Operating labor costs based on a minimum manpower requirement of 1 hour/day plus 1 hour/day for every 10,000 gpd of septage received.
- Electrical power costs based on pumping as required to meet design flow over 24 hour period (5-day week.
- Does not include cost of accessory buildings, access roads, or grit and screenings disposal.





Description
Raw septage and septage solids may be spread on the surface of the land or incorporated into the subsurface topsoil layers. Surface spreading includes spreading from septage hauler trucks or transfer vehicles such as tank wagons, spray irrigation, ridge and furrow practices, and overland flow. Application by the hauler trucks is the most common method practiced. Spray irrigation of septage requires the use of high-pressure large nozzle systems to prevent clogging. Ridge and furrow methods involve spreading septage in the furrows and planting crops on the ridges. Overland flow methods are best suited to lands with a slope of 2 to 6 percent.

Subsurface application techniques include plow furrow cover (PFC), subsurface injection (SSI), and injection using a device such as a Terreator (a patented device). The PFC method of application applies septage in a narrow furrow created by the plow shear and is immediately covered by the plow moldboard. The SSI method of application applies septage in a narrow band behind a sweep which opens a cavity 10 to 15 cm (6 to 8 in.) deep. A Terreator or similar device opens a mole-type hole with an oscillating chisel point and injects the septage into the hold.

Common Modification
The most common modifications to a septage land application site are related to variations in the method of application and the type of crop grown.

Pretreatment and Post-Treatment Requirements
Federal "criteria" (40 CFR 257) specify that septage applied to the land or incorporated into the soil must be treated by a "process to significantly reduce pathogens" (PSRP) prior to application or incorporation, unless public access to the facility is restricted for at least 12 months after application has ceased, and unless grazing by animals whose products are consumed by humans is prevented for at least 1 month after application. PSRP's include aerobic digestion, air drying, anaerobic digestion, composting, lime stabilization, or other techniques which provide equivalent pathogen reduction.

The criteria also require septage to be treated by a "process to further reduce pathogens" (PFRP prior to application or incorporation, if crops for direct human consumption are grown within 18 months subsequent to application or incorporation, and if contact between the septage applied and edible portion of the crop is possible. PFRP's include composting, heat drying, heat treatment, thermophilic aerobic digestion, or other techniques that provide equivalent pathogen reduction

Technology Status
Successfully implemented on a full-scale basis in the United States and Europe.

Typical Equipment
See Description section above.

Limitations
Constituents of the septage may limit the acceptable rate of application, the crop that can be grown, or the management or location of the site. Nitrogen requirements of the crop normally dictates the annual septage application rates. It is also required that soil pH be maintained at 6.5 or above to minimize the uptake of the trace elements.

The potential for contaminated runoff, soil compaction, crop damage, or trucks getting stuck preclude the application of septage during periods when soil moisture is too high. Therefore, septage application is limited only a portion of the year. For the period of the year when septage can not be applied, storage facilities must be provided. Many states regulate the total volume of septage that can be applied as a function of soil drainage characteristics.

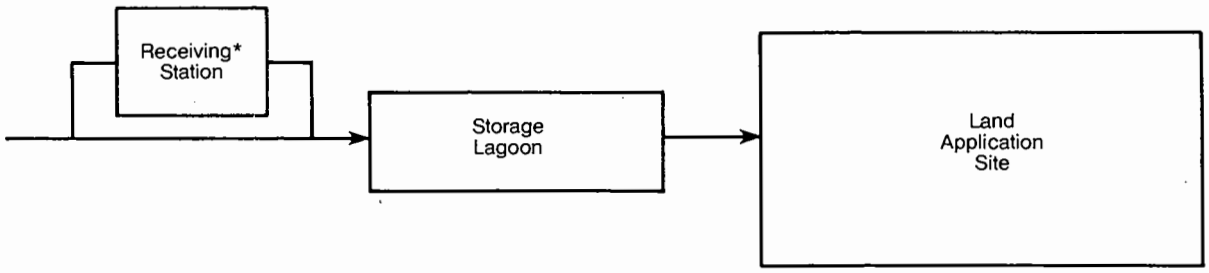
Performance
Septage contains all of the essential plant nutrients. It can be applied at rates which will supply all the nitrogen and phosphorus needed by most crops.

Design Criteria
Application rates depend on septage composition, soil characteristics, and cropping practices. Annual application rates have varied from 282 m^3/ha (30,000 gal/acre) to 1,880 m^3/ha (200,000 gal/acre). Applying septage at a rate to support the nitrogen needs of a crop avoids problems with overloading the soil.

Unit Process Reliability
As a disposal process, very reliable/ as a utilization process, careful monitoring and control should be exercised to maximize the efficiency and minimize health risks

Environmental Impact
Potential for heavy metals and pathogens to contaminate soil, water, air, vegetation, and animal life, and ultimately to be hazardous to humans. Accumulations of metals in the soil may cause phytoxic effects, the degree of which varies with the tolerance level of the particular crop. Toxic substances such as cadmium that accumulate in plant tissues can subsequently enter the food chain, reaching human beings directly by ingestion or indirectly through animals. if available nitrogen exceeds plant requirements, it can be expected to reach groundwater in the nitrate form. Toxic materials can contaminate groundwater supplies or can be transported by runoff or erosion to surface waters if improper loading occurs. Aerosols which contain pathogenic organisms may be present in the air over a landspreading site, especially where spray irrigation is the means of septage aplication. Other potential impacts include public acceptance and odor.

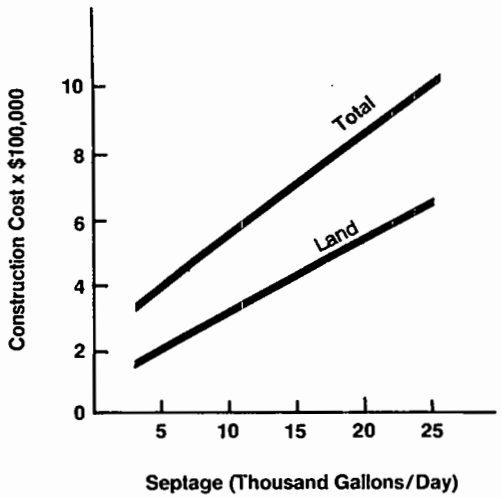
References
8, 9, 10, 11, 12, 13.

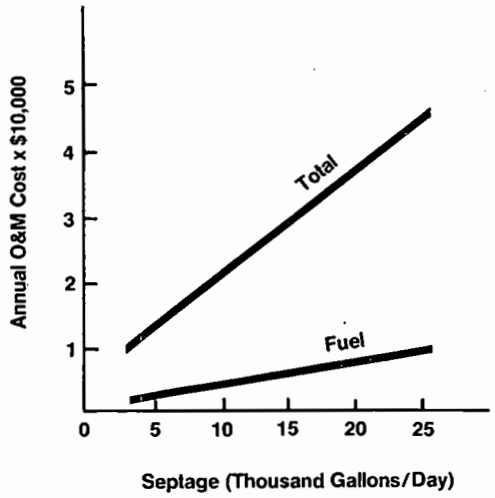


*See Receiving Station Fact Sheets

Energy Notes - Energy required to apply septage to the land will range from approximately (20,000 Btu/wet ton) for hauler truck spreading to (80,000 Btu/wet ton) for subsurface injection.

Costs - Assumptions:
ENR Index = 3875
Construction cost includes equipment, materials, installation, and land.
Land $5,000/A includes 200' buffer strip around disposal area
Fuel costs $1.25/gal





Construction cost includes land (assuming surface application on fescue field), storage lagoon (6 week capacity), spreading equipment, land preparation, equipment storage building, site protection and improvement.

Reference 14

Description
The use of lagoons for the disposal of septage is a common alternative in rural areas. The design and operation of lagoons vary from simple septage pits to sealed basins with separate percolation beds. Most lagoons are operated in the unheated anaerobic of faculative phase.

A typical lagoon system consists of two earthen basins arranged in series. The first or primary lagoon receives the raw septage via a vertical discharge chamber entering under the surface of the liquid near the lagoon bottom to minimize odors. It may be lined or unlined, depending on the geological conditions of the site. The supernatant from the primary lagoon, which has undergone some clarification and possibly anaerobic digestion is drawn off into the second lagoon or percolation bed where it is allowed to percolate into the ground. Once the solids have accumulated in the primary lagoon until the point where no further clarification occurs, the lagoon is drained and the solids are allowed to dry. The dried solids are then removed, sometimes further dewatered, and disposed of at a landfill or buried.

Common Modifications
Aeration may be applied to supplement the supply of oxygen to the system and for mixing. Lagoons may be lined with various impervious materials such as rubber, plastic, or clay as required by geological conditions. Where groundwater quality is of concern, the effluent from septage lagoons can be applied to the land or treated and discharged to a surface water, rather than use percolation beds.

Pretreatment and Post-Treatment Requirements
The pH of the lagoon must be maintained at 8.0 or greater to control odors. This may be accomplished with the use of hydrated lime added each time a truckload is discharged to the receiving chamber. Lagoon effluent can be disposed of by applying spray irrigation or overland flow. If the effluent is to be discharged to a surface water it should be further treated using either polishing ponds of sand filters, and disinfected as required.

Technology Status
Fully demonstrated and in use throughout the United States for the treatment of municipal wastewaters in areas where real estate costs are not a restricting factor; limited experience with septage lagoons, mostly in the northeastern United States.

Typical Equipment
Lining systems and hydraulic control structures (i.e., inlest and outlets); a simple receiving station (i.e., providing coarse screening) is recommended.

Limitations
In very cold climated, reduced biological activity occurs and ice may form on the surface. Overloading may create potential odor problems. Potential exists for groundwater contamination with percolation beds and seepage pits or lagoons. Extensive site evaluation recommended inn all cases.

Performance
Limited data available.

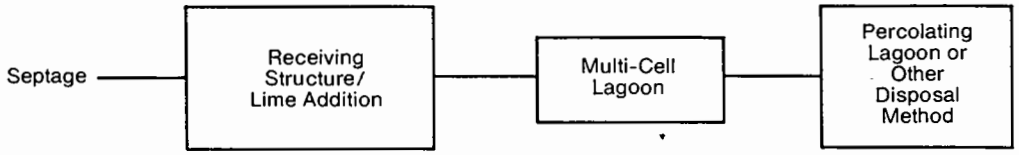
Residuals Generated
Settled solids from primary lagoon have to be removed and properly disposed of periodically (every few months to once every 5 or 10 years depending on size of lagoon).

Design Criteria
Detention Time - 20 to 30 days for settling alone; 1 to 2 years for stabilization (i.e., 80-90% removal of BOD and volatile solids)
Area Loading Rate - 20 lbs. vs./day/1,000 square feet (facultative sludge lagoon (38))
pH - 8.0 using lime
Minimum Depth - 0.9 m (3 ft) (Plus additional depth for sludge storage and anaerobic zone.)
Minimum Separation Distance from High Groundwater Level - 1.3 m (4 ft)
Land Application of Effluent - see References 15, 16

Unit Process Reliability
Estimated service life of 20 to 30 years with periodic cleaning (see above); little operator expertise required overall; the system is highly reliable.

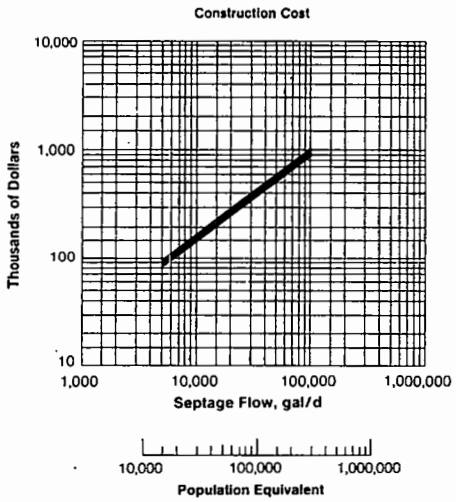
Environmental Impacts
Potential for groundwater contamination. Groundwater should be monitored near the lagoon site. Odor and vector problems possible in immediate vicinity of lagoons.

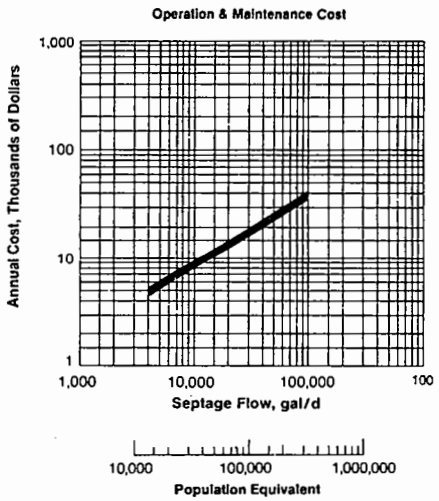
References
17, 18, 19, 20.

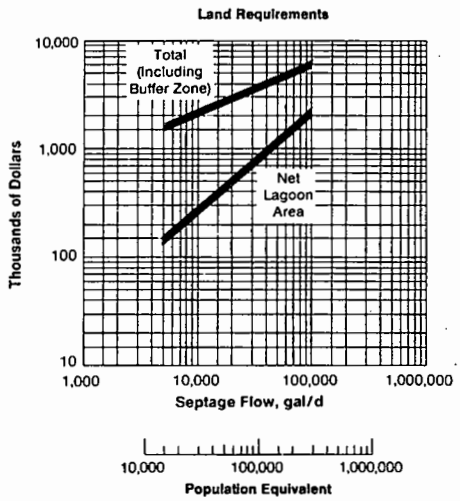


Energy Notes - Faculative lagoons generally have no energy requirements, although surface aerators are optional; sludge removal operation will involve fuel costs.

Costs - Assumptions: ENR Index = 3875
Facility includes multi-cell lagoon, receiving structure, lime storage building, and fencing.
Construction cost includes equipment, materials, and installation.
Operating labor costs based on minimum manpower requirement of .5 hour/day plus .5 hour/day for every 10,000 gpd of septage treated.
Lime Dosage - 8.4 lbs. $Ca(OH)_2$/1,000 gallons septage
Does not include cost of accessory buildings (other than lime storage), access roads, sludge removal.







Composting (Aerated Static Pile) — Fact Sheet 5

Description

Composting is the stabilization of organic material through the process of aerobic, thermophilic decomposition. It is a disposal technique that offers good bactericidal action and up to 25 percent reduction in organic carbon. Septage is transformed into a humus-like material that can be used as a soil conditioner.

Composting is classified into three types of operations, which differ principally by the aeration mechanism they employ. They are windrow, aerated static pile, and mechanical composting. Although all three methods may be applied for composting septage, the method that appears to offer the greatest potential as a septage treatment alternative is the aerated static pile method because it permits more uniform composting and minimizes land requirements.

Septage is usually first dewatered and then mixed with bulking agents (e.g., woodchips, sawdust, bark chips, leaves, etc.) prior to composting to decrease the moisture content of the mixture, increase the porosity of the septage, and assure aerobic conditions during composting. The mixture is then constructed into a pile as shown in the illustration presented under "Flow Diagram." A blanket of finished compost completely surrounds the composting mixture in order to reduce heat loss and minimize odors.

The aerated pile undergoes decomposition by thermophilic organisms, whose activity generates a concomitant elevation in temperature to 60°C (140°F) or more. Aerated conditions in the pile are maintained by drawing air through the pile at a predetermined rate. Exhaust air is forced through a small pile of screened finished compost for odor control. The composting period normally lasts 3 weeks.

Following the composting period, the aerated piles are taken down, moved and stored in piles for 4 or more weeks to assure no offensive odors remain, and to complete stabilization. The composted material can be separated from the bulking agent which is generally recycled for further usage. The finished compost material is then ready for utilization as a low-grade organic fertilizer, soil conditioner, or for land reclamation.

Common Modifications

Windrow and mechanical composting are commonly used to stabilize wastewater sludges, and can be adapted to treat septage. The Lebo process which is a variation of windrow composting treats raw septage without dewatering, by first aerating the septage in a reactor and then mixing it with sawdust before composting, which takes up to 6 months. The aerated static pile method can also be used to compost raw septage, however, excessive quantities of bulking agent are required to maintain the desired moisture content.

Pretreatment and Post-Treatment Requirements

Dewatering of septage is recommended prior to composting to minimize the amount of bulking agent required. However, if large quantities of bulking agent are available at reasonable cost, raw septage can be treated.

Technology Status

Well developed technology in use, or in the design stage at over fifty locations in the United States for wastewater sludge and septage treatment.

Typical Equipment

Commonly available equipment can be used including front-end loader, 4-in. perforated plastic pipe, blower, rotary screen, etc.

Limitations

In areas of significant rainfall it may be necessary to provide a cover for the pile. A drainage and collection system is generally required to control storm water runoff and leachate from the pile.

Performance

Septage is generally stabilized after 21 days, during which time septage odors and pathogens are destroyed.

Residuals Generated

Final product is compost; leachate from piles may be generated in some cases.

Design Criteria

Composting represents the combined activity of succession of mixed populations of bacteria, actinomycetes, and other fungi. The principle factors that affect the biology of composting are moisture, temperature, pH, nutrient concentration, and availability and concentration of oxygen. A summary of pertinent design parameters follows:

Moisture Content - 40-60%
Oxygen - 5-15%
Temperature Peak - 55-65°C (130°-150°F)
pH - 5-8
C/N Ratio - 20:1 - 30:1
Land Requirement - 0.2-0.3 acre/dry ton septage solids/day (0.09-0.13 ha/dry metric ton/day)
Blower Size ¼ KW (1/3 HP)

Septage Pile Dimensions
2.7 m (9 ft) High
4.6 m (15 ft) Diameter
0.3 m (12 in.) Base
0.5 m (18 in.) Blanket
0.75 m^3 (1 cu yd) Filter Pile

Unit Process Reliability

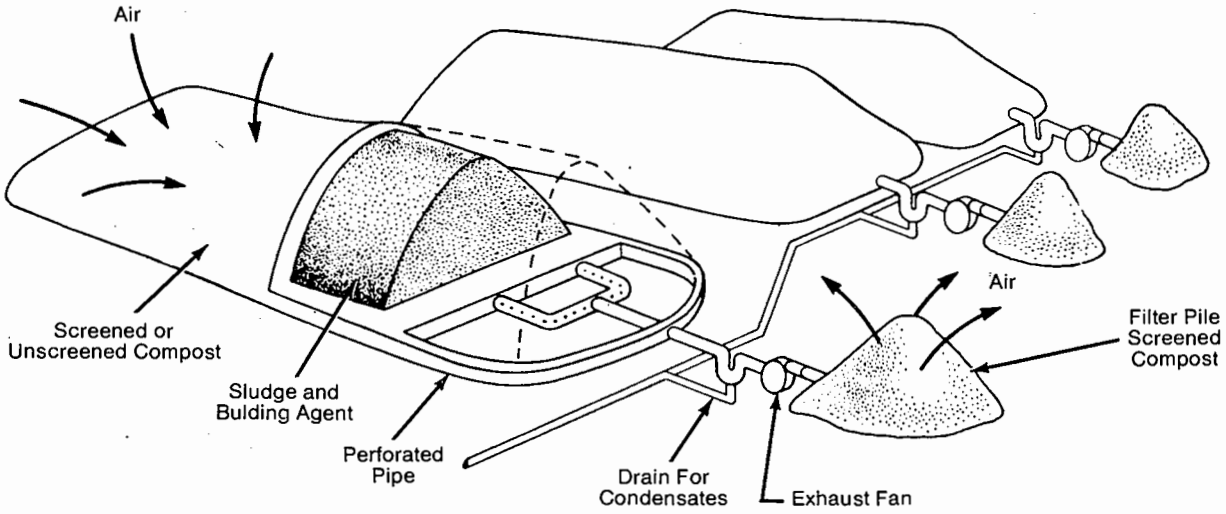
High degree of process reliability through simplicity of operation.

Environmental Impact

Potential odor problems can occur for a brief period between the time the septage arrives at the site and is mixed and covered by the insulation layer.

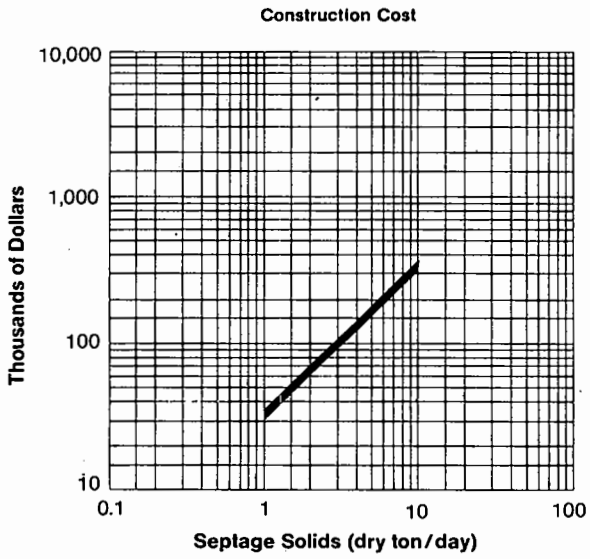
References

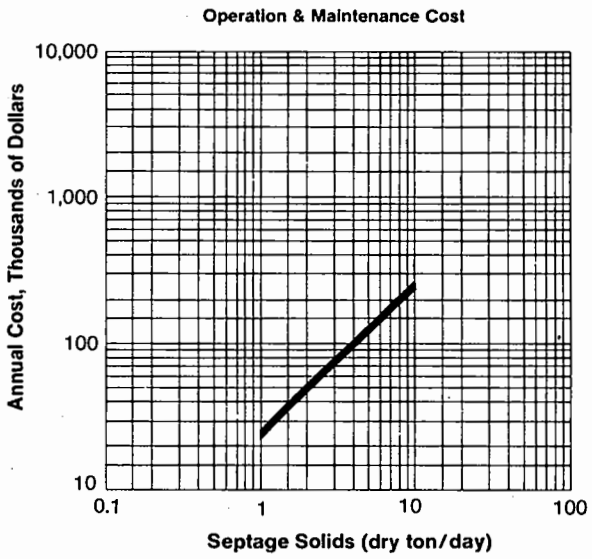
21, 22, 23, 24, 25, 26, 27, 28, 29, 37.



Energy Requirements - Electrical power to operate blowers (7.5-17.5 KW hr/dry ton/day); fuel to drive front end loaders (1.1 gal. gasoline/dry ton/day), (2.7-3.5 gal. diesel fuel/dry ton/day), (ref. 37).

Costs - Assumptions: ENR Index = 3875
Capital cost not including purchase of front end loader, estimated at $85/dry ton septage solids treated annually (ref. 31).
Operating cost estimated at $66/dry ton septage solids (ref. 31).
Assuming septage is dewatered (20% solids prior to composting.
Costs of dewatering not included.





Description
Addition of lime to septage in sufficient quantities to maintain a high pH (>pH 12 for 30 min) creates an environment that will effectively destroy most pasthogenic and odor producing microorganisms. Lime-stabilized septage is typically disposed of on land. Lime stabilization improves septage dewaterability; the stabilization may be followed by a dewatering step, or the stabilized liquid septage may be spread on the land directly.

Common Modifications
Dry lime can be added directly to the hauler truck prior to discharging to a holding facility, treatment facility, or land application site. In smaller facilities, lime is often added manually in the form of bagged lime.

Pretreatment and Post-Treatment Requirements
Septage must be screened prior to lime stabilization to remove rags and other debris. Grit removal is optional and depends on the equipment in the process train. Grit removal should be provided to protect downstream pumps and/or dewatering equipment.

Lime-stabilized septage may be dewatered prior to disposal, although the stabilized liquid may be applied directly on a land disposal site. Stabilized septge may be stored prior to land disposal. Because pH drops during storage, it is desirable to dispose of the stabilized septage as soon as possible to avoid regrowth of organisms and resulting noxious odors.

Technology Status
Lime has been in widespread use for over 100 years, both for sludge and septage treatment. Shipping, handling, and feeling techniques for lime are well proven.

Typical Equipment
Chemical feed equipment; pH instrumentation; lime storage bins; sludge handing and control equipment.

Limitations
Lime treatment provides essentially no reduction or organics, O&M problems due to scaling in the lime addition system; lime addition increased the quantity of material for disposal.

Performance (4)
A full-scale study indicated the following effects of lime treatment on pathogenic bacteria (initial pH = 12.5, maintained at pH>12 for at least 30 min). Units: orgamisms/100 ml of sample.

Parameter	Raw Septage	Lime-Stabilized Septage
Total Coliform[a]	2.9×10^8	2.1×10^3
Fecal Coliform[a]	1.5×10^7	265
Fecal Streptococci	6.7×10^5	665
Salmonella[b]	6	<3
Ps. Aeruginosa[b]	754	<3

[a]Millipore filter technique used.
[b]Detection limit = 3.

Residuals Generated
Lime addition increases the quantity of material for disposal. Lime-stabilized septage can be disposed of directly on land or can be dewatered first.

Design Criteria
Lime dosage to maintain>pH 12.5 for at least 30 min: 0.1 - 0.3 kg lime/kg dry solids (0.1 - 0.3 lb lime/lb dry solids)

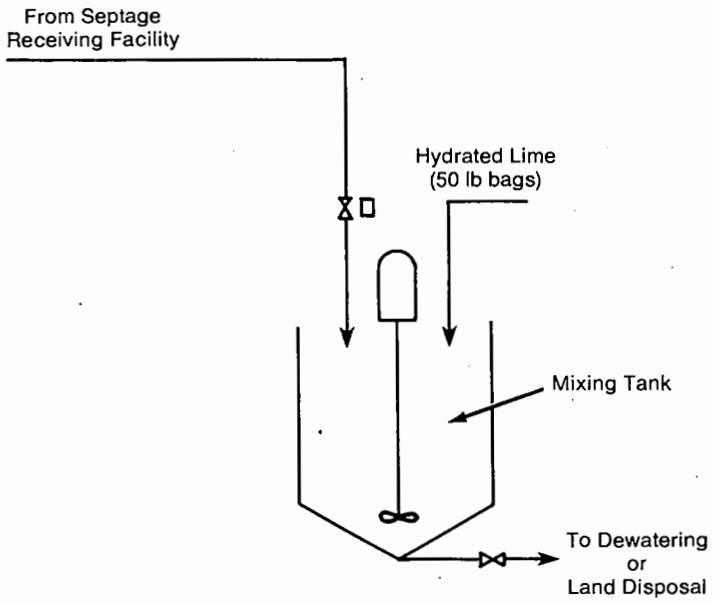
Mixing Requirements:
Air: 150 - 250 m^3/1,000 m^3/min (150 - 250 cfm/1,000 ft^3)
Mechanical: Bulk fluid velocity = 7.9 m/min (26 ft/min)

Unit Process Reliability
Highly reliable from a process standpoint. Operator must clean and maintain frequently in order to avoid corrosion and scaling, and to ensure the mechanical reliability of the lime feed.

Environmental Impact
The quantity of solids for disposal is increased, compared with other methods of stabilization. However, lime stabilization can significantly reduce the number of pathogenic bacteria, and attentuate the odor normally associated with septage, making it more acceptable for land disposal in most cases.

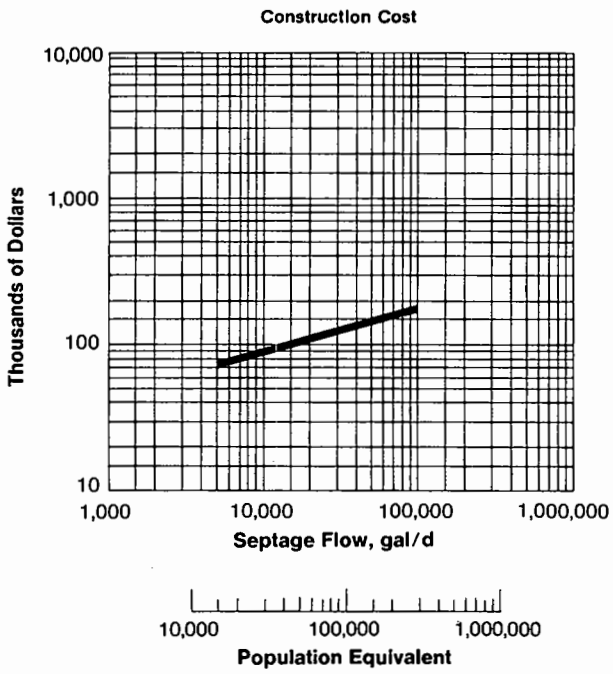
References
6, 30, 31, 32.

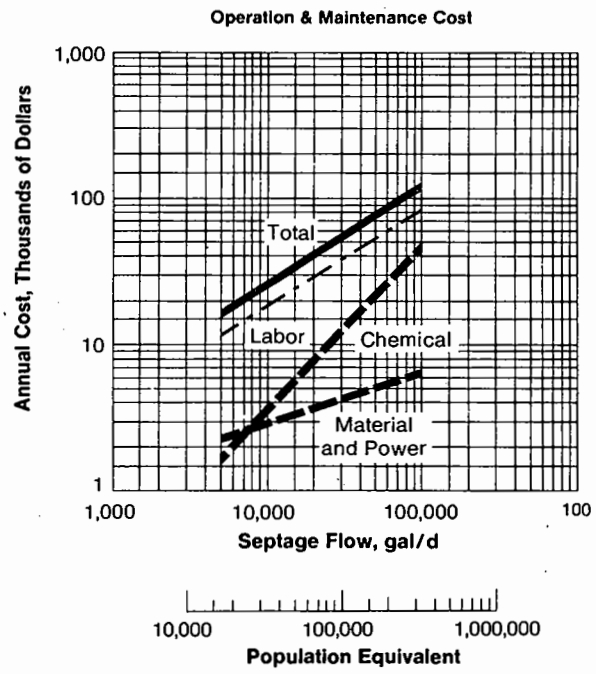
Flow Diagram



Energy Notes - Energy costs are relatively minor compared to labor and chemical costs.

Costs - Assumptions: ENR Index = 3875
Facility includes mixing tanks, mechanical mixers, sludge pumps, portable pH meters, and lime storage building.
Construction costs includes equipment, materials, and installation.
Operating labor cost based on minimum manpower requirement of 2 hours/day plus 2 hours/day for every 10,000 gpd of septage treated.
Lime dosage - 26-60 Kg lime/m³ (15-35 lb lime/1,000 gal) septge $70 ton





Description
Soil filters provide breakdown of malodorous compounds by both chemical and biological means. This is accomplished by collection and forcing air from contained process units through networks of perforated pipe buried in the soil, or through a mixture of iron oxide and woodchips.

Common Modifications
Use of compost rather than soil as filter media; above ground, enclosed filters for smaller volumes of gas; use of rooted vegetation to maintain loose soil and enhanced biological activity. Alternative odor control methods include exhaust gas scrubbing in aeration basins, and incineration in sludge combustion units. Chemical scrubbers and activated carbon filters have also been used with mixed success.

Pretreatment and Post-Treatment Requirements
None.

Technology Status
Extensive use in Europe; more recent adoption in United States at smaller facilities.

Typical Equipment
Ventilation systems, fans, piping, etc.

Limitations
Cessation of biological activity due to inhibiting or toxic substances may render filter ineffective. Design life for soil filter is not well documented.

Performance
Odorous gases are contained and vented to the soil filter area via a piping network. Given sustained biological activity, filters may regenerate during periods when no gases are passing through. Pilot-scale sutdies have demonstrated complete elimination of odors by use of soil filters (i.e., no detectable odors in vicinity of soil filter). Gases with H_2S concentrations greater than 100 mg/l have been deodorized ($H_2S < 1$ mg/l) by this method.

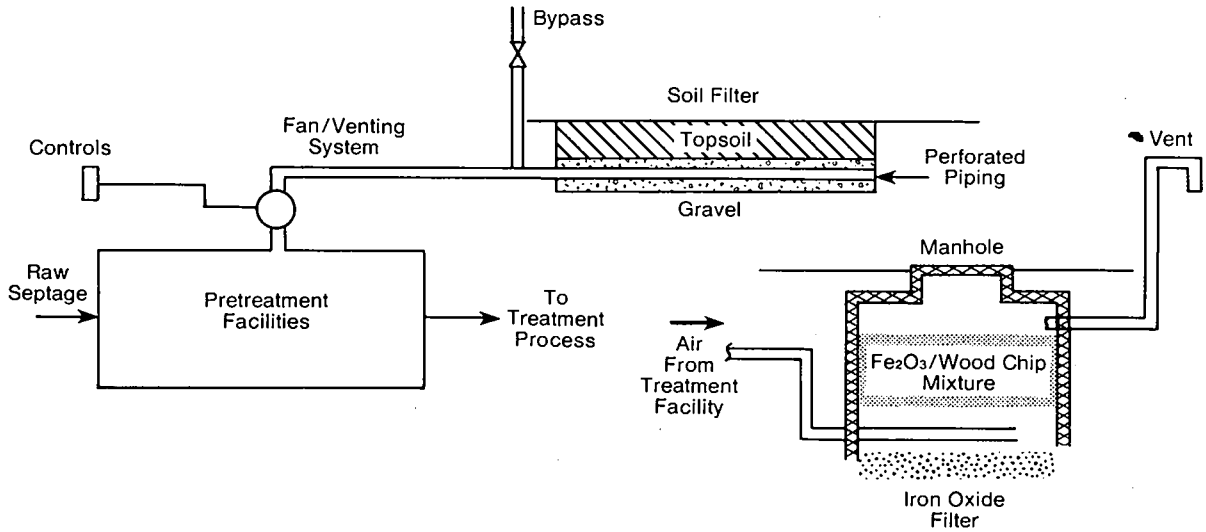
Residuals Generated
None.

Design Criteria
- Minimum Soil Depth - 0.5 m (20 in.)
- Air Loading Rate - 60 $m^3/m^2/hr$ (200 ft^3/ft^2hr) for soil filters at full scale
- Detention Time - not lett than 30 sec at peak air flow
- Soil Type - moist loam, sandy loam, compost
- Soil Temperature - above 3°C (38°F)
- Soil Moisture - sprinkling may be required in dry summer periods; proper drainage must be provided to prevent saturation of the soil.

Unit Process Reliability
Excellent under normal conditions of use.

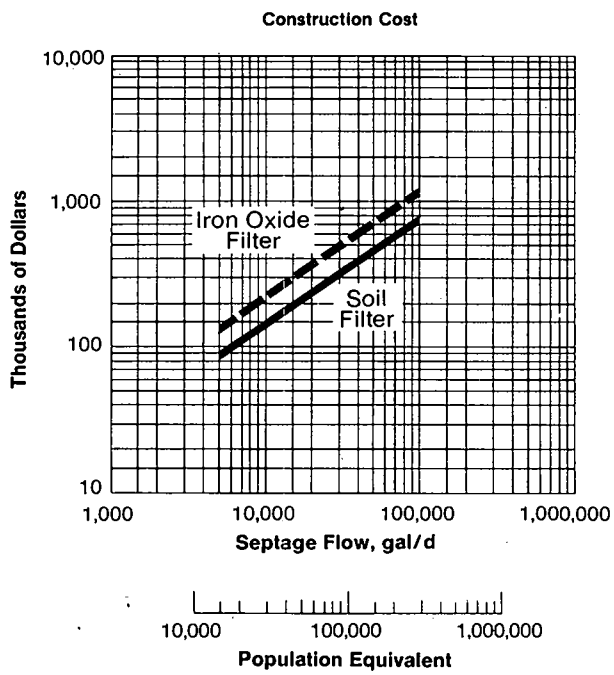
Environmental Impact
Potential release of odorous gases if filter malfunctions; land requirements are relatively small.

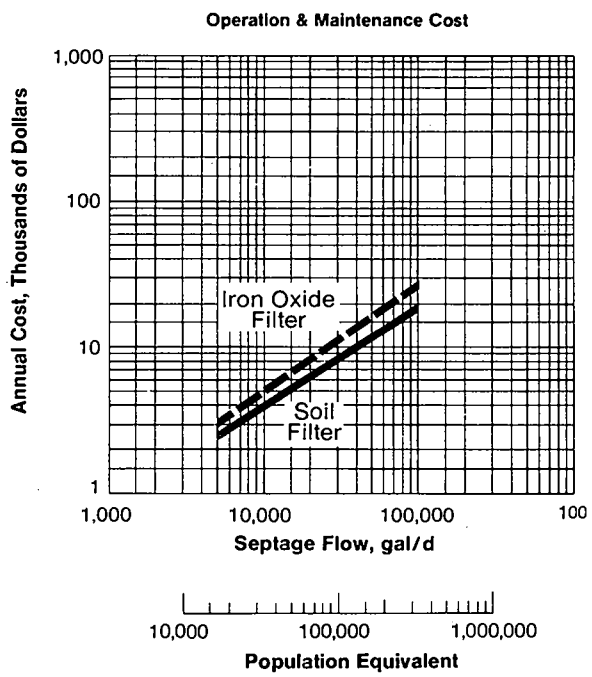
References
1, 8, 9, 10, 11, 12, 13, 14, 15, 16, 39, 40, 41, 42, 43, 44.



Energy Notes - Electrical power to operate fan. Power consumption will depend on operating schedule.

Costs - Assumptions: ENR Index = 3875
Facility includes exhaust fans, piping, electrical controls, and filter unit (either soil filter or iron oxide filter)
Maximum Air Flow - 1800 cfm per 10,000 gpd septage treated
Operating labor costs assume 0.5 hour/day for 10,000 gpd facility, and 1 hour/day for 50,000 gpd facility.
Soil filter life - at least 5 years
Iron oxide media life - 2 years





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APPENDIX A

SUMMARY OF STATE REQUIREMENTS REGARDING LAND DISPOSAL OF SEPTAGE

State	Land Disposal Allowed	Land Application Permit Required	Comments
Alabama	No	No	Disposal approval by local DPH. Method of disposal reviewed by county health officer. Sanitary sewers and waste treatment plants used for disposal. Permits required since 1982.
Alaska	Information unavailable	Information unavailable	DEC requires review. Reluctant to allow septage to treatment plants because of upsets. DEC may require pretreatment before STP.
Arkansas	Yes	Information unavailable	STP also used for disposal.
Arizona	Yes	Information unavailable	County Health Department may approve disposal at STP or burial.
California	Yes	Information unavailable	RWQCB may approve disposal at STP or Class II sanitary landfill. Landfills must have surface drainage and leachate controls, and are limited to accepting 25 to 40 gallons of septage per cubic yard of refuse in bay area.
Colorado	Yes	Information unavailable	Municipalities have ordinances on disposal. STP also used. Land disposal regulated by counties.
Connecticut	Yes; lagoon design included	Yes	DEP requires permits for STP, lagoons, occasional landfill.
Delaware	Yes	No	Two of three counties go to STP. Other county "plows in," with road setback of 300 feet.
Florida	Yes	No	Sites inspected by state. State prefers use of STP. Land application allowed but septage must be treated first.
Georgia	Information unavailable	Information unavailable	Counties regulate disposal. STP most common method.
Idaho	Yes	Information unavailable	STP also used.
Illinois	Yes	Yes	State code regulates disposal. IEPA and State Health Department require permits for 1) application to farm land, 2) landfill, 3) STP, and 4) sludge drying beds.
Indiana	Yes	No	State prefers use of STP, subject to municipal approval. Written approval for landfill as contingency only. Burial on private property with owner's approval.

State	Land Disposal Allowed	Land Application Permit Required	Comments
Kansas	Yes	Yes	Sixteen out of 105 counties have regulations. Other approved methods of disposal include 1) STP, 2) plow under in cropland, 3) sanitary landfill, and 4) dewatering by vacuum filtration.
Kentucky	Yes	No	Burial 200 yds from residences and roads. STP also used.
Louisiana	Yes	No	Land disposal options include soil absorption trenches, sand filter beds, and small oxidation ponds. Discharges greater than 3,000 gal must go to STP.
Maine	Yes	Information unavailable	Disposal is municipal responsibility subject to DEP approval, except STP. Recommended practices include 1) STP, 2) land spreading, 3) spray irrigation, and 4) lagooning.
Maryland	Yes	Information unavailable	DHMH must approve all sites in writing. Set back 200 feet from highway.
Massachusetts	Yes		
Michigan	Yes	No	State prefers STP, but needs local approval. Land spreading and/or burial permitted. It must be 1,000 feet from property, and with written approval of owner and local Health Department.
Minnesota	Yes	No	Land spreading with written approval of owner and Health Department. STP also used.
Mississippi	Yes	Yes	No state regulations governing disposal. Little enforcement of few laws that apply to disposal. STP also used.
Missouri	Yes	No	No statewide rules; responsibility of municipalities.
Montana	Information unavailable	Information unavailable	No statewide regulations; responsibility of counties.
Nebraska	Yes	No	Local Health Department regulates disposal in some areas. Options include 1) shallow trench disposal, 2) soil injection, 3) lagoons, 4) STP, and 5) burial (under certain conditions).
Nevada	Yes	Information unavailable	STP also used for disposal.
New Hampshire	Yes	No	Disposal site reviewed by DEHS. Options include 1) seepage pits, 2) trench dewatering, and 3) land spreading.
New Jersey	Yes	Yes	1982 statewide septage disposal law set up regional disposal sites (STP). Commercial haulers utilize some land application.
New Mexico	Yes	Yes	Rural areas (and the need to conserve water) promote individual systems under state guidelines. Such systems include 1) land application, 2) sand filters, 3) split flow systems, and 4) evapotranspiration. STP used in urban areas.
New York	Yes	Yes	Different levels of government have different regulations for disposal. Disposal sites (STP, lagoons, etc.) must be permitted with owner's approval.

State	Land Disposal Allowed	Land Application Permit Required	Comments
North Carolina	Yes	Yes	County responsible for less than 3,000 gal. Div. Environmental Management responsible for greater than 3,000 gal.
North Dakota	Yes	No	STP with permission. Land spreading or burial 1,000 feet from residences or roads.
Ohio	Yes	Information unavailable	Land spreading on farmland most common. STP also used for disposal.
Oregon	Yes	No	Disposal site approved by DEQ. DEQ recommends 1) STP, 2) lagoons, 3) land disposal on fields without crops, and 4) plowing under if near habitations.
Pennsylvania	Yes	Yes	State recommends use of STP, but land disposal most frequent. 90-95% septage to land; 5-10% to STP. Landfills, lagoons, and trenches also allowed. Five out of 62 counties have regulations (state issues guidelines).
Rhode Island	Yes	No	Disposal site approved by Department of Health. STP disposal most common.
South Carolina	Yes	Yes	Trench absorption and STP most common methods of disposal.
South Dakota	Yes	No	Burial or other (with written approval of DWNR). STP also used for disposal.
Tennessee	Yes	No	Local Health Department has regulations for disposal. Land spreading or burial 200 feet from roads or residences.
Texas	Yes	Information	Disposal site set back 300 feet from highway unless buried or treated. Department of Public Health encourages STP.
Vermont	Yes	Yes	Disposal is broken up as follows: 60% land, 25% trench dewatering, and 15% STP. At present time all regulations are proposed; hopefully will become law soon.
Virginia	Yes	Information unavailable	
Washington	Yes	Yes	In unsewered metropolitan areas, disposal via discharge to a municipal wastewater treatment plant. In rural areas, disposal to designated pit or trench for septage disposal, sometimes at a solid waste landfill site which may be publicly or privately operated.
West Virginia	Yes	Yes	Disposal in sewer or STP with local approval. Lagoons, sludge beds, and incineration are acceptable. Burial requires approval of State Department of Health.
Wisconsin	Yes	Yes	STP and sanitary landfill most common. Burial, land integration, and spreading are allowable 200 feet from well or reservoir and 500 feet from place of habitation (1,000 feet of land spreading is used).
Wyoming	Yes	Yes	STP most common. Landfill used if STP unavailable.

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